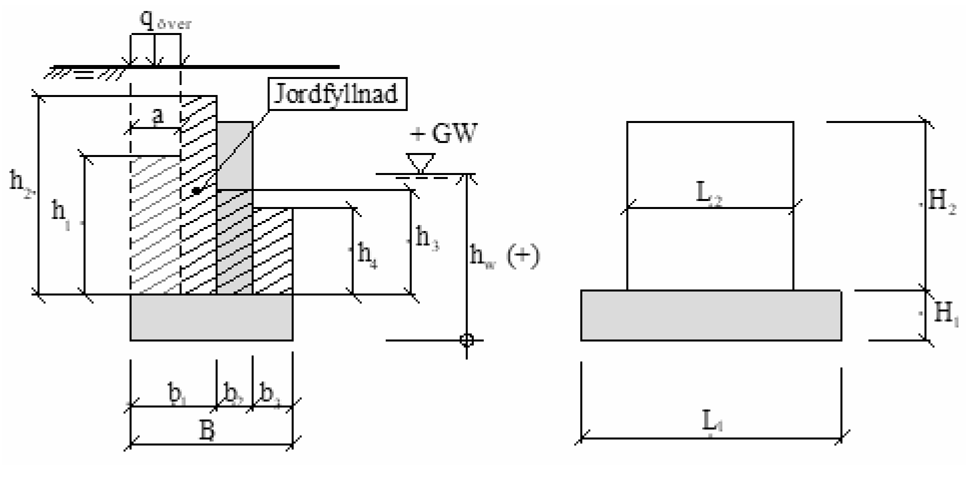
Object: Support 2

PRINCIPLE SKETCH



INPUT - internal loads against abutment

Level GW

$h_w \equiv 209.31 \cdot m - 200.2 \cdot m = 9.11\ m$

Density concrete above GW

$\gamma_{btg} \equiv 25 \cdot \frac{kN}{m^3}$

$\gamma'_{btg} \equiv 15 \cdot \frac{kN}{m^3}$

Density filling

$\gamma_{jord} \equiv 20 \cdot \frac{kN}{m^3}$

$\gamma'_{jord} \equiv 13 \cdot \frac{kN}{m^3}$

Surcharge

$q_{över} \equiv 0 \cdot kPa$

$a \equiv 0 \cdot m$

Height filling

$h_1 \equiv 0.3 \cdot m$

$h_2 \equiv 0.3 \cdot m$

$h_3 \equiv 0.3 \cdot m$

$h_4 \equiv 0.3 \cdot m$

Geometry bottom slab

$b_1 \equiv 1.85 \cdot m$

$b_2 \equiv 2.30 \cdot m$

$b_3 \equiv 1.85 \cdot m$

$H_1 \equiv 1.50 \cdot m$

$L_1 \equiv 10.0 \cdot m$

Geometry abutment

$H_2 \equiv 1 \cdot mm$

$L_2 \equiv 6.58 \cdot m$

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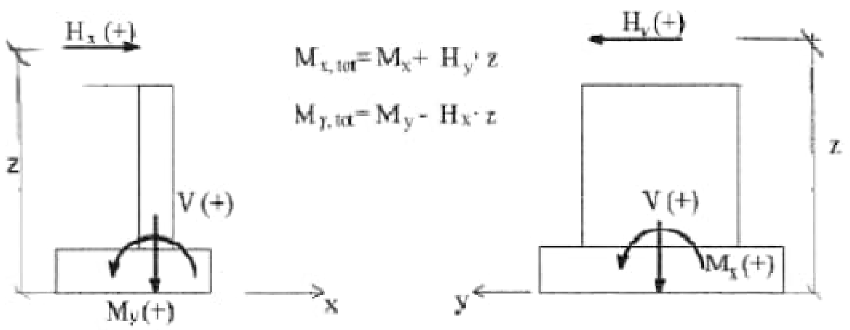
INPUT - external reactions

