Client: **Hexion B.V.**
Project: **Formaline Storage Bund**

Load and Strength Calculation
Tank Foundation Slab and Tank Pit
Formaline Storage Bund

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Annexes:

Annex Nr.	Title document	Revision	Date
Annex A	Scia Engineer Input & Output	1	07-2020
Annex B	Technosoft Input & Output	1	07-2020
Annex C	Anchor bolt check Input & Output	1	10-2020
Annex D	Anchors steel structure	1	09-2020

1 Introduction

See chapter 1 of 53591-1311001: Uitgangspunten (basis of design)

1.1 Scope of this document

In this document, calculations of the strength, stability and reinforcement of the tank foundation slab and tank pit are presented.

1.2 Design description

This figure below shows the foundation plan of the project.

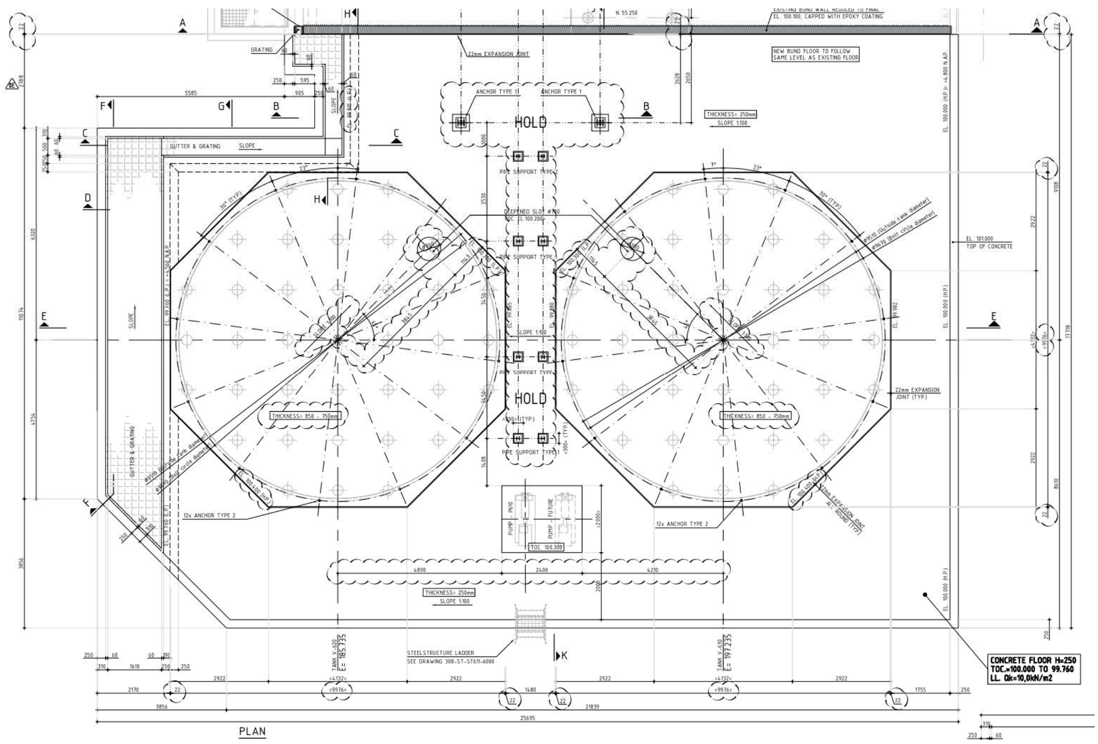


Figure 1-1 Foundation plan

Tank foundation slab

The tank foundation slab is octagonal, width approximately 10m and a thickness variating from 750mm to 850mm. Concrete piles (type “Fundex” Ø380/450) support this slab. The effect of the soil under the tank foundation slab is neglected.

Tank Pit

The area of the tank-pit is approximately 460m2 (= 26x18m) and the slab thickness is 250mm except the pump foundation slab which has thickness 550mm (the bottom level is same). The tank-pit wall height is 1,1m for the normal slab part and 1,5m at the drainage pit. Both wall have a thickness of 250mm.

The tank-pit slab is founded on the ground soil, no piles to be used. Therefore, to avoid any negative effect from the tank foundation, expansion joints between the tank foundation and the tank-pit slab are introduced.

1.3 Revisions

1.3.1 Revision 0A

First issue.

1.3.2 Revision 0B

Additional information about foundation settlement is provided.

1.3.3 Revision 1

Items below have been updated.

- Tank design loads
- Pump foundation location
- Piping support loads
- Expansion joints

2 Applicable codes & regulations

See chapter 2 of 53591-01-1311001: Uitgangspunten (basis of design)

3 Loads, load cases and combination

See chapter 3 of 53591-01-1311001: Uitgangspunten (basis of design) for general information

3.1 Tank foundation slab

3.1.1 LC_01: Self-weight

	Permanente Belasting (= D_e)			
	OW reinforced concrete = 2500 kg/m³ →	g_k =	25,0	kN/m³
	OW galv. steel m = 8000 kg/m³ →	g_k =	80,0	kN/m³

<u>Note:</u>

Scia Engineer generates the self-weight of the structure automatically

3.1.2 LC_02: Tank empty

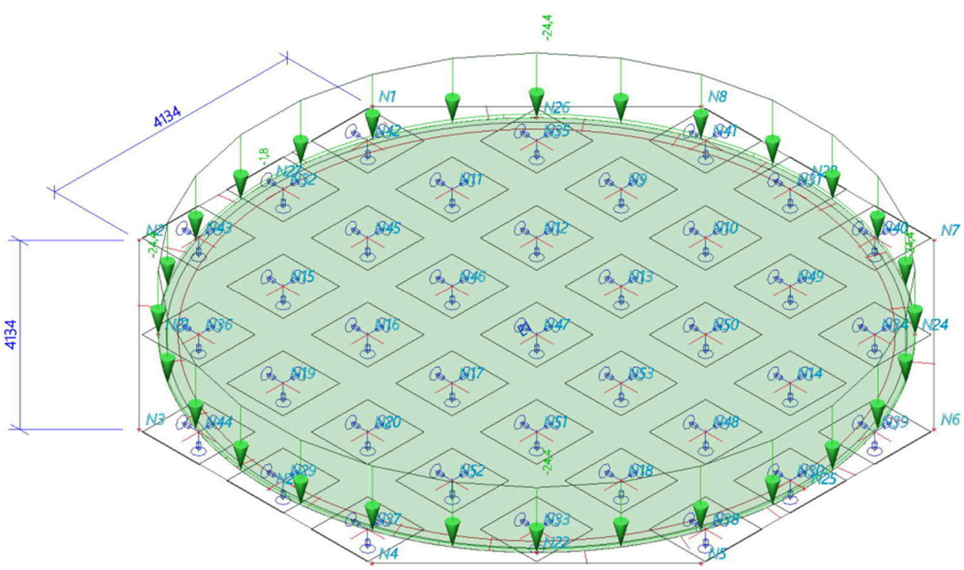


Figure 3-1 Tank empty weight

LC_02:	**Tank empty Equipment (= D_s)**			
	Tanks V620 / V630: D = Ø9,5m, H = 10,0m V=720m³ Acc. to information Hexion (dd.11-07-2019) doc. 308-EQ-ED-V620-6000-Bulk Formalin Storage Vessel--Spec[0A]	g_k =	500	kN
	10% extra for connecting piping on tank → p_k = 1,1 × 500 →	g_k =	550	kN
	Load on foundation tank D = Ø9,5m: $\rightarrow m_k = \dfrac{550}{\pi \times 9{,}5} = 18{,}5\,kN/m \rightarrow$	g_k =	18,5	kN/m¹
	Insulation and finishing: $\rightarrow m_k = 40\,kg/m^2 \rightarrow$			

	Roof: $\rightarrow m_k = \frac{\frac{1}{4}\pi 9{,}7^2 \times 0{,}4}{\pi \times 9{,}5} = 1{,}0\,kN/m \rightarrow$	g_k =	1,0	kN/m¹
	Perimeter: $\rightarrow m_k = 10 \times 0{,}4 = 4{,}0\,kN/m \rightarrow$	g_k =	4,0	kN/m¹
	Hand railing	g_k =	0,4	kN/m¹
	Cage ladder and platform: $\rightarrow m_k = \frac{13{,}2}{\pi \times 9{,}5} = 18{,}5\,kN/m \rightarrow$	g_k =	0,5	kN/m¹
		$\sum g_k$ =	**24,4**	**kN/m¹**
	Cage ladder (2x) H = 6m $\rightarrow m_k = 2 \times 6{,}0 \times 70 = 840kg \rightarrow$	g_k =	8,4	kN
	Platform LxB = 2,4 x 1,2 m: $\rightarrow m_k = 2{,}4 \times 1{,}2 \times 100 = 288\,kg \rightarrow$	g_k =	2,9	kN
	Handrailing platform: $\rightarrow m_k = (2{,}4 + 2 \times 1{,}2) \times 40 = 192\,kg \rightarrow$	g_k =	1,9	kN
		$\sum g_k$ =	**13,2**	**kN**
	Bottom tank: D = Ø9,5m: $\rightarrow m_k = 0{,}006 \times 8000 = 48\,kg/m^2$	g_k =	0,5	kN/m²
	Oil-sand layer H=50mm: $\rightarrow m_k = 0{,}05 \times 2000 = 100\,kg/m^2 \rightarrow$	g_k =	1,0	kN/m²
	Foamglass 100mm: $\rightarrow m_k = 10\,kg/m^2 \rightarrow$	g_k =	0,1	kN/m²
		Σg_k =	1,6	kN/m²
	10% extra for connecting piping $\rightarrow p_k = 1{,}1 \times 1{,}6 \rightarrow$	**g_k =**	**1,8**	**kN/m²**

3.1.3 LC_11: Tank operating

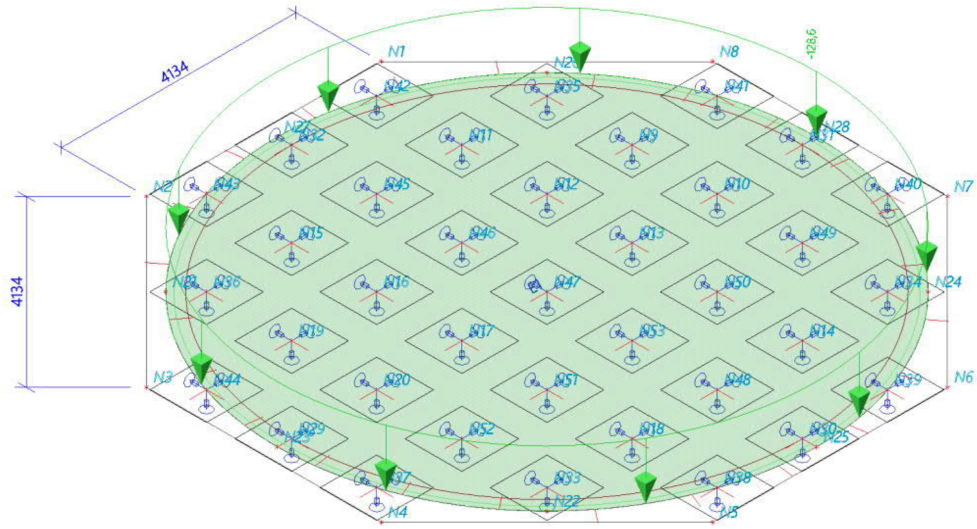


Figure 3-2 Tank operating weight

LC_11:	**Tank operating Equipment (= D_o)**			
	Tanks V620 / V630: D = Ø9,5m, H = 10,0m V=720m³ Acc. to information Hexion (dd.11-07-2019) doc. 308-EQ-ED-V620-6000-Bulk Formalin Storage Vessel--Spec[0A]	g_k =	8288	kN
	10% extra for connecting piping on tank → p_k = 1,1 × 8288→	g_k =	9117	kN
	Load on foundation tank D = Ø9,5m:			
	$\rightarrow m_k = \frac{9117}{\frac{1}{4}\pi 9{,}5^2} = 1{,}1\, kN/m^2$	**g_k =**	**128,6**	**kN/m²**

3.1.4 LC_12: Platform live load

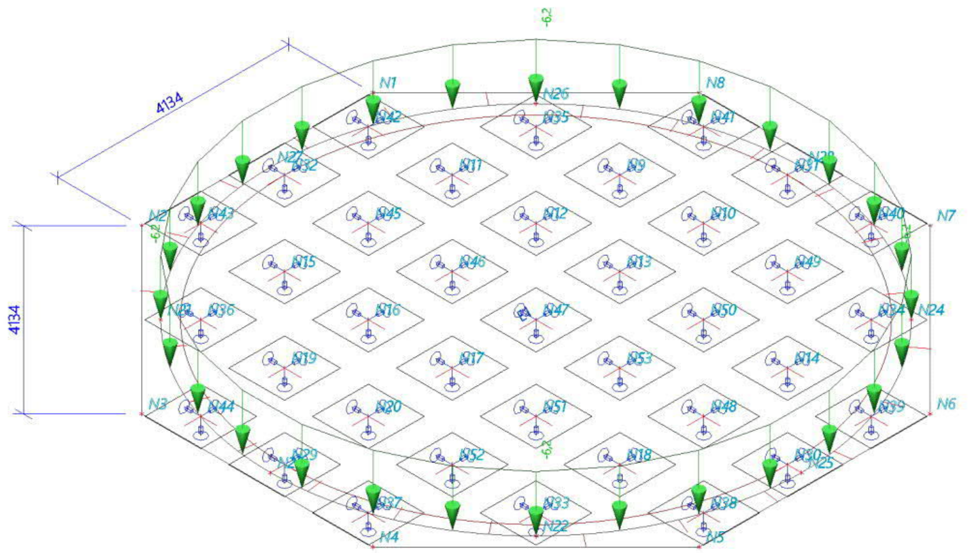


Figure 3-3 Platform live load

LC_12:	**Platform live load (= L)**			
	Tanks V620 / V630: D = Ø9,5m, H = 10,0m V=720m³			
	Load Roof on foundation tank D = Ø9,5m: $\rightarrow m_k = \dfrac{\frac{1}{4}\pi 9{,}5^2 \times 1{,}6}{\pi \times 9{,}5} = 3{,}8\, kN/m \rightarrow$	g_k =	**3,8**	kN/m¹
	Hand railing	g_k =	2,0	kN/m¹
	Cage ladder or platform: $\rightarrow m_k = 2{,}4 \times 1{,}2 \times 400 = 1152\, kg \rightarrow$ $\rightarrow m_k = \dfrac{1152}{\pi \times 9{,}5} = 38{,}6\, kN/m \rightarrow$	g_k =	0,4	kN/m¹
		$\sum g_k$ =	**6,2**	**kN/m¹**

3.1.5 LC_13: Tank uplift pressure

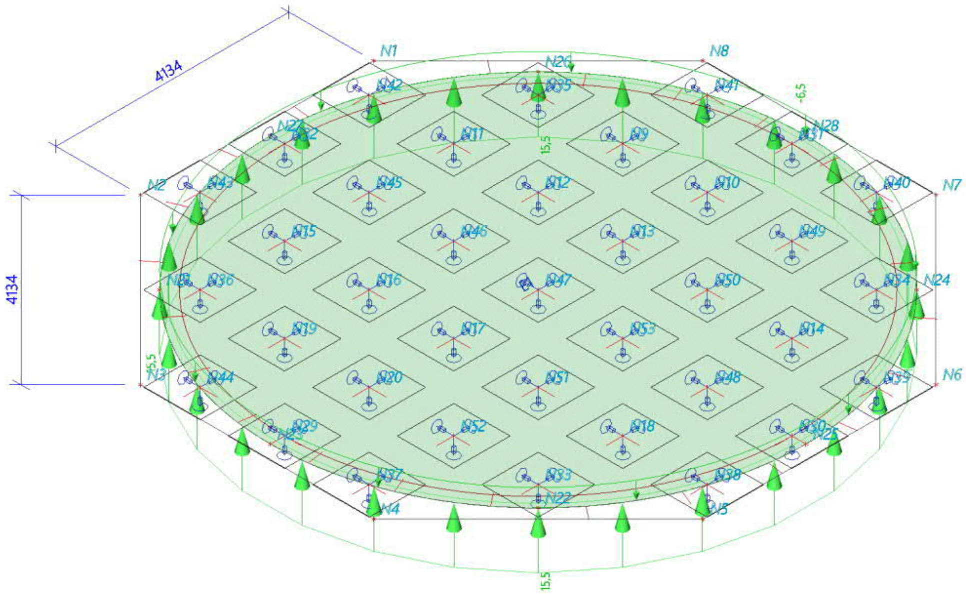


Figure 3-4 Uplift pressure

LC_13:	**Tank uplift pressure (= L)**			
	Tanks V620 / V630: D = Ø9,5m, H = 10,0m V=720m³ Acc. to information Hexion (dd.11-07-2019) doc. 308-EQ-ED-V620-6000-Bulk Formalin Storage Vessel--Spec[0A]			
	Design pressure Q = 0,065 barg	P_k =	6,5	kN/m²
	Load Roof on foundation tank D = Ø9,5m: $\rightarrow m_k = \frac{-\frac{1}{4}\pi 9{,}5^2 \times 6{,}5}{\pi \times 9{,}5} = -15{,}5\, kN/m \rightarrow$	g_k =	-15,5	kN/m¹

3.1.6 LC_21 to LC_28: Wind load

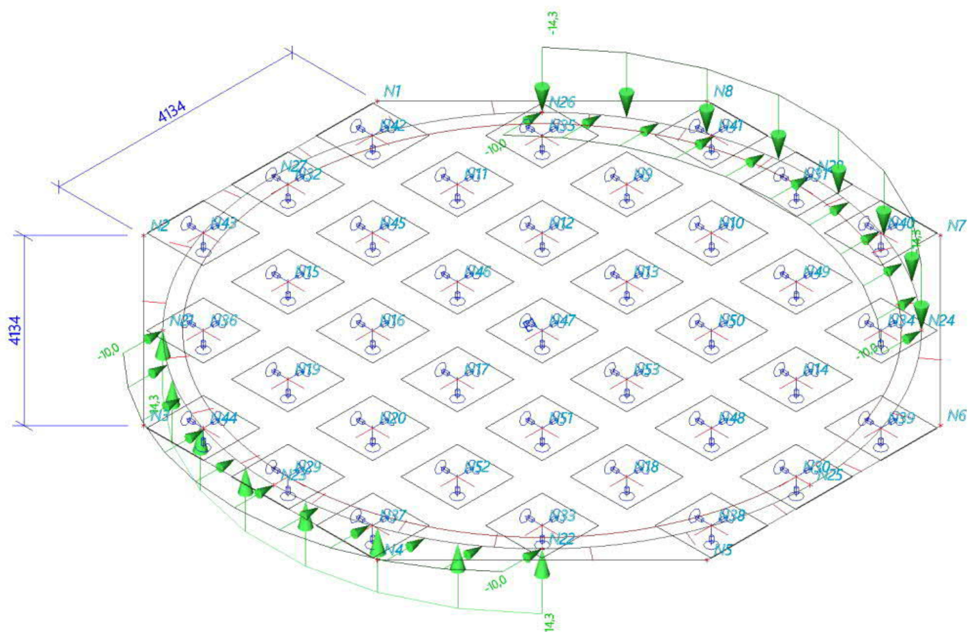


Figure 3-5 Wind load LC_21

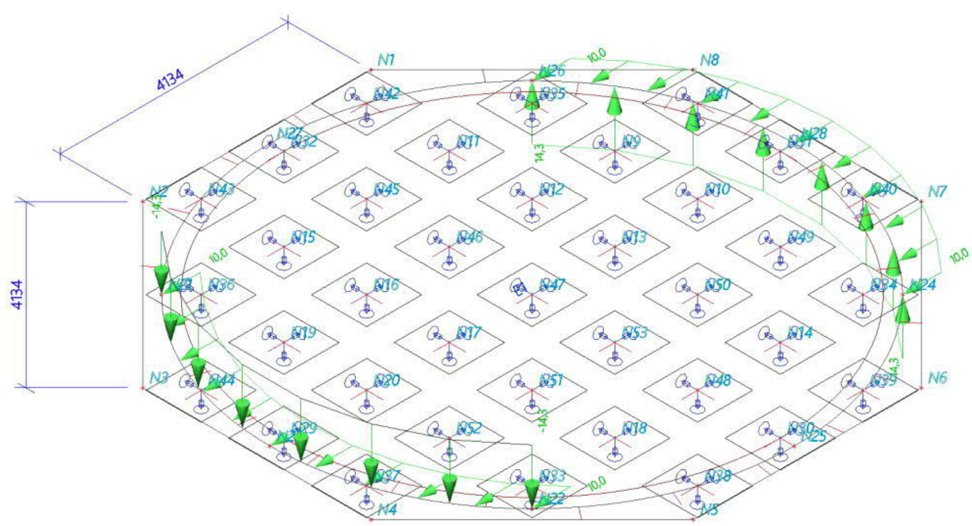


Figure 3-6 Wind load LC_22

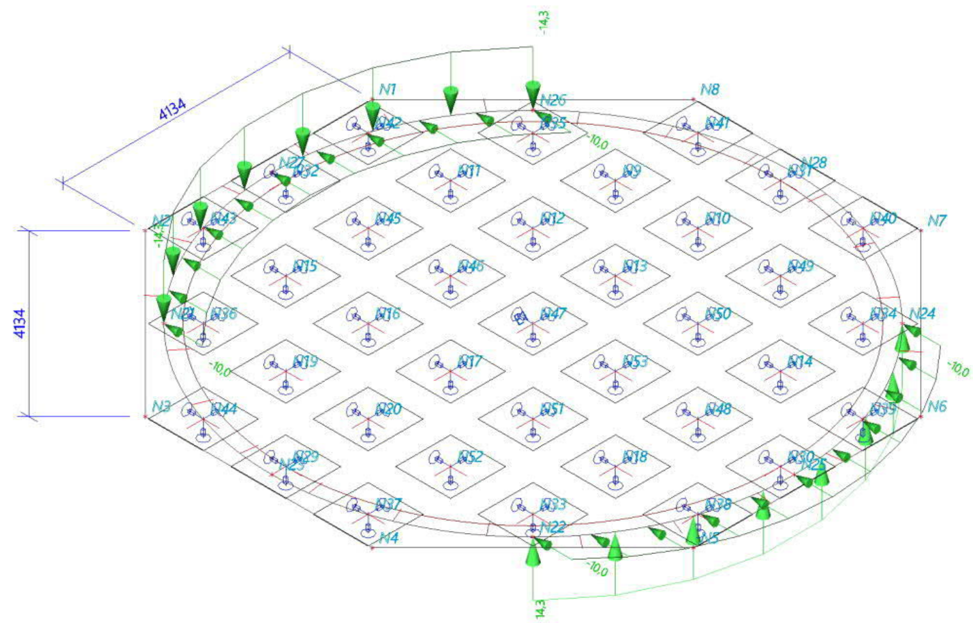


Figure 3-7 Wind load LC-23

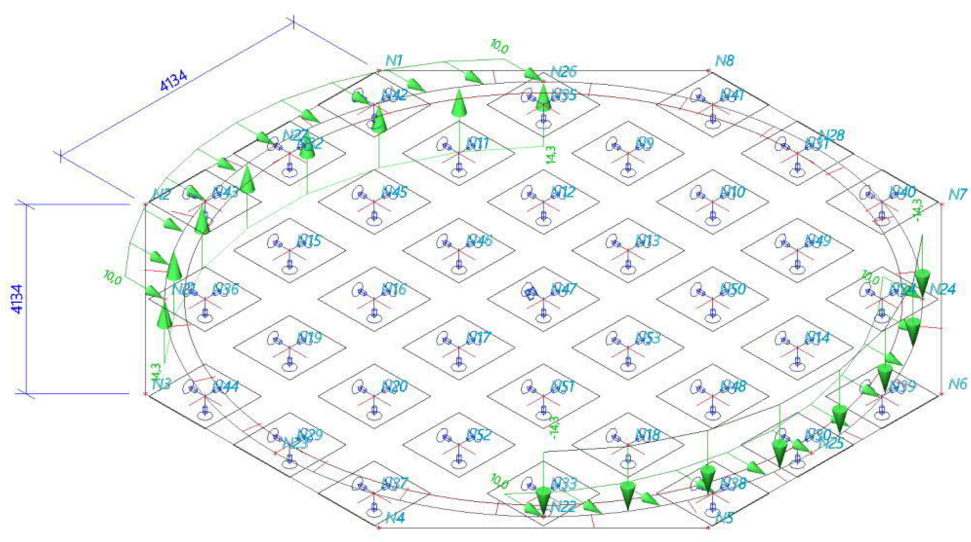


Figure 3-8 Wind load LC_24

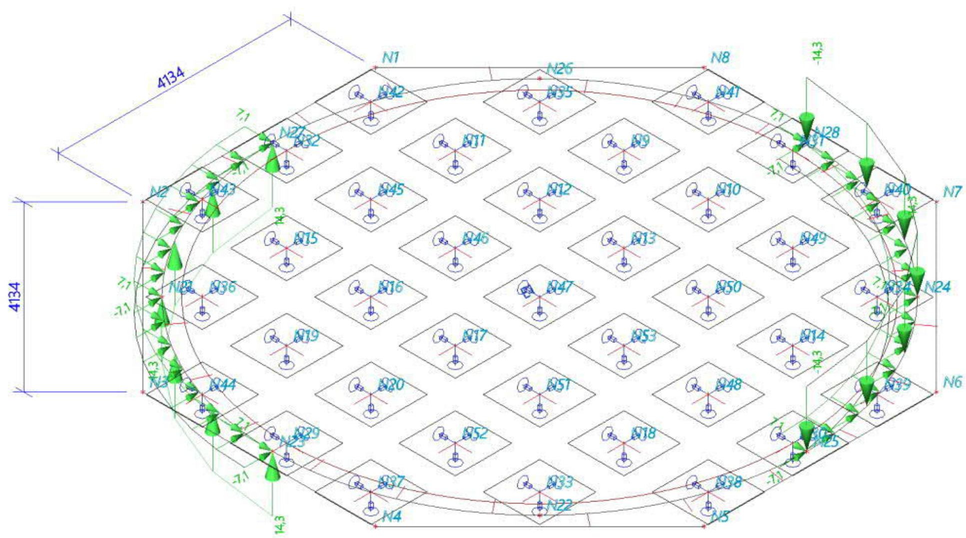


Figure 3-9 Wind load LC-25

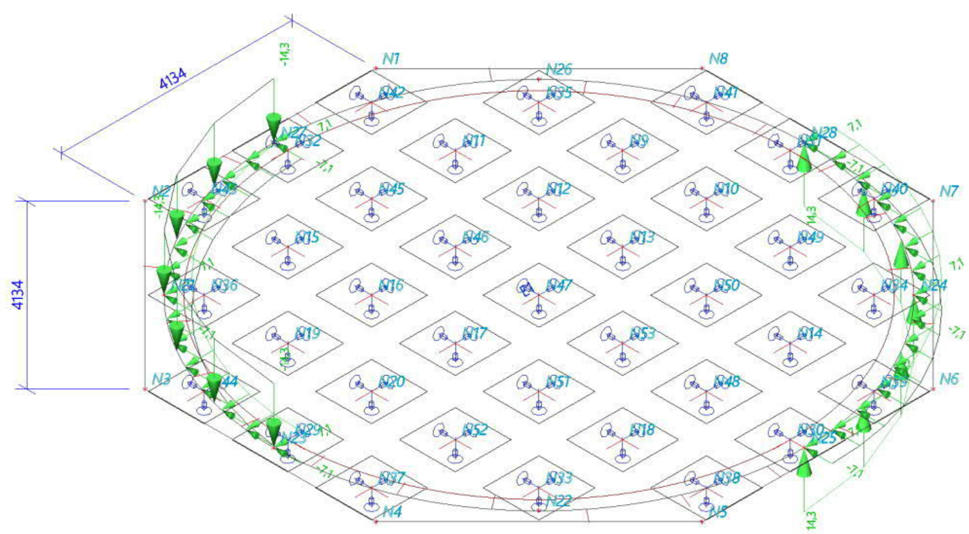


Figure 3-10 Wind load LC_26

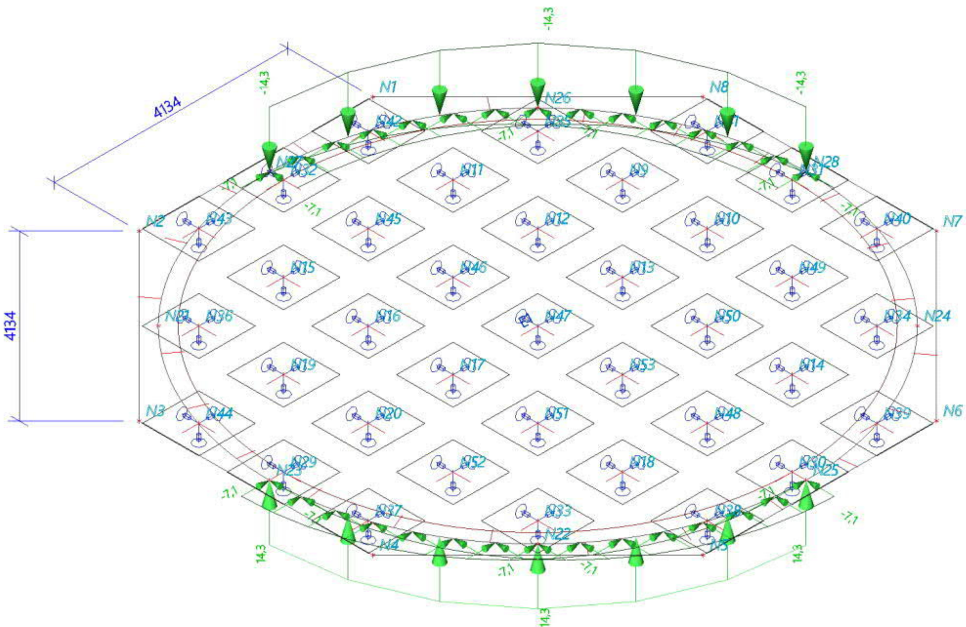


Figure 3-11 Wind load LC-27

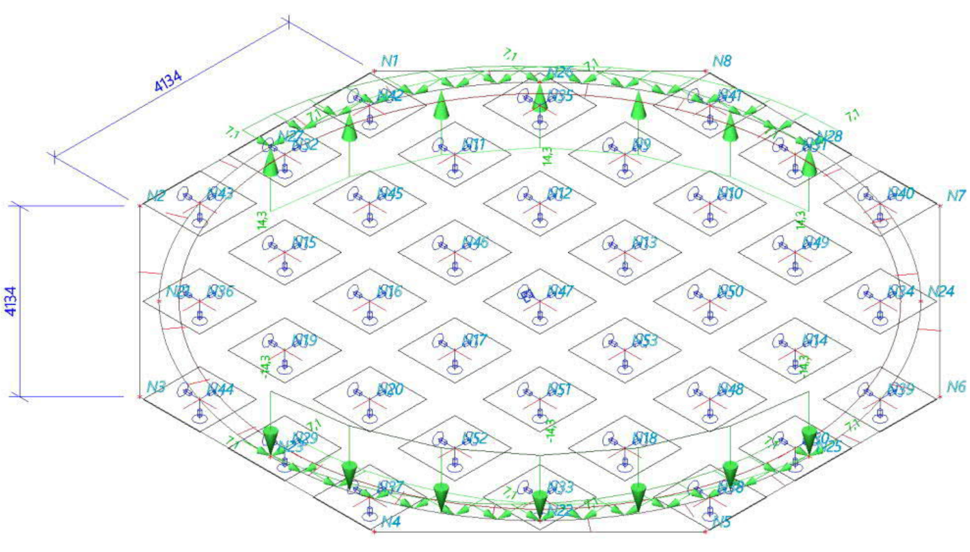


Figure 3-12 Wind load LC_28

The height of the structure is assumed 12m incl. influence of a platform.

LC_21 → LC_28:	**Wind load (= W)**			
	Wind load acc. NEN-EN 1991-1-4 + NB			
	Orography factor acc. A.3 NEN-EN 1991-1-4/NB	c_o=	**1,0**	
	Terrain category acc. figure NB.1 and table NB.3-4.1		**II**	
	Wind area (unbuilt area)		**II**	
	Max. height (from EL.0.000+)	h_{max} =	**12,0**	m
	Basic wind velocity $v_{b,0}$ acc. table NB.1	$v_{b,0}$ =	**27,0**	m/s
	Wind force $q_w(z)$ vlgs. 4.5	$q_w(z)$ =	**0,91**	kN/m²
	Structural factor c_sc_d acc. 6.2 NEN-EN 1991-1-4/NB	c_sc_d =	**1,0**	-
	Wind forcet $q_p(z)$ = c_sc_d $q_p(z)$ = 1,0 x 0,90 =	$q_p(z)$ =	**0,91**	kN/m²
	Force coefficient tank	C_f =	+1,2	
	Factor κ acc to NEN-EN 1991-1-4 7.9.3	κ =	1,15	
	End factor ψ_λ acc. to NEN-EN 1991-1-4 7.13	ψ_λ =	1,0	
	Force coëfficiënt $C_{f;0} = C_f \kappa \psi_\lambda = 1{,}2 \times 1{,}15 \times 1{,}0 =$	$C_{f;0}$ =	**1,38**	
	Friction Roof	$c_{f;r}$ =	**0,04**	
	Wind moment on foundation $M_{wk} = \frac{1}{2} D_p C_{f0} q_p(z) H^2 + C_{fr} q_p(z) A_p H \rightarrow$			
	$M_{wk} = \frac{1}{2} \times 1{,}38 \times 9{,}7 \times 0{,}91 \times 12{,}0^2 =$	$M_{w;k}$ =	878	kNm
	$M_{wk} = 0{,}04 \times 0{,}91 \times \frac{1}{4}\pi 9{,}7^2 \times 12{,}0 =$	$M_{w;k}$ =	32	kNm
		$\sum M_{w;k}$ =	**910**	**kNm**
	Distribution wind load on foundation with angle	α =	**90**	°
	$q_w(z) = \frac{M_{wk}}{D_p^2 \sin\frac{\alpha}{2}} = \frac{910}{9{,}5^2 \times \sin\frac{90}{2}} =$	q_w =	**±14,3**	kN/m
	$H_{w;k} = \frac{C_{f0} q_p(z) D_p H + C_{fr} q_p(z) A_p}{\frac{1}{4}\pi D_p} \rightarrow$ $H_{w;k} = \frac{1{,}38 \times 0{,}91 \times 9{,}7 \times 12{,}0 + 0{,}04 \times 0{,}91 \times \frac{1}{4}\pi 9{,}7^2}{\frac{1}{2}\pi 9{,}5} =$	$H_{w;k}$ =	**±10,0**	kN/m

3.1.7 LC_31: Snow load

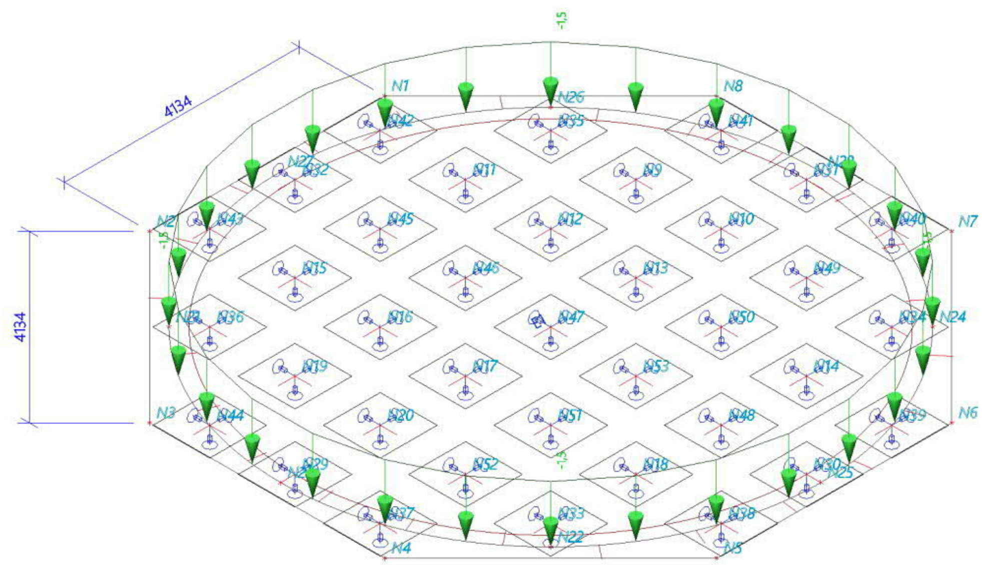


Figure 3-13 Snow load

LC_31:	Snow load (= S)			
	Tanks V620 / V630: D = Ø9,5m, H = 10,0m V=720m³			
	$s = \mu_1 C_e C_t s_k = 0{,}8 \times 1{,}0 \times 1{,}0 \times 0{,}7 \ \rightarrow$	s =	0,6	kN/m²
	Snow load acc. To NEN-EN 1991-1-3/NB			
	Load Roof on foundation tank D = Ø9,7m: $\rightarrow m_k = \frac{\frac{1}{4}\pi 9{,}7^2 \times 0{,}6}{\pi \times 9{,}7} = 1{,}5\, kN/m \rightarrow$	g_k =	1,5	kN/m¹

3.2 Tank-pit slab

Note:

At the moment of writing this report, the weight of pump, location of piping supports and the loads from the steel member are not fixed. Therefore, some assumptions are made for them. These assumptions should be verified when there are fixed information available.

3.2.1 LC_01: Self-weight

	Self Weight (= D_e)			
	SW reinforced concrete = 2500 kg/m^3 $\rightarrow$	g_k =	25,0	kN/m^3
	SW galv. steel m = 8000 kg/m^3 $\rightarrow$	g_k =	80,0	kN/m^3

Note:

Scia Engineer generates the self-weight of the structure automatically

3.2.2 LC_11: Live load on the floor

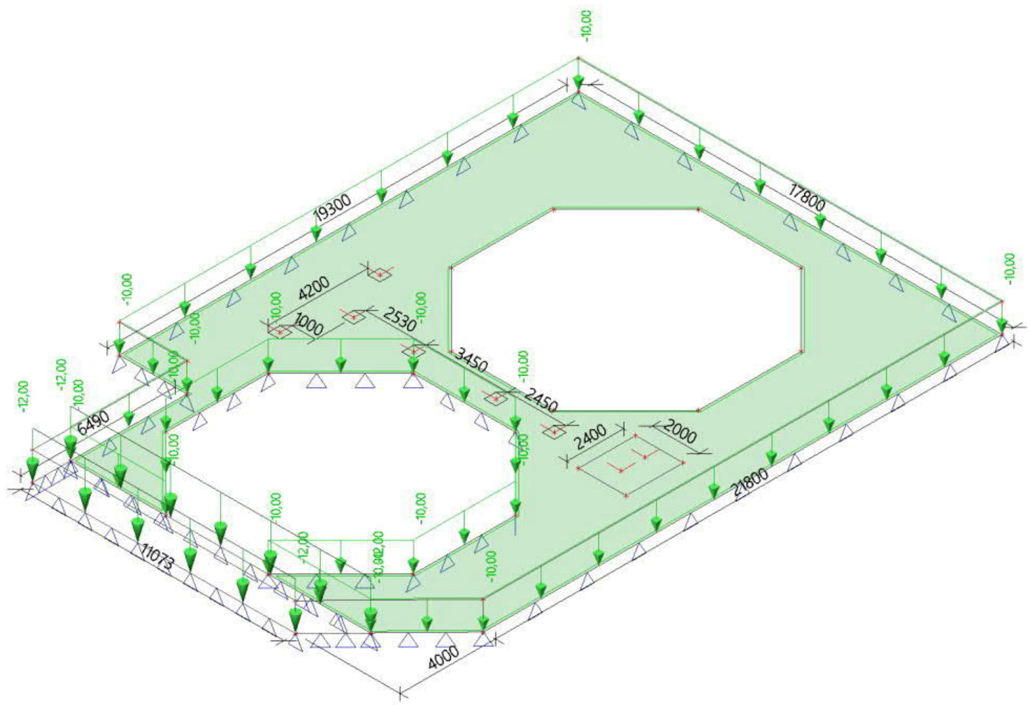


Figure 3-14 Live load in the tank pit

	Opgelegde belasting (= L) (volgens de bestaande berekening: 1134001 Strenght Calculation R.C. Foundation)			
	Vloer tankput: $m_k = 1000\,kg/m^2 \rightarrow$	q_k =	10,0	kN/m²
	Dak tank Conform opgave datasheet tank Hexion: $m_k = 160\,kg/m^2 \rightarrow$	q_k =	**1,6**	kN/m²
	Looppaden, bordessen en trappen: $m_k = 400\,kg/m^2 \rightarrow$	q_k =	4,0	kN/m²
	Handrailing	q_k =	2,0	kN/m¹

3.2.3 LC_12: Pumps

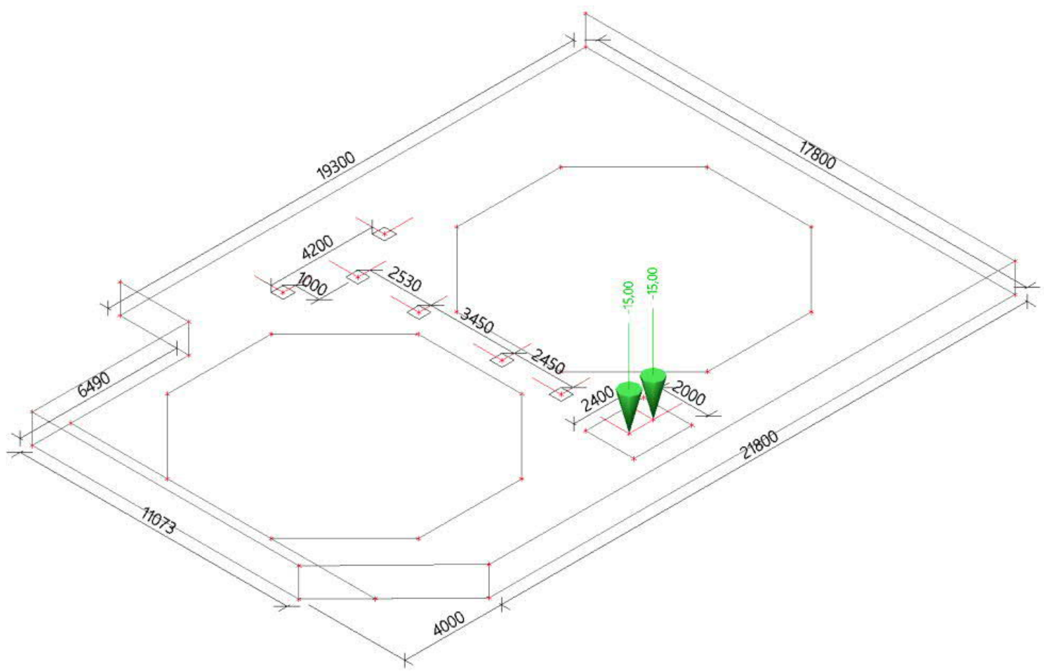


Figure 3-15 Pump weight

	Pump			
	Pump (per pump, acc. to Hexion)	F_k =	15,0	kN

3.2.4 LC_13: Reaction force from steel structure

Reaction forces as given in layout below for both (1) columns for the expansion of the existing pipe rack and (2) for piping supports between the tank foundations are based on preliminary design loads and assumptions.

In a later stage when the steel structures are final, the correct loads in the model will be added to verify the strength of the foundation of the tank pit.

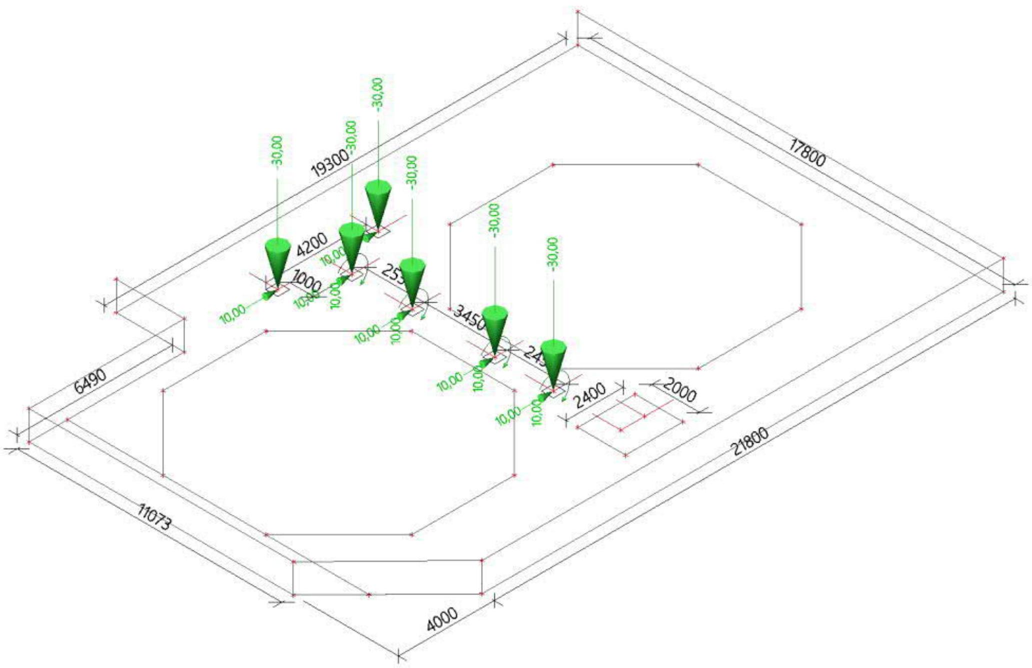


Figure 3-16 Reaction force from steel structure

3.2.5 LC_14: Calamity load

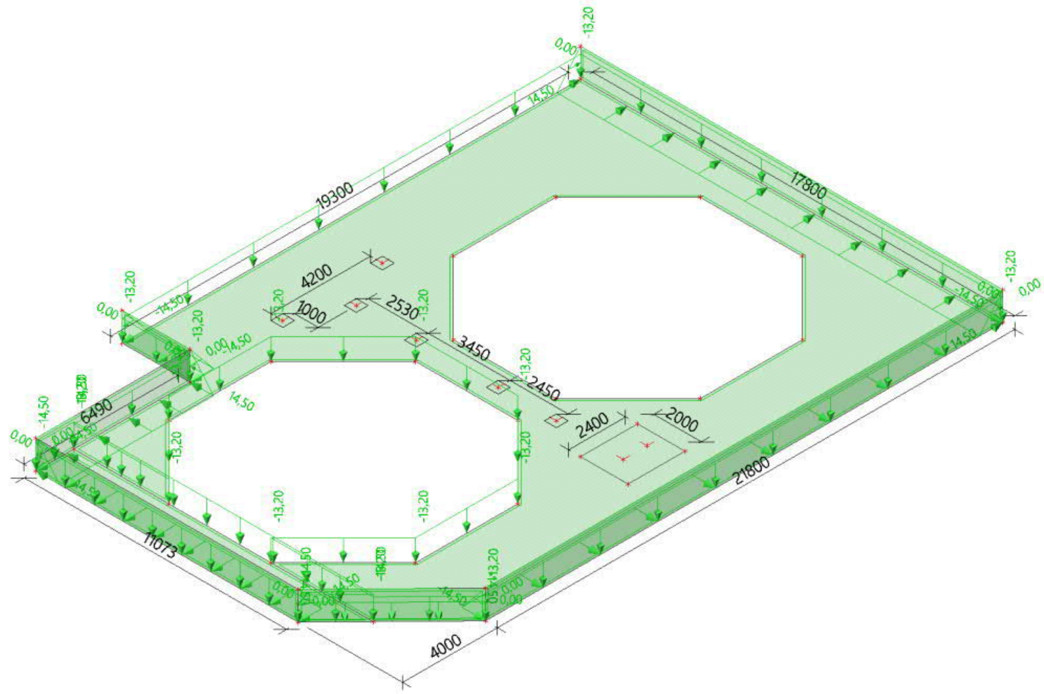


Figure 3-17 Reaction force from steel structure

	Calamity Load (= C)			
	0,8m Formaline and 0,4m fire water (lowest elavation))			
	On floor tank pit $\rightarrow m_k = 0{,}8 \times 1150 + 0{,}3 \times 1000 = 1320\,kg/m^2 \rightarrow$	q_k =	13,2	kN/m²
	In gutter and tank pit wall $\rightarrow m_k = 1{,}0 \times 1150 + 0{,}3 \times 1000 = 1450\,kg/m^2 \rightarrow$	q_k =	14,5	kN/m²

4 Combinations of actions

See chapter 4 of 53591-01-1311001 Uitgangspunten (basis of design)

5 Load and strength calculation Tank foundation

For the results given in the following chapters, see SCIA calculation in Annex A.

Foundation data is taken from the foundation advice (R1901679-02) which was made by MOS.

5.1 Load calculation Tank foundation

Pile data

- Pile dimensions: 380 mm / 450 mm
- Pile length: approximately 22 m (pile tip elevation: NAP -17,5 m)
- Bearing resistance capacity of the pile: 680 kN
- Stiffness in z direction: 62 MN/m
- Stiffness in x,y direction: 3,1 MN/m

Pile reaction force

- The largest compression on pile: 551,2 kN < 680 kN → O.K.
- The largest tension on pile: N/A

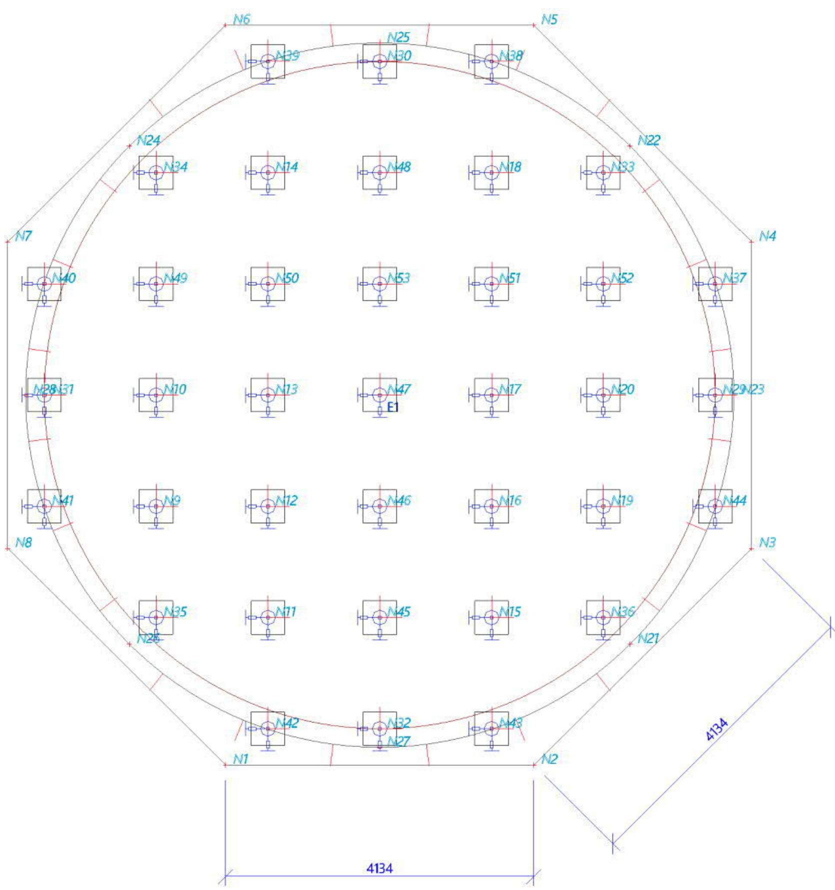


Figure 5-1 Layout piling plan

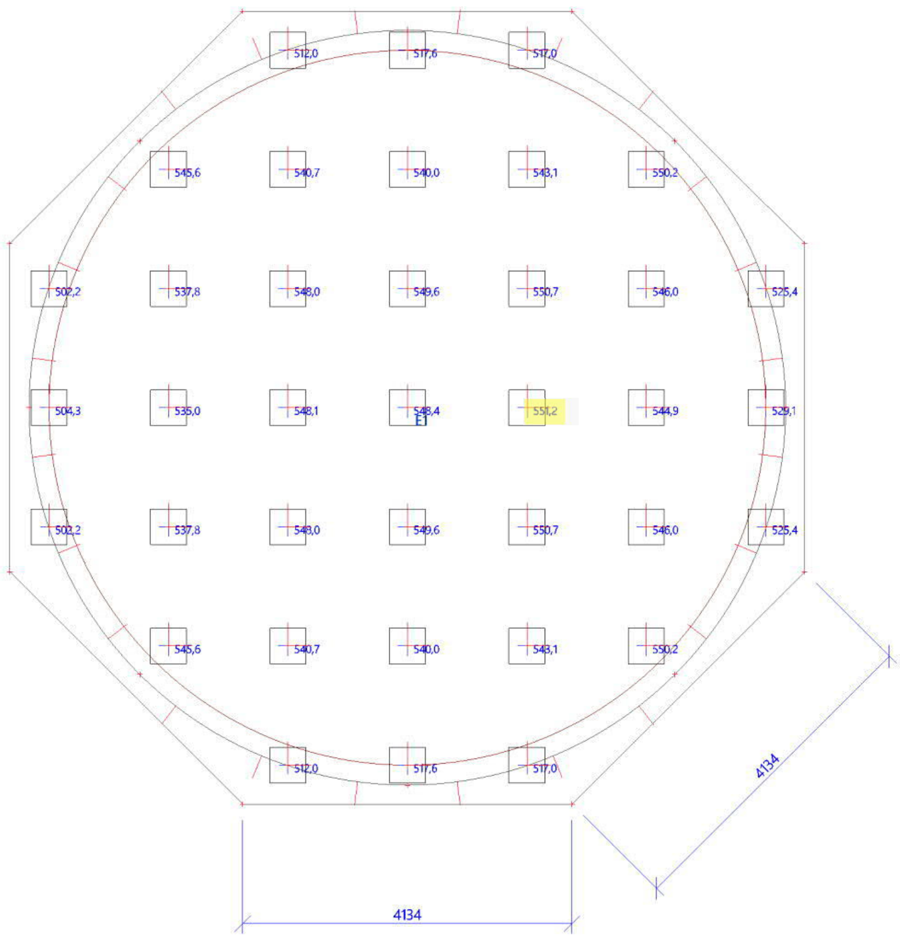


Figure 5-2 Maximum pile reactions

Reacties

Lineaire berekening

Klasse: ULS_All

Knoopreacties

Naam	BG	R_x [kN]	R_y [kN]	R_z [kN]	M_x [kNm]	M_y [kNm]	M_z [kNm]
Sn15/N31	ULS_02/1	**-6,7**	0,0	19,2	0,0	0,0	0,0
Sn15/N31	ULS_01/2	**6,7**	0,0	80,5	**0,0**	**0,0**	**0,0**
Sn14/N30	ULS_04/3	0,0	**-6,7**	85,8	0,0	0,0	0,0
Sn14/N30	ULS_03/4	0,0	**6,7**	25,5	0,0	0,0	0,0
Sn24/N40	ULS_02/1	-6,7	0,0	**18,4**	0,0	0,0	0,0
Sn9/N17	ULS_12/5	-6,7	0,0	**551,2**	0,0	0,0	0,0

5.2 Concrete foundation slab

5.2.1 Minimum reinforcement in tank foundation

The minimum cross-section for the reinforcement to be used acc. to NEN-EN 1992-1-1 art.9.2.1.

ASSUMPTION: main reinforcement in the foundation Ø16-100 (A_s = 2010 mm²/m)

5.2.1.1 Top reinforcement

X-direction:

$$d_x = 800 - 50 - 16 - 0{,}5 \times 16 = 726\,mm$$

$$A_{sx;min} = 0{,}26 \frac{f_{ctm}}{f_{yk}} b_t d = 0{,}26 \times \frac{2{,}9}{500} \times 1000 \times 726 = 1094\,mm^2/m \rightarrow \emptyset 16 - 100 \;\; (A_s = 2010\,mm^2/m)$$

$$A_{sx;min} = 0{,}0013 b_t d = 0{,}0013 \times 1{,}0 \times 0{,}726 \times 10^6 = 944\;\, mm^2/m$$

Y-direction:

$$d_y = 800 - 50 - 0{,}5 \times 16 = 742 mm$$

$$A_{sy;min} = 0{,}26 \frac{f_{ctm}}{f_{yk}} b_t d = 0{,}26 \times \frac{2{,}9}{500} \times 1000 \times 742 = 1119\,mm^2/m \rightarrow \emptyset 16 - 100 \;\; (A_s = 2010\,mm^2/m)$$

$$A_{sy;min} = 0{,}0013 b_t d = 0{,}0013 \times 1{,}0 \times 0{,}742 \times 10^6 = 965\;\, mm^2/m$$

5.2.1.2 Bottom reinforcement

X-direction:

$$d_x = 800 - 50 - 16 - 0{,}5 \times 16 = 726\,mm$$

$$A_{sx;min} = 0{,}26 \frac{f_{ctm}}{f_{yk}} b_t d = 0{,}26 \times \frac{2{,}9}{500} \times 1000 \times 726 = 1094\,mm^2/m \rightarrow \emptyset 16 - 100 \;\; (A_s = 2010\,mm^2/m)$$

$$A_{sx;min} = 0{,}0013 b_t d = 0{,}0013 \times 1{,}0 \times 0{,}726 \times 10^6 = 944\;\, mm^2/m$$

Y-direction:

$$d_y = 800 - 50 - 0{,}5 \times 16 = 742 mm$$

$$A_{sy;min} = 0{,}26 \frac{f_{ctm}}{f_{yk}} b_t d = 0{,}26 \times \frac{2{,}9}{500} \times 1000 \times 742 = 1119\,mm^2/m \rightarrow \emptyset 16 - 100 \;\; (A_s = 2010\,mm^2/m)$$

$$A_{sy;min} = 0{,}0013 b_t d = 0{,}0013 \times 1{,}0 \times 0{,}742 \times 10^6 = 965\;\, mm^2/m$$

5.3 Reinforcement

5.3.1 Liquid tightening

The tank foundation is designed to be a liquid tight. According to CUR65, the minimum spacing for the reinforcement is 100 mm.

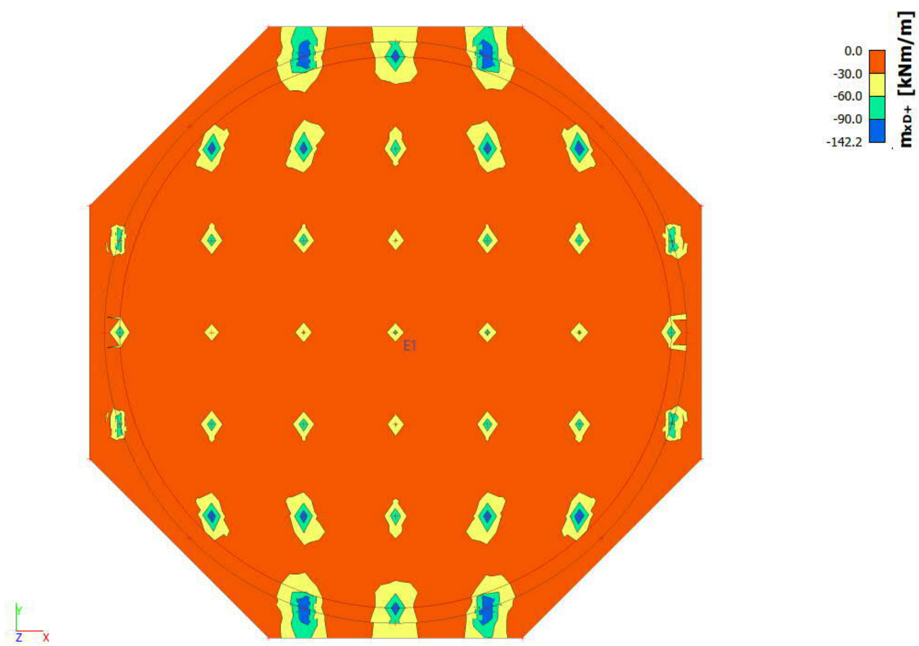
Acc. to CUR65 art. 4.4.2.3.a Minimum applied reinforcement, top: $\rho_0 = 0{,}42\%$

$$\rho = \frac{A_s}{b_c d} \rightarrow A_s = \frac{\rho b_c d}{100} = \frac{0{,}42 \times 1000 \times 740}{100} = 3108\, mm^2 \rightarrow \emptyset 20 - 100\ (A_s = 3142\, mm^2)$$

- Applied main reinforcement, top: Ø20-100
- Applied main reinforcement, bottom: Ø16-100

5.3.2 Top Reinforcement

5.3.2.1 X-direction LIN-ULS



Height for top reinforcement: $d_x = 800 - 50 - 16 - 0{,}5 \times 16 = 726\, mm$

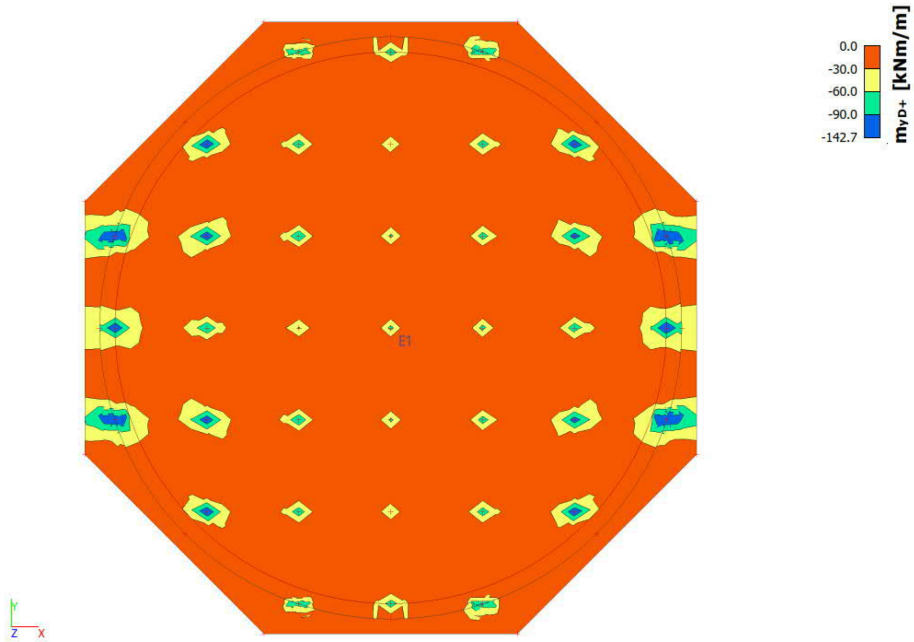
At location maximum field moment: $mxD^+ = 142{,}2\, kNm/m$

$$\frac{M_{Ed}}{bd^2} = \frac{142{,}2}{1{,}0 \times 0{,}726^2} = 275\, kN/m^2 \rightarrow 100\rho = 0{,}065$$

$$A_s = \frac{0{,}065}{100} \times 1{,}0 \times 0{,}726 \times 10^6 = 468\, mm^2/m$$

$$A_s = 468\, mm^2/m < A_{sx;min} = 1094\, mm^2/m \rightarrow \emptyset 16 - 100\ \ (A_s = 2011\, mm^2/m)$$

5.3.2.2 Y-direction LIN-ULS



Height for top reinforcement: $d_y = 800 - 50 - 0{,}5 \times 16 = 742\ mm$

At location maximum field moment: $myD^+ = 142{,}7\ kNm/m$

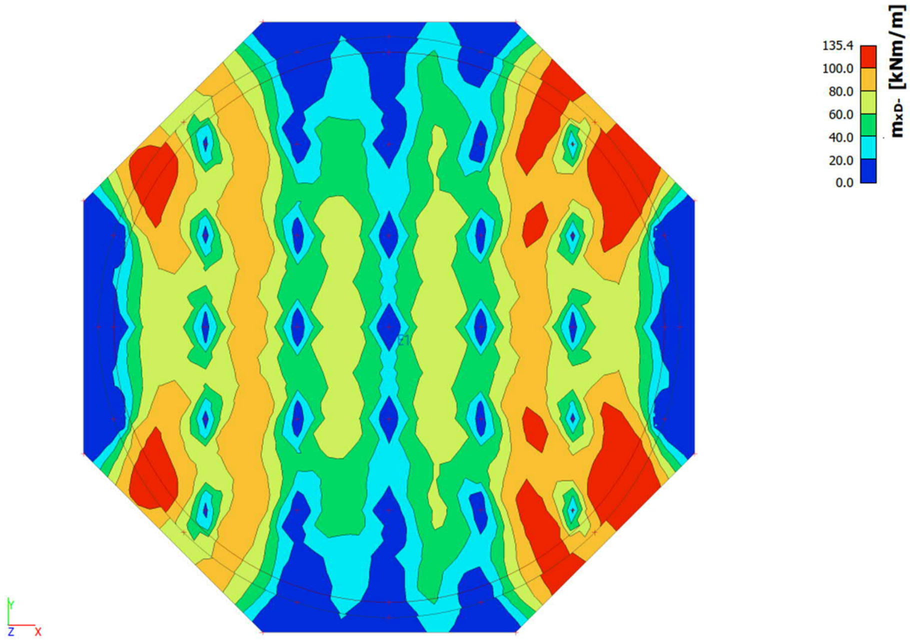
$$\frac{M_{Ed}}{bd^2} = \frac{142{,}7}{1{,}0 \times 0{,}742^2} = 261\ kN/m^2 \rightarrow 100\rho = 0{,}062$$

$$A_s = \frac{0{,}062}{100} \times 1{,}0 \times 0{,}742 \times 10^6 = 461\ mm^2/m$$

$$A_s = 461\ mm^2/m < A_{sy;min} = 1119\ mm^2/m \rightarrow \emptyset 16 - 100\ \ (A_s = 2011\ mm^2/m)$$

5.3.3 Bottom reinforcement

5.3.3.1 X-direction LIN-ULS



Height for bottom reinforcement: $d_x = 800 - 50 - 16 - 0{,}5 \times 16 = 726\ mm$

At location maximum field moment:

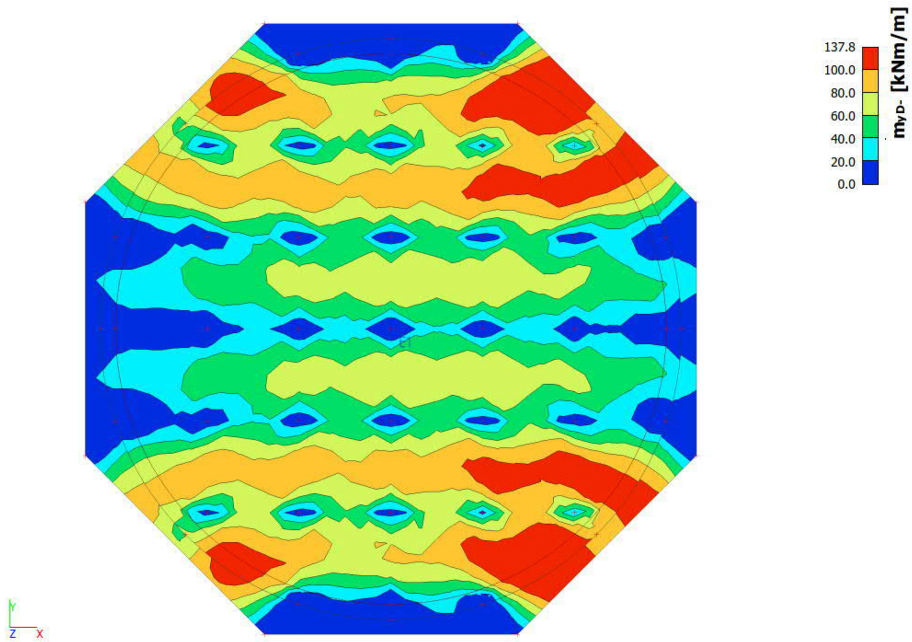
$$mxD^- = 135{,}4\ kNm/m$$

$$\frac{M_{Ed}}{bd^2} = \frac{135{,}4}{1{,}0 \times 0{,}726^2} = 256\ kN/m^2 \rightarrow 100\rho = 0{,}061$$

$$A_s = \frac{0{,}061}{100} \times 1{,}0 \times 0{,}726 \times 10^6 = 445\ mm^2/m$$

$$A_s = 445\ mm^2/m < A_{sx;min} = 1094\ mm^2/m \rightarrow \emptyset 16 - 100\ \ (A_s = 2010\ mm^2/m)$$

5.3.3.2 Y-direction LIN-ULS



Height for bottom reinforcement: $d_y = 800 - 50 - 0{,}5 \times 16 = 742mm$

At location maximum field moment:

$$myD^- = 137{,}8\, kNm/m$$

$$\frac{M_{Ed}}{bd^2} = \frac{137{,}8}{1{,}0 \times 0{,}742^2} = 250\, kN/m^2 \rightarrow 100\rho = 0{,}060$$

$$A_s = \frac{0{,}060}{100} \times 1{,}0 \times 0{,}742 \times 10^6 = 446\, mm^2/m$$

$$A_s = 446\, mm^2/m < A_{sy;min} = 1119\, mm^2/m \rightarrow \text{Ø}16 - 100\ \ (A_s = 2010\, mm^2/m)$$

5.3.4 Results LIN-ULS

Interne 2D-krachten

Lineaire berekening

Klasse: ULS_All

Extreem: Globaal

Selectie: E1

Elementaire ontwerpgrootheden

Naam	Net	Positie [mm]	BG	m_{xD+} [kNm/m]	m_{yD+} [kNm/m]	m_{xD-} [kNm/m]	m_{yD-} [kNm/m]
E1	Element: 2499 Knoop: 43	1,500 -4,500 0,000	ULS_17/1	**-142,2**	-98,4	0,0	0,0
E1	Element: 2453 Knoop: 173	3,975 -2,600 0,000	ULS_16/2	**0,0**	**0,0**	**135,4**	97,8
E1	Element: 2502 Knoop: 37	4,500 1,500 0,000	ULS_16/2	-99,2	**-142,7**	0,0	0,0
E1	Element: 2451 Knoop: 335	2,600 -3,975 0,000	ULS_16/2	0,0	0,0	99,2	**137,8**

5.3.5 Results LIN-SLS

Interne 2D-krachten

Lineaire berekening

Klasse: SLS_All

Extreem: Globaal

Selectie: E1

Elementaire ontwerpgrootheden

Naam	Net	Positie [mm]	BG	m_{xD+} [kNm/m]	m_{yD+} [kNm/m]	m_{xD-} [kNm/m]	m_{yD-} [kNm/m]
E1	Element: 2499 Knoop: 43	1,500 -4,500 0,000	SLS_15/1	**-89,4**	-61,2	0,0	0,0
E1	Element: 2453 Knoop: 173	3,975 -2,600 0,000	SLS_14/2	**0,0**	**0,0**	**82,4**	58,5
E1	Element: 2502 Knoop: 37	4,500 1,500 0,000	SLS_14/2	-61,7	**-90,1**	0,0	0,0
E1	Element: 2451 Knoop: 335	2,600 -3,975 0,000	SLS_14/2	0,0	0,0	59,6	**83,8**

5.4 Tank foundation CRACK WIDTH

5.4.1 Shrinkage strain tank foundation

5.4.1.1 Drying shrinkage strain acc. to GTB2010 5.4.a t/m 5.4.c

$$\varepsilon_{cd}(t) = \beta_{ds}(t,t_s)k_h\varepsilon_{cd;0}$$

$$\varepsilon_{cd;0} = 0{,}85\left[(220+110\alpha_{ds1})e^{\left(-\alpha_{ds2}\frac{f_{cm}}{f_{cm,0}}\right)}\right]10^{6}\times 1{,}55\left[1-\left(\frac{RV}{RV_0}\right)^3\right]$$

Where:

$RV = 80\%\ en\ RV_0 = 100\%$

$Cement\ CEM32{,}5 \rightarrow \alpha_{ds1} = 4\ en\ \alpha_{ds2} = 0{,}12$

$f_{cm} = 38\ N/mm^2\ en\ f_{cm,0} = 10\,N/mm^2$

$$\varepsilon_{cd;0} = 0{,}85\left[(220+110\times 4)e^{\left(-0{,}12\frac{38}{10}\right)}\right]10^{-6}\times 1{,}55\left[1-\left(\frac{80}{100}\right)^3\right] = 0{,}000269 = 0{,}0269\%$$

$$h_0 = \frac{2A_c}{u} = \frac{2\times 9900\times 800}{300+9900+300} = 1510\,mm > 500\,mm \rightarrow h_0 = 500\,mm$$

$h_0 > 500\,mm \rightarrow k_h = 0{,}70$

$\beta_{ds}(t,t_s)k_h = 0{,}70$

$$\varepsilon_{cd}(t) = \beta_{ds}(t,t_s)k_h\varepsilon_{cd;0} = 0{,}70\times 0{,}0269 = 0{,}0188\%$$

5.4.1.2 Autogene shrinkage strain acc. to GTB2010 5.4.d

$$\varepsilon_{ca}(t) = \beta_{as}(t)\varepsilon_{ca}(\infty)$$

$t = \infty$

$\beta_{as}(t) = 1-e^{(-0{,}2\sqrt{t})} = 1-e^{(-0{,}2\sqrt{\infty})} = 1{,}0$

$\varepsilon_{ca}(\infty) = 2{,}5(f_{ck}-10)\times 10^{-6} = 2{,}5(30-10)\times 10^{-6} = 0{,}00005 = 0{,}005\%$

$$\varepsilon_{ca}(t) = \beta_{as}(t)\varepsilon_{ca}(\infty) = 0{,}005\%$$

5.4.1.3 Total shrinkage strain:

$\varepsilon_{cs} = \varepsilon_{cd} + \varepsilon_{ca}$

$\varepsilon_{cs} = 0{,}0188\% + 0{,}005\% = 0{,}0238\%$

Shrinkage:

$$\sigma_{cs} = \varepsilon_{cs}E_s = \frac{0{,}0238}{100}\times 2{,}1\cdot 10^5 = 50{,}0\,N/mm^2$$

5.4.2 Top Reinforcement

5.4.2.1 X-direction LIN-SLS

$w_k = s_{r;max}(\varepsilon_{sm} - \varepsilon_{cm})$

Effective height: $d_x = 800 - 50 - 16 - 0{,}5 \times 16 = 726\ mm$

At location maximum moment: $mxD^+ = 142{,}2\ kNm/m$

$mxD^+ = 89{,}4\ kNm$

$w_{max} = 0{,}07mm$ (acc. to CUR65)