Sign conventions



Laster

Nr	Namn	V	H x	H y	z	M x	M y	Bearing
1	-							
2	Weight abutment	1350	0	0	0	0	0	No
3	Weight filling	175	0	0	0	0	0	No
4	-							
5	Reaction forces ULS:							
6	Max FX	3816	643	0	0	0	-1311	Yes
7	Min FX	5089	1192	155	0	478	-2149	Yes
8	Max FY	4914	698	-454	0	-2435	-1540	Yes
9	Min FY	4221	1083	454	0	2435	-1886	Yes
10	Max FZ	7700	1257	109	0	-1352	-2611	Yes
11	Min FZ	3361	620	-247	0	-1061	-1216	Yes
12	Max MX	6100	1177	353	0	3310	-2278	Yes
13	Min MX	5151	710	-353	0	-3310	-1589	Yes
14	Max MY	3816	643	0	0	0	-1311	Yes
15	Min MY	5089	1192	155	0	478	-2149	Yes
16	-							
17	-							
18	Vertical surcharge	0	0	0	0	0	0	No
19	-							
20	-							
21	-							
22	-							
23	-							
24	-							
25	-							
26	-							
-	-	kN	kN	kN	m	kNm	kNm	Yes/No

Load coefficients ψγ

Nr	Namn	ULS a	ULS b	ULS c	ULS d	ULS e	ULS f	ULS g	ULS h	ULS i	ULS j
1	-										
2	Weight abutment	1,33	1,00	1,00	1,00	1,00	1,33	1,33	1,00	1,00	1,33
3	Weight filling	1,33	0,90	0,90	0,90	0,90	1,33	1,33	1,00	1,00	1,33
4	-										
5	Reaction forces ULS:										
6	Max FX	1,00									
7	Min FX		1,00								
8	Max FY			1,00							
9	Min FY				1,00						
10	Max FZ					1,00					
11	Min FZ						1,00				
12	Max MX							1,00			
13	Min MX								1,00		
14	Max MY									1,00	
15	Min MY										1,00
16	-										
17	-										
18	Vertical surcharge	0	0	0	0	0	0	0	0	0	0
19	-										
20	-										
21	-										
22	-										
23	-										
24	-										
25	-										
26	-										

Second order effects

$P_{cr.x} := 1000 \cdot MN$

$P_{cr.y} := 1000 \cdot MN$

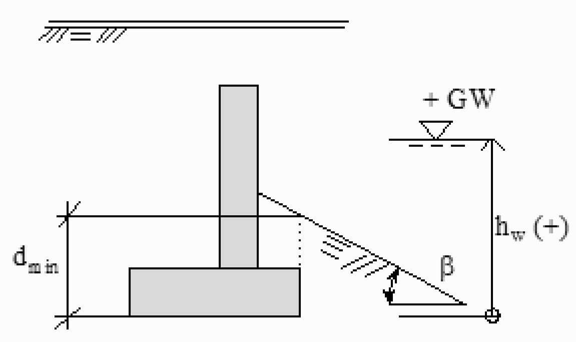
$e_{xd} := 100 \cdot mm$

$e_{yd} := 100 \cdot mm$

Number of loadcombinations

$N \equiv 10 \cdot pcs$

INPUT - geotechnical resistisabce according to "allmänna bärighets ekvationen"
(Calculation accordning to SS-EN 1997-1 attachment D)



Charateristic friction angle: $\phi_k := 39 \cdot °$

Level GW : $h_w = 9.11\ m$

Slope inclination : $\beta := 0 \cdot °$

Lowest foundation depth (= d_1 + d_2): $d_{min} := 1.8 \cdot m$

Dry density : $\gamma := 20 \cdot \frac{kN}{m^3}$

Wet densitet : $\gamma' := 12 \cdot \frac{kN}{m^3}$

Partial material coefficient (M2 och Geo PM):

$\gamma_M := 1.30$

Partial safety coefficient:

$\gamma_d := 0.91$

Partial vertical resistance coeffient (R3):

$\gamma_{R.v} := 1.0$

Partial horizontal resistance coefficient (R3):