Required reinforcement: $A_s = 468\ mm^2$

Main reinforcement: $A_s = 2011\ mm^2 \rightarrow \emptyset 16 - 100$

$$\varepsilon_{sm} - \varepsilon_{cm} = \frac{\sigma_s - k_t \frac{f_{ct;eff}}{\rho_{p;eff}}\left(1 + \alpha_e \rho_{p;eff}\right)}{E_s} \geq 0{,}6 \frac{\sigma_s}{E_s}$$

Creep coëfficiënt acc. to. NEN-EN 1992-1-1: $\varphi(\infty, t_0) = 2$

Where:

$k_t = 0{,}4$

$f_{ct;eff} = f_{ctm} = 2{,}9\ N/mm^2$

$$\alpha_e = \frac{E_s\left(1 + \varphi(\infty, t_0)\right)}{E_{cm}} = \frac{2{,}1 \cdot 10^5 (1 + 2{,}0)}{33000} = 19{,}1$$

$N_s = A_s f_{yd} = 2011 \times 435 = 874.785\ N$

$N_c = \frac{3}{4} x_u f_{cd} b = \frac{3}{4} \times x_u \times 20 \times 1000 = 15.000\ x_u$

$$\rightarrow x_u = \frac{N_s}{N_c} = \frac{874.785}{15.000} = 58{,}3\ mm$$

$\rightarrow z = d - 0{,}39 x_u = 726 - 0{,}39 \times 58{,}3 = 703\ mm$

$\rightarrow M_{Rd} = A_s f_{yd} z = 2011 \times 435 \times 703 \times 10^{-6} = 615{,}0\ kNm$

$$\sigma_s = \frac{89{,}4}{615{,}0} \times 435 = 41{,}6 = 63{,}2\ N/mm^2$$

$$h_{c;eff} = min\left\{2{,}5(h - d); \frac{(h - x_u)}{3}; \frac{h}{2}\right\} = min\left\{2{,}5 \times (800 - 726); \frac{(800 - 58{,}3)}{3}; \frac{800}{2}\right\} = 185\ mm$$

$$\rho_{p;eff} = \frac{A_s}{A_{c;eff}} = \frac{A_s}{b_c h_{c;eff}} = \frac{2011}{1000 \times 185} = 0{,}011$$

$$\varepsilon_{sm} - \varepsilon_{cm} = \frac{63{,}2 - 0{,}4 \times \frac{2{,}9}{0{,}011} \times (1 + 19{,}1 \times 0{,}011)}{2{,}1 \cdot 10^5} \geq 0{,}6 \frac{63{,}2}{2{,}1 \cdot 10^5} \rightarrow \varepsilon_{sm} - \varepsilon_{cm} = 0{,}018\%$$

$$s_{r;max} = k_3 c + \frac{k_1 k_2 k_4 \emptyset}{\rho_{p;eff}} = 3{,}4 \times 65 + \frac{0{,}8 \times 0{,}5 \times 0{,}425 \times 16}{0{,}011} = 468\ mm$$

$w_k = s_{r;max}(\varepsilon_{sm} - \varepsilon_{cm}) = 468 \times 0{,}00018 = 0{,}08\ mm > 0{,}07\ mm \rightarrow ACCEPTABLE$

Conclusion: crack width tank foundation sufficient

Main reinforcement: $\emptyset 16 - 100\ (A_s = 2011\ mm^2)$

5.4.2.2 Y-richting LIN-SLS

$w_k = s_{r;max}(\varepsilon_{sm} - \varepsilon_{cm})$

Effective height: $d_y = 800 - 50 - 0{,}5 \times 16 = 742\ mm$

At location maximum moment: $myD^+ = 142{,}7\ kNm$

$myD^+ = 90{,}1\ kNm$

$w_{max} = 0{,}07 mm$ (acc. to CUR65)

Required reinforcement: $A_s = 461\ mm^2$

Main reinforcement: $A_s = 2010\ mm^2 \rightarrow \emptyset 16 - 100$

$$\varepsilon_{sm} - \varepsilon_{cm} = \frac{\sigma_s - k_t \frac{f_{ct;eff}}{\rho_{p;eff}}\left(1 + \alpha_e \rho_{p;eff}\right)}{E_s} \geq 0{,}6 \frac{\sigma_s}{E_s}$$

Creep coëfficiënt acc. to. NEN-EN 1992-1-1: $\varphi(\infty, t_0) = 2$

Where:

$k_t = 0{,}4$

$f_{ct;eff} = f_{ctm} = 2{,}9\ N/mm^2$

$$\alpha_e = \frac{E_s\left(1 + \varphi(\infty, t_0)\right)}{E_{cm}} = \frac{2{,}1 \cdot 10^5 (1 + 2{,}0)}{33000} = 19{,}1$$

$N_s = A_s f_{yd} = 2010 \times 435 = 874.785\ N$

$N_c = \frac{3}{4} x_u f_{cd} b = \frac{3}{4} \times x_u \times 20 \times 1000 = 15.000\ x_u$

$$\rightarrow x_u = \frac{N_s}{N_c} = \frac{874.785}{15.000} = 58{,}3\ mm$$

$\rightarrow z = d - 0{,}39 x_u = 742 - 0{,}39 \times 58{,}3 = 719\ mm$

$\rightarrow M_{Rd} = A_s f_{yd} z = 2010 \times 435 \times 719 \times 10^{-6} = 629{,}2\ kNm$

$$\sigma_s = \frac{90{,}1}{629{,}2} \times 435 = 62{,}3\ N/mm^2$$

$$h_{c;eff} = min\left\{2{,}5(h-d); \frac{(h - x_u)}{3}; \frac{h}{2}\right\} = min\left\{2{,}5 \times (800 - 742); \frac{(800 - 58{,}3)}{3}; \frac{800}{2}\right\} = 145\ mm$$

$$\rho_{p;eff} = \frac{A_s}{A_{c;eff}} = \frac{A_s}{b_c h_{c;eff}} = \frac{2010}{1000 \times 145} = 0{,}014$$

$$\varepsilon_{sm} - \varepsilon_{cm} = \frac{62{,}3 - 0{,}4 \times \frac{2{,}9}{0{,}014} \times (1 + 19{,}1 \times 0{,}014)}{2{,}1 \cdot 10^5} \geq 0{,}6 \frac{62{,}3}{2{,}1 \cdot 10^5} \rightarrow \varepsilon_{sm} - \varepsilon_{cm} = 0{,}018\%$$

$$s_{r;max} = k_3 c + \frac{k_1 k_2 k_4 \emptyset}{\rho_{p;eff}} = 3{,}4 \times 50 + \frac{0{,}8 \times 0{,}5 \times 0{,}425 \times 16}{0{,}014} = 364\ mm$$

$w_k = s_{r;max}(\varepsilon_{sm} - \varepsilon_{cm}) = 364 \times 0{,}00018 = 0{,}07\ mm \cong 0{,}07\ mm \rightarrow OK$

<u>Conclusion:</u> crack width tank foundation sufficient

Main reinforcement: $\emptyset 16 - 100\ (A_s = 2010\ mm^2)$

5.4.3 Bottom Reinforcement

5.4.3.1 X-direction LIN-SLS

Shrinkage: $\sigma_{cs} = 50{,}0\ N/mm^2$

Effective height: $d_x = 800 - 50 - 16 - 0{,}5 \times 16 = 726\ mm$

At location maximum moment: $mxD^- = 135{,}4\ kNm/m$

$mxD^- = 82{,}4\ kNm$

$w_{max} = 0{,}2\ mm$

Required reinforcement: $A_s = 445\ mm^2$

Main reinforcement: $A_s = 2010\ mm^2 \rightarrow \emptyset 16 - 100$

$$\sigma_s = \frac{445}{2010} \times \frac{82{,}4}{135{,}4} \times 435 + \sigma_{cs} = 58{,}6 + 50{,}0 = 108{,}6\ N/mm^2 \rightarrow \sigma^*_{max} = 25\ mm$$

Acc. to GTB 21010 14.5a

$$\emptyset_{max} = 25 \times \frac{2{,}9}{2{,}9} \times \frac{0{,}4 \times 0{,}5 \times 800}{2(800 - 726)} = 27{,}0 mm > 16\ mm \rightarrow OK$$

Acc. to GTB 21010 14.5b

$s_{max} = 200\ mm > 100 mm \rightarrow OK$

Conclusion: crack width tank foundation sufficient

Main reinforcement: $\emptyset 16 - 100\ (A_s = 2010\ mm^2)$

5.4.3.2 Y-direction LIN-SLS

Shrinkage: $\sigma_{cs} = 50{,}0\ N/mm^2$

Effective height: $d_y = 800 - 50 - 0{,}5 \times 16 = 742\ mm$

At location maximum field moment: $myD^- = 137{,}8\ kNm/m$

$myD^- = 83{,}8\ kNm$

$w_{max} = 0{,}2\ mm$

Required reinforcement: $A_s = 446\ mm^2$

Main reinforcement: $A_s = 2010\ mm^2 \rightarrow \emptyset 16 - 100$

$$\sigma_s = \frac{446}{2010} \times \frac{83{,}8}{137{,}8} \times 435 + \sigma_{cs} = 58{,}7 + 50{,}0 = 108{,}7\ N/mm^2 \rightarrow \sigma^*_{max} = 25\ mm$$

Acc. to GTB 21010 14.5a

$$\emptyset_{max} = 25 \times \frac{2{,}9}{2{,}9} \times \frac{0{,}4 \times 0{,}5 \times 800}{2(800 - 742)} = 34{,}5\ mm > 16\ mm \rightarrow OK$$

Acc. to GTB 21010 14.5b

$s_{max} = 200\ mm > 100 mm \rightarrow OK$

Conclusion: crack width tank foundation sufficient

Main reinforcement: $\emptyset 16 - 100\ (A_s = 2010\ mm^2)$

5.5 Settlements tank foundation

5.5.1 Minimum settlements tank foundation

The figure below shows the minimum settlement of the tank foundation under the expected characteristic load (no partial factors on the loads). The highest settlement is $\delta = 5{,}5\ mm$ and differential settlement is $\Delta\delta = 0{,}6\ mm$ based on the pile stiffness from the foundation advice (chapter 4.4, R1901679-02).

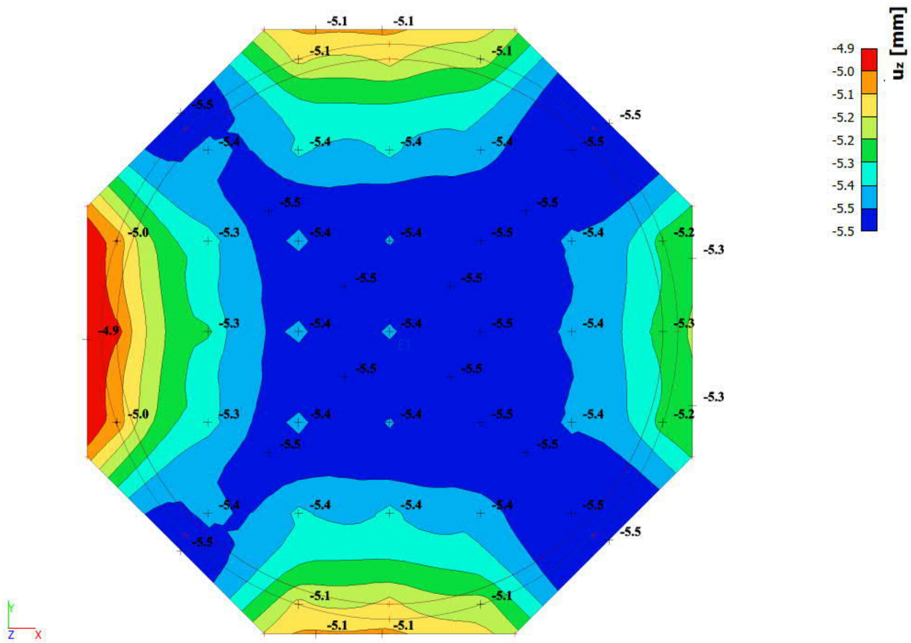


Figure 5-3 Tank concrete foundation settlement

<u>Note:</u>

$$\Delta\delta_z = 0{,}6\ mm < \frac{1}{300} \times \frac{1}{2} \times 9900 = 16{,}5\ mm \rightarrow OK$$

According to the foundation advice (chapter 4.4, R1901679-02) from MOS, the maximum settlement under the maximum characteristic pile compression loads are approximately 5 mm to 10 mm.

5.5.2 Maximum settlements tank foundation

The figure below shows the maximum settlement of the tank foundation under the expected characteristic load (no partial factors on the loads). The highest settlement is $\delta = 1{,}0\ mm$ and differential settlement is $\Delta\delta = 0{,}4\ mm$ based on the pile stiffness from the foundation advice (chapter 4.4, R1901679-02).

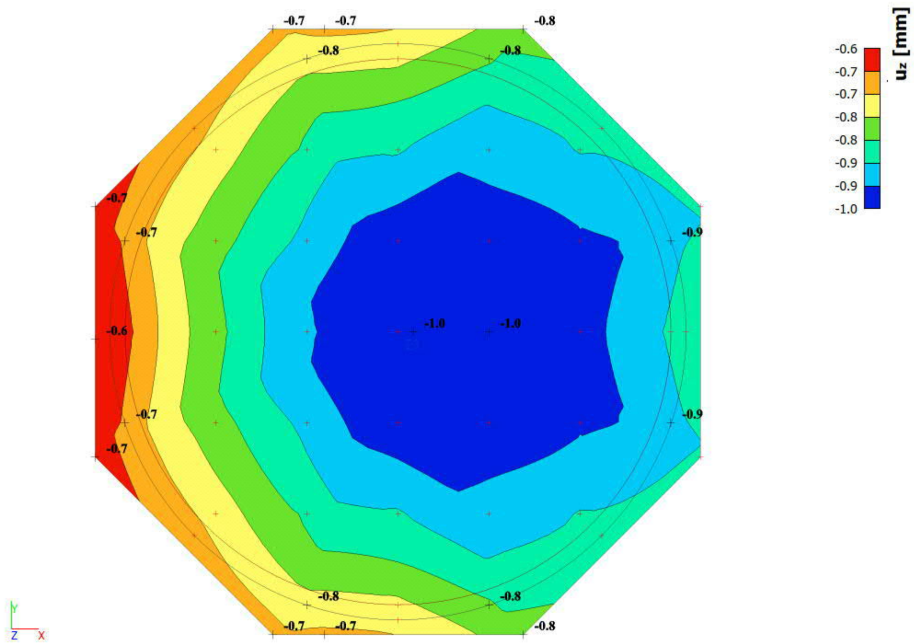


Figure 5-4 Tank concrete foundation settlement

<u>Note:</u>

$\Delta\delta_z = 0{,}4\ mm < \frac{1}{300} \times \frac{1}{2} \times 9900 = 16{,}5\ mm \rightarrow OK$

According to the foundation advice (chapter 4.4, R1901679-02) from MOS, the maximum settlement under the maximum characteristic pile compression loads are approximately 5 mm to 10 mm.

5.5.3 Settlements LIN-SLS

2D-verplaatsing

Lineaire berekening

Klasse: SLS_All

Extreem: Globaal

Selectie: Alle

Locatie: In knooppunten gem. bij macro. Systeem: LCS net element

Naam	Net	Positie [mm]	BG	u_z [mm]
E1	Element: 1357 Knoop: 404	3,614 -3,443 0,000	SLS_14/1	**-5,5**
E1	Element: 1234 Knoop: 140	-4,990 -0,122 0,000	SLS_02/7	**-0,6**

6 Floor foundation Tank-pit

Foundation data is taken from the foundation advice (R1901679-02) which was made by MOS.

Shallow foundation data

- Bearing resistance capacity of the soil: not normative according to advice
- Stiffness: advised 7,5 MN/m³ to 10,0 MN/m³, applied 7,5 MN/m³

6.1 Concrete foundation slab

6.1.1 Minimum reinforcement in tank foundation

The minimum cross-section for the reinforcement to be used acc. to NEN-EN 1992-1-1 art.9.2.1.

ASSUMPTION: main reinforcement in the foundation Ø12-100 (A_s = 1131 mm²/m)

6.1.1.1 Top reinforcement

X-direction:

$$d_x = 250 - 50 - 0{,}5 \times 12 = 194\,mm$$

$$A_{sx;min} = 0{,}26\frac{f_{ctm}}{f_{yk}}b_t d = 0{,}26 \times \frac{2{,}9}{500} \times 1000 \times 194 = 293\,mm^2/m \rightarrow \emptyset 12 - 100\ \ (A_s = 1131\,mm^2/m)$$

$$A_{sx;min} = 0{,}0013 b_t d = 0{,}0013 \times 1{,}0 \times 0{,}194 \times 10^6 = 253\,mm^2/m$$

Y-direction:

$$d_y = 250 - 50 - 12 - 0{,}5 \times 12 = 182\,mm$$

$$A_{sy;min} = 0{,}26\frac{f_{ctm}}{f_{yk}}b_t d = 0{,}26 \times \frac{2{,}9}{500} \times 1000 \times 182 = 275\,mm^2/m \rightarrow \emptyset 12 - 100\ \ (A_s = 1131\,mm^2/m)$$

$$A_{sy;min} = 0{,}0013 b_t d = 0{,}0013 \times 1{,}0 \times 0{,}182 \times 10^6 = 237\,mm^2/m$$

6.1.1.2 Bottom reinforcement

X-direction:

$$d_x = 250 - 50 - 0{,}5 \times 12 = 194\,mm$$

$$A_{sx;min} = 0{,}26\frac{f_{ctm}}{f_{yk}}b_t d = 0{,}26 \times \frac{2{,}9}{500} \times 1000 \times 194 = 293\,mm^2/m \rightarrow \emptyset 12 - 100\ \ (A_s = 1131\,mm^2/m)$$

$$A_{sx;min} = 0{,}0013 b_t d = 0{,}0013 \times 1{,}0 \times 0{,}194 \times 10^6 = 253\,mm^2/m$$

Y-direction:

$$d_y = 250 - 50 - 12 - 0{,}5 \times 12 = 182\,mm$$

$$A_{sy;min} = 0{,}26\frac{f_{ctm}}{f_{yk}}b_t d = 0{,}26 \times \frac{2{,}9}{500} \times 1000 \times 182 = 275\,mm^2/m \rightarrow \emptyset 12 - 100\ \ (A_s = 1131\,mm^2/m)$$

$$A_{sy;min} = 0{,}0013 b_t d = 0{,}0013 \times 1{,}0 \times 0{,}182 \times 10^6 = 237\,mm^2/m$$

6.2 Reinforcement

6.2.1 Liquid tightening

Tank-pit shall be designed as a liquid tight structure according to CUR-65 (see the calculation below)

Calculation Liquid Tight Reinforcement

according to CUR-65

Project: T53591 Hexion Formalin Storage Bund
Date: 10.2019

L1. Material Input				
L1.1 Concrete				
Class:	C30/37			
f_{ck}=	30 N/mm2			
h_c=	250 mm	Concrete thickness	OK	
$h_{c;min}$=	250	Minimum concrete thickness		
b_c=	1000 mm	Concrete width		
L1.2 Reinforcement				
L1.2.1 Top reinforcement bars				
D_{top}=	12 mm	Diameter of top reinforcement bar		
s_{top}=	100 mm	Distance of top reinforcement bar	OK	
$s_{top;min}$=	100	Minimum distance of top reinforcement bar		
A_{top}=	1131 mm2	Amount of top reinforcement bar		
L1.2.2 Bottom reinforcement bars				
D_{bottom}=	10 mm	Diameter of bottom reinforcement bar		
s_{bottom}=	100 mm	Distance of bottom reinforcement bar	OK	
$s_{bottom;min}$=	100	Minimum distance of bottom reinforcement bar		
A_{bottom}=	785 mm2	Amount of bottom reinforcement bar		
L2. Required verifications				
L2.1 Lquid ≤ 0,5 h (thicknees of the concrete slab)				
$\bar{\omega}_{0;top;required}$=	0,43 %	Minimum required top reinforcement percentage		CUR 65, 4.4.2.3
$\bar{\omega}_{0;top}$=	0,45 %	Percentage of applied top reinforcement bar		
Utilization ratio =	0,94 OK			
L2.2 Lquid ≥ 0,5 h (thicknees of the concrete slab)				
$\bar{\omega}_{0;total;required}$=	0,70 %	Minimum required total reinforcement percentage		CUR 65, 4.4.2.3
$\bar{\omega}_{0;total;applied}$=	0,77 %	Percentage of applied total reinforcement bar		
Utilization ratio =	0,91 OK			

The tank foundation is designed to be a liquid tight. According to CUR65, the minimum spacing for the reinforcement is 100 mm.

Acc. to CUR65 art. 4.4.2.3.a Minimum applied reinforcement, top: $\rho_0 = 0{,}42\%$

$$\rho = \frac{A_s}{b_c d} \rightarrow A_s = \frac{\rho b_c d}{100} = \frac{0{,}42 \times 1000 \times 194}{100} = 815\ mm^2 \rightarrow \emptyset 12 - 100\ (A_s = 1131\ mm^2)$$

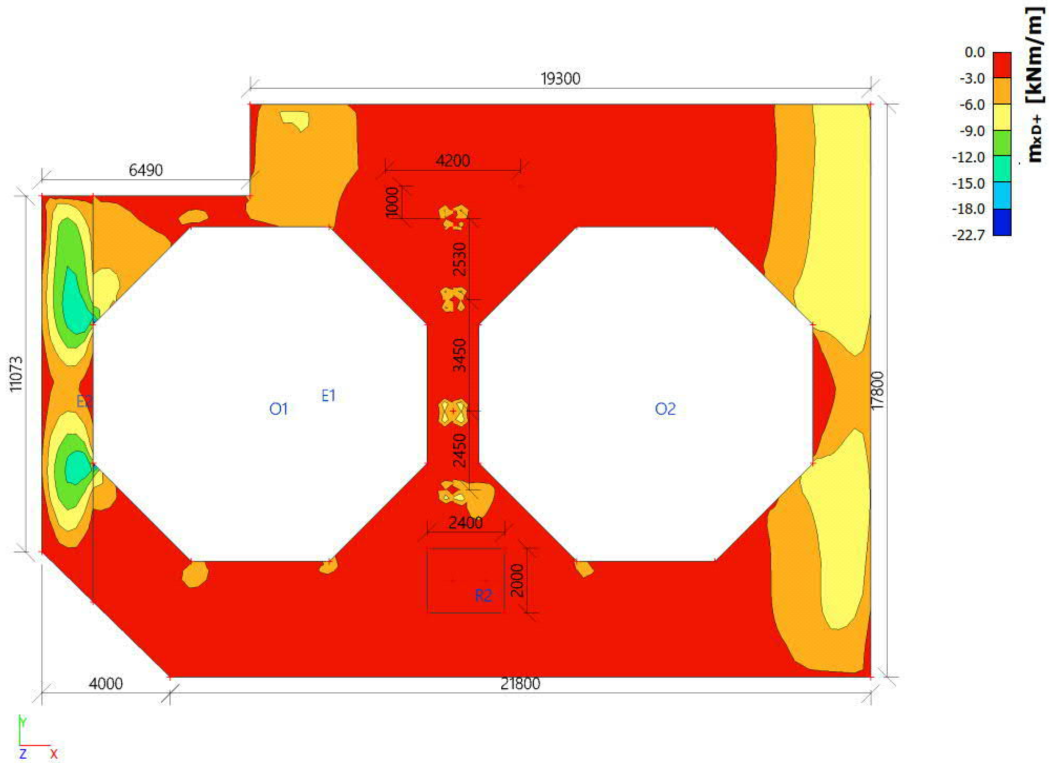
As a result, applied reinforcement bars are:

- Applied main reinforcement, top: Ø12-100
- Applied main reinforcement, bottom: Ø12-100

Note: For the tank-pit reinforcement design, liquid tightening is the decisive requirement.

6.2.2 Top Reinforcement

6.2.2.1 X-direction LIN-ULS



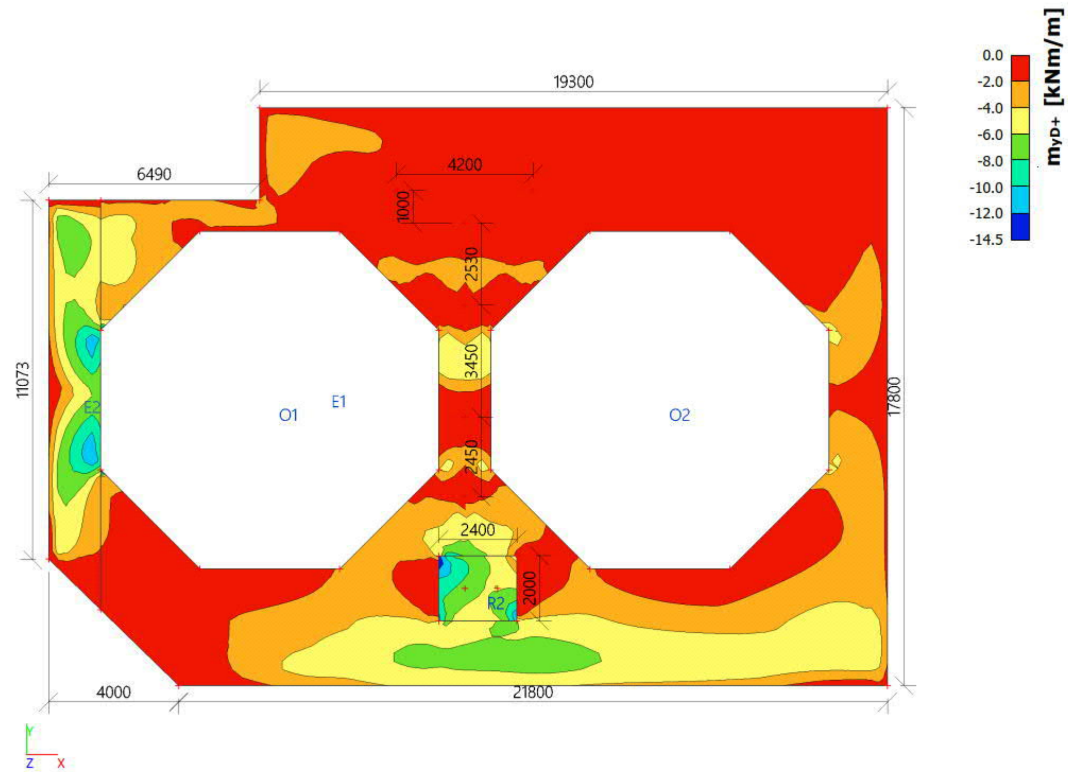
Height for top reinforcement: $d_x = 250 - 50 - 0,5 \times 12 = 194\ mm$

At location maximum field moment: $mxD^+ = 22,7\ kNm/m$

$$\frac{M_{Ed}}{bd^2} = \frac{22,7}{1,0 \times 0,194^2} = 603\ kN/m^2 \rightarrow 100\rho = 0,141$$

$$A_s = \frac{0,141}{100} \times 1,0 \times 0,194 \times 10^6 = 273\ mm^2/m\ \rightarrow \emptyset 12 - 100\ \ (A_s = 1131\ mm^2/m)$$

6.2.2.2 Y-direction LIN-ULS



Height for top reinforcement: $d_y = 250 - 50 - 12 - 0{,}5 \times 12 = 182\,mm$

At location maximum field moment: $myD^{+} = 14{,}5\,kNm/m$

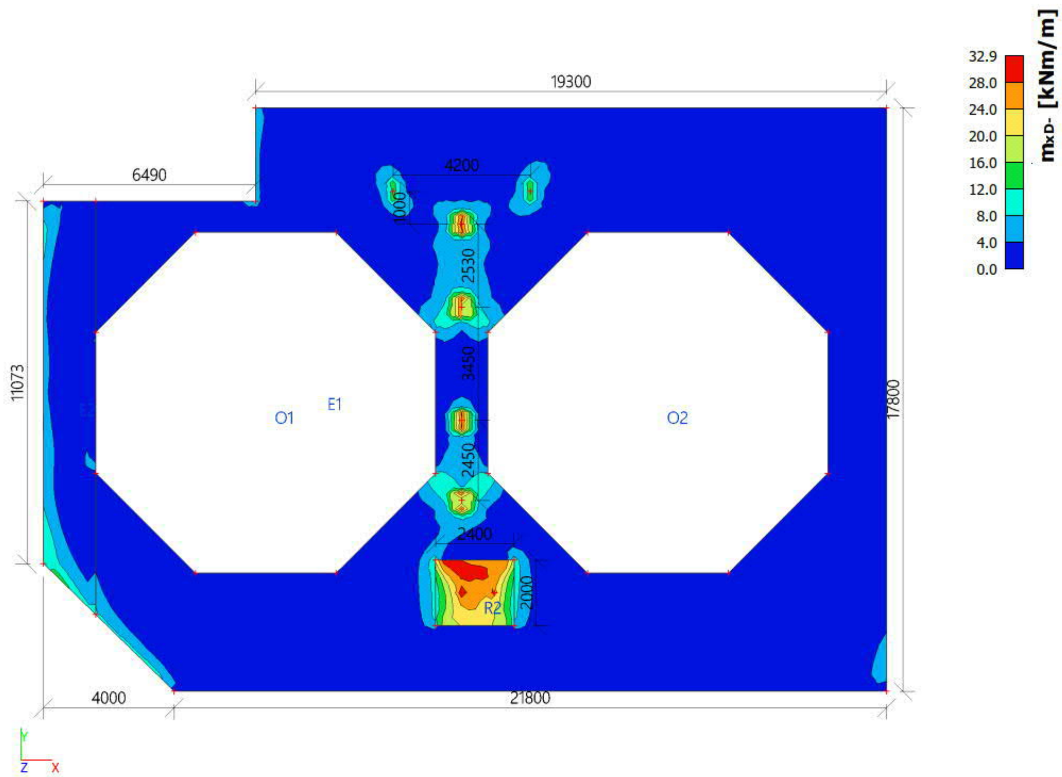
$$\frac{M_{Ed}}{bd^2} = \frac{14{,}5}{1{,}0 \times 0{,}182^2} = 438\,kN/m^2 \rightarrow 100\rho = 0{,}101$$

$$A_s = \frac{0{,}101}{100} \times 1{,}0 \times 0{,}182 \times 10^6 = 185\,mm^2/m$$

$$A_s = 185\,mm^2/m < A_{sy;min} = 275\,mm^2/m \rightarrow Ø12 - 100 \;\; (A_s = 1131\,mm^2/m)$$

6.2.3 Bottom reinforcement

6.2.3.1 X-direction LIN-ULS



Height for bottom reinforcement: $d_x = 250 - 50 - 0{,}5 \times 12 = 194\ mm$

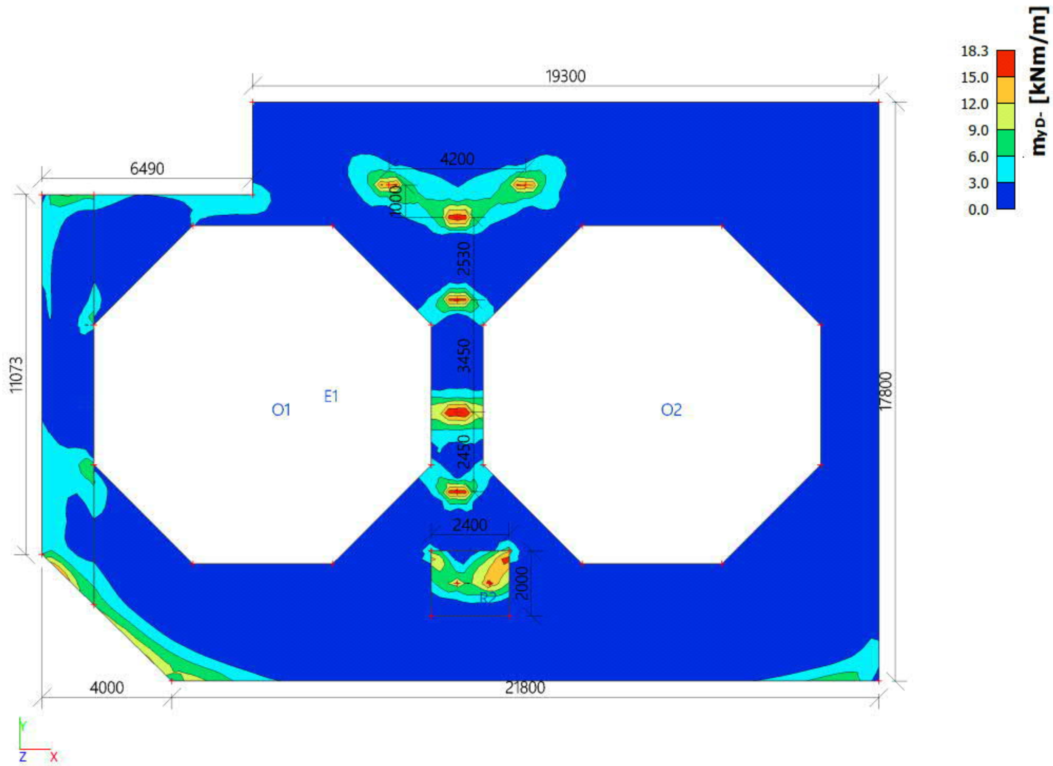
At location maximum field moment:

$$mxD^{-} = 32{,}9\ kNm/m$$

$$\frac{M_{Ed}}{bd^2} = \frac{32{,}9}{1{,}0 \times 0{,}194^2} = 875\ kN/m^2 \rightarrow 100\rho = 0{,}205$$

$$A_s = \frac{0{,}205}{100} \times 1{,}0 \times 0{,}194 \times 10^6 = 398\ mm^2/m\ \rightarrow \emptyset 12 - 100\ \ (A_s = 1131\ mm^2/m)$$

6.2.3.2 Y-direction LIN-ULS



Height for bottom reinforcement: $d_y = 250 - 50 - 12 - 0{,}5 \times 12 = 182\ mm$

At location maximum field moment:

$$myD^- = 18{,}3\ kNm/m$$

$$\frac{M_{Ed}}{bd^2} = \frac{18{,}3}{1{,}0 \times 0{,}182^2} = 553\ kN/m^2 \rightarrow 100\rho = 0{,}131$$

$$A_s = \frac{0{,}131}{100} \times 1{,}0 \times 0{,}182 \times 10^6 = 238\ mm^2/m$$

$$A_s = 238\ mm^2/m < A_{sy;min} = 275\ mm^2/m \rightarrow \emptyset 12 - 100\ \ (A_s = 1131\ mm^2/m)$$

6.2.4 Results LIN-ULS

Interne 2D-krachten

Lineaire berekening

Klasse: ULS_All

Extreem: Globaal

Selectie: E1, E2

Elementaire ontwerpgrootheden

Naam	Net	Positie [m]	BG	m_{xD+} [kNm/m]	m_{yD+} [kNm/m]	m_{xD-} [kNm/m]	m_{yD-} [kNm/m]
E1	Element: 3792 Knoop: 34	8,800 3,000 0,000	ULS_08/1	**0,0**	**0,0**	**32,9**	12,7
E1	Element: 235 Knoop: 9	-2,400 6,650 0,000	ULS_06/2	-22,7	**-14,5**	**0,0**	0,0
E1	Element: 1 Knoop: 1	-2,400 10,950 0,000	ULS_05/3	**-22,7**	-14,4	0,0	**0,0**
E1	Element: 3801 Knoop: 35	9,800 3,000 0,000	ULS_08/1	0,0	0,0	26,4	**18,3**

6.2.5 Results LIN-SLS

Interne 2D-krachten

Lineaire berekening

Klasse: SLS_All

Extreem: Globaal

Selectie: E1, E2

Elementaire ontwerpgrootheden

Naam	Net	Positie [m]	BG	m_{xD+} [kNm/m]	m_{yD+} [kNm/m]	m_{xD-} [kNm/m]	m_{yD-} [kNm/m]
E1	Element: 3792 Knoop: 34	8,800 3,000 0,000	SLS_08/1	**0,0**	**0,0**	**20,6**	7,7
E1	Element: 235 Knoop: 9	-2,400 6,650 0,000	SLS_06/2	**-14,1**	**-9,1**	**0,0**	**0,0**
E1	Element: 3801 Knoop: 35	9,800 3,000 0,000	SLS_08/1	0,0	0,0	16,6	**11,1**

For the results given in the following chapters, see SCIA calculation in Annex B.

6.3 Floor CRACK WIDTH

6.3.1 Shrinkage strain floor

6.3.1.1 Drying shrinkage strain acc. to GTB2010 5.4.a t/m 5.4.c

$$\varepsilon_{cd}(t) = \beta_{ds}(t,t_s)k_h\varepsilon_{cd;0}$$

$$\varepsilon_{cd;0} = 0{,}85\left[(220+110\alpha_{ds1})e^{\left(-\alpha_{ds2}\frac{f_{cm}}{f_{cm,0}}\right)}\right]10^{6}\times 1{,}55\left[1-\left(\frac{RV}{RV_0}\right)^3\right]$$

Where:

$RV = 80\%\ en\ RV_0 = 100\%$

$Cement\ CEM32{,}5 \rightarrow \alpha_{ds1} = 4\ en\ \alpha_{ds2} = 0{,}12$

$f_{cm} = 38\ N/mm^2\ en\ f_{cm,0} = 10\ N/mm^2$

$$\varepsilon_{cd;0} = 0{,}85\left[(220+110\times 4)e^{\left(-0{,}12\frac{38}{10}\right)}\right]10^{-6}\times 1{,}55\left[1-\left(\frac{80}{100}\right)^3\right] = 0{,}000269 = 0{,}0269\%$$

$$h_0 = \frac{2A_c}{u} = \frac{2\times b\times 250}{b} = 500\ mm \rightarrow h_0 = 500\ mm$$

$h_0 = 500\ mm \rightarrow k_h = 0{,}70$

$\beta_{ds}(t,t_s)k_h = 0{,}70$

$$\varepsilon_{cd}(t) = \beta_{ds}(t,t_s)k_h\varepsilon_{cd;0} = 0{,}70\times 0{,}0269 = 0{,}0188\%$$

6.3.1.2 Autogene shrinkage strain acc. to GTB2010 5.4.d

$$\varepsilon_{ca}(t) = \beta_{as}(t)\varepsilon_{ca}(\infty)$$

$t = \infty$

$\beta_{as}(t) = 1 - e^{(-0{,}2\sqrt{t})} = 1 - e^{(-0{,}2\sqrt{\infty})} = 1{,}0$

$\varepsilon_{ca}(\infty) = 2{,}5(f_{ck}-10)\times 10^{-6} = 2{,}5(30-10)\times 10^{-6} = 0{,}00005 = 0{,}005\%$

$$\varepsilon_{ca}(t) = \beta_{as}(t)\varepsilon_{ca}(\infty) = 0{,}005\%$$

6.3.1.3 Total shrinkage strain:

$\varepsilon_{cs} = \varepsilon_{cd} + \varepsilon_{ca}$

$\varepsilon_{cs} = 0{,}0188\% + 0{,}005\% = 0{,}0238\%$

Shrinkage:

$$\sigma_{cs} = \varepsilon_{cs}E_s = \frac{0{,}0238}{100}\times 2{,}1\cdot 10^5 = 50{,}0\ N/mm^2$$

6.3.2 Top Reinforcement

6.3.2.1 X-direction LIN-SLS

$w_k = s_{r;max}(\varepsilon_{sm} - \varepsilon_{cm})$

Effective height: $d_x = 250 - 50 - 0{,}5 \times 12 = 194\ mm$

At location maximum moment: $mxD^+ = 22{,}7\ kNm/m$

$mxD^+ = 14{,}1\ kNm$

$w_{max} = 0{,}07 mm$ (acc. to CUR65)

Required reinforcement: $A_s = 286\ mm^2$

Main reinforcement: $A_s = 1131\ mm^2 \rightarrow \emptyset 12 - 100$

$$\varepsilon_{sm} - \varepsilon_{cm} = \frac{\sigma_s - k_t \frac{f_{ct;eff}}{\rho_{p;eff}}\left(1 + \alpha_e \rho_{p;eff}\right)}{E_s} \geq 0{,}6 \frac{\sigma_s}{E_s}$$

Creep coëfficiënt acc. to. NEN-EN 1992-1-1: $\varphi(\infty, t_0) = 2$

Where:

$k_t = 0{,}4$

$f_{ct;eff} = f_{ctm} = 2{,}9\ N/mm^2$

$$\alpha_e = \frac{E_s\left(1 + \varphi(\infty, t_0)\right)}{E_{cm}} = \frac{2{,}1 \cdot 10^5 (1 + 2{,}0)}{33000} = 19{,}1$$

$N_s = A_s f_{yd} = 1131 \times 435 = 491.985\ N$

$N_c = \frac{3}{4} x_u f_{cd} b = \frac{3}{4} \times x_u \times 20 \times 1000 = 15.000\ x_u$

$$\rightarrow x_u = \frac{N_s}{N_c} = \frac{491.985}{15.000} = 32{,}8\ mm$$

$\rightarrow z = d - 0{,}39 x_u = 182 - 0{,}39 \times 32{,}8 = 169\ mm$

$\rightarrow M_{Rd} = A_s f_{yd} z = 1131 \times 435 \times 169 \times 10^{-6} = 83{,}2\ kNm$

$$\sigma_s = \frac{14{,}1}{83{,}2} \times 435 = 73{,}7\ N/mm^2$$

$$h_{c;eff} = min\left\{2{,}5(h-d); \frac{(h - x_u)}{3}; \frac{h}{2}\right\} = min\left\{2{,}5 \times (250 - 182); \frac{(250 - 32{,}8)}{3}; \frac{250}{2}\right\} = 72\ mm$$

$$\rho_{p;eff} = \frac{A_s}{A_{c;eff}} = \frac{A_s}{b_c h_{c;eff}} = \frac{1131}{1000 \times 72} = 0{,}016$$

$$\varepsilon_{sm} - \varepsilon_{cm} = \frac{73{,}7 - 0{,}4 \times \frac{2{,}9}{0{,}016} \times (1 + 19{,}1 \times 0{,}016)}{2{,}1 \cdot 10^5} \geq 0{,}6 \frac{73{,}7}{2{,}1 \cdot 10^5} \rightarrow \varepsilon_{sm} - \varepsilon_{cm} = 0{,}021\%$$

$$s_{r;max} = k_3 c + \frac{k_1 k_2 k_4 \emptyset}{\rho_{p;eff}} = 3{,}4 \times 50 + \frac{0{,}8 \times 0{,}5 \times 0{,}425 \times 12}{0{,}016} = 298\ mm$$

$w_k = s_{r;max}(\varepsilon_{sm} - \varepsilon_{cm}) = 297 \times 0{,}00021 = 0{,}06\ mm < 0{,}07\ mm \rightarrow OK$

Conclusion: crack width tank foundation sufficient

Main reinforcement: $\emptyset 12 - 100$ ($A_s = 1131\ mm^2$)

6.3.2.2 Y-richting LIN-SLS

$w_k = s_{r;max}(\varepsilon_{sm} - \varepsilon_{cm})$

Effective height: $d_y = 250 - 50 - 12 - 0{,}5 \times 12 = 182\ mm$

At location maximum moment: : $myD^+ = 14{,}5\ kNm$

$myD^+ = 9{,}1\ kNm$

$w_{max} = 0{,}07mm$ (acc. to CUR65)

Required reinforcement: $A_s = 172\ mm^2$

Main reinforcement: $A_s = 1131\ mm^2 \rightarrow \emptyset 12 - 100$

$$\varepsilon_{sm} - \varepsilon_{cm} = \frac{\sigma_s - k_t \frac{f_{ct;eff}}{\rho_{p;eff}}\left(1 + \alpha_e \rho_{p;eff}\right)}{E_s} \geq 0{,}6\frac{\sigma_s}{E_s}$$

Creep coëfficiënt acc. to. NEN-EN 1992-1-1: $\varphi(\infty, t_0) = 2$

Where:

$k_t = 0{,}4$

$f_{ct;eff} = f_{ctm} = 2{,}9\ N/mm^2$

$$\alpha_e = \frac{E_s\left(1 + \varphi(\infty, t_0)\right)}{E_{cm}} = \frac{2{,}1 \cdot 10^5(1 + 2{,}0)}{33000} = 19{,}1$$

$N_s = A_s f_{yd} = 1131 \times 435 = 491.985\ N$

$N_c = \frac{3}{4} x_u f_{cd} b = \frac{3}{4} \times x_u \times 20 \times 1000 = 15.000\ x_u$

$$\rightarrow x_u = \frac{N_s}{N_c} = \frac{491.985}{15.000} = 32{,}8\ mm$$

$\rightarrow z = d - 0{,}39 x_u = 194 - 0{,}39 \times 32{,}8 = 182\ mm$

$\rightarrow M_{Rd} = A_s f_{yd} z = 1131 \times 435 \times 182 \times 10^{-6} = 89{,}2\ kNm$

$$\sigma_s = \frac{9{,}1}{89{,}2} \times 435 = 44{,}3\ N/mm^2$$

$$h_{c;eff} = min\left\{2{,}5(h - d); \frac{(h - x_u)}{3}; \frac{h}{2}\right\} = min\left\{2{,}5 \times (250 - 194); \frac{(250 - 32{,}8)}{3}; \frac{250}{2}\right\} = 72\ mm$$

$$\rho_{p;eff} = \frac{A_s}{A_{c;eff}} = \frac{A_s}{b_c h_{c;eff}} = \frac{1131}{1000 \times 72} = 0{,}016$$

$$\varepsilon_{sm} - \varepsilon_{cm} = \frac{44{,}3 - 0{,}4 \times \frac{2{,}9}{0{,}015} \times (1 + 19{,}1 \times 0{,}016)}{2{,}1 \cdot 10^5} \geq 0{,}6\frac{44{,}3}{2{,}1 \cdot 10^5} \rightarrow \varepsilon_{sm} - \varepsilon_{cm} = 0{,}013\%$$

$$s_{r;max} = k_3 c + \frac{k_1 k_2 k_4 \emptyset}{\rho_{p;eff}} = 3{,}4 \times 62 + \frac{0{,}8 \times 0{,}5 \times 0{,}425 \times 12}{0{,}016} = 338\ mm$$

$w_k = s_{r;max}(\varepsilon_{sm} - \varepsilon_{cm}) = 338 \times 0{,}00013 = 0{,}04\ mm < 0{,}07\ mm \rightarrow ACCEPTABLE$

<u>Conclusion:</u> crack width tank foundation sufficient

Main reinforcement: $\emptyset 12 - 100\ (A_s = 1131\ mm^2)$

6.3.3 Bottom Reinforcement

6.3.3.1 X-direction LIN-SLS

Shrinkage: $\sigma_{cs} = 50{,}0\ N/mm^2$

Effective height: $d_x = 250 - 50 - 0{,}5 \times 12 = 194\ mm$

At location maximum moment: $mxD^- = 32{,}9\ kNm/m$

$mxD^- = 20{,}6\ kNm$

$w_{max} = 0{,}2\ mm$

Required reinforcement: $A_s = 433\ mm^2$

Main reinforcement: $A_s = 1131 mm^2 \rightarrow \emptyset 12 - 100$

$$\sigma_s = \frac{433}{1131} \times \frac{20{,}6}{32{,}9} \times 435 + \sigma_{cs} = 104{,}3 + 50{,}0 = 154{,}3\ N/mm^2 \rightarrow \sigma^*_{max} = 25\ mm$$

Acc. to GTB 21010 14.5a

$$\emptyset_{max} = 25 \times \frac{2{,}9}{2{,}9} \times \frac{0{,}4 \times 0{,}5 \times 250}{2(250 - 182)} = 9{,}2\ mm < 12\ mm \rightarrow NIET\ OK$$

Acc. to GTB 21010 14.5b

$s_{max} = 200\ mm > 100\ mm \rightarrow OK$

<u>Conclusion:</u> crack width tank foundation sufficient

Main reinforcement: $\emptyset 12 - 100\ (A_s = 1131\ mm^2)$

6.3.3.2 Y-direction LIN-SLS

Shrinkage: $\sigma_{cs} = 50{,}0\ N/mm^2$

Effective height: $d_y = 250 - 50 - 12 - 0{,}5 \times 12 = 182\ mm$

At location maximum field moment: $myD^- = 18{,}3\ kNm/m$

$myD^- = 11{,}1\ kNm$

$w_{max} = 0{,}2 mm$

Required reinforcement: $A_s = 446\ mm^2$

Main reinforcement: $A_s = 2010\ mm^2 \rightarrow \emptyset 16 - 100\ (A_s = 2010\ mm^2)$

$$\sigma_s = \frac{446}{2010} \times \frac{83{,}8}{137{,}8} \times 435 + \sigma_{cs} = 58{,}7 + 50{,}0 = 108{,}7\ N/mm^2 \rightarrow \sigma^*_{max} = 25\ mm$$

Acc. to GTB 21010 14.5a

$$\emptyset_{max} = 25 \times \frac{2{,}9}{2{,}9} \times \frac{0{,}4 \times 0{,}5 \times 800}{2(800 - 742)} = 34{,}5\ mm > 16\ mm \rightarrow OK$$

Acc. to GTB 21010 14.5b

$s_{max} = 200\ mm > 100mm \rightarrow OK$

<u>Conclusion:</u> crack width tank foundation sufficient

Main reinforcement: $\emptyset 16 - 100\ (A_s = 2010\ mm^2)$

6.4 Settlement

6.4.1 Minimum settlements foundation tank pit

The figure below shows the minimum settlement of the tank foundation under the expected characteristic load (no partial factors on the loads). The highest settlement is $\delta = 4{,}5\ mm$ and differential settlement is $\Delta\delta = 3{,}3\ mm$ based on the applied soil stiffness of 7,5 MN/m³.

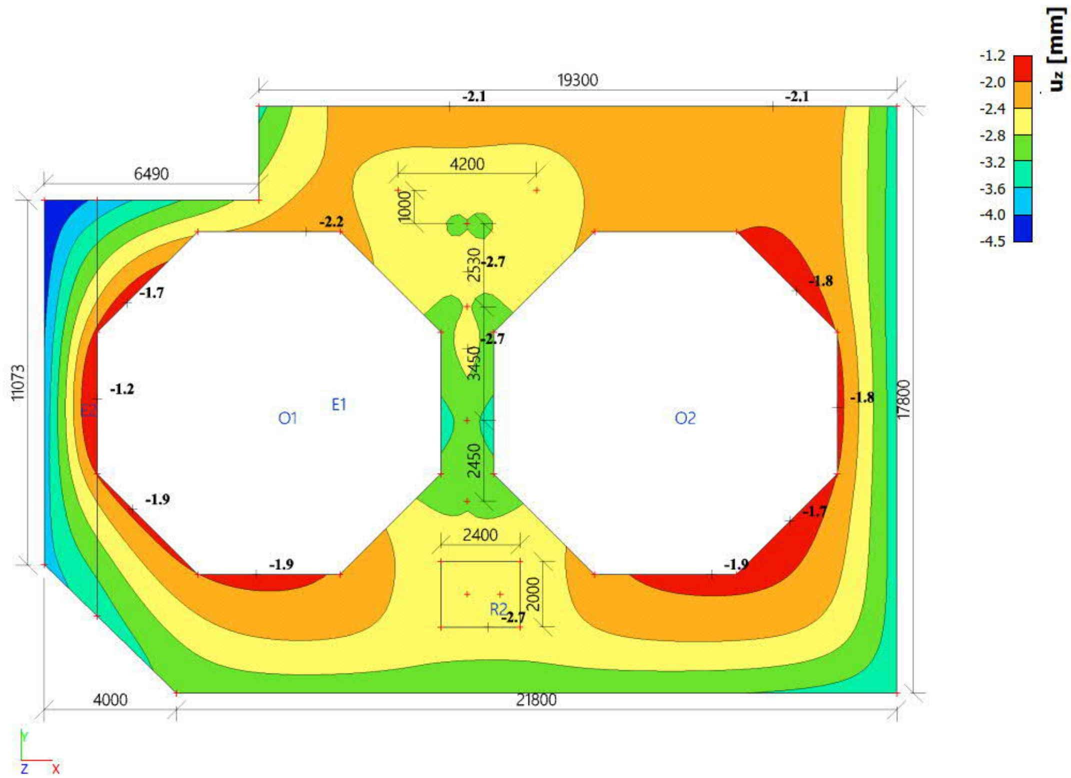


Figure 6-1 Tank concrete foundation settlement

<u>Note:</u>

Assuming the existing bund was fully settled because it had enough time to be settled, a differential settlement about 2 mm (in theory) between the existing bund and the new bund is expected. Therefore, although the settlements are not expected to be large, regular monitoring and maintenance should be planned to avoid any inconvenience.

6.4.2 Maximum settlements tank foundation

The figure below shows the maximum settlement of the floor under the expected characteristic load (no partial factors on the loads). The highest settlement is $\delta = 2{,}4\ mm$ and differential settlement is $\Delta\delta = 2{,}0\ mm$ based on the applied soil stiffness of 7,5 MN/m³.

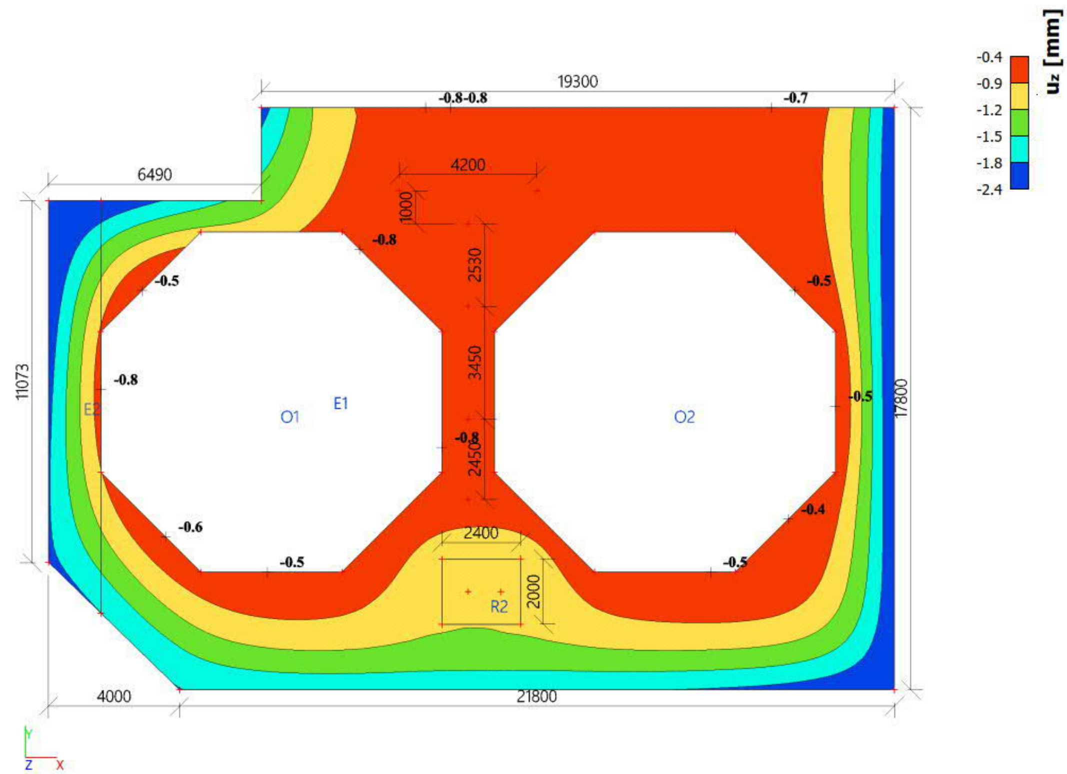


Figure 6-2 Tank concrete foundation settlement

<u>Note:</u>

Assuming the existing bund was fully settled because it had enough time to be settled, a differential settlement about 2 mm (in theory) between the existing bund and the new bund is expected. Therefore, although the settlements are not expected to be large, regular monitoring and maintenance should be planned to avoid any inconvenience.

6.4.3 Settlements LIN-SLS

2D-verplaatsing

Lineaire berekening

Klasse: SLS_All

Extreem: Globaal

Selectie: E1, E2

Locatie: In knooppunten gem. bij macro. Systeem: LCS net element

Naam	Net	Positie [mm]	BG	u_z [mm]
E2	Element: 4094 Knoop: 36	-4,000 14,953 0,000	SLS_07/4	**-4,5**
E1	Element: 427 Knoop: 528	18,565 5,215 0,000	SLS_01/6	**-0,4**

7 Walls foundation Tank-pit

7.1 Concrete walls foundation slab

7.1.1 Minimum reinforcement in tank foundation

The minimum cross-section for the reinforcement to be used acc. to NEN-EN 1992-1-1 art.9.2.1.

ASSUMPTION: main reinforcement in the foundation Ø12-100 (A_s = 1131 mm²/m)

7.1.1.1 Inside reinforcement

Horizontal direction:

$$d_{hor} = 250 - 50 - 12 - 0{,}5 \times 12 = 182\ mm$$

$$A_{sx;min} = 0{,}26 \frac{f_{ctm}}{f_{yk}} b_t d = 0{,}26 \times \frac{2{,}9}{500} \times 1000 \times 182 = 275\, mm^2/m \rightarrow \emptyset 12 - 100\ \ (A_s = 1131\, mm^2/m)$$

$$A_{sx;min} = 0{,}0013 b_t d = 0{,}0013 \times 1{,}0 \times 0{,}182 \times 10^6 = 237\, mm^2/m$$

Vertical direction:

$$d_{ver} = 250 - 50 - 0{,}5 \times 12 = 194\ mm$$

$$A_{sy;min} = 0{,}26 \frac{f_{ctm}}{f_{yk}} b_t d = 0{,}26 \times \frac{2{,}9}{500} \times 1000 \times 194 = 293\, mm^2/m \rightarrow \emptyset 12 - 100\ \ (A_s = 1131\, mm^2/m)$$

$$A_{sy;min} = 0{,}0013 b_t d = 0{,}0013 \times 1{,}0 \times 0{,}194 \times 10^6 = 253\, mm^2/m$$

7.2 Reinforcement

7.2.1 Liquid tightening

Tank-pit shall be designed as a liquid tight structure according to CUR-65 (see the calculation below)

Calculation Liquid Tight Reinforcement
according to CUR-65

Project: T53591 Hexion Formalin Storage Bund
Date: 10.2019

L1. Material Input
L1.1 Concrete

Class:	C30/37			
f_{ck}=	30	N/mm2		
h_c=	250	mm	Concrete thickness	OK
$h_{c;min}$=	250		Minimum concrete thickness	
b_c=	1000	mm	Concrete width	

L1.2 Reinforcement
L1.2.1 Top reinforcement bars

D_{top}=	12	mm	Diameter of top reinforcement bar	
s_{top}=	100	mm	Distance of top reinforcement bar	OK
$s_{top;min}$=	100		Minimum distance of top reinforcement bar	
A_{top}=	1131	mm2	Amount of top reinforcement bar	

L1.2.2 Bottom reinforcement bars

D_{bottom}=	10	mm	Diameter of bottom reinforcement bar	
s_{bottom}=	100	mm	Distance of bottom reinforcement bar	OK
$s_{bottom;min}$=	100		Minimum distance of bottom reinforcement bar	
A_{bottom}=	785	mm2	Amount of bottom reinforcement bar	

L2. Required verifications
L2.1 Lquid ≤ 0,5 h (thicknees of the concrete slab)

$\bar{\omega}_{0,top;required}$=	0,43 %	Minimum required top reinforcement percentage	CUR 65, 4.4.2.3
$\bar{\omega}_{0,top}$=	0,45 %	Percentage of applied top reinforcement bar	
Utilization ratio =	0,94 OK		

L2.2 Lquid ≥ 0,5 h (thicknees of the concrete slab)

$\bar{\omega}_{0,total;required}$=	0,70 %	Minimum required total reinforcement percentage	CUR 65, 4.4.2.3
$\bar{\omega}_{0,total;applied}$=	0,77 %	Percentage of applied total reinforcement bar	
Utilization ratio =	0,91 OK		

The tank foundation is designed to be a liquid tight. According to CUR65, the minimum spacing for the reinforcement is 100 mm.

Acc. to CUR65 art. 4.4.2.3.a Minimum applied reinforcement, top: $\rho_0 = 0{,}42\%$

$$\rho = \frac{A_s}{b_c d} \rightarrow A_s = \frac{\rho b_c d}{100} = \frac{0{,}42 \times 1000 \times 194}{100} = 815\ mm^2 \rightarrow \emptyset 12 - 100\ (A_s = 1131\ mm^2)$$

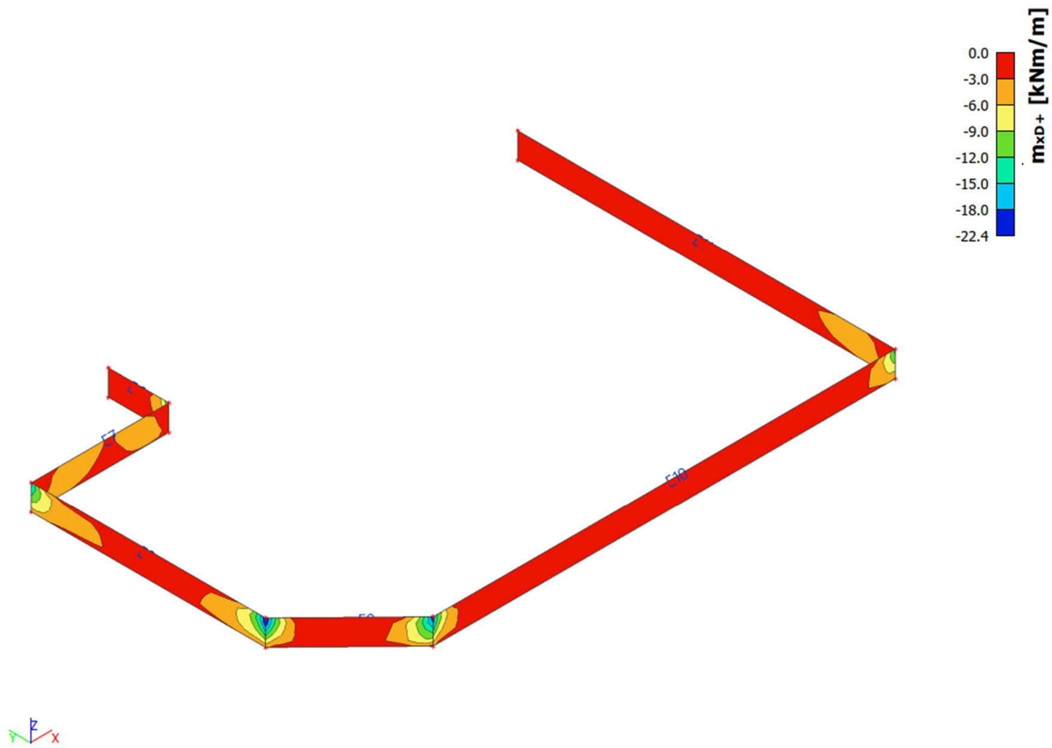
As a result, applied reinforcement bars are:

- Applied main reinforcement, inside: Ø12-100
- Applied main reinforcement, outside: Ø12-100

Note: For the tank-pit reinforcement design, liquid tightening is the decisive requirement.

7.2.2 Inside Reinforcement

7.2.2.1 Horizontal direction LIN-ULS



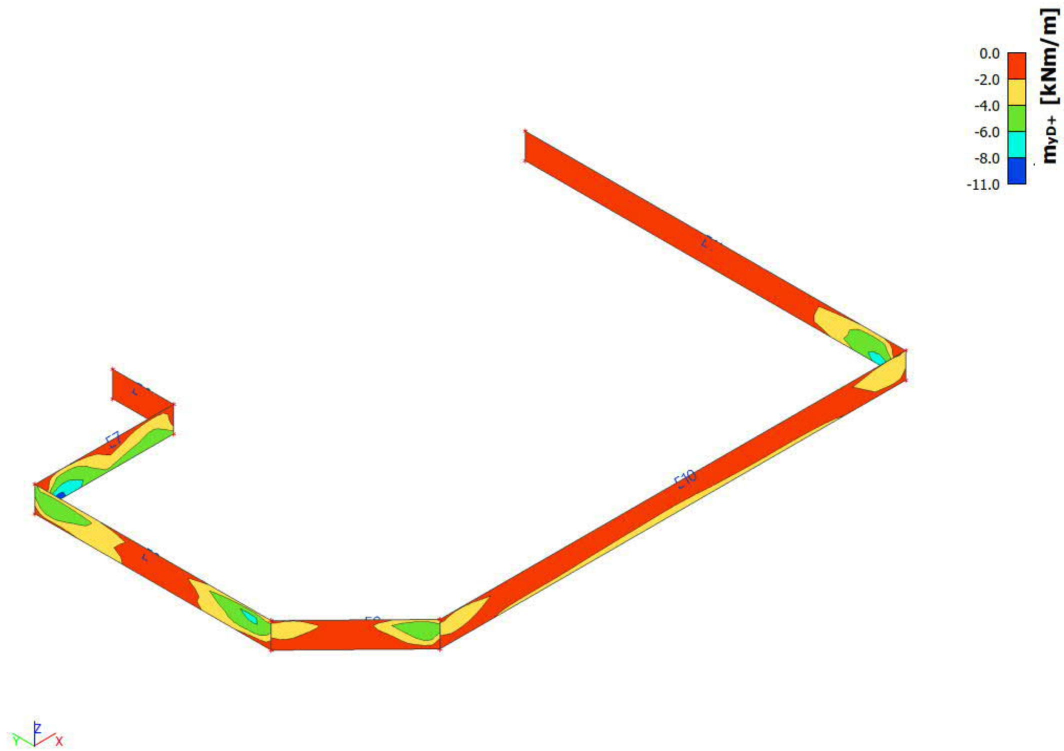
Height for top reinforcement: $d_x = 250 - 50 - 12 - 0{,}5 \times 12 = 182\ mm$

At location maximum field moment: $mxD^{+} = 22{,}4\ kNm/m$

$$\frac{M_{Ed}}{bd^2} = \frac{22{,}4}{1{,}0 \times 0{,}182^2} = 685\ kN/m^2 \rightarrow 100\rho = 0{,}157$$

$$A_s = \frac{0{,}157}{100} \times 1{,}0 \times 0{,}182 \times 10^6 = 286\ mm^2/m\ \rightarrow \emptyset 12 - 100\ \ (A_s = 1131\ mm^2/m)$$

7.2.2.2 Vertical direction LIN-ULS



Height for top reinforcement: $d_y = 250 - 50 - 0{,}5 \times 12 = 194\,mm$

At location maximum field moment: $myD^{+} = 11{,}0\,kNm/m$

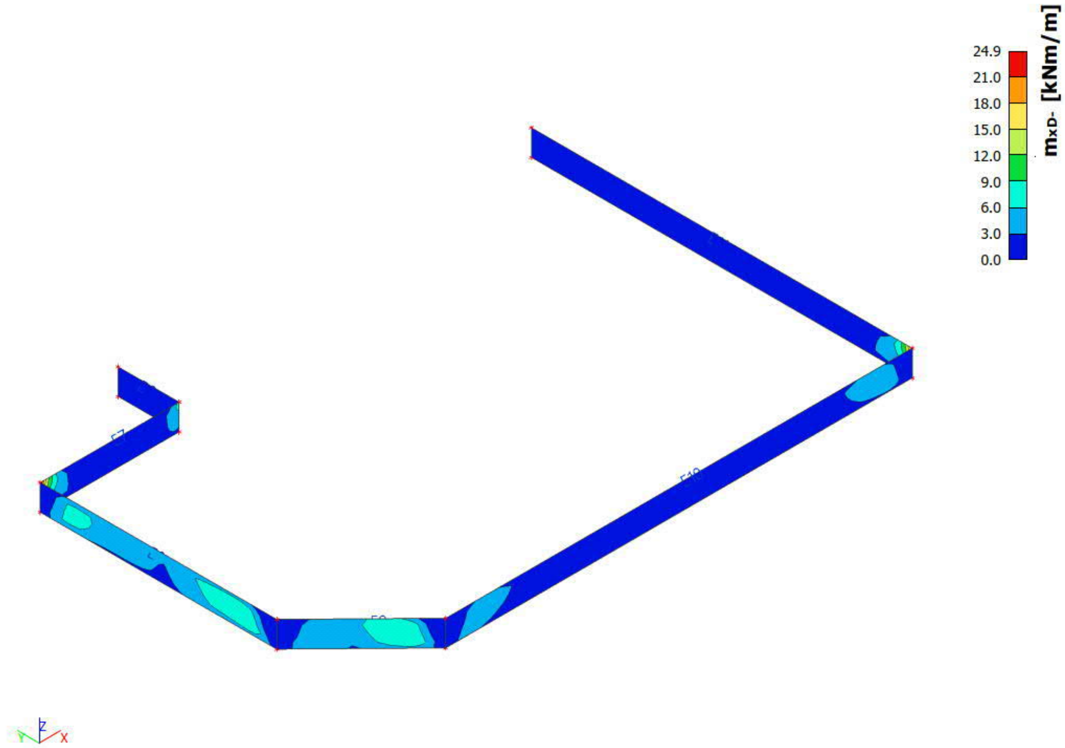
$$\frac{M_{Ed}}{bd^2} = \frac{11{,}0}{1{,}0 \times 0{,}194^2} = 293\,kN/m^2 \rightarrow 100\rho = 0{,}068$$

$$A_s = \frac{0{,}068}{100} \times 1{,}0 \times 0{,}194 \times 10^6 = 133\,mm^2/m$$

$$A_s = 133\,mm^2/m < A_{sy;min} = 293\,mm^2/m \rightarrow \emptyset 12 - 100 \;\; (A_s = 1131\,mm^2/m)$$

7.2.3 Outside reinforcement

7.2.3.1 Horizontal direction LIN-ULS



Height for bottom reinforcement: $d_x = 250 - 50 - 12 - 0{,}5 \times 12 = 182\ mm$

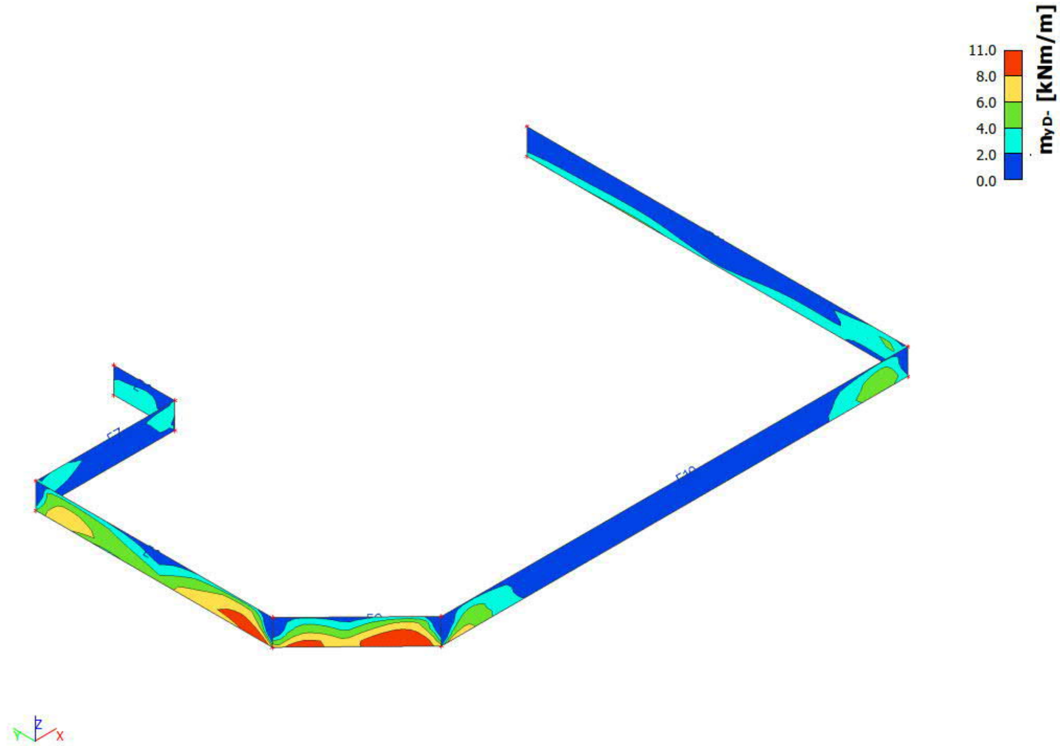
At location maximum field moment:

$$mxD^- = 24{,}9\ kNm/m$$

$$\frac{M_{Ed}}{bd^2} = \frac{24{,}9}{1{,}0 \times 0{,}182^2} = 751\ kN/m^2 \rightarrow 100\rho = 0{,}175$$

$$A_s = \frac{0{,}175}{100} \times 1{,}0 \times 0{,}182 \times 10^6 = 320\ mm^2/m\ \rightarrow \emptyset 12 - 100\ \ (A_s = 1131\ mm^2/m)$$

7.2.3.2 Vertical direction LIN-ULS



Height for bottom reinforcement: $d_y = 250 - 50 - 0{,}5 \times 12 = 194\ mm$

At location maximum field moment:

$$myD^- = 11{,}0\ kNm/m$$

$$\frac{M_{Ed}}{bd^2} = \frac{11{,}0}{1{,}0 \times 0{,}194^2} = 293\ kN/m^2 \rightarrow 100\rho = 0{,}068$$

$$A_s = \frac{0{,}068}{100} \times 1{,}0 \times 0{,}194 \times 10^6 = 133\ mm^2/m$$

$$A_s = 133\ mm^2/m < A_{sy;min} = 293\ mm^2/m \rightarrow \emptyset 12 - 100\ \ (A_s = 1131\ mm^2/m)$$

7.2.4 Results LIN-ULS

Interne 2D-krachten

Lineaire berekening

Klasse: ULS_All

Extreem: Globaal

Selectie: All

Elementaire ontwerpgrootheden

Naam	Net	Positie [m]	BG	m_{xD+} [kNm/m]	m_{yD+} [kNm/m]	m_{xD-} [kNm/m]	m_{yD-} [kNm/m]
E8	Element: 4510 Knoop: 41	-4,000 3,900 1,200	ULS_20/1	**-22,4**	-2,5	0,0	**0,0**
E7	Element: 4290 Knoop: 40	-4,000 14,953 1,200	ULS_20/1	**0,0**	**0,0**	**24,9**	3,1
E7	Element: 4183 Knoop: 4058	-3,200 14,953 0,000	ULS_06/2	-4,5	**-11,0**	0,3	0,0
E9	Element: 4527 Knoop: 4785	-0,920 0,897 0,240	ULS_08/3	-3,8	-0,7	7,9	**11,0**

7.2.5 Results LIN-SLS

Interne 2D-krachten

Lineaire berekening

Klasse: SLS_All

Extreem: Globaal

Selectie: All

Elementaire ontwerpgrootheden

Naam	Net	Positie [m]	BG	m_{xD+} [kNm/m]	m_{yD+} [kNm/m]	m_{xD-} [kNm/m]	m_{yD-} [kNm/m]
E8	Element: 4510 Knoop: 41	-4,000 3,900 1,200	SLS_07/1	**-14,0**	-1,8	0,0	**0,0**
E7	Element: 4290 Knoop: 40	-4,000 14,953 1,200	SLS_06/2	**0,0**	**0,0**	**14,0**	1,7
E7	Element: 4183 Knoop: 4058	-3,200 14,953 0,000	SLS_06/2	-2,9	**-7,1**	0,2	0,0
E9	Element: 4527 Knoop: 4785	-0,920 0,897 0,240	SLS_08/3	-2,4	-0,3	5,1	**7,2**

For the results given in the following chapters, see SCIA calculation in Annex B.