$\gamma_{R.h} := 1.0$

CALCULATON

Dead weight bottom slab

$B \equiv (b_1 + b_2 + b_3) = 6.0\ m$

$$V_{bpl} \equiv \begin{cases} \text{if } h_w \le 0 \cdot m \\ \quad B \cdot H_1 \cdot L_1 \cdot \gamma_{btg} \\ \text{also if } h_w \ge H_1 \\ \quad B \cdot H_1 \cdot L_1 \cdot \gamma'_{btg} \\ \text{else} \\ \quad B \cdot L_1 \cdot (h_w \cdot \gamma'_{btg} + (H_1 - h_w) \cdot \gamma_{btg}) \end{cases}$$

$V_{bpl} = 1350\ kN$

$$M_{y.bpl} \equiv V_{bpl} \cdot \frac{B - b_2 - 2 \cdot b_3}{2}$$

$M_{y.bpl} = 0\ kNm$

Dead weight abutment

$$V_{skiva} \equiv \begin{cases} \text{if } h_w \le H_1 \\ \quad b_2 \cdot H_2 \cdot L_2 \cdot \gamma_{btg} \\ \text{also if } h_w \ge (H_1 + H_2) \\ \quad b_2 \cdot H_2 \cdot L_2 \cdot \gamma'_{btg} \\ \text{else} \\ \quad b_2 \cdot L_2 \cdot ((H_1 + H_2 - h_w) \cdot \gamma_{btg} + (h_w - H_1) \cdot \gamma'_{btg}) \end{cases}$$

$V_{skiva} = 0\ kN$

Dead weight filling

$$V_{jord}(b, h, l) \equiv \begin{cases} \text{if } b > 0 \cdot m \\ \quad \begin{cases} \text{if } h_w \le H_1 \\ \quad b \cdot h \cdot l \cdot \gamma_{jord} \\ \text{also if } h_w \ge (H_1 + h) \\ \quad b \cdot h \cdot l \cdot \gamma'_{jord} \\ \text{else} \\ \quad b \cdot l \cdot ((H_1 + h - h_w) \cdot \gamma_{jord} + (h_w - H_1) \cdot \gamma'_{jord}) \end{cases} \\ \text{else} \\ \quad 0 \cdot kN \end{cases}$$

$V_{jord.1} \equiv V_{jord}(a, h_1, L_1) = 0\ kN$

$x_{tp1} \equiv 0.5 \cdot (2 \cdot b_1 - a + b_2) = 3\ m$

$V_{jord.2} \equiv V_{jord}(b_1 - a, h_2, L_1) = 72\ kN$

$x_{tp2} \equiv 0.5 \cdot (b_1 - a + b_2) = 2.075\ m$

$V_{jord.3} \equiv V_{jord}(b_2, h_3, L_1 - L_2) = 31\ kN$

$V_{jord.4} \equiv V_{jord}(b_3, h_4, L_1) = 72\ kN$

$x_{tp4} \equiv -0.5 \cdot (b_2 + b_3) = -2.075\ m$

$V_{jord.tot} \equiv (V_{jord.1} + V_{jord.2} + V_{jord.3} + V_{jord.4}) = 175\ kN$

$M_{y.jord} \equiv V_{jord.1} \cdot x_{tp1} + V_{jord.2} \cdot x_{tp2} + V_{jord.4} \cdot x_{tp4} = 0\ kNm$

Vertical surcharge on bottom slab

$$V_{över} \equiv \begin{cases} 0 \cdot kN & \text{if } a \le 0 \cdot m \\ a \cdot L_1 \cdot q_{över} & \end{cases}$$

$V_{över} = 0\ kN$

$$x_{över} \equiv 0.5 \cdot (2 \cdot b_1 - a + b_2) = 3\ m$$

$$M_{y.över} \equiv x_{över} \cdot V_{över} = 0\ kNm$$

Resulting moments

$$M_{x.tot} = M_x + H_y \cdot z$$

$$M_{y.tot} = M_y - H_x \cdot z$$

Design reactions without second order effects

$V_d = V \cdot \psi_\gamma$ $\quad H_{xd} = H_x \cdot \psi_\gamma$ $\quad H_{yd} = H_y \cdot \psi_\gamma$