7.3 Walls CRACK WIDTH

7.3.1 Shrinkage strain walls

7.3.1.1 Drying shrinkage strain acc. to GTB2010 5.4.a t/m 5.4.c

$$\varepsilon_{cd}(t) = \beta_{ds}(t,t_s)k_h\varepsilon_{cd;0}$$

$$\varepsilon_{cd;0} = 0{,}85\left[(220+110\alpha_{ds1})e^{\left(-\alpha_{ds2}\frac{f_{cm}}{f_{cm,0}}\right)}\right]10^{6}\times 1{,}55\left[1-\left(\frac{RV}{RV_0}\right)^3\right]$$

Where:

$RV = 80\%\ en\ RV_0 = 100\%$

$Cement\ CEM32{,}5 \rightarrow \alpha_{ds1} = 4\ en\ \alpha_{ds2} = 0{,}12$

$f_{cm} = 38\ N/mm^2\ en\ f_{cm,0} = 10\,N/mm^2$

$$\varepsilon_{cd;0} = 0{,}85\left[(220+110\times 4)e^{\left(-0{,}12\frac{38}{10}\right)}\right]10^{-6}\times 1{,}55\left[1-\left(\frac{80}{100}\right)^3\right] = 0{,}000269 = 0{,}0269\%$$

$$h_0 = \frac{2A_c}{u} = \frac{2\times 1200\times 250}{1200+250+1200} = 226\ mm$$

$h_0 = 226\ mm \rightarrow k_h = 0{,}824$

$\beta_{ds}(t,t_s)k_h = 0{,}824$

$$\varepsilon_{cd}(t) = \beta_{ds}(t,t_s)k_h\varepsilon_{cd;0} = 0{,}824\times 0{,}0269 = 0{,}0222\%$$

7.3.1.2 Autogene shrinkage strain acc. to GTB2010 5.4.d

$$\varepsilon_{ca}(t) = \beta_{as}(t)\varepsilon_{ca}(\infty)$$

$t = \infty$

$$\beta_{as}(t) = 1 - e^{(-0{,}2\sqrt{t})} = 1 - e^{(-0{,}2\sqrt{\infty})} = 1{,}0$$

$$\varepsilon_{ca}(\infty) = 2{,}5(f_{ck}-10)\times 10^{-6} = 2{,}5(30-10)\times 10^{-6} = 0{,}00005 = 0{,}005\%$$

$$\varepsilon_{ca}(t) = \beta_{as}(t)\varepsilon_{ca}(\infty) = 0{,}005\%$$

7.3.1.3 Total shrinkage strain:

$$\varepsilon_{cs} = \varepsilon_{cd} + \varepsilon_{ca}$$

$$\varepsilon_{cs} = 0{,}0222\% + 0{,}005\% = 0{,}0272\%$$

Shrinkage:

$$\sigma_{cs} = \varepsilon_{cs}E_s = \frac{0{,}0272}{100}\times 2{,}1\cdot 10^5 = 57{,}0\,N/mm^2$$

7.3.2 Wall Reinforcement

7.3.2.1 Horizontal reinforcement LIN-SLS

Shrinkage: $\sigma_{cs} = 57{,}0\ N/mm^2$

Effective height: $d_{hor} = 250 - 50 - 12 - 0{,}5 \times 12 = 182\ mm$

At location maximum moment: $mxD^- = 24{,}9\ kNm/m$

$mxD^- = 14{,}0\ kNm$

$w_{max} = 0{,}2\ mm$

Required reinforcement: $A_s = 320\ mm^2$

Main reinforcement: $A_s = 1131\ mm^2 \rightarrow \emptyset 12 - 100$

$$\sigma_s = \frac{320}{1131} \times \frac{14{,}0}{24{,}9} \times 435 + \sigma_{cs} = 69{,}2 + 57{,}0 = 126{,}2\ N/mm^2 \rightarrow \sigma^*_{max} = 25\ mm$$

Acc. to GTB 21010 14.5a

$$\emptyset_{max} = 25 \times \frac{2{,}9}{2{,}9} \times \frac{0{,}4 \times 0{,}5 \times 250}{2(250 - 182)} = 9{,}2\ mm < 12\ mm \rightarrow NIET\ OK$$

Acc. to GTB 21010 14.5b

$s_{max} = 200\ mm > 100mm \rightarrow OK$

<u>Conclusion:</u> crack width tank foundation sufficient

Main reinforcement: $\emptyset 12 - 100\ (A_s = 1131\ mm^2)$

7.3.2.2 Vertical direction LIN-SLS

Shrinkage: $\sigma_{cs} = 57{,}0\ N/mm^2$

Effective height: $d_{ver} = 250 - 50 - 0{,}5 \times 12 = 194\ mm$

At location maximum field moment: $myD^- = 11{,}0\ kNm/m$

$myD^- = 7{,}2\ kNm$

$w_{max} = 0{,}2\ mm$

Required reinforcement: $A_s = 133\ mm^2$

Main reinforcement: $A_s = 1131\ mm^2 \rightarrow \emptyset 12 - 100$

$$\sigma_s = \frac{133}{1131} \times \frac{7{,}2}{11{,}0} \times 435 + \sigma_{cs} = 33{,}5 + 57{,}0 = 90{,}5\ N/mm^2 \rightarrow \sigma^*_{max} = 25\ mm$$

Acc. to GTB 21010 14.5a

$$\emptyset_{max} = 25 \times \frac{2{,}9}{2{,}9} \times \frac{0{,}4 \times 0{,}5 \times 250}{2(250 - 194)} = 11{,}2\ mm > 12\ mm \rightarrow OK$$

Acc. to GTB 21010 14.5b

$s_{max} = 200\ mm > 100mm \rightarrow OK$

<u>Conclusion:</u> crack width tank foundation sufficient

Main reinforcement: $\emptyset 12 - 100\ (A_s = 1131\ mm^2)$

8 Anchor bolt check

8.1 Anchor bolt for the tank

8.1.1 Anchor data

Anchor type, number, size, position and force on the anchor are proposed by the client.

- Anchor type: chemical anchor,
- Number of anchor: 12
- Anchor size: M30
- Distance between the anchor and the concrete edge: 190 mm
- Maximum characteristic value tension per anchor: 35 kN, design value 60 kN

8.1.2 Anchor depth

With the input from the client, the anchor depth is checked with HILTI anchor design program (PROFIS ENGINEERING) and it is proven that the applied anchor depth 450mm is okay.

See for input and results par. 9.3 “Annex C: Anchors Tank foundation”:

- Anchor depth in concrete: 450mm → OK.

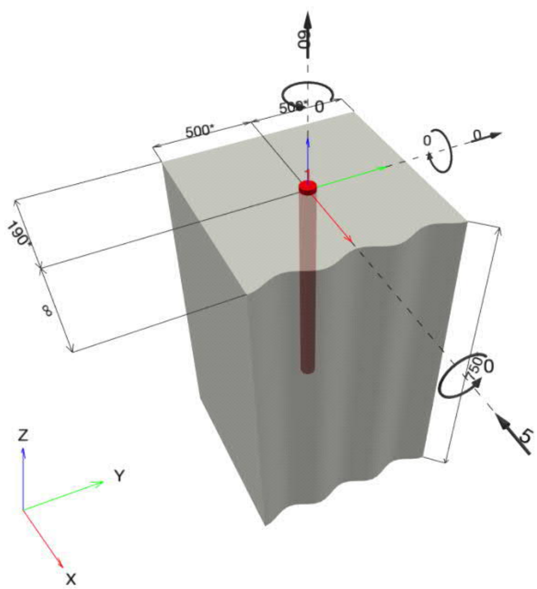


Figure 8-1 Geometry and loading

8.2 Anchor bolt for steel column

There are two steel columns connecting to the tank-pit slab from the existing steel pipe rack.

8.2.1 Anchor data

Anchor type, number, size, position and force on the anchor are proposed by the client.

- Anchor type: M20-8.8 (2 pcs for each column)
- Number of anchor: 12
- Effective depth: 220 mm
- Distance between the anchors: 150 mm

Result of a preliminary steel calculation the force at the base of the column are as below.

- Design value compression force: 47 kN
- Design value tension force: -10 kN
- Design value shear force: 5 kN

8.2.2 Anchor depth

With the input from the client, the anchor depth is checked with XColumnBase, and it is proven that the applied anchor depth 220mm is okay.

See for input and results par. 9.4 “Annex D: Anchors main steel structure”:

- Anchor depth in concrete: 220mm → OK.

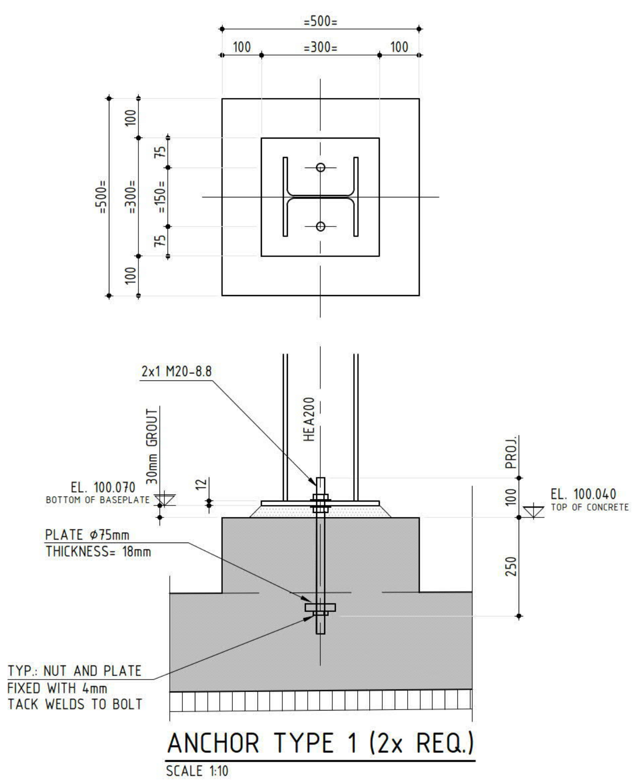
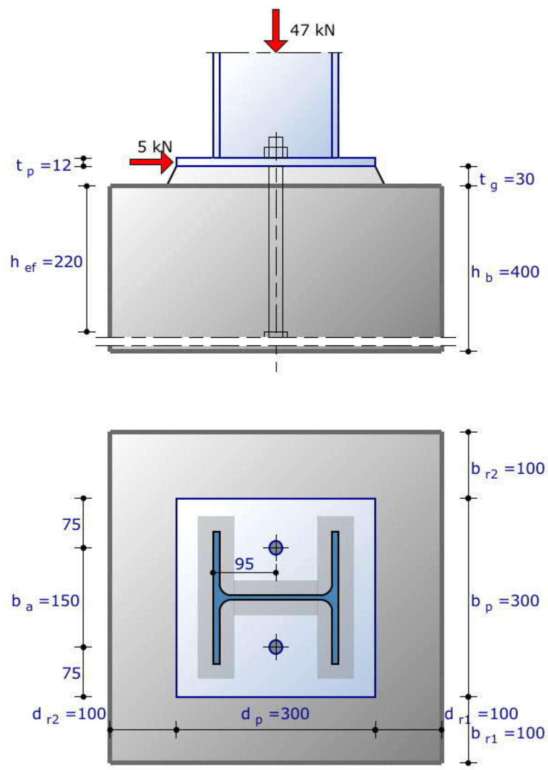


Figure 8-2 Anchor bolt design for steel column base plate connection to concrete foundation

According to the a preliminary steel calculation the force at the base of the column is as below.

- Design value compression force: 47 kN
- Design value tension force: -10 kN
- Design value shear force: 5 kN

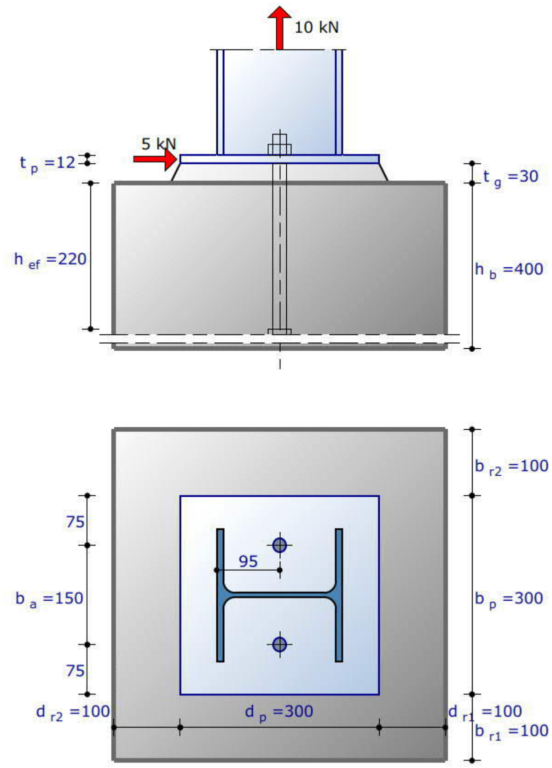
To take into account the effects of the anchors a preliminary anchor calculation is in this paragraph worked out. Below the input for the anchor calculations based on above design values are given.



Profiel:	HEA200, sterkteklasse S235
Ankers:	M 20, ankerbout, klasse 8.8 gerolde draad normale gatspeling h_{ef} = 220 mm
Grout:	zand-cement mortel, t_g = 30 mm
Fundering:	betonsterkteklasse C30/37, gescheurd, betonstaalsoort B500B h_b = 400 mm, c_{min} =30 mm
Afmetingen voetplaat:	b_p = 300 mm, d_p = 300 mm, t_p = 12 mm
Las:	dubbele hoeklas a = 5 mm
Afstanden van de ankers:	b_a = 150 mm, d_a = 0 mm
Randafstanden van de ankers:	r_2 = 75 mm, r_1 = 150 mm
Belastingen:	N_{Ed} = 47 kN, V_{Ed} = 5 kN, M_{Ed} = 0 kNm

Figure 8-3 Anchor bolts configuration by XColumnBase (Annex D)

INVOERGEGEVENS



Profiel:	HEA200, sterkteklasse S235
Ankers:	M 20, ankerbout, klasse 8.8 gerolde draad
	normale gatspeling
	h_{ef} = 220 mm
Grout:	zand-cement mortel, t_g = 30 mm
Fundering:	betonsterkteklasse C30/37, gescheurd, betonstaalsoort B500B
	h_b = 400 mm, c_{min} =30 mm
Afmetingen voetplaat:	b_p = 300 mm, d_p = 300 mm, t_p = 12 mm
Las:	dubbele hoeklas a = 5 mm
Afstanden van de ankers:	b_a = 150 mm, d_a = 0 mm
Randafstanden van de ankers:	r_2 = 75 mm, r_1 = 150 mm
Belastingen:	N_{Ed} = 10 kN, V_{Ed} = 5 kN, M_{Ed} = 0 kNm

Figure 8-4 Anchor bolts configuration by XColumnBase (Annex D)

The check of the anchors is done with XColumnBase, and the designed anchor bolt satisfies the anchor bolt design requirements.

9 Annex

9.1 Annex A: Tank Foundation

9.2 Annex B: Foundation floor and wall

9.3 Annex C: Anchors Tank foundation

9.4 Annex D: Anchors main steel structure

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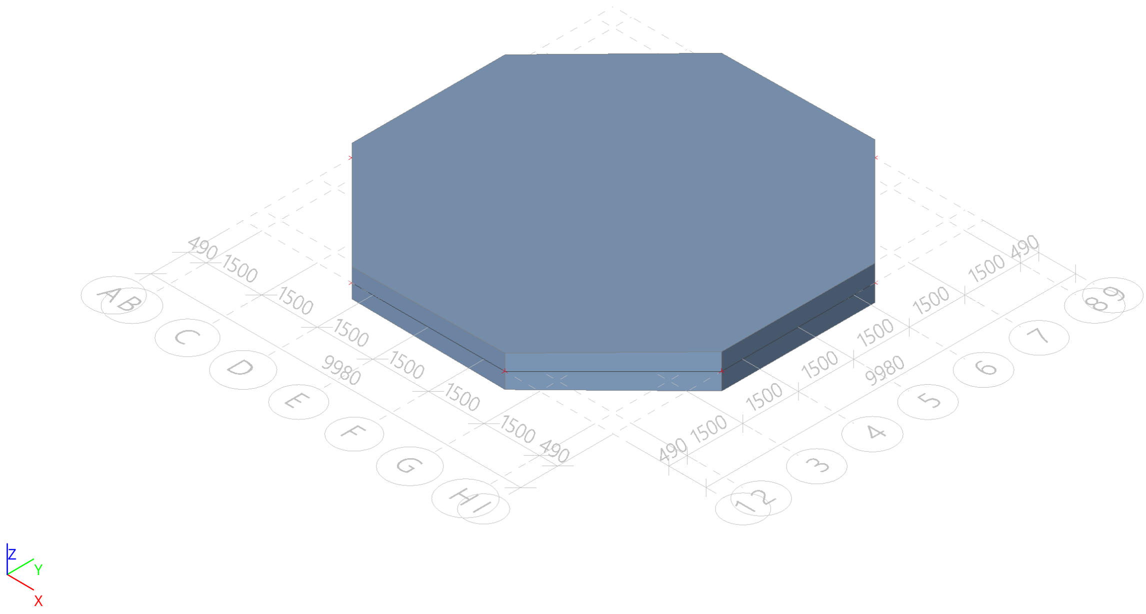
2. Project

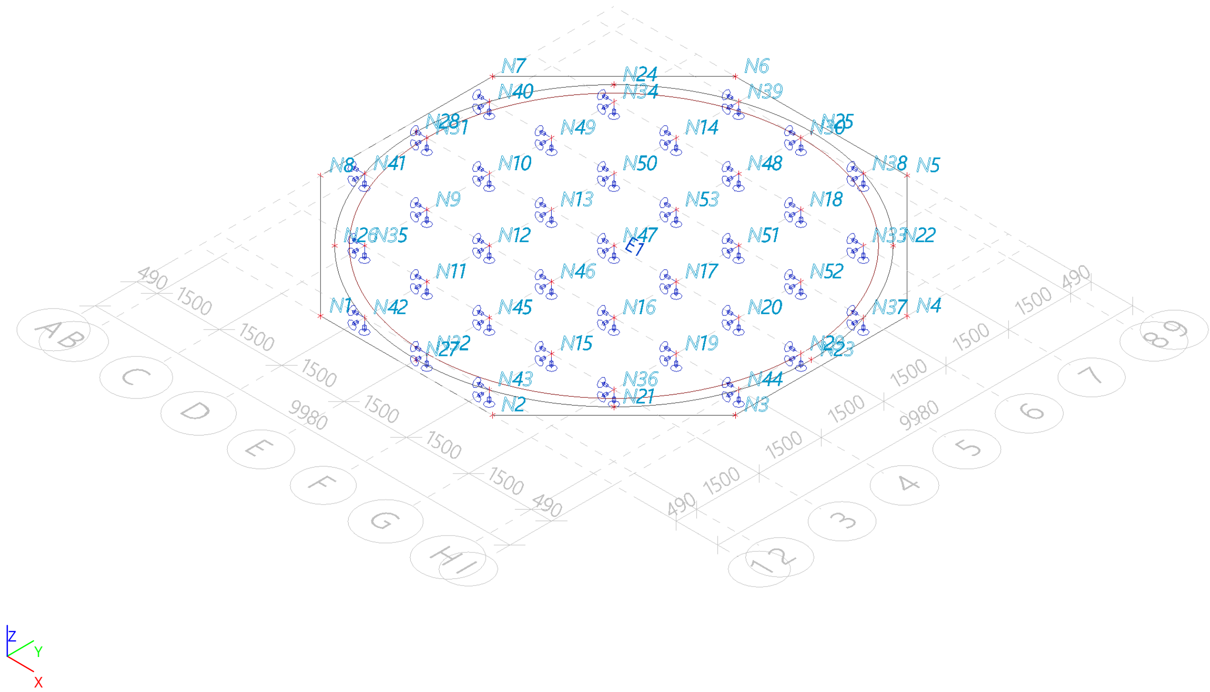
Licence name	Bilfinger Tebodin Netherlands B.V.
Project	T53591-01: Hexion Formaline Storage Bund
Part	1334001: Tank Foundation Slab
Description	03: Load ans strenght calculation
Author	Bilfinger Tebodin Netherlands B.V.
Date	21-08-2020
Structure	General XYZ
No. of nodes :	53
No. of beams :	0
No. of slabs :	1
No. of solids :	0
No. of used profiles :	0
No. of load cases :	14
No. of used materials :	1
Acceleration of gravity [m/s^2]	9,812
National code	EC - EN

3. Model Data

3.1. Model



3.2. Rekenmodel



3.3. Knoop

Name	Coord X [m]	Coord Y [m]	Coord Z [m]
N1	-2,067	-4,990	0,000
N2	2,067	-4,990	0,000
N3	4,990	-2,067	0,000
N6	-2,067	4,990	0,000
N7	-4,990	2,067	0,000
N8	-4,990	-2,067	0,000
N9	-3,000	-1,500	0,000
N10	-3,000	0,000	0,000
N11	-1,500	-3,000	0,000
N12	-1,500	-1,500	0,000
N13	-1,500	0,000	0,000
N14	-1,500	3,000	0,000
N15	1,500	-3,000	0,000
N16	1,500	-1,500	0,000
N17	1,500	0,000	0,000
N18	1,500	3,000	0,000
N19	3,000	-1,500	0,000
N20	3,000	0,000	0,000
N21	3,359	-3,359	0,000
N22	3,359	3,359	0,000
N23	4,750	0,000	0,000
N24	-3,359	3,359	0,000
N25	0,000	4,750	0,000
N26	-3,359	-3,359	0,000
N27	0,000	-4,750	0,000
N28	-4,750	0,000	0,000

Name	Coord X [m]	Coord Y [m]	Coord Z [m]
N29	4,500	0,000	0,000
N30	0,000	4,500	0,000
N31	-4,500	0,000	0,000
N32	0,000	-4,500	0,000
N33	3,000	3,000	0,000
N34	-3,000	3,000	0,000
N35	-3,000	-3,000	0,000
N36	3,000	-3,000	0,000
N37	4,500	1,500	0,000
N38	1,500	4,500	0,000
N39	-1,500	4,500	0,000
N40	-4,500	1,500	0,000
N41	-4,500	-1,500	0,000
N42	-1,500	-4,500	0,000
N43	1,500	-4,500	0,000
N44	4,500	-1,500	0,000
N45	0,000	-3,000	0,000
N46	0,000	-1,500	0,000
N47	0,000	0,000	0,000
N48	0,000	3,000	0,000
N49	-3,000	1,500	0,000
N50	-1,500	1,500	0,000
N51	1,500	1,500	0,000
N52	3,000	1,500	0,000
N53	0,000	1,500	0,000

3.4. 2D-element

Name	Layer	Type	Element type	Material	Thickness type	Th. [mm]
E1	Concrete slab	vloer (90)	Standaard	C30/37_cracked	variable	750
						850

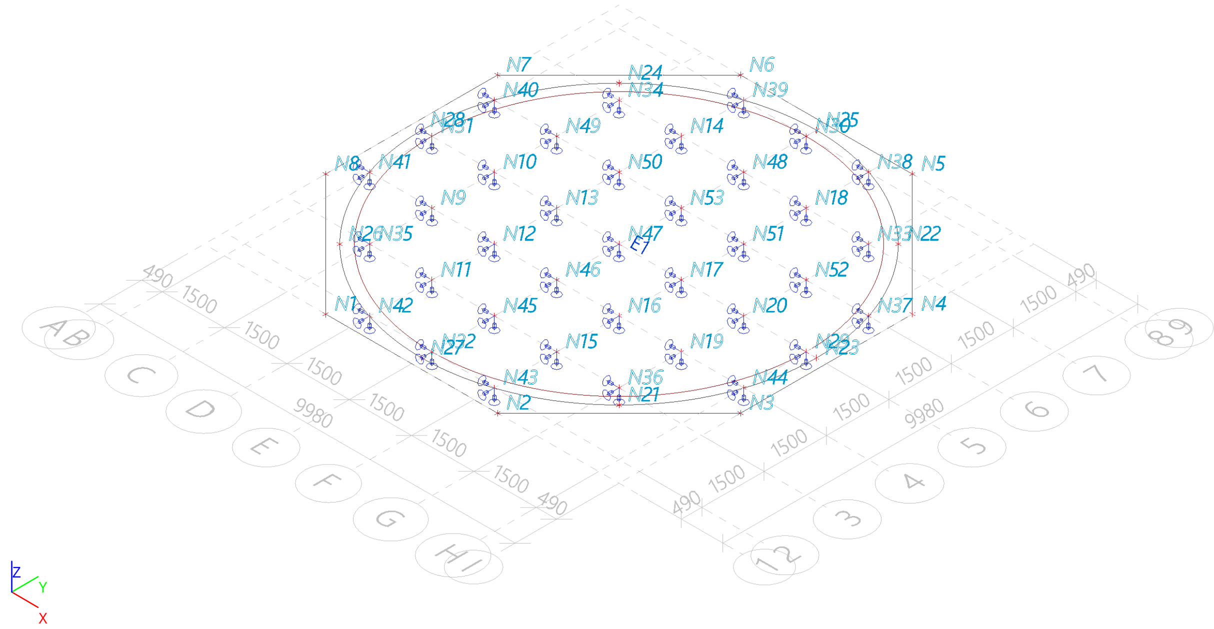
3.5. Knoopondersteuningen

Name	Node	System	X	Stiffness X [MN/m]	Y	Stiffness Y [MN/m]	Z	Stiffness Z [MN/m]	Rx	Ry	Rz
Sn1	N9	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn2	N10	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn3	N11	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn4	N12	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn5	N13	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn6	N14	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn7	N15	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn8	N16	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn9	N17	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn10	N18	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn11	N19	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn12	N20	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn13	N29	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn14	N30	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn15	N31	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn16	N32	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn17	N33	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn18	N34	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn19	N35	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn20	N36	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn21	N37	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn22	N38	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn23	N39	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn24	N40	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn25	N41	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn26	N42	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn27	N43	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn28	N44	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn29	N45	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn30	N46	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn31	N47	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn32	N48	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn33	N49	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn34	N50	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn35	N51	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn36	N52	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free
Sn37	N53	GCS	Flexible	3,1000e+00	Flexible	3,1000e+00	Flexible	6,2000e+01	Free	Free	Free

4. Load cases

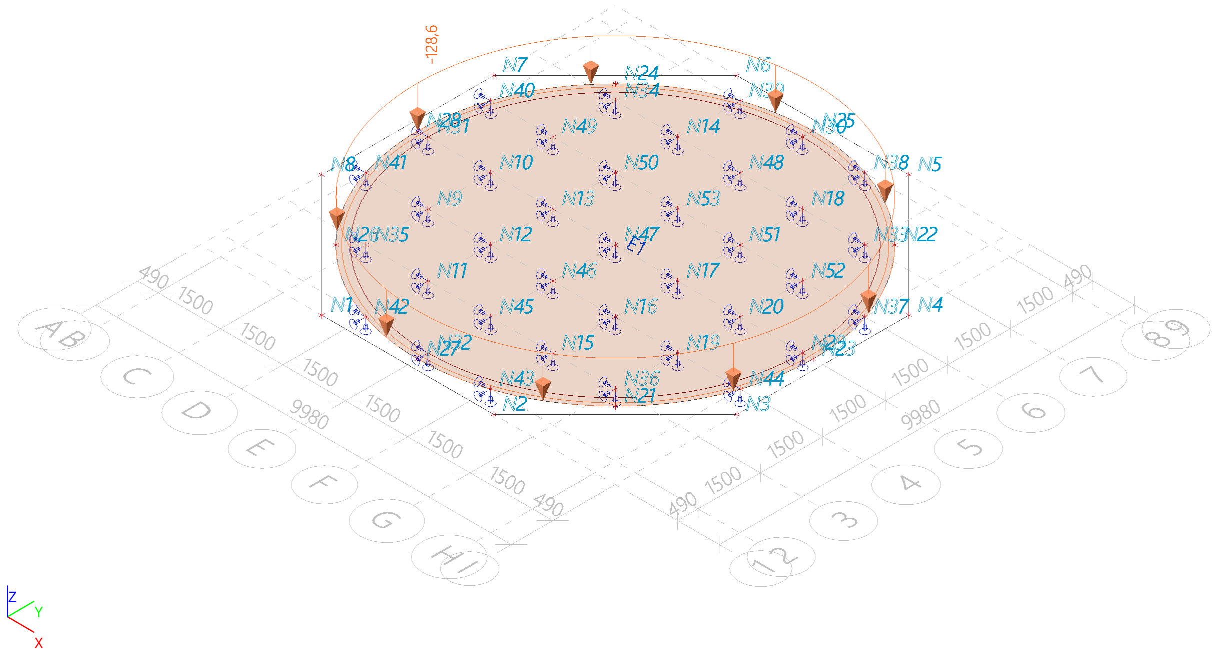
4.1. LC_01

4.1.1. LC_01 / Totale waarde



4.2. LC_11

4.2.1. LC_11 / Totale waarde

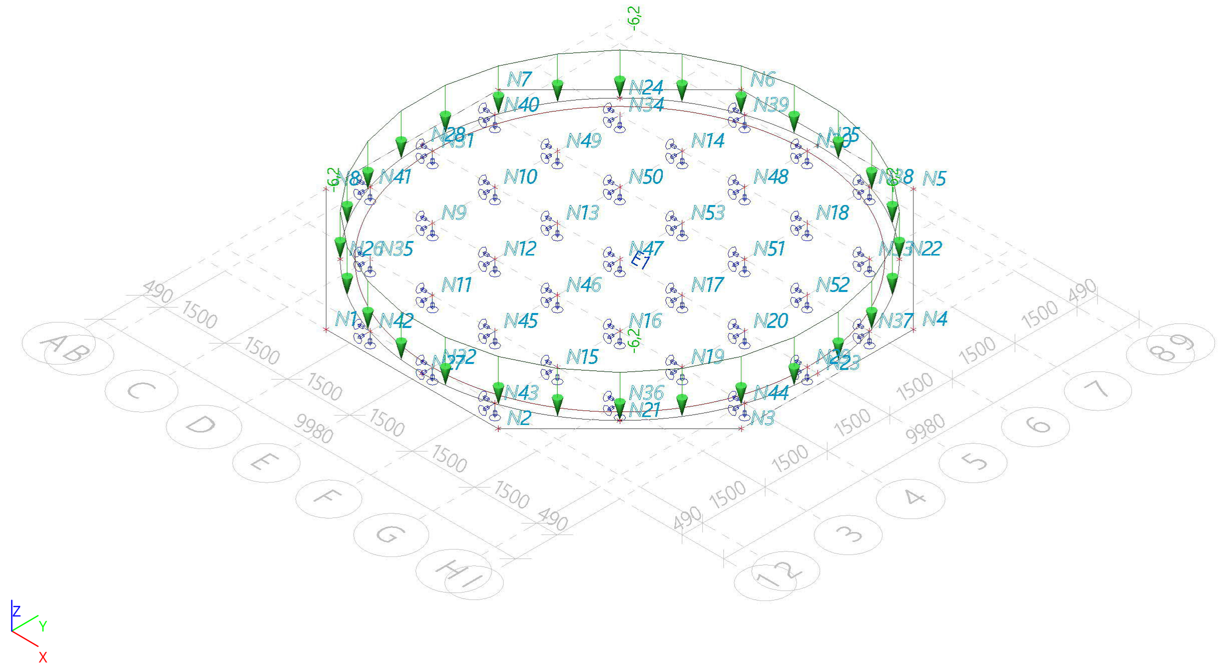


4.2.2. Genereer vrije lasten

Name	Load case	2D member	Dir	Distribution	Type load	q [kN/m^2]	System
GFF1	LC_11 - Tank Operating	E1	Z	Uniform	Surface	-128,6	GCS

4.3. LC_12

4.3.1. LC_12 / Totale waarde

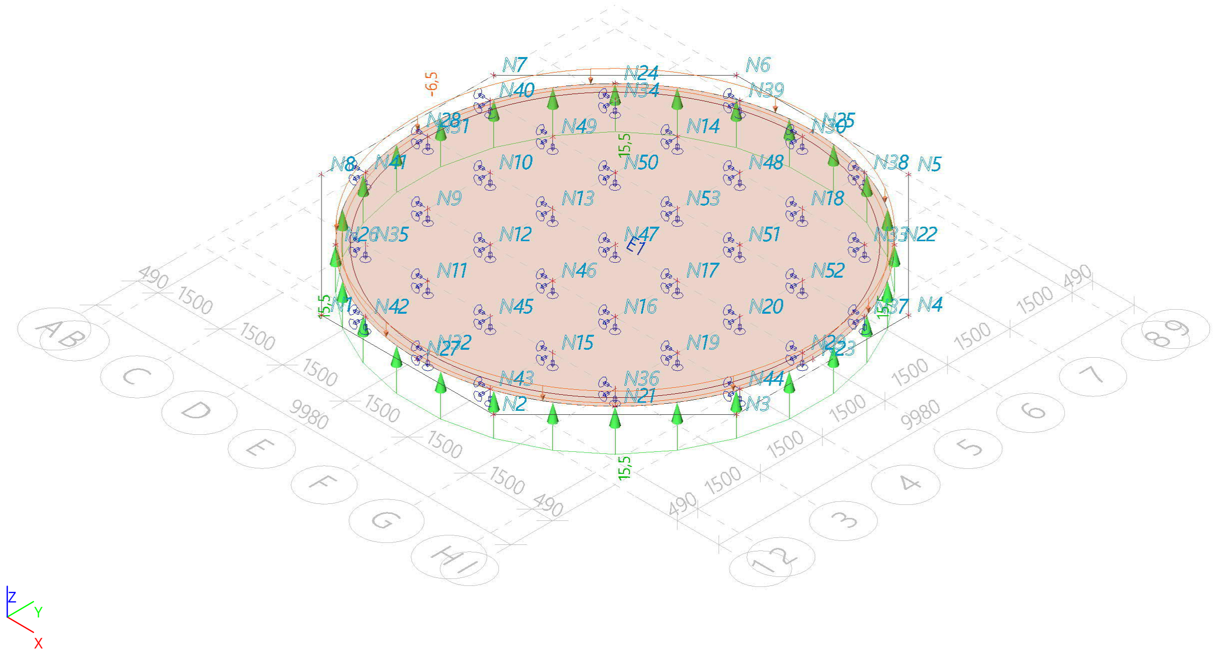


4.3.2. Lijnlasten op 2D elementranden

Name	Load case	Dir	Type	Distribution	Loc	Value - P_1 [kN/m]	System
LFS15	LC_12 - Platform Live Load	Z	Force	Uniform	Length	-6,2	GCS
LFS20	LC_12 - Platform Live Load	Z	Force	Uniform	Length	-6,2	GCS
LFS23	LC_12 - Platform Live Load	Z	Force	Uniform	Length	-6,2	GCS
LFS26	LC_12 - Platform Live Load	Z	Force	Uniform	Length	-6,2	GCS

4.4. LC_13

4.4.1. LC_13 / Totale waarde



4.4.2. Lijnlasten op 2D elementranden

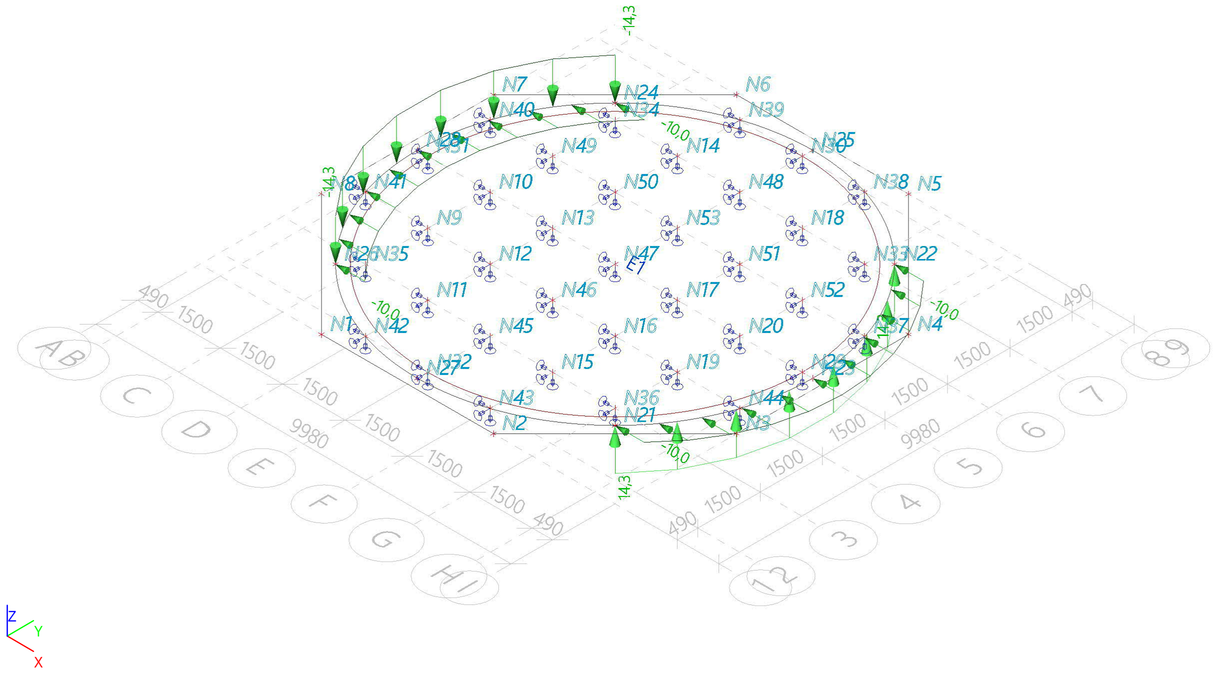
Name	Load case	Dir	Type	Distribution	Loc	Value - P_1 [kN/m]	System
LFS72	LC_13 - Tank_Pressure Uplift	Z	Force	Uniform	Length	15,5	GCS
LFS73	LC_13 - Tank_Pressure Uplift	Z	Force	Uniform	Length	15,5	GCS
LFS74	LC_13 - Tank_Pressure Uplift	Z	Force	Uniform	Length	15,5	GCS
LFS75	LC_13 - Tank_Pressure Uplift	Z	Force	Uniform	Length	15,5	GCS

4.4.3. Genereer vrije lasten

Name	Load case	2D member	Dir	Distribution	Type load	q [kN/m^2]	System
GFF3	LC_13 - Tank_Pressure Uplift	E1	Z	Uniform	Surface	-6,5	GCS

4.5. LC_21

4.5.1. LC_21 / Totale waarde

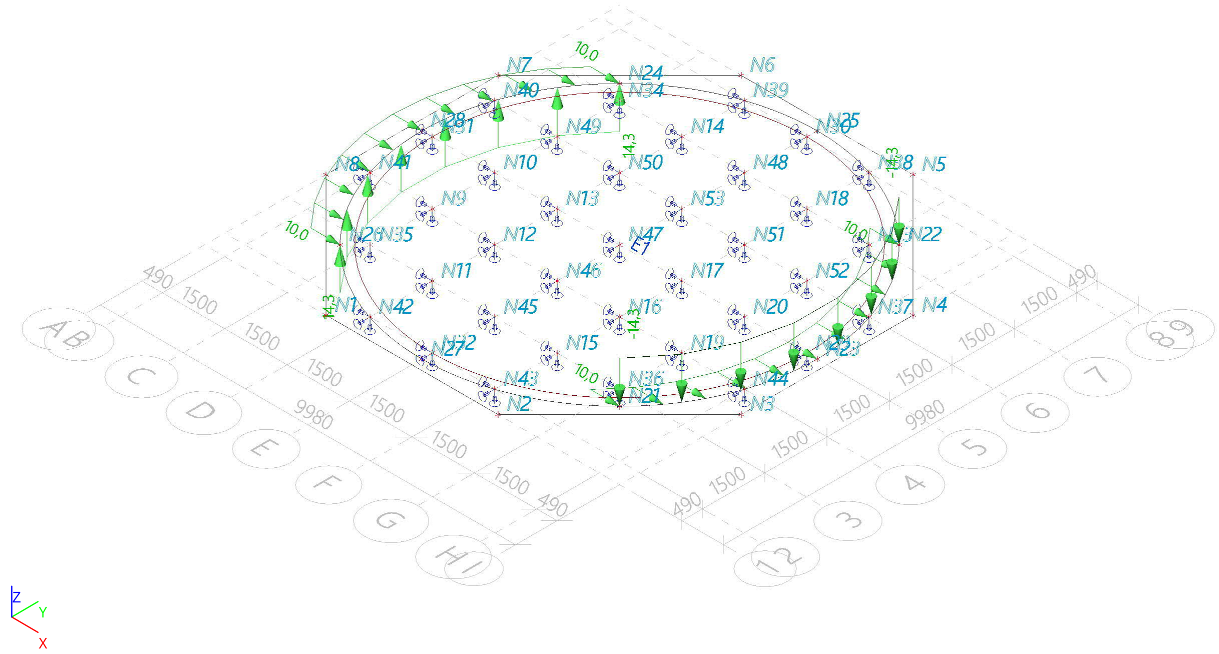


4.5.2. Lijnlasten op 2D elementranden

Name	Load case	Dir	Type	Distribution	Loc	Value - P1 [kN/m]	System
LFS35	LC_21 - E-W	X	Force	Uniform	Length	-10,0	GCS
LFS36	LC_21 - E-W	X	Force	Uniform	Length	-10,0	GCS
LFS39	LC_21 - E-W	Z	Force	Uniform	Length	14,3	GCS
LFS42	LC_21 - E-W	Z	Force	Uniform	Length	-14,3	GCS

4.6. LC_22

4.6.1. LC_22 / Totale waarde

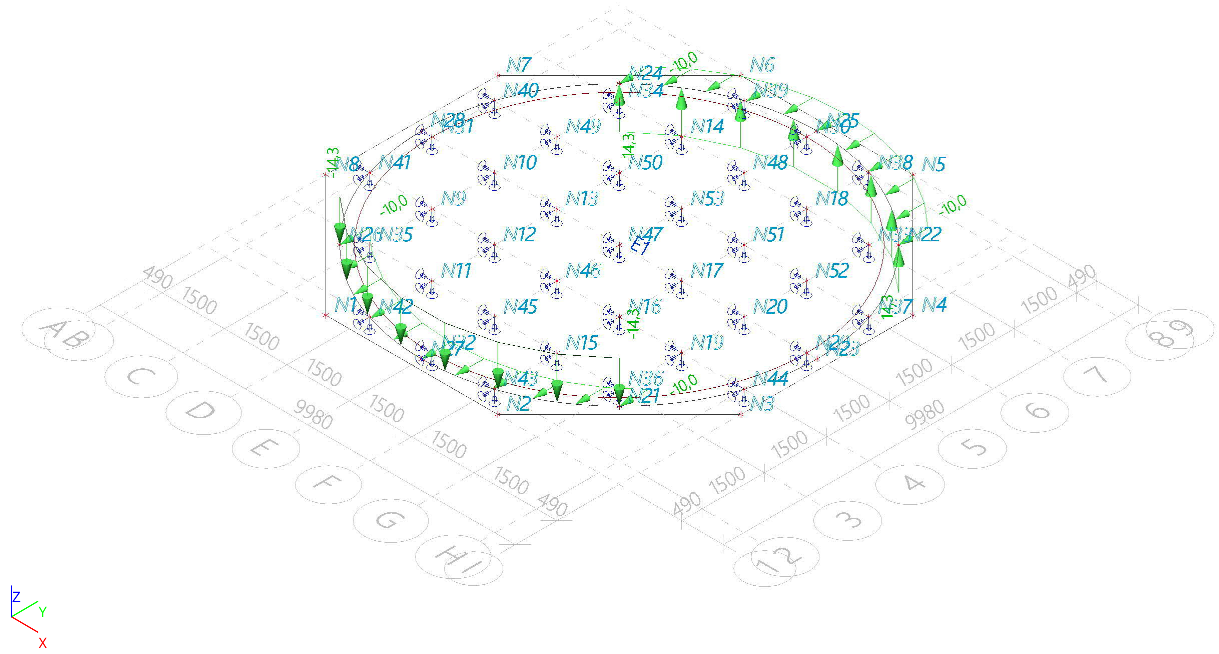


4.6.2. Lijnlasten op 2D elementranden

Name	Load case	Dir	Type	Distribution	Loc	Value - P1 [kN/m]	System
LFS43	LC_22 - W-E	X	Force	Uniform	Length	10,0	GCS
LFS44	LC_22 - W-E	X	Force	Uniform	Length	10,0	GCS
LFS45	LC_22 - W-E	Z	Force	Uniform	Length	-14,3	GCS
LFS46	LC_22 - W-E	Z	Force	Uniform	Length	14,3	GCS

4.7. LC_23

4.7.1. LC_23 / Totale waarde

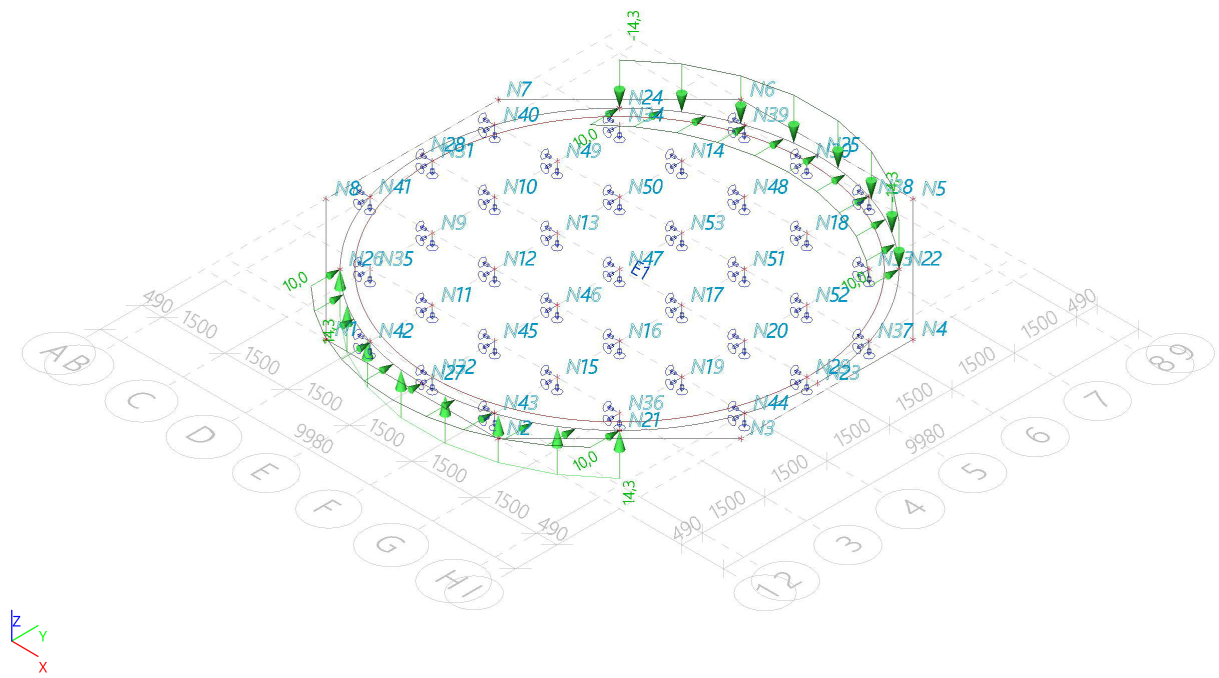


4.7.2. Lijnlasten op 2D elementranden

Name	Load case	Dir	Type	Distribution	Loc	Value - P1 [kN/m]	System
LFS37	LC_23 - N-S	Y	Force	Uniform	Length	-10,0	GCS
LFS38	LC_23 - N-S	Y	Force	Uniform	Length	-10,0	GCS
LFS40	LC_23 - N-S	Z	Force	Uniform	Length	14,3	GCS
LFS41	LC_23 - N-S	Z	Force	Uniform	Length	-14,3	GCS

4.8. LC_24

4.8.1. LC_24 / Totale waarde

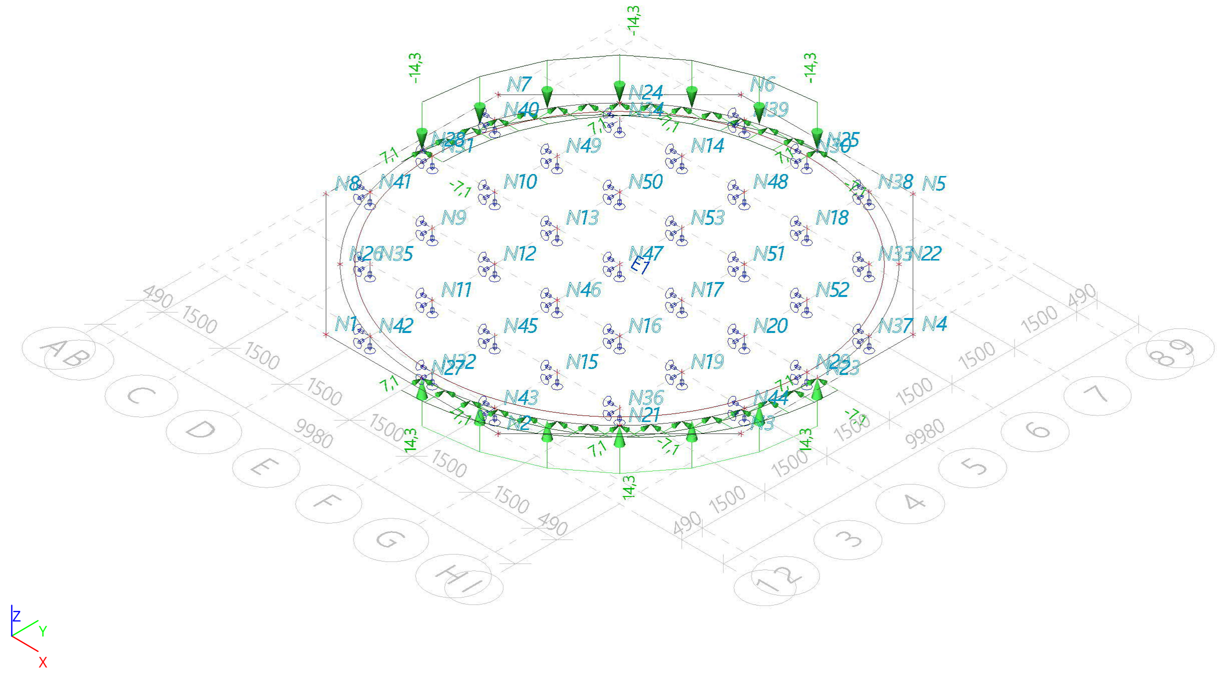


4.8.2. Lijnlasten op 2D elementranden

Name	Load case	Dir	Type	Distribution	Loc	Value - P_1 [kN/m]	System
LFS47	LC_24 - S-N	Y	Force	Uniform	Length	10,0	GCS
LFS48	LC_24 - S-N	Y	Force	Uniform	Length	10,0	GCS
LFS49	LC_24 - S-N	Z	Force	Uniform	Length	-14,3	GCS
LFS50	LC_24 - S-N	Z	Force	Uniform	Length	14,3	GCS

4.9. LC_25

4.9.1. LC_25 / Totale waarde

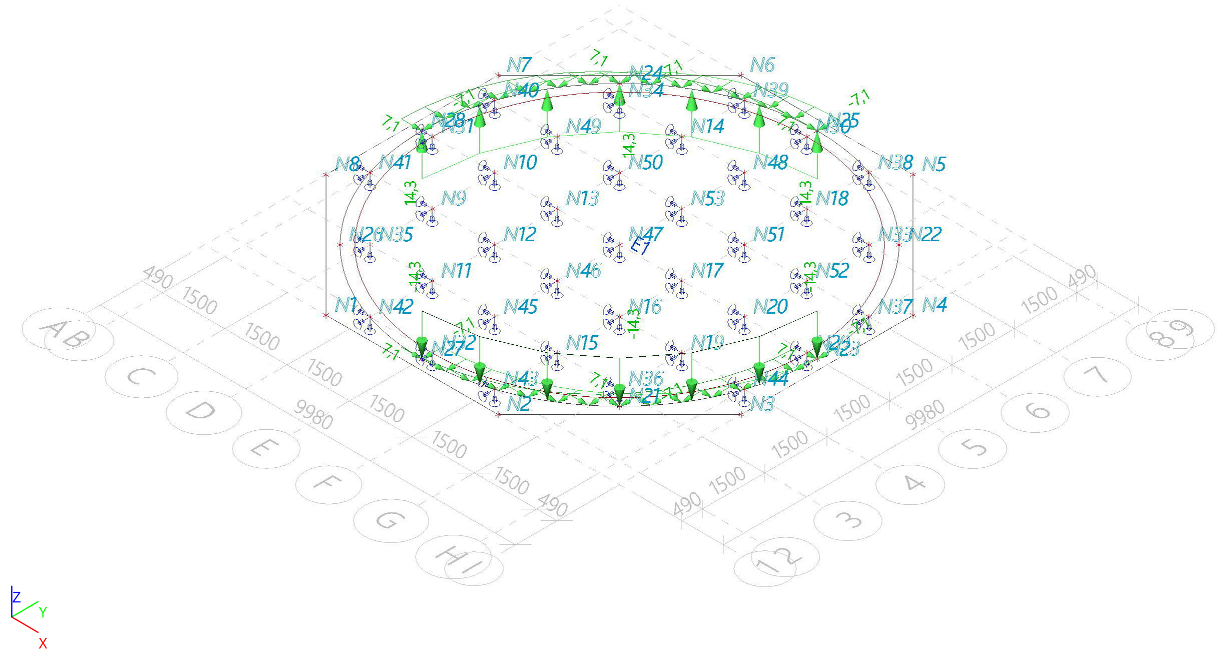


4.9.2. Lijnlasten op 2D elementranden

Name	Load case	Dir	Type	Distribution	Loc	Value - P_1 [kN/m]	System
LFS53	LC_25 - SE-NW	Z	Force	Uniform	Length	14,3	GCS
LFS54	LC_25 - SE-NW	Z	Force	Uniform	Length	-14,3	GCS
LFS56	LC_25 - SE-NW	Z	Force	Uniform	Length	-14,3	GCS
LFS57	LC_25 - SE-NW	Z	Force	Uniform	Length	14,3	GCS
LFS76	LC_25 - SE-NW	X	Force	Uniform	Length	-7,1	GCS
LFS77	LC_25 - SE-NW	X	Force	Uniform	Length	-7,1	GCS
LFS78	LC_25 - SE-NW	X	Force	Uniform	Length	-7,1	GCS
LFS79	LC_25 - SE-NW	X	Force	Uniform	Length	-7,1	GCS
LFS80	LC_25 - SE-NW	Y	Force	Uniform	Length	7,1	GCS
LFS81	LC_25 - SE-NW	Y	Force	Uniform	Length	7,1	GCS
LFS82	LC_25 - SE-NW	Y	Force	Uniform	Length	7,1	GCS
LFS83	LC_25 - SE-NW	Y	Force	Uniform	Length	7,1	GCS

4.10. LC_26

4.10.1. LC_26 / Totale waarde

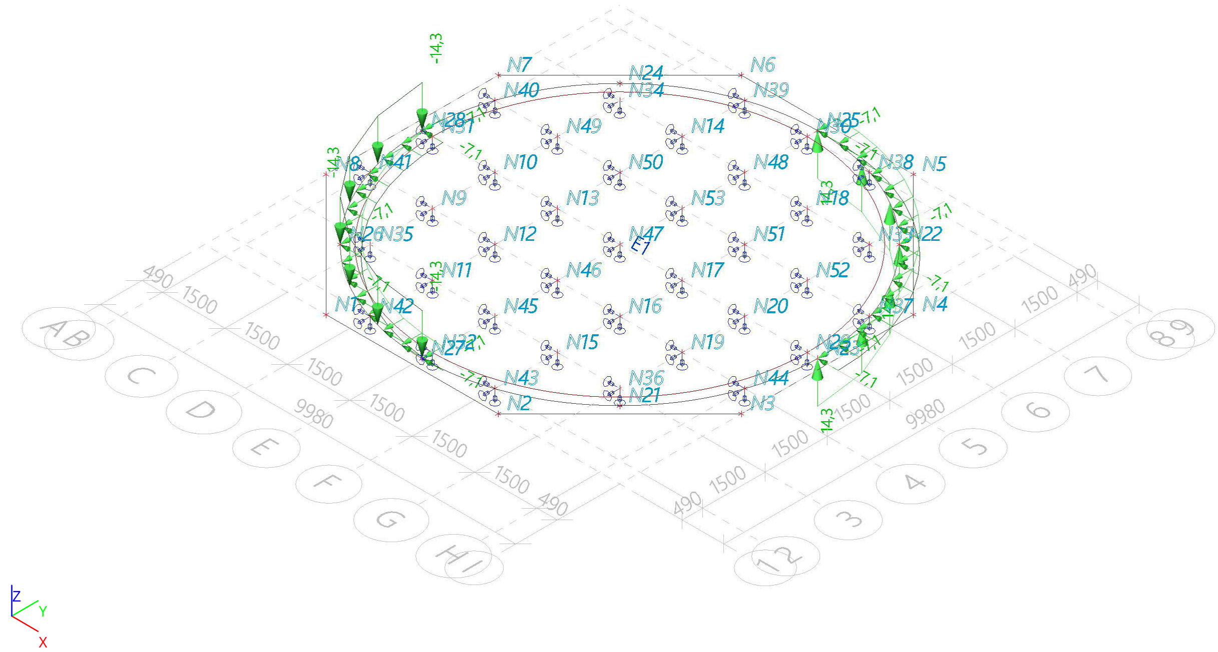


4.10.2. Lijnlasten op 2D elementranden

Name	Load case	Dir	Type	Distribution	Loc	Value - P1 [kN/m]	System
LFS58	LC_26 - NW-SE	Z	Force	Uniform	Length	-14,3	GCS
LFS59	LC_26 - NW-SE	Z	Force	Uniform	Length	14,3	GCS
LFS60	LC_26 - NW-SE	Z	Force	Uniform	Length	14,3	GCS
LFS61	LC_26 - NW-SE	Z	Force	Uniform	Length	-14,3	GCS
LFS84	LC_26 - NW-SE	X	Force	Uniform	Length	7,1	GCS
LFS85	LC_26 - NW-SE	X	Force	Uniform	Length	7,1	GCS
LFS86	LC_26 - NW-SE	X	Force	Uniform	Length	7,1	GCS
LFS87	LC_26 - NW-SE	X	Force	Uniform	Length	7,1	GCS
LFS88	LC_26 - NW-SE	Y	Force	Uniform	Length	-7,1	GCS
LFS89	LC_26 - NW-SE	Y	Force	Uniform	Length	-7,1	GCS
LFS90	LC_26 - NW-SE	Y	Force	Uniform	Length	-7,1	GCS
LFS91	LC_26 - NW-SE	Y	Force	Uniform	Length	-7,1	GCS

4.11. LC_27

4.11.1. LC_27 / Totale waarde

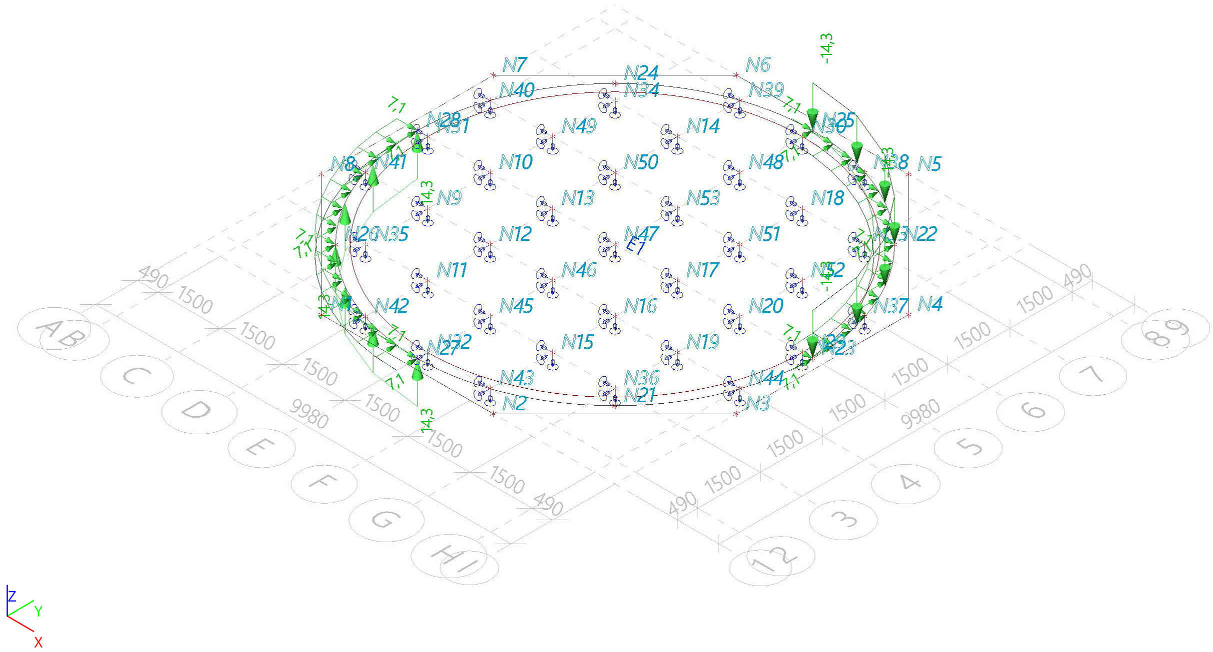


4.11.2. Lijnlasten op 2D elementranden

Name	Load case	Dir	Type	Distribution	Loc	Value - P_1 [kN/m]	System
LFS64	LC_27 - SW-NE	Z	Force	Uniform	Length	14,3	GCS
LFS65	LC_27 - SW-NE	Z	Force	Uniform	Length	-14,3	GCS
LFS66	LC_27 - SW-NE	Z	Force	Uniform	Length	-14,3	GCS
LFS67	LC_27 - SW-NE	Z	Force	Uniform	Length	14,3	GCS
LFS92	LC_27 - SW-NE	X	Force	Uniform	Length	-7,1	GCS
LFS93	LC_27 - SW-NE	X	Force	Uniform	Length	-7,1	GCS
LFS94	LC_27 - SW-NE	X	Force	Uniform	Length	-7,1	GCS
LFS95	LC_27 - SW-NE	X	Force	Uniform	Length	-7,1	GCS
LFS96	LC_27 - SW-NE	Y	Force	Uniform	Length	-7,1	GCS
LFS97	LC_27 - SW-NE	Y	Force	Uniform	Length	-7,1	GCS
LFS98	LC_27 - SW-NE	Y	Force	Uniform	Length	-7,1	GCS
LFS99	LC_27 - SW-NE	Y	Force	Uniform	Length	-7,1	GCS

4.12. LC_28

4.12.1. LC_28 / Totale waarde

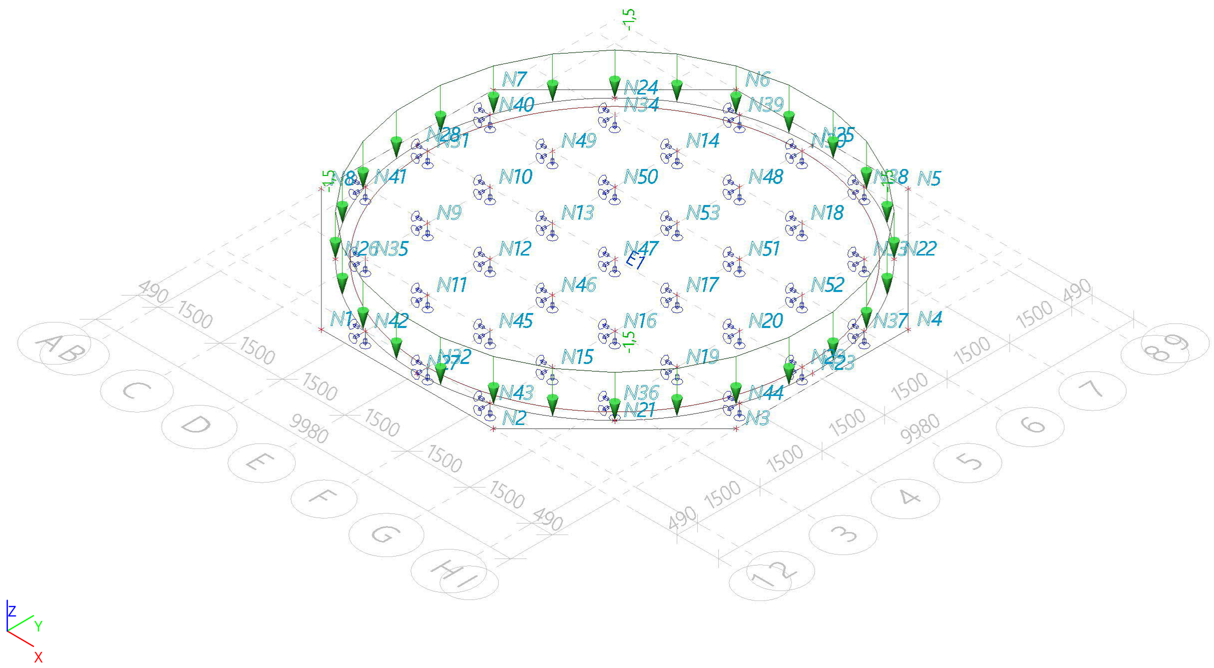


4.12.2. Lijnlasten op 2D elementranden

Name	Load case	Dir	Type	Distribution	Loc	Value - P_1 [kN/m]	System
LFS68	LC_28 - NE-SW	Z	Force	Uniform	Length	-14,3	GCS
LFS69	LC_28 - NE-SW	Z	Force	Uniform	Length	14,3	GCS
LFS70	LC_28 - NE-SW	Z	Force	Uniform	Length	14,3	GCS
LFS71	LC_28 - NE-SW	Z	Force	Uniform	Length	-14,3	GCS
LFS100	LC_28 - NE-SW	X	Force	Uniform	Length	7,1	GCS
LFS101	LC_28 - NE-SW	X	Force	Uniform	Length	7,1	GCS
LFS102	LC_28 - NE-SW	X	Force	Uniform	Length	7,1	GCS
LFS103	LC_28 - NE-SW	X	Force	Uniform	Length	7,1	GCS
LFS104	LC_28 - NE-SW	Y	Force	Uniform	Length	7,1	GCS
LFS105	LC_28 - NE-SW	Y	Force	Uniform	Length	7,1	GCS
LFS106	LC_28 - NE-SW	Y	Force	Uniform	Length	7,1	GCS
LFS107	LC_28 - NE-SW	Y	Force	Uniform	Length	7,1	GCS

4.13. LC_31

4.13.1. LC_31 / Totale waarde



4.13.2. Lijnlasten op 2D elementranden

Name	Load case	Dir	Type	Distribution	Loc	Value - P_1 [kN/m]	System
LFS5	LC_31 - Snow	Z	Force	Uniform	Length	-1,5	GCS
LFS28	LC_31 - Snow	Z	Force	Uniform	Length	-1,5	GCS
LFS29	LC_31 - Snow	Z	Force	Uniform	Length	-1,5	GCS
LFS30	LC_31 - Snow	Z	Force	Uniform	Length	-1,5	GCS

5. Load combinations

5.1. Load cases

Name	Description	Action type	Load group	Direction	Duration	Master load case
	Spec	Load type				
LC_01	Self Weight	Permanent Self weight	LG1	-Z		
LC_02	Tank_Empty	Permanent Standard	LG1			
LC_11	Tank Operating Standard	Variable Static	LG2 vloer		Short	None
LC_12	Platform Live Load Standard	Variable Static	LG2 vloer		Long	None
LC_13	Tank_Pressure Uplift	Permanent Standard	LG1			
LC_21	E-W Standard	Variable Static	LG4 wind		Short	None
LC_22	W-E Standard	Variable Static	LG4 wind		Short	None
LC_23	N-S Standard	Variable Static	LG4 wind		Short	None
LC_24	S-N Standard	Variable Static	LG4 wind		Short	None
LC_25	SE-NW Standard	Variable Static	LG4 wind		Short	None
LC_26	NW-SE Standard	Variable Static	LG4 wind		Short	None
LC_27	SW-NE Standard	Variable Static	LG4 wind		Short	None
LC_28	NE-SW Standard	Variable Static	LG4 wind		Short	None
LC_31	Snow Standard	Variable Static	LG5 sneeuw		Long	None

5.2. Load groups

Name	Load	Relation	Type
LG1	Permanent		
LG2 vloer	Variable	Standard	Cat E : Storage
LG3 dak	Variable	Standard	Cat H : Roofs
LG4 wind	Variable	Standard	Wind
LG5 sneeuw	Variable	Standard	Snow

5.3. Combinations

Name	Description	Type	Load cases	Coeff. [-]
ULS_01		Linear - ultimate	LC_01 - Self Weight	0,90
			LC_02 - Tank_Empty	0,90
			LC_13 - Tank_Pressure Uplift	1,65
			LC_21 - E-W	1,65
ULS_02		Linear - ultimate	LC_01 - Self Weight	0,90
			LC_02 - Tank_Empty	0,90
			LC_13 - Tank_Pressure Uplift	1,65
			LC_22 - W-E	1,65
ULS_03		Linear - ultimate	LC_01 - Self Weight	0,90
			LC_02 - Tank_Empty	0,90
			LC_13 - Tank_Pressure Uplift	1,65
			LC_23 - N-S	1,65
ULS_04		Linear - ultimate	LC_01 - Self Weight	0,90
			LC_02 - Tank_Empty	0,90
			LC_13 - Tank_Pressure Uplift	1,65
			LC_24 - S-N	1,65
ULS_05		Linear - ultimate	LC_01 - Self Weight	0,90
			LC_02 - Tank_Empty	0,90
			LC_13 - Tank_Pressure Uplift	1,65
			LC_25 - SE-NW	1,65
ULS_06		Linear - ultimate	LC_01 - Self Weight	0,90
			LC_02 - Tank_Empty	0,90
			LC_13 - Tank_Pressure Uplift	1,65
			LC_26 - NW-SE	1,65
ULS_07		Linear - ultimate	LC_01 - Self Weight	0,90
			LC_02 - Tank_Empty	0,90
			LC_13 - Tank_Pressure Uplift	1,65
			LC_27 - SW-NE	1,65
ULS_08		Linear - ultimate	LC_01 - Self Weight	0,90
			LC_02 - Tank_Empty	0,90
			LC_13 - Tank_Pressure Uplift	1,65
			LC_28 - NE-SW	1,65
ULS_10		Linear - ultimate	LC_01 - Self Weight	1,50
			LC_02 - Tank_Empty	1,50
			LC_11 - Tank Operating	1,65
			LC_12 - Platform Live Load	1,65
			LC_31 - Snow	1,65
ULS_11		Linear - ultimate	LC_01 - Self Weight	1,50
			LC_02 - Tank_Empty	1,50
			LC_11 - Tank Operating	1,65
			LC_12 - Platform Live Load	1,65
			LC_21 - E-W	1,65
ULS_12		Linear - ultimate	LC_01 - Self Weight	1,50
			LC_02 - Tank_Empty	1,50
			LC_11 - Tank Operating	1,65
			LC_12 - Platform Live Load	1,65
			LC_22 - W-E	1,65
ULS_13		Linear - ultimate	LC_01 - Self Weight	1,50
			LC_02 - Tank_Empty	1,50
			LC_11 - Tank Operating	1,65
			LC_12 - Platform Live Load	1,65
			LC_23 - N-S	1,65
ULS_14		Linear - ultimate	LC_01 - Self Weight	1,50
			LC_02 - Tank_Empty	1,50
			LC_11 - Tank Operating	1,65
			LC_12 - Platform Live Load	1,65
			LC_24 - S-N	1,65
ULS_15		Linear - ultimate	LC_01 - Self Weight	1,50
			LC_02 - Tank_Empty	1,50
			LC_11 - Tank Operating	1,65
			LC_12 - Platform Live Load	1,65
			LC_25 - SE-NW	1,65
ULS_16		Linear - ultimate	LC_01 - Self Weight	1,50