$M_{xd.0} = M_{x.tot} \cdot \psi_\gamma$ $\quad M_{yd.0} = M_{y.tot} \cdot \psi_\gamma$

Design veritical bearing load

$V_{d.lager} := V \cdot \psi\gamma$ if $Bearing$ = "Yes"

Design moment incl. seconder effect and geometrical imperfections

$$M_{xd} = \begin{cases} (M_{xd.0} + V_{d.lager} \cdot e_{yd}) \cdot \dfrac{1}{1 - \dfrac{V_{d.lager}}{P_{cr.x}}} & \text{if } M_{xd.0} > 0kNm \\ (M_{xd.0} - V_{d.lager} \cdot e_{yd}) \cdot \dfrac{1}{1 - \dfrac{V_{d.lager}}{P_{cr.x}}} & \text{if } M_{xd.0} \le 0kNm \end{cases}$$

$$M_{yd} = \begin{cases} (M_{yd.0} + V_{d.lager} \cdot e_{xd}) \cdot \dfrac{1}{1 - \dfrac{V_{d.lager}}{P_{cr.y}}} & \text{if } M_{yd.0} > 0kNm \\ (M_{yd.0} - V_{d.lager} \cdot e_{xd}) \cdot \dfrac{1}{1 - \dfrac{V_{d.lager}}{P_{cr.y}}} & \text{if } M_{yd.0} \le 0kNm \end{cases}$$

Load excentricity

$e_x = -\dfrac{M_{yd}}{V_d}$ $\quad e_y = \dfrac{M_{xd}}{V_d}$

Effective width and length

$$B_{ef} = \begin{cases} b_2 + 2b_3 - 2e_x & \text{if } (0.5b_2 + b_3 - e_x) < (b_1 + 0.5b_2 + e_x) \\ 2b_1 + b_2 + 2e_x & \text{otherwise} \end{cases}$$

$$L_{ef} = L_1 - 2|e_y|$$

Verify if bottom slab is standing on at front edge (= "toe") or edge towards bank filling

$$Toe := \begin{cases} \text{if } (0.5 \cdot b_2 + b_3 - e_{x1}) < (b_1 + 0.5 \cdot b_2 + e_{x1}) \\ \quad \text{"Yes"} \\ \text{else} \\ \quad \text{"No"} \end{cases}$$

Verify friction

$$H_d = \sqrt{H_{xd}^2 + H_{yd}^2}$$

$$\mu_d = \frac{H_d}{V_d}$$

Calculate ground pressure

$$\sigma_d = \frac{V_d}{B_{ef} \cdot L_{ef}}$$

Design friction angle

$$\phi_d = \operatorname{atan}\left(\frac{\tan(\phi_k)}{\gamma_M \cdot \gamma_d}\right)$$ $\phi_d = 34\ °$

Overlay pressure

$$d_1 = \text{if}(h_w \geq 0m, \text{if}(h_w \geq d_{min}, 0m, d_{min} - h_w), d_{min})$$ $d_1 = 0\ m$

$$d_2 = d_{min} - d_1$$ $d_2 = 1.8\ m$

$$q = \gamma \cdot d_1 + \gamma' \cdot d_2$$ $q = 22\ kPa$

Calculate θ

$$\theta = \operatorname{asin}\left(\frac{H_{xd}}{H_d}\right)$$

Calculate m_θ

$$m_b = \frac{2 + \frac{B_{ef}}{L_{ef}}}{1 + \frac{B_{ef}}{L_{ef}}} \qquad m_l = \frac{2 + \frac{L_{ef}}{B_{ef}}}{1 + \frac{L_{ef}}{B_{ef}}}$$

$$m_\theta = m_l \cdot \cos(\theta)^2 + m_b \cdot \sin(\theta)^2$$

Density of soil under foundation level

$$\gamma_{ef} = \text{if}\left(h_w \ge 0m, \gamma', \text{if}\left(-h_w \ge B_{ef}, \gamma, \gamma' \cdot \frac{B_{ef} + h_w}{B_{ef}} - \gamma \cdot \frac{h_w}{B_{ef}}\right)\right)$$