Name	Description	Type	Load cases	Coeff. [-]
			LC_02 - Tank_Empty	1,50
			LC_11 - Tank Operating	1,65
			LC_12 - Platform Live Load	1,65
			LC_26 - NW-SE	1,65
ULS_17		Linear - ultimate	LC_01 - Self Weight	1,50
			LC_02 - Tank_Empty	1,50
			LC_11 - Tank Operating	1,65
			LC_12 - Platform Live Load	1,65
			LC_27 - SW-NE	1,65
ULS_18		Linear - ultimate	LC_01 - Self Weight	1,50
			LC_02 - Tank_Empty	1,50
			LC_11 - Tank Operating	1,65
			LC_12 - Platform Live Load	1,65
			LC_28 - NE-SW	1,65
SLS_01		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_13 - Tank_Pressure Uplift	1,00
			LC_21 - E-W	1,00
SLS_02		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_13 - Tank_Pressure Uplift	1,00
			LC_22 - W-E	1,00
SLS_03		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_13 - Tank_Pressure Uplift	1,00
			LC_23 - N-S	1,00
SLS_04		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_13 - Tank_Pressure Uplift	1,00
			LC_24 - S-N	1,00
SLS_05		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_13 - Tank_Pressure Uplift	1,00
			LC_25 - SE-NW	1,00
SLS_06		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_13 - Tank_Pressure Uplift	1,00
			LC_26 - NW-SE	1,00
SLS_07		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_13 - Tank_Pressure Uplift	1,00
			LC_27 - SW-NE	1,00
SLS_08		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_13 - Tank_Pressure Uplift	1,00
			LC_28 - NE-SW	1,00
SLS_09		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_11 - Tank Operating	1,00
			LC_12 - Platform Live Load	1,00
			LC_21 - E-W	1,00
SLS_10		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_11 - Tank Operating	1,00
			LC_12 - Platform Live Load	1,00
			LC_22 - W-E	1,00
SLS_11		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_11 - Tank Operating	1,00
			LC_12 - Platform Live Load	1,00
			LC_23 - N-S	1,00
SLS_12		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_11 - Tank Operating	1,00
			LC_12 - Platform Live Load	1,00

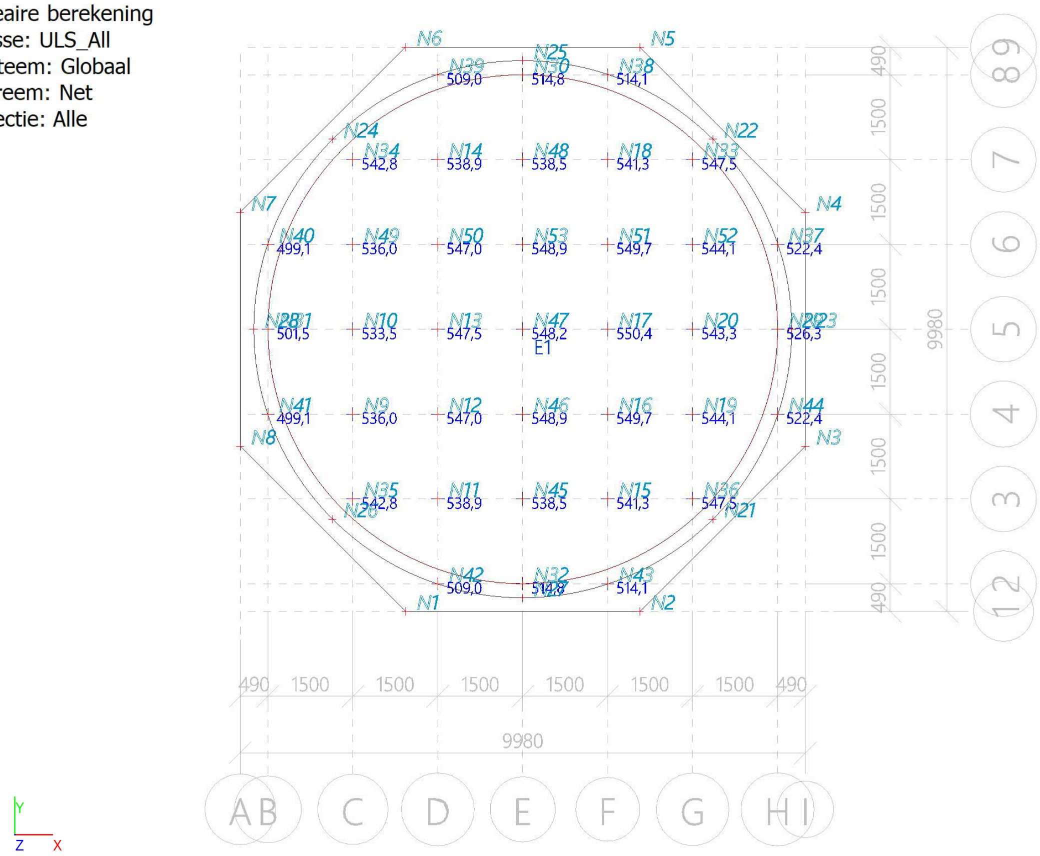
Name	Description	Type	Load cases	Coeff. [-]
			LC_24 - S-N	1,00
SLS_13		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_11 - Tank Operating	1,00
			LC_12 - Platform Live Load	1,00
			LC_25 - SE-NW	1,00
SLS_14		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_11 - Tank Operating	1,00
			LC_12 - Platform Live Load	1,00
			LC_26 - NW-SE	1,00
SLS_15		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_11 - Tank Operating	1,00
			LC_12 - Platform Live Load	1,00
			LC_27 - SW-NE	1,00
SLS_16		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_11 - Tank Operating	1,00
			LC_12 - Platform Live Load	1,00
			LC_28 - NE-SW	1,00
SLS_17		Linear - serviceability	LC_01 - Self Weight	1,00
			LC_02 - Tank_Empty	1,00
			LC_11 - Tank Operating	1,00
			LC_12 - Platform Live Load	1,00
			LC_31 - Snow	1,00

6. Results

6.1. Reactions

6.1.1. Reacties; R_z

Waardes: $\mathbf{R_z}$
Lineaire berekening
Klasse: ULS_All
Systeem: Globaal
Extreem: Net
Selectie: Alle



6.1.2. Reactions

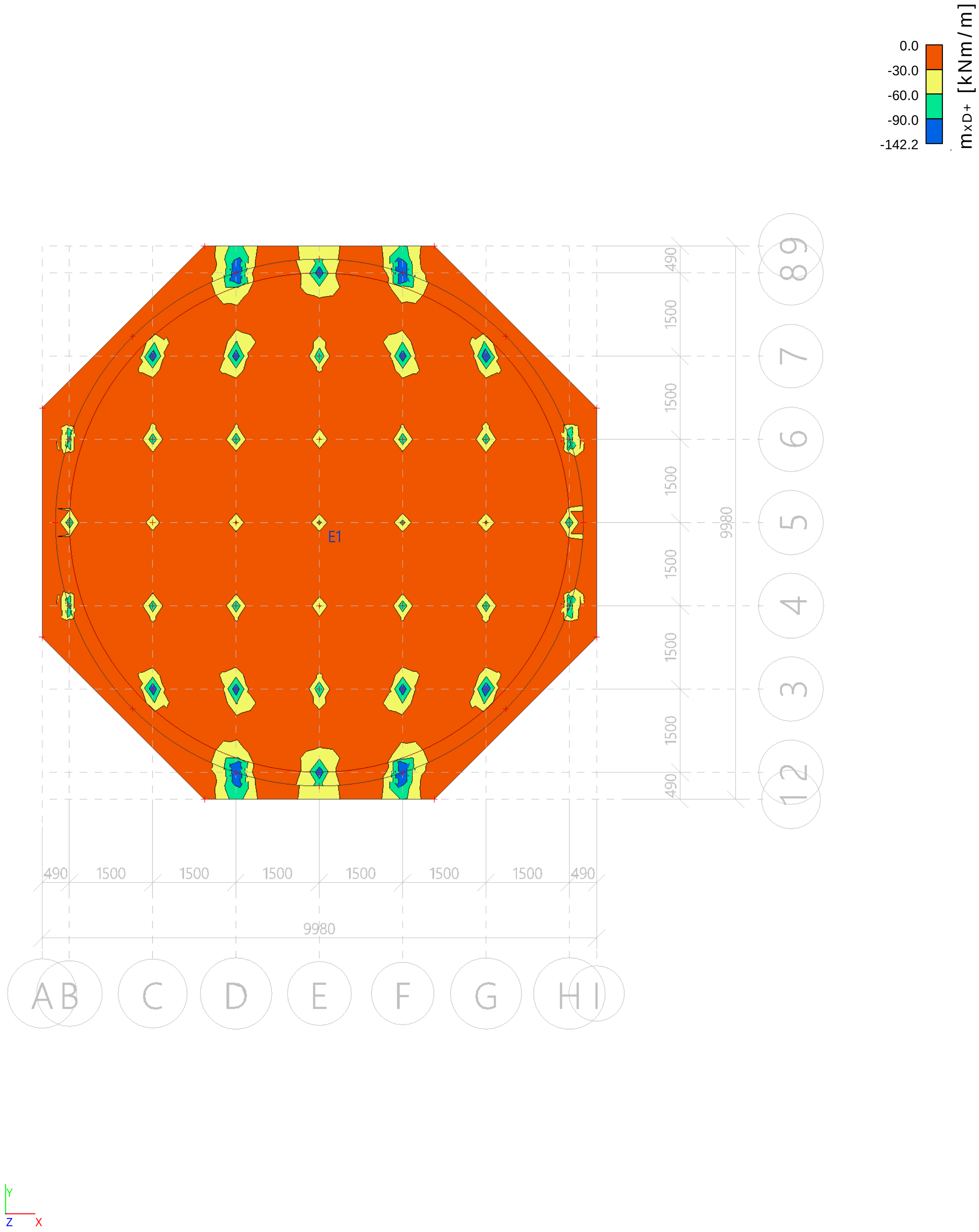
Linear calculation
Class: ULS_All
System: Global
Extreme: Global
Selection: All
Nodal reactions

Name	Case	R_x [kN]	R_y [kN]	R_z [kN]	M_x [kNm]	M_y [kNm]	M_z [kNm]	e_x [mm]	e_y [mm]
Sn15/N31	ULS_02/1	-6,7	0,0	19,2	0,0	0,0	0,0	0,0	0,0
Sn15/N31	ULS_01/2	6,7	0,0	80,5	0,0	0,0	0,0	0,0	0,0
Sn14/N30	ULS_04/3	0,0	-6,7	85,8	0,0	0,0	0,0	0,0	0,0
Sn14/N30	ULS_03/4	0,0	6,7	25,5	0,0	0,0	0,0	0,0	0,0
Sn24/N40	ULS_02/1	-6,7	0,0	18,4	0,0	0,0	0,0	0,0	0,0
Sn9/N17	ULS_12/5	-6,7	0,0	550,4	0,0	0,0	0,0	0,0	0,0

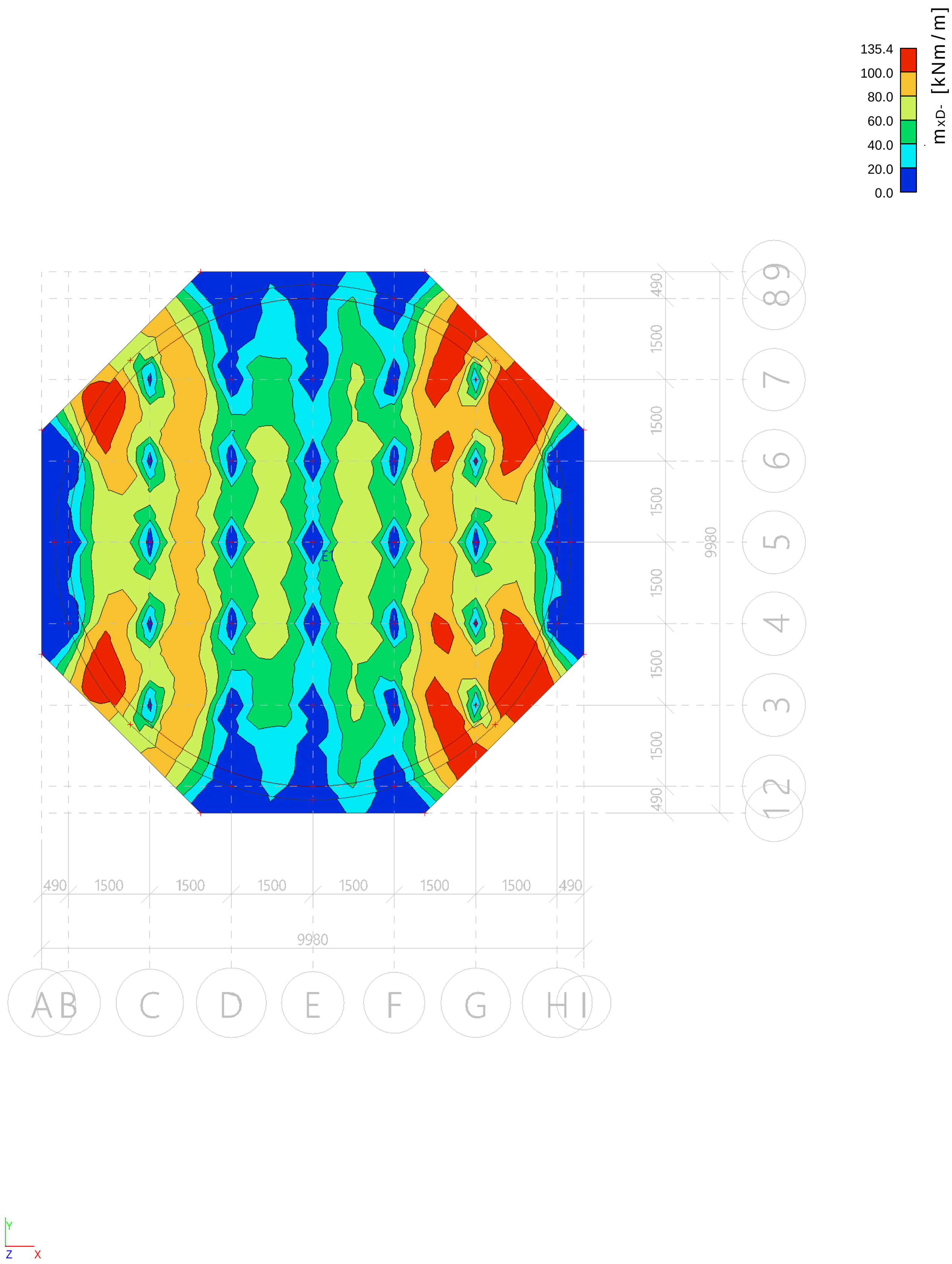
6.2. Internal Forces

6.2.1. ULS

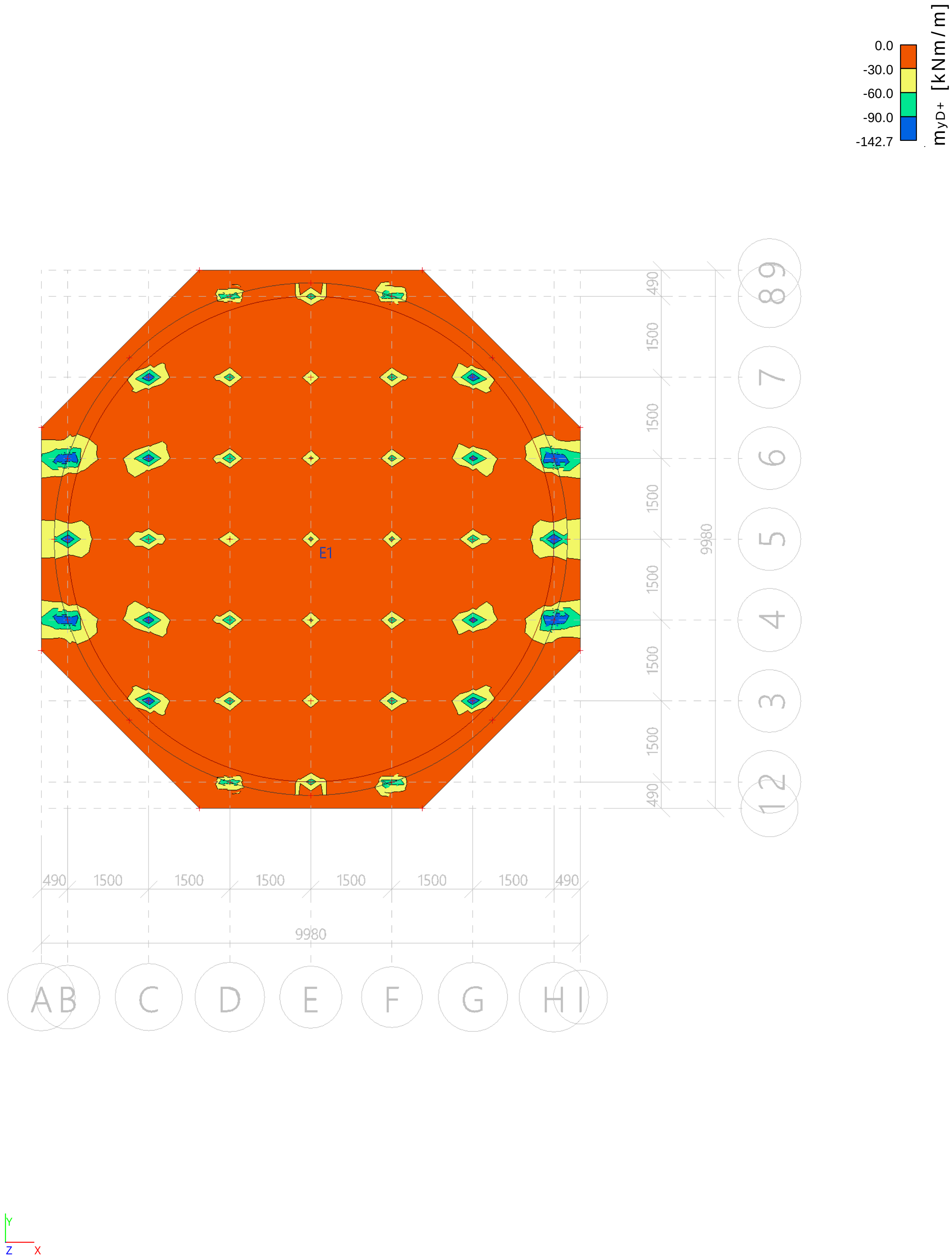
6.2.1.1. Interne 2D-krachten; m_xD+



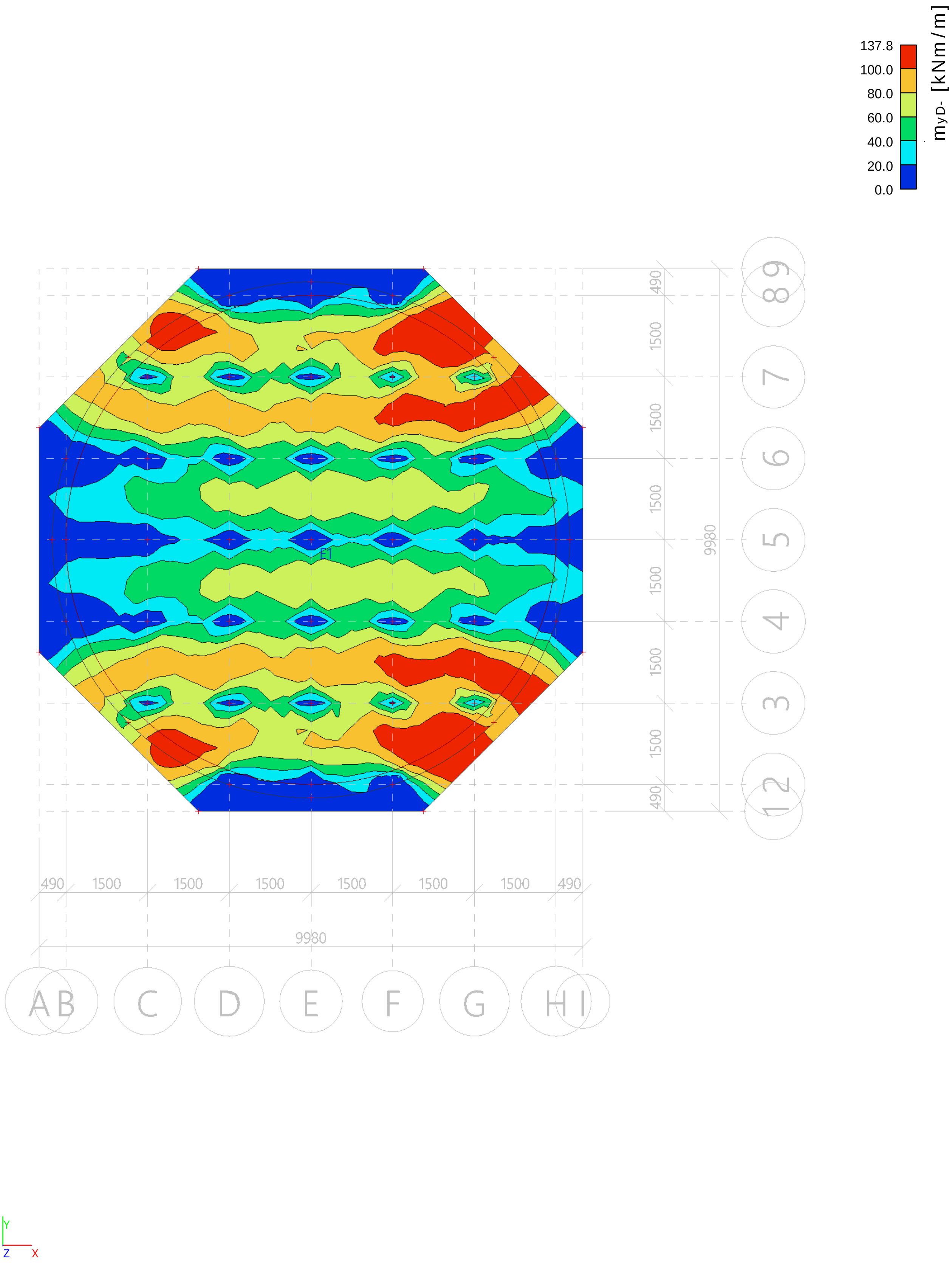
6.2.1.2. Interne 2D-krachten; m_xD-



6.2.1.3. Interne 2D-krachten; m_yD+



6.2.1.4. Interne 2D-krachten; m_yD-



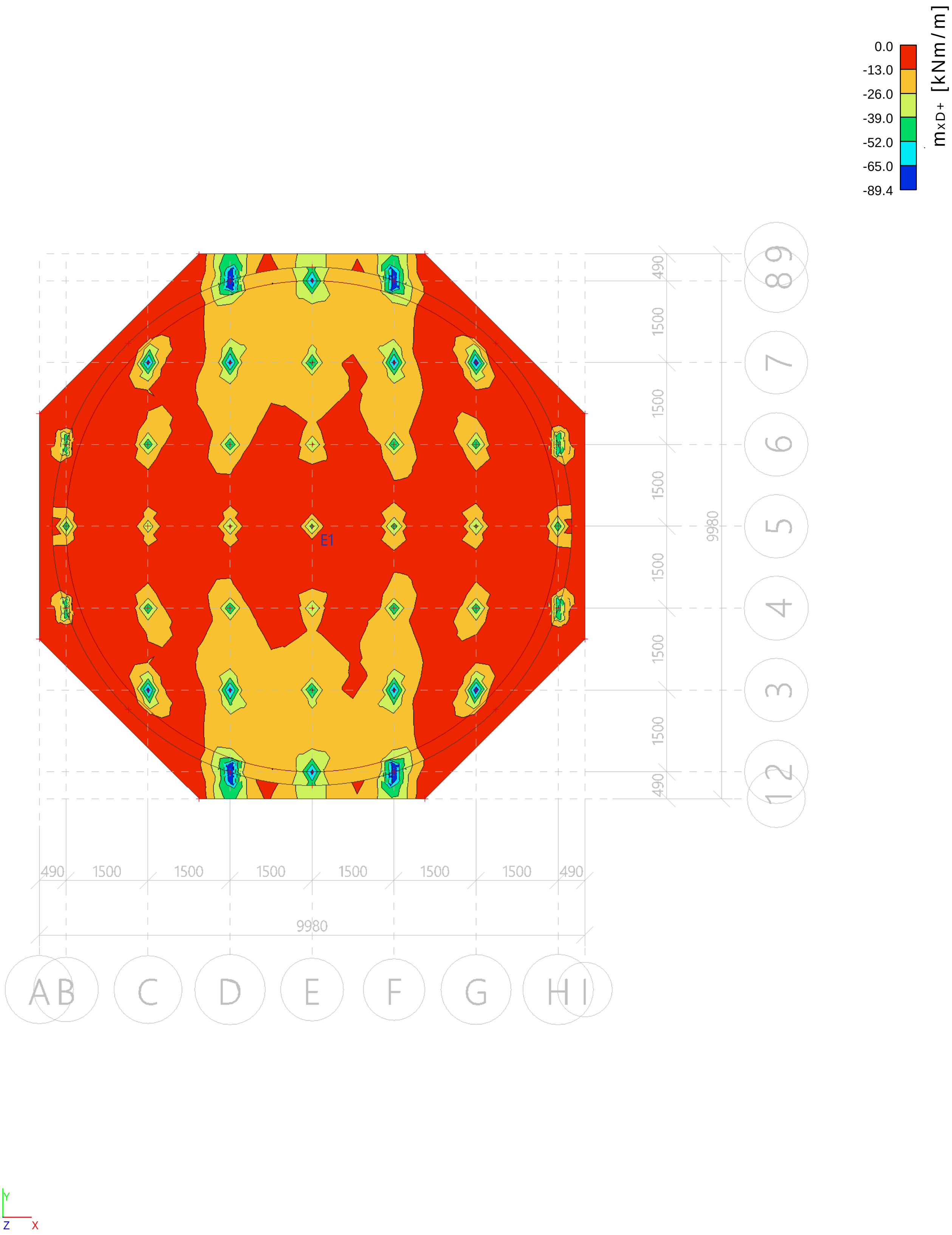
6.2.1.5. 2D internal forces

Linear calculation
Class: ULS_All
Extreme: Global
Selection: All
Location: In nodes avg. on macro. System: LCS mesh element
Elementary design magnitudes

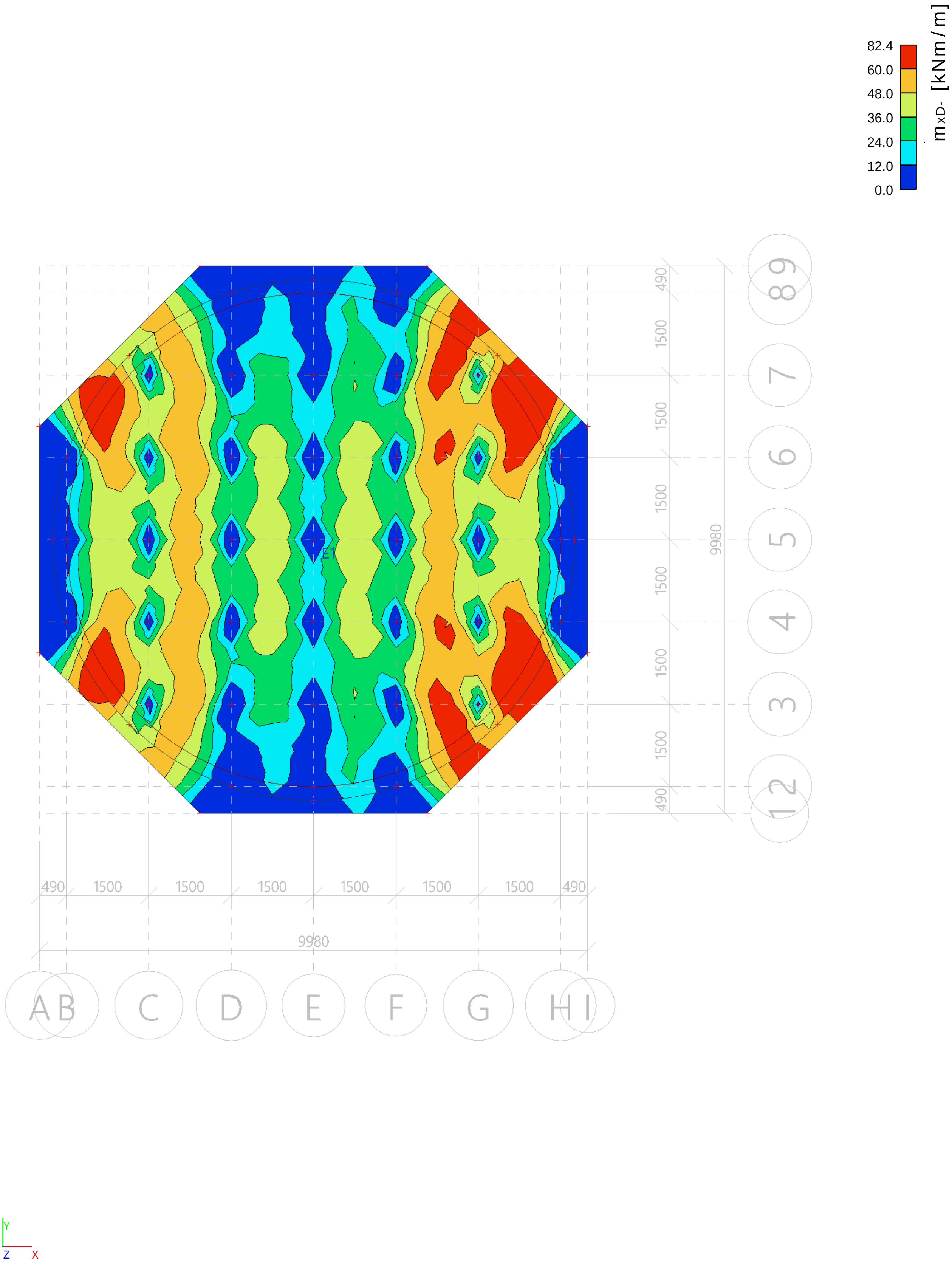
Name	Mesh	x [m]	y [m]	z [m]	Case	m_{xD+} [kNm/m]	m_{xD-} [kNm/m]	m_{yD+} [kNm/m]	m_{yD-} [kNm/m]
E1	Element: 2499; Node: 43	1,500	-4,500	0,000	ULS_17/1	-142,2	0,0	-98,4	0,0
E1	Element: 2453; Node: 173	3,975	-2,600	0,000	ULS_16/2	0,0	135,4	0,0	97,8
E1	Element: 2502; Node: 37	4,500	1,500	0,000	ULS_16/2	-99,2	0,0	-142,7	0,0
E1	Element: 2451; Node: 335	2,600	-3,975	0,000	ULS_16/2	0,0	99,2	0,0	137,8

6.2.2. SLS

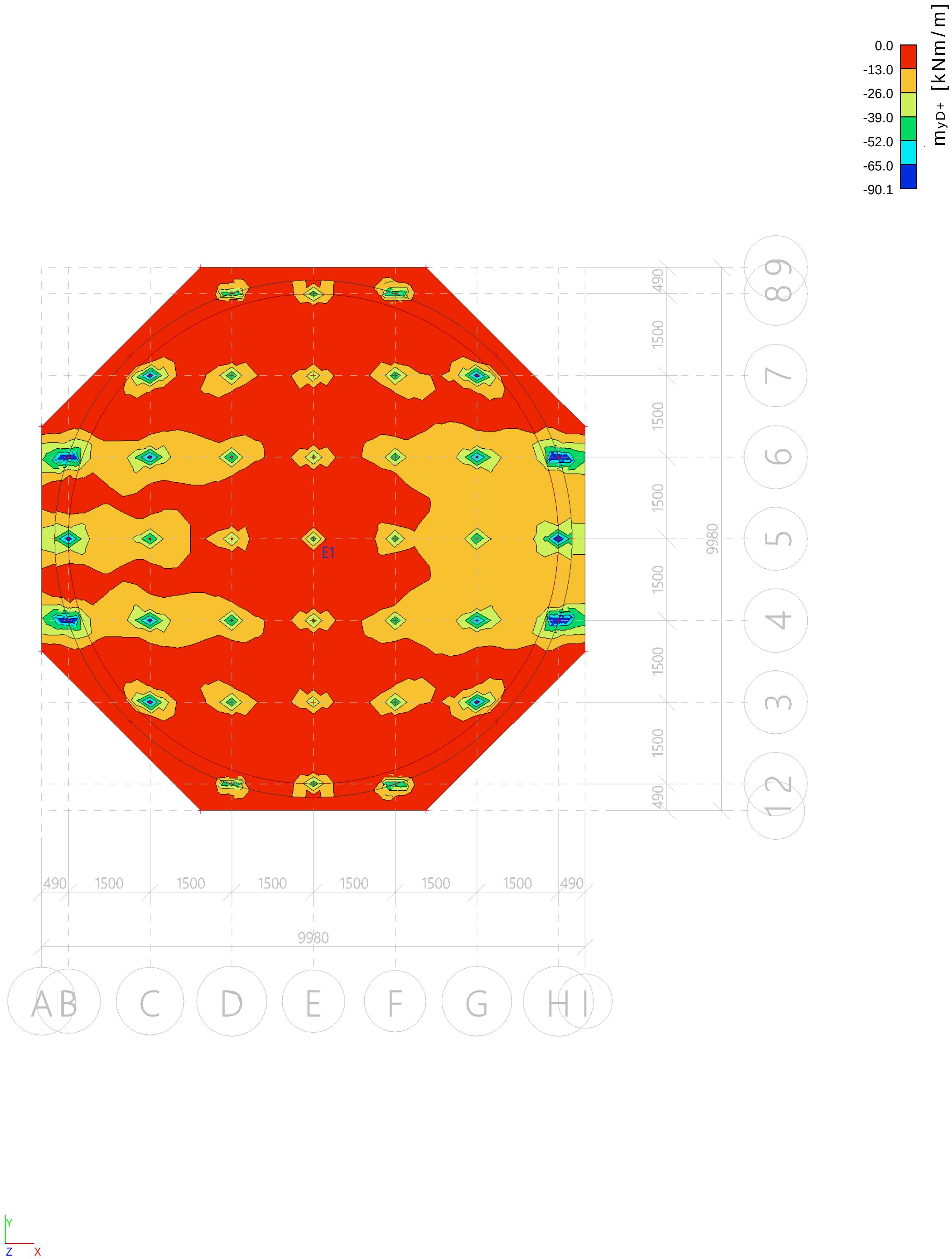
6.2.2.1. Interne 2D-krachten; m_xD+



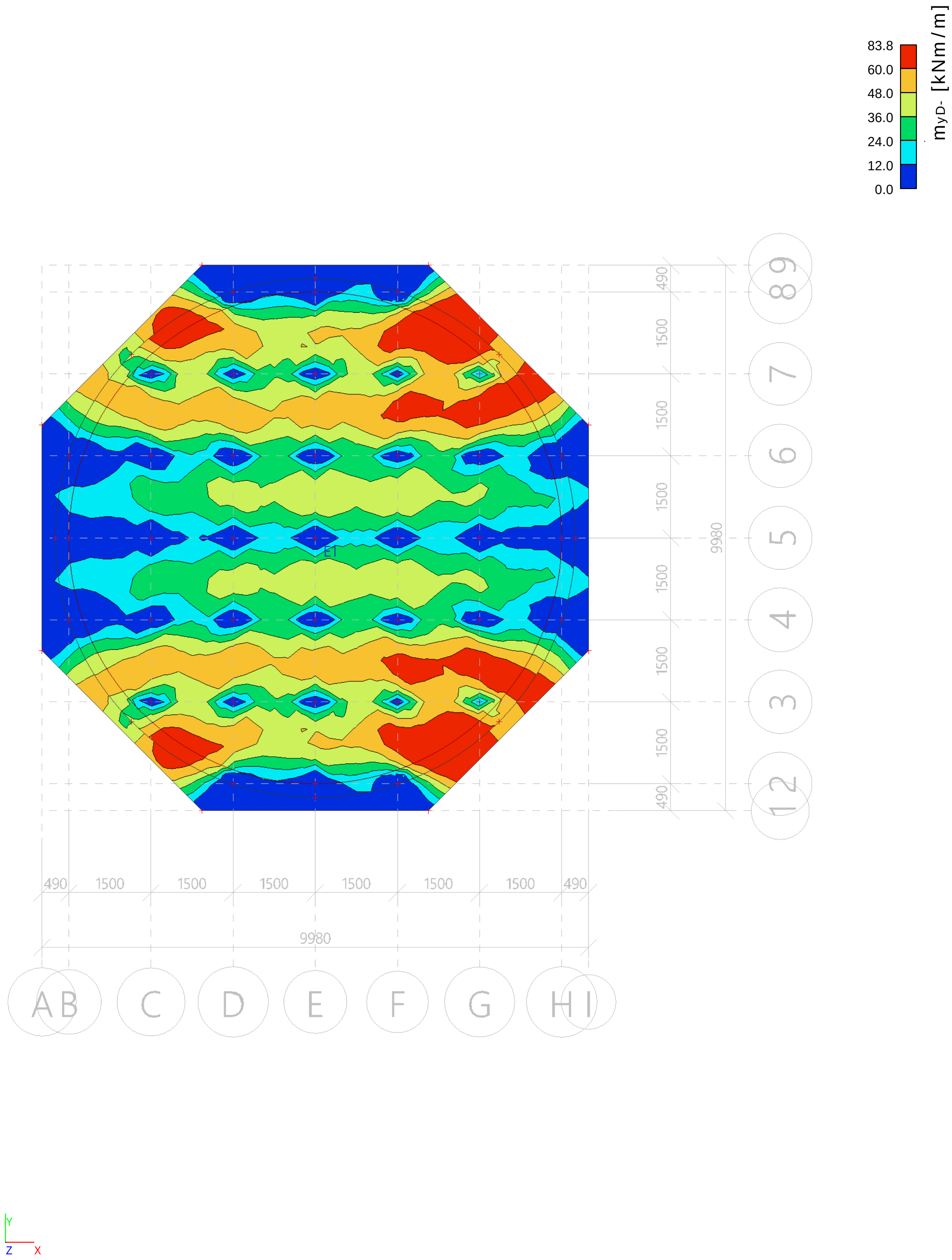
6.2.2.2. Interne 2D-krachten; m_xD-



6.2.2.3. Interne 2D-krachten; m_yD+



6.2.2.4. Interne 2D-krachten; m_yD-



6.2.2.5. 2D internal forces

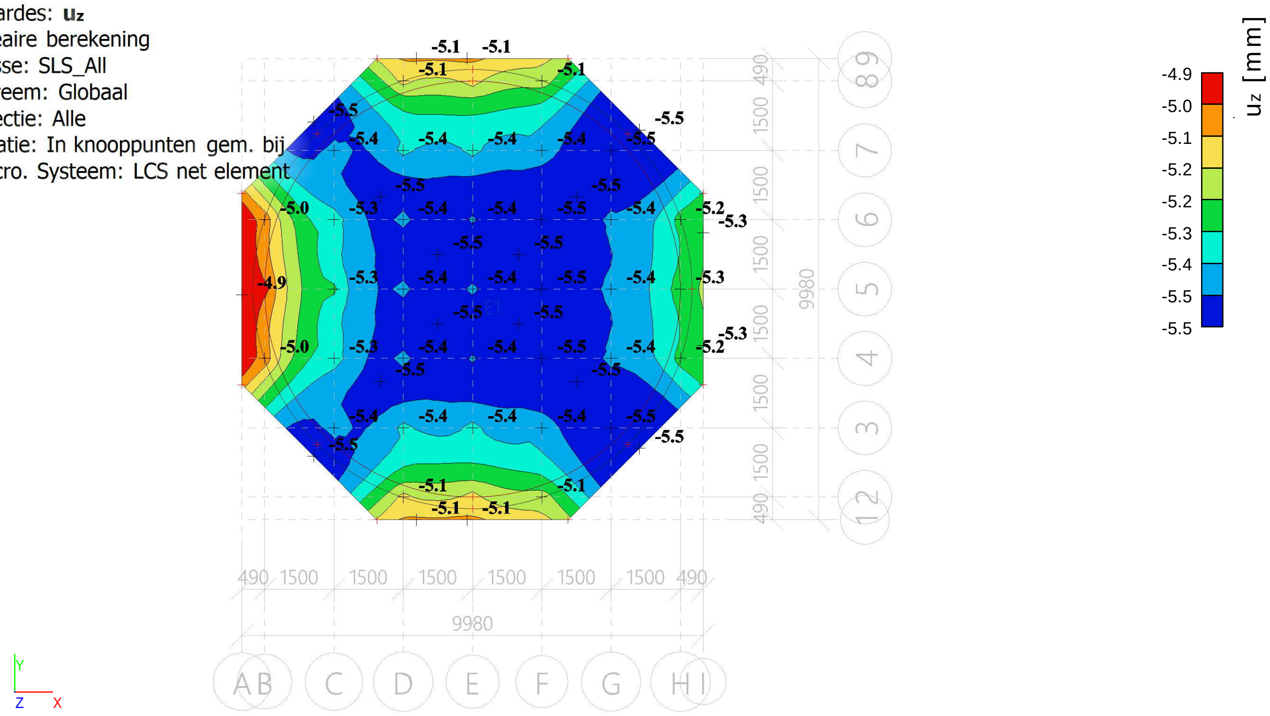
Linear calculation
Class: SLS_All
Extreme: Global
Selection: All
Location: In nodes avg. on macro. System: LCS mesh element
Elementary design magnitudes