Calculate R_q

$$N_q = \frac{1 + \sin(\phi_d)}{1 - \sin(\phi_d)} \cdot e^{\pi \cdot \tan(\phi_d)}$$

$$d_q = \text{if}\left(1 + 0.35 \cdot \frac{d_{min}}{B_{ef}} \ge 1.7, 1.7, 1 + 0.35 \cdot \frac{d_{min}}{B_{ef}}\right)$$

$$s_q = 1 + \frac{B_{ef}}{L_{ef}} \cdot \tan(\phi_d)$$

$$i_q = \left(1 - \frac{H_d}{V_d}\right)^{m_\theta}$$

$$g_q = 1 - \sin(2 \cdot \beta)$$

$$b_q = 1$$

$$R_q = q \cdot N_q \cdot d_q \cdot s_q \cdot i_q \cdot g_q \cdot b_q \cdot \frac{B_{ef} \cdot L_{ef}}{\gamma_{R.v}}$$

Calculate R_γ

$$F_\phi = 0.08705 + 0.3231 \cdot \sin(2 \cdot \phi_d) - 0.04836 \cdot \sin(2 \cdot \phi_d)^2$$

$$N_\gamma = F_\phi \cdot \left(\frac{1 + \sin(\phi_d)}{1 - \sin(\phi_d)} \cdot e^{1.5 \cdot \pi \cdot \tan(\phi_d)} - 1 \right)$$

$$d_\gamma = 1$$

$$s_\gamma = 1 - 0.4 \cdot \frac{B_{ef}}{L_{ef}}$$

$$i_\gamma = \left(1 - \frac{H_d}{V_d} \right)^{m_b + 1}$$

$$g_\gamma = g_q$$

$$b_\gamma = 1$$

$$R_\gamma = 0.5 \cdot \gamma_{ef} \cdot B_{ef} \cdot N_\gamma \cdot d_\gamma \cdot s_\gamma \cdot i_\gamma \cdot g_\gamma \cdot b_\gamma \cdot \frac{B_{ef} \cdot L_{ef}}{\gamma_{R.v}}$$

Calculate geotechnical resistance R_d

$$R_d = R_q + R_\gamma$$

Calculate permissible ground pressure

$$\sigma_{d.till} = \frac{R_d}{B_{ef} \cdot L_{ef}}$$

Calculate permissible design frictional coeffecient

$$\mu_{d.till} = \frac{\tan(\phi_d)}{\gamma_{R.h}}$$

RESULTS

Bearing loads

Refers to load from the superstructure that is supplemented by second-order effects.

	ULS a	ULS b	ULS c	ULS d	ULS e	ULS f	ULS g	ULS h	ULS i	ULS j	Enhet
$V_{d.lager}$	3816	5089	4914	4221	7700	3361	6100	5151	3816	5089	kN

First-order reactions excl. second-order effects

	ULS a	ULS b	ULS c	ULS d	ULS e	ULS f	ULS g	ULS h	ULS i	ULS j	Enhet
V_d	5845	6597	6422	5729	9208	5390	8129	6676	5341	7118	kN
H_{xd}	643	1192	698	1083	1257	620	1177	710	643	1192	kN
H_{yd}	0	155	-454	454	109	-247	353	-353	0	155	kN
$M_{xd.0}$	0	478	-2435	2435	-1352	-1061	3310	-3310	0	478	kNm
$M_{yd.0}$	-1311	-2149	-1540	-1886	-2611	-1216	-2278	-1589	-1311	-2149	kNm

Dead weight abutment

$V_{bpl} = 1350\ kN$

$V_{skiva} = 0\ kN$

$V_{egen.tot} \equiv V_{bpl} + V_{skiva}$

$V_{egen.tot} = 1350\ kN$

$M_{y.egen} \equiv M_{y.bpl}$

$M_{y.egen} = 0\ kNm$

Load of earth filling on bottom slab

$V_{jord.tot} = 175\ kN$

$M_{y.jord} = 0\ kNm$

Vertical load effect on bottom slab

$V_{över} = 0\ kN$

$M_{y.över} = 0\ kNm$

Design friction angle

$\phi_d = 34\ °$

Overlay pressure

$q = 22\ kPa$

Resultat inkl. geometriska imperfektioner och 2:a ordningens moment

	ULS a	ULS b	ULS c	ULS d	ULS e	ULS f	ULS g	ULS h	ULS i	ULS j	Unit
V_d	5845	6597	6422	5729	9208	5390	8129	6676	5341	7118	kN
H_{xd}	643	1192	698	1083	1257	620	1177	710	643	1192	kN
H_{yd}	0	155	-454	454	109	-247	353	-353	0	155	kN
M_{xd}	-383	992	-2941	2869	-2138	-1402	3944	-3845	-383	992	kNm
M_{yd}	-1699	-2671	-2041	-2318	-3407	-1557	-2906	-2115	-1699	-2671	kNm
e_x	0,29	0,40	0,32	0,40	0,37	0,29	0,36	0,32	0,32	0,38	m
e_y	-0,07	0,15	-0,46	0,50	-0,23	-0,26	0,49	-0,58	-0,07	0,14	m
B_{ef}	5,42	5,19	5,36	5,19	5,26	5,42	5,29	5,37	5,36	5,25	m
L_{ef}	9,87	9,70	9,08	9,00	9,54	9,48	9,03	8,85	9,86	9,72	m
σ_d	109	131	132	123	184	105	170	141	101	139	kPa
$\sigma_{d,till}$	1424	1179	1378	1133	1324	1390	1294	1411	1384	1224	kPa
μ_d	0,11	0,18	0,13	0,20	0,14	0,12	0,15	0,12	0,12	0,17	-
$\mu_{d,till}$	0,68	0,68	0,68	0,68	0,68	0,68	0,68	0,68	0,68	0,68	-
"Toe"	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes/No
Θ	90	83	57	67	85	68	73	64	90	83	deg
m	1,65	1,65	1,55	1,59	1,64	1,60	1,61	1,57	1,65	1,64	-
N_q	30,9	30,9	30,9	30,9	30,9	30,9	30,9	30,9	30,9	30,9	-
d_q	1,12	1,12	1,12	1,12	1,12	1,12	1,12	1,12	1,12	1,12	-
s_q	1,38	1,37	1,40	1,39	1,38	1,39	1,40	1,42	1,37	1,37	-
i_q	0,83	0,72	0,81	0,69	0,79	0,81	0,77	0,82	0,81	0,74	-
g_q	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	-
b_q	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	-
R_q	45230	36950	41121	33814	40522	43116	38340	41055	43792	38528	kN
γ_{ef}	12,0	12,0	12,0	12,0	12,0	12,0	12,0	12,0	12,0	12,0	kN/m^3
F_ϕ	0,35	0,35	0,35	0,35	0,35	0,35	0,35	0,35	0,35	0,35	-
N_γ	30,99	30,99	30,99	30,99	30,99	30,99	30,99	30,99	30,99	30,99	-
d_γ	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	-
s_γ	0,78	0,79	0,76	0,77	0,78	0,77	0,77	0,76	0,78	0,78	-
i_γ	0,73	0,59	0,70	0,55	0,68	0,71	0,65	0,72	0,71	0,61	-
g_γ	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	-
b_γ	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	-
R_γ	30893	22425	26048	19129	25903	28349	23423	25921	29377	23946	kN
R_d	76124	59374	67169	52944	66425	71465	61763	66976	73168	62475	kN