Name	Mesh	x [m]	y [m]	z [m]	Case	m_{xD+} [kNm/m]	m_{xD-} [kNm/m]	m_{yD+} [kNm/m]	m_{yD-} [kNm/m]
E1	Element: 2499; Node: 43	1,500	-4,500	0,000	SLS_15/1	-89,4	0,0	-61,2	0,0
E1	Element: 2453; Node: 173	3,975	-2,600	0,000	SLS_14/2	0,0	82,4	0,0	58,5
E1	Element: 2502; Node: 37	4,500	1,500	0,000	SLS_14/2	-61,7	0,0	-90,1	0,0
E1	Element: 2451; Node: 335	2,600	-3,975	0,000	SLS_14/2	0,0	59,6	0,0	83,8

6.3. Settlements_SLS

6.3.1. 2D-verplaatsing; u_z

Waardes: u_z
Lineaire berekening
Klasse: SLS_All
Extreem: Globaal
Selectie: Alle
Locatie: In knooppunten gem. bij macro. Systeem: LCS net element



6.3.2. 2D displacement

Linear calculation
Class: SLS_All
Extreme: Global
Selection: All
Location: In nodes avg. on macro. System: LCS mesh element

Name	Mesh	Position [m]	Case	u_x [mm]	u_y [mm]	u_z [mm]
E1	Element: 1202 Node: 301	-4,689 0,761 0,000	SLS_01/1	-1,3	0,0	-1,3
E1	Element: 1231 Node: 361	-0,761 -4,689 0,000	SLS_03/2	0,0	-1,3	-1,4
E1	Element: 1231 Node: 361	-0,761 -4,689 0,000	SLS_04/3	0,0	1,3	-0,8
E1	Element: 1357 Node: 404	3,614 -3,443 0,000	SLS_14/4	0,9	-0,9	-5,5
E1	Element: 1234 Node: 140	-4,990 -0,122 0,000	SLS_02/5	1,3	0,0	-0,6

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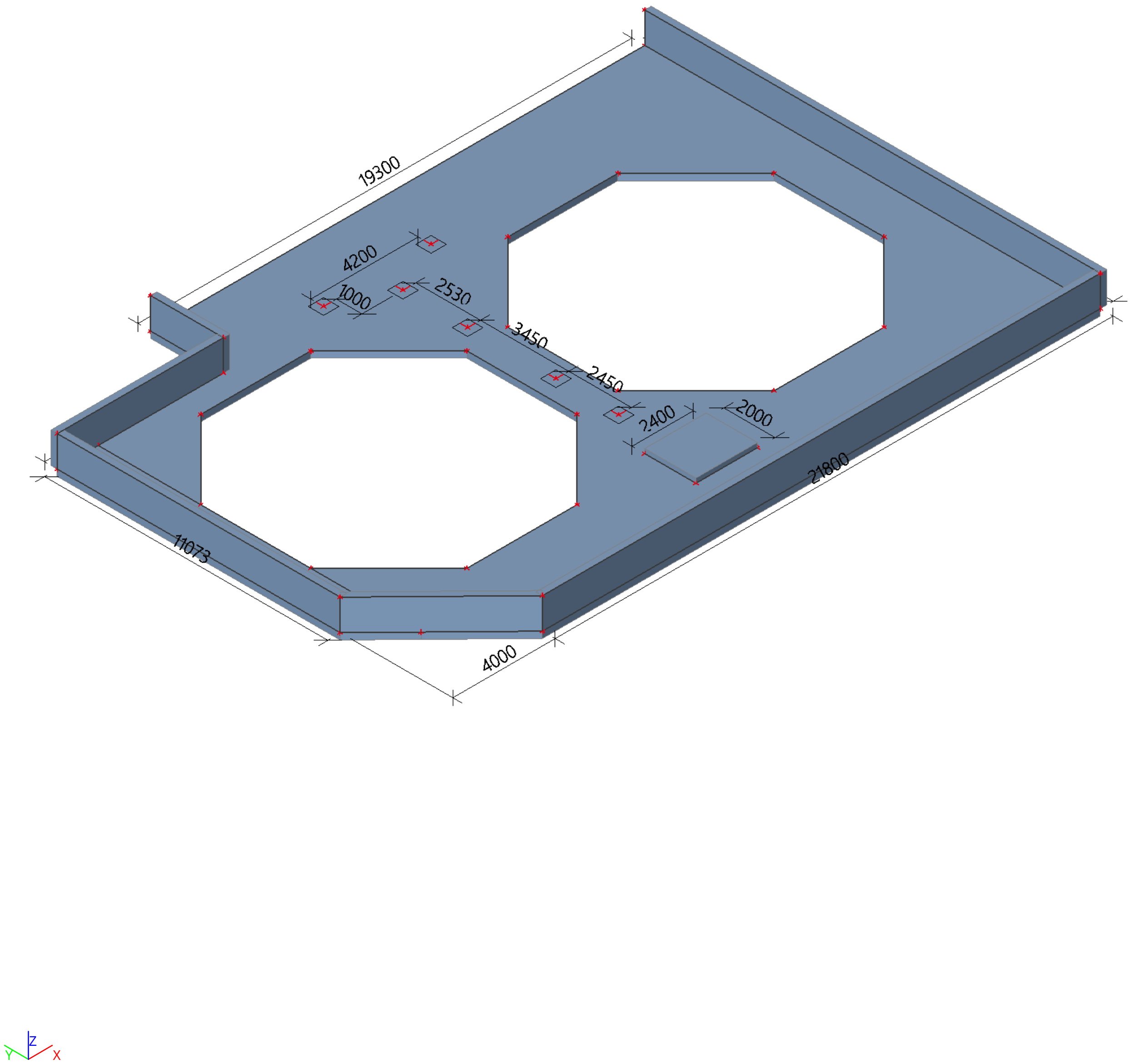
2. Project

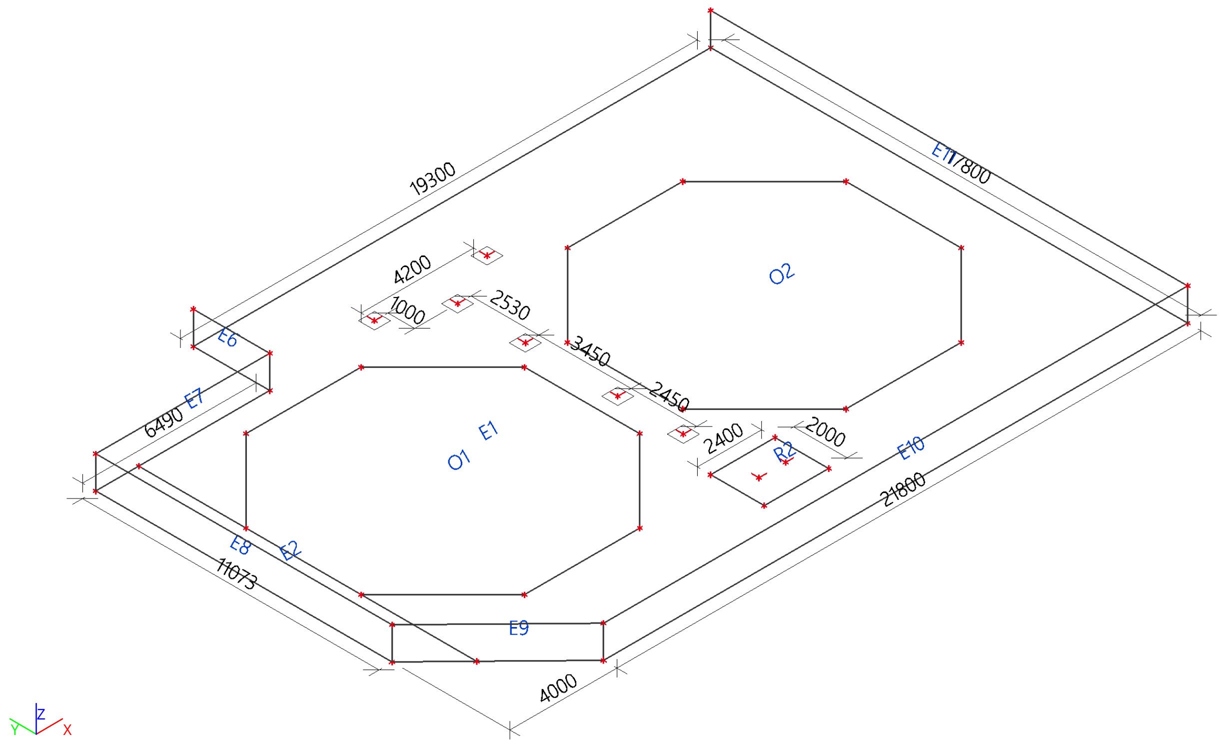
Licence name	Bilfinger Tebodin Netherlands B.V.
Project	53591-01: Hexion Formaline Storage Bund
Part	1334001 : Floor tank pit
Description	03: Load and strenght calculation
Author	Bilfinger Tebodin Netherlands B.V.
Date	31-08-2020
Structure	General XYZ
No. of nodes :	44
No. of beams :	0
No. of slabs :	8
No. of solids :	0
No. of used profiles :	0
No. of load cases :	13
No. of used materials :	3
Acceleration of gravity [m/s^2]	9,812
National code	EC - EN

3. Analysis Model

3.1. Model



3.2. Rekenmodel



3.3. Knoop

Name	Coord X [m]	Coord Y [m]	Coord Z [m]
N1	21,800	17,800	0,000
N3	0,000	0,000	0,000
N4	2,490	14,953	0,000
N5	2,490	17,800	0,000
N6	12,650	3,600	0,000
N7	16,950	3,600	0,000
N8	20,000	6,650	0,000
N9	20,000	10,950	0,000
N10	16,950	14,000	0,000
N11	12,650	14,000	0,000
N12	9,600	10,950	0,000
N13	9,600	6,650	0,000
N14	0,650	3,600	0,000
N15	4,950	3,600	0,000
N16	8,000	6,650	0,000
N17	8,000	10,950	0,000
N18	4,950	14,000	0,000
N19	0,650	14,000	0,000
N20	-2,400	10,950	0,000
N21	-2,400	6,650	0,000
N26	6,700	15,250	0,000

Name	Coord X [m]	Coord Y [m]	Coord Z [m]
N27	10,900	15,250	0,000
N39	-2,400	14,953	0,000
N40	-2,400	2,340	0,000
N41	-4,000	14,953	0,000
N44	-4,000	3,900	0,000
N98	8,000	2,000	0,000
N100	10,400	2,000	0,000
N101	10,400	4,000	0,000
N102	8,000	4,000	0,000
N103	8,800	3,000	0,000
N104	9,800	3,000	0,000
N106	2,490	14,953	1,200
N107	2,490	17,800	1,200
N110	-4,000	3,900	1,200
N111	-4,000	14,953	1,200
N112	0,000	0,000	1,200
N115	8,800	14,250	0,000
N116	8,800	11,720	0,000
N117	8,800	8,270	0,000
N118	8,800	5,820	0,000

3.4. Opening

Name	2D member
O1	E1
O2	E1

3.5. Subregio

R2			
2D member, Material, Thickness type	E1	C30/37	constant
MSP at, Ecc. z [mm]	Centre	0	
Th. [mm]	600		
Node, Edge, Weight	N102	Lijn	
	N98	Lijn	
	N100	Lijn	
	N101	Lijn	

3.6. 2D-element

Name	Layer	Type	Element type	Material	Thickness type	Th. [mm]
E1	Floor	vloer (90)	Standaard	C30/37_cracked	constant	250
E2	Floor	vloer (90)	Standaard	C30/37_cracked	constant	250
E6	wall	wand (80)	Standaard	C30/37_cracked	constant	250
E7	wall	wand (80)	Standaard	C30/37_cracked	constant	250
E8	wall	wand (80)	Standaard	C30/37_cracked	constant	250
E9	wall	wand (80)	Standaard	C30/37	constant	250
E10	wall	wand (80)	Standaard	C30/37_cracked	constant	250
E11	wall	wand (80)	Standaard	C30/37_cracked	constant	250

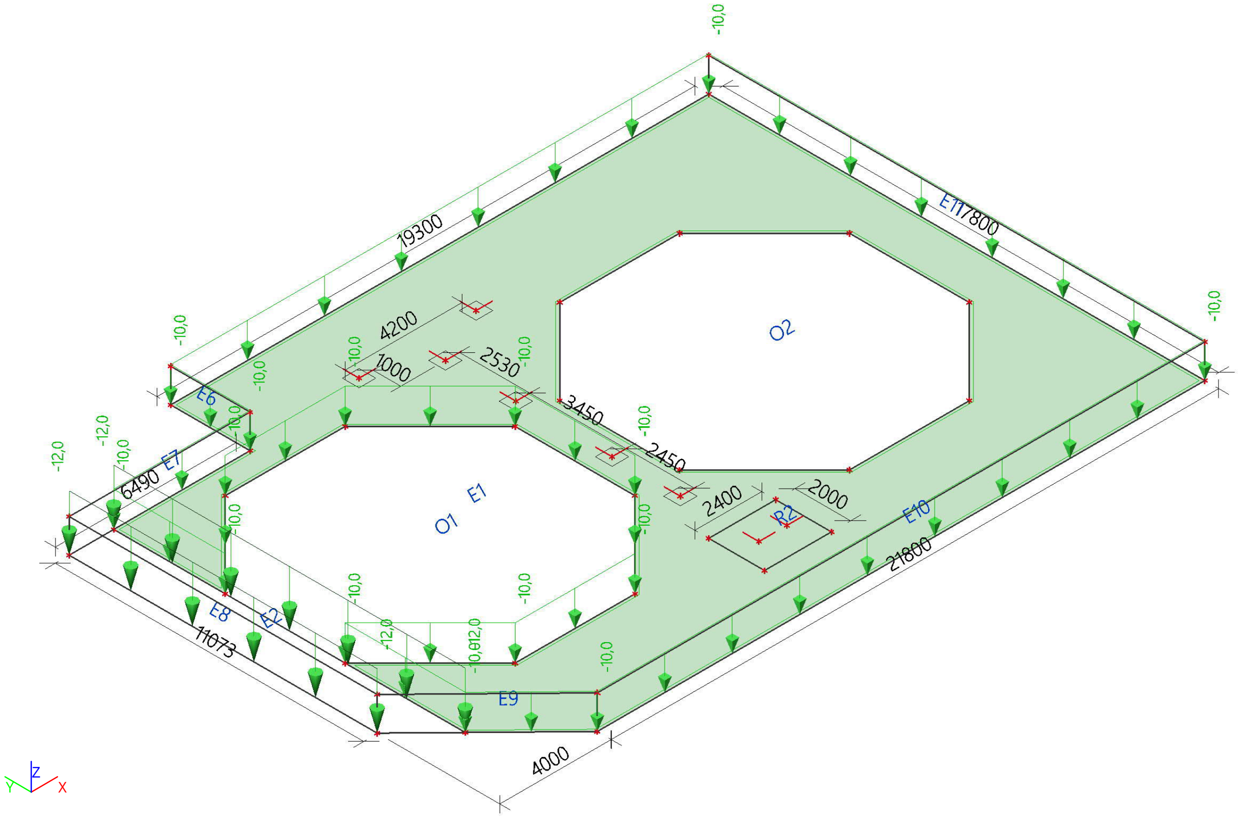
3.7. Oppervlakte ondersteuning op oppervlak

Name	Type	Subsoil	2D member
SS1	Individual	Soil stiffness - without soil improvement	E1
SS2	Individual	Soil stiffness - without soil improvement	E2

4. Load cases

4.1. LC_11

4.1.1. LC_11 / Totale waarde



4.1.2. Lasten op oppervlak

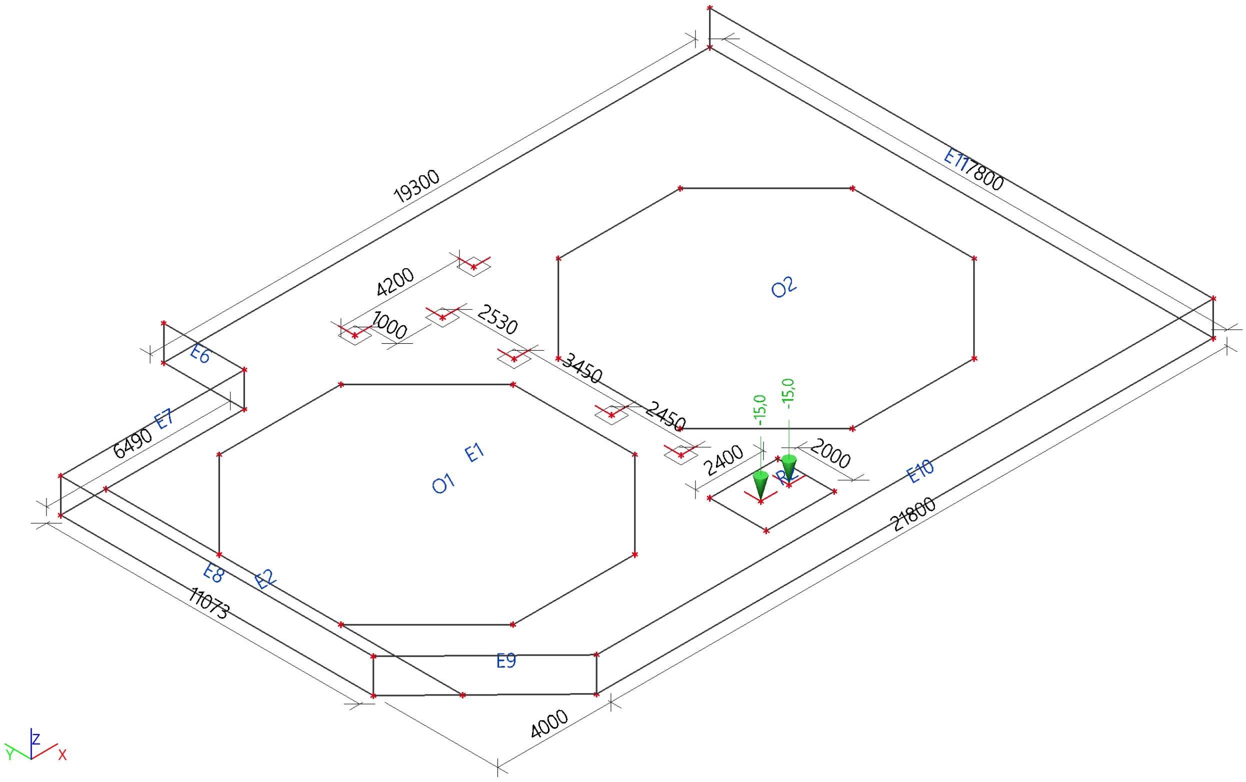
Name	2D member	Load case	Dir	Type	Value [kN/m²]	System	Loc
SF2	E1	LC_11 - LL - Live Load on the floor	Z	Force	-10,0	LCS	Length

4.1.3. Lijnlasten op 2D elementranden

Name	2D member	Load case	Dir	Type	Distribution	Value - P1 [kN/m]
LFS1	E1	LC_11 - LL - Live Load on the floor	Z	Force	Uniform	-12,0
LFS2	E2	LC_11 - LL - Live Load on the floor	Z	Force	Uniform	-12,0

4.2. LC_12

4.2.1. LC_12 / Totale waarde

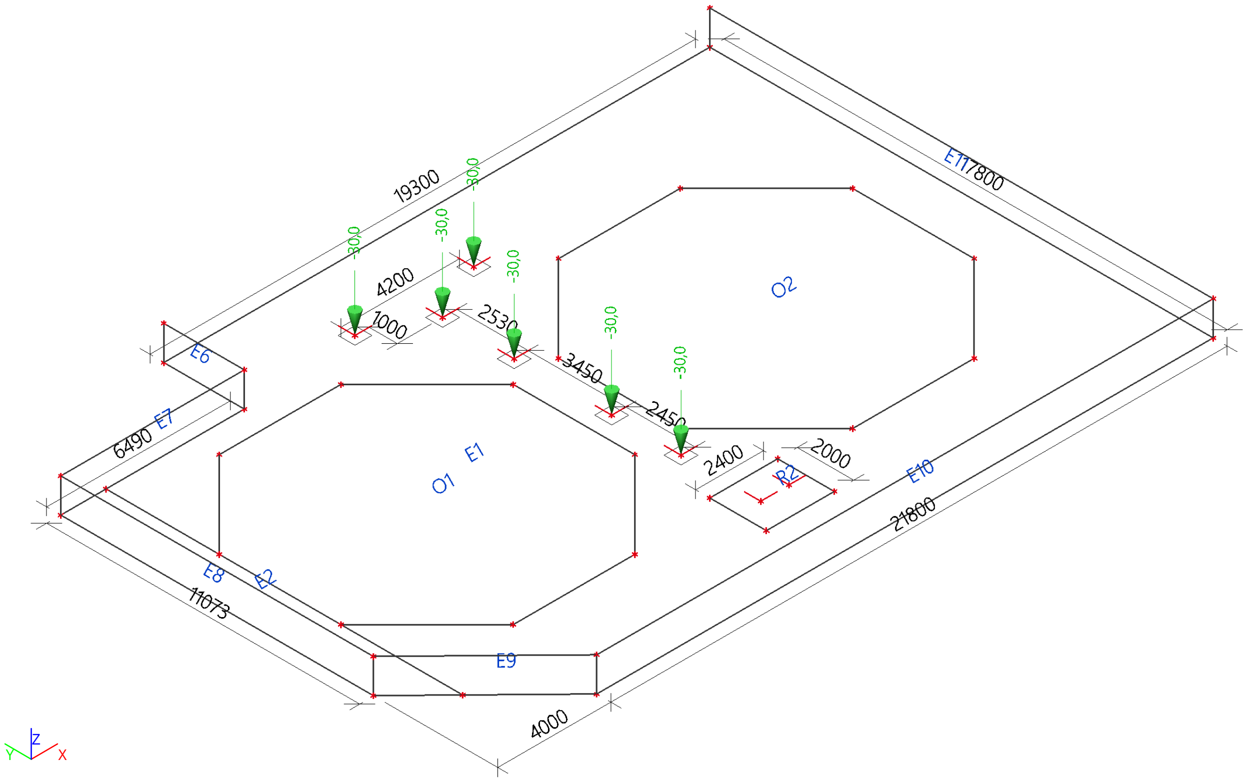


4.2.2. Puntlasten in knopen

Name	Node	Load case	System	Dir	Type	Value - F [kN]
F6	N103	LC_12 - Do - Pumps	GCS	Z	Force	-15,0
F7	N104	LC_12 - Do - Pumps	GCS	Z	Force	-15,0

4.3. LC_13-1

4.3.1. LC_13-1 / Totale waarde

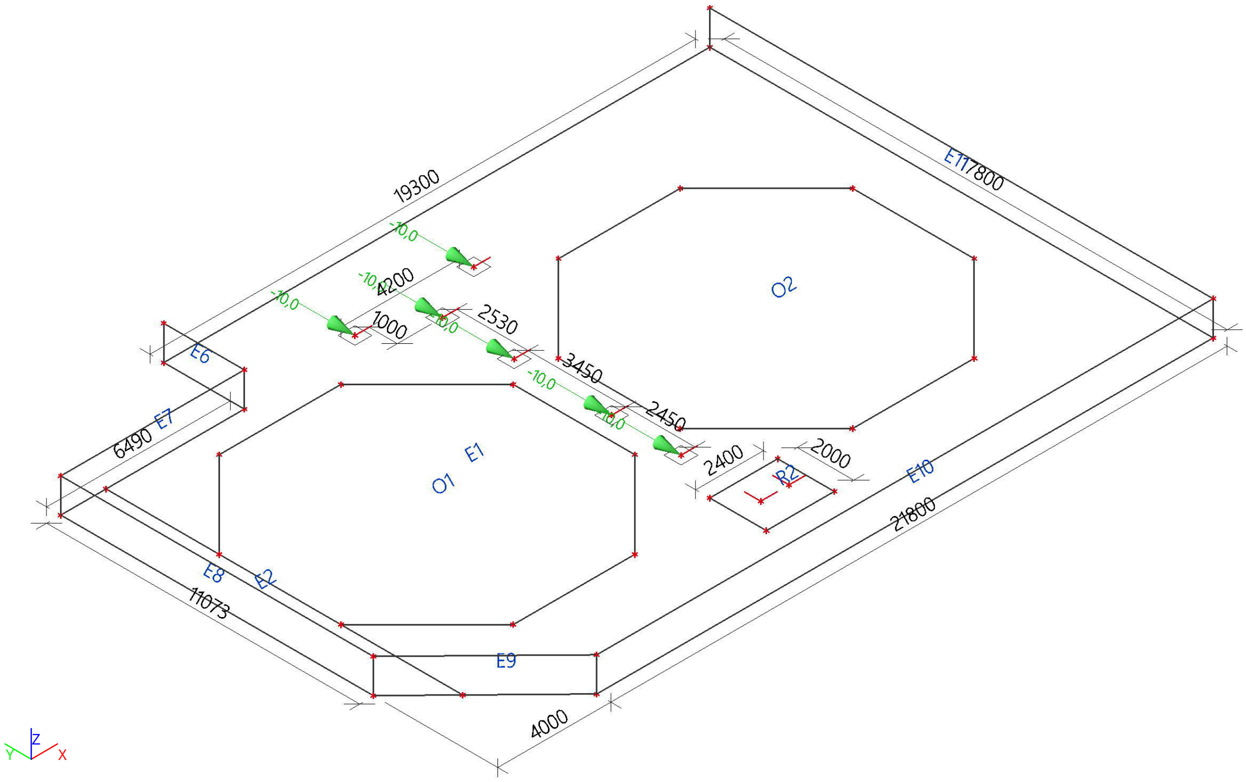


4.3.2. Puntlasten in knopen

Name	Node	Load case	System	Dir	Type	Value - F [kN]
F4	N26	LC_13-1 - Do - Piping Load	GCS	Z	Force	-30,0
F5	N27	LC_13-1 - Do - Piping Load	GCS	Z	Force	-30,0
F8	N115	LC_13-1 - Do - Piping Load	GCS	Z	Force	-30,0
F9	N116	LC_13-1 - Do - Piping Load	GCS	Z	Force	-30,0
F10	N117	LC_13-1 - Do - Piping Load	GCS	Z	Force	-30,0
F11	N118	LC_13-1 - Do - Piping Load	GCS	Z	Force	-30,0

4.4. LC_13-2

4.4.1. LC_13-2 / Totale waarde

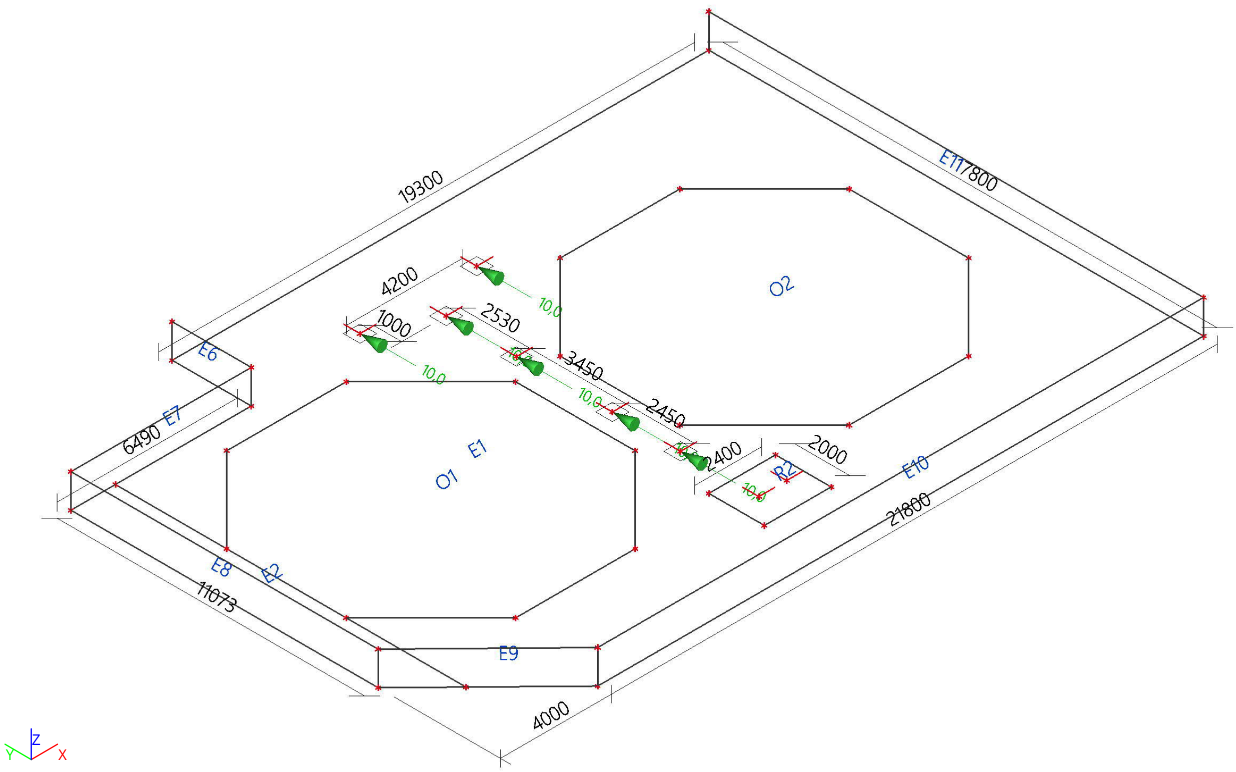


4.4.2. Puntlasten in knopen

Name	Node	Load case	System	Dir	Type	Value - F [kN]
F24	N26	LC_13-2 - Do - Piping Load N-->S	GCS	Y	Force	-10,0
F25	N27	LC_13-2 - Do - Piping Load N-->S	GCS	Y	Force	-10,0
F26	N115	LC_13-2 - Do - Piping Load N-->S	GCS	Y	Force	-10,0
F27	N116	LC_13-2 - Do - Piping Load N-->S	GCS	Y	Force	-10,0
F28	N117	LC_13-2 - Do - Piping Load N-->S	GCS	Y	Force	-10,0
F29	N118	LC_13-2 - Do - Piping Load N-->S	GCS	Y	Force	-10,0

4.5. LC_13-3

4.5.1. LC_13-3 / Totale waarde

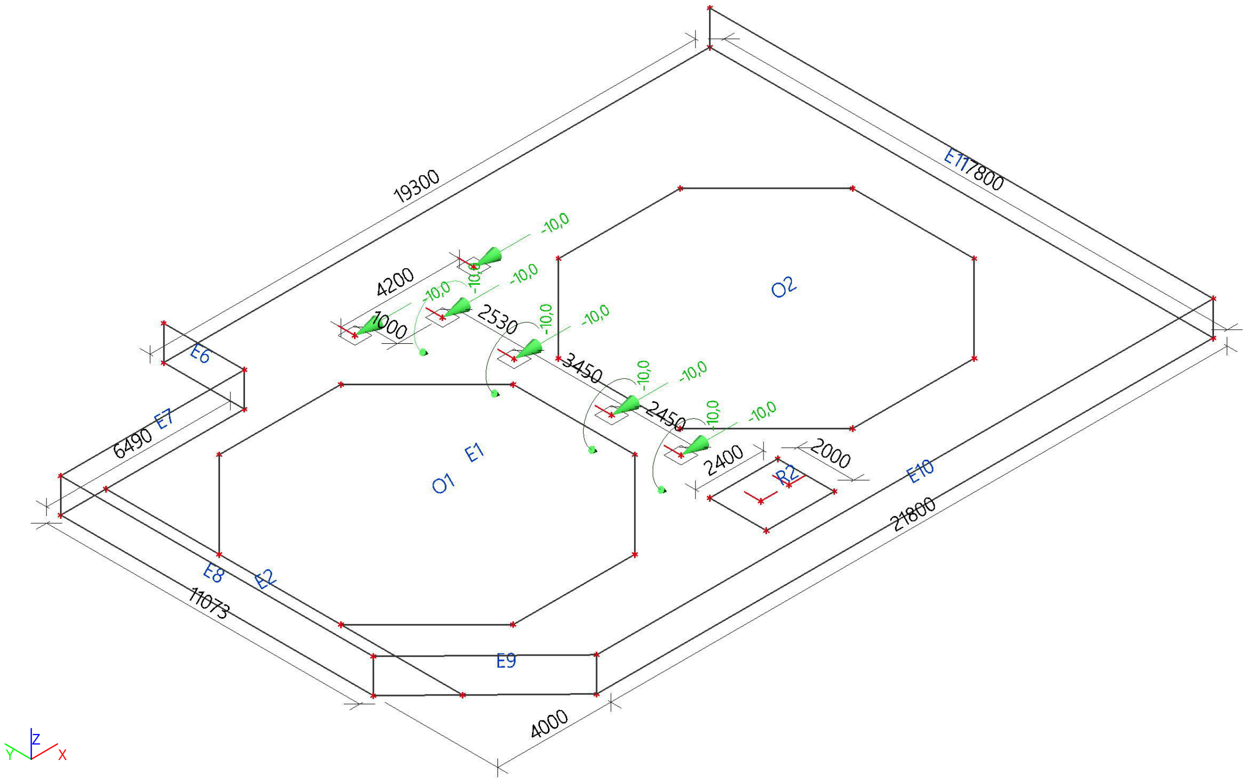


4.5.2. Puntlasten in knopen

Name	Node	Load case	System	Dir	Type	Value - F [kN]
F30	N117	LC_13-3 - Do - Piping Load S-->N	GCS	Y	Force	10,0
F31	N118	LC_13-3 - Do - Piping Load S-->N	GCS	Y	Force	10,0
F32	N116	LC_13-3 - Do - Piping Load S-->N	GCS	Y	Force	10,0
F33	N115	LC_13-3 - Do - Piping Load S-->N	GCS	Y	Force	10,0
F34	N27	LC_13-3 - Do - Piping Load S-->N	GCS	Y	Force	10,0
F35	N26	LC_13-3 - Do - Piping Load S-->N	GCS	Y	Force	10,0

4.6. LC_13-4

4.6.1. LC_13-4 / Totale waarde



4.6.2. Puntlasten in knopen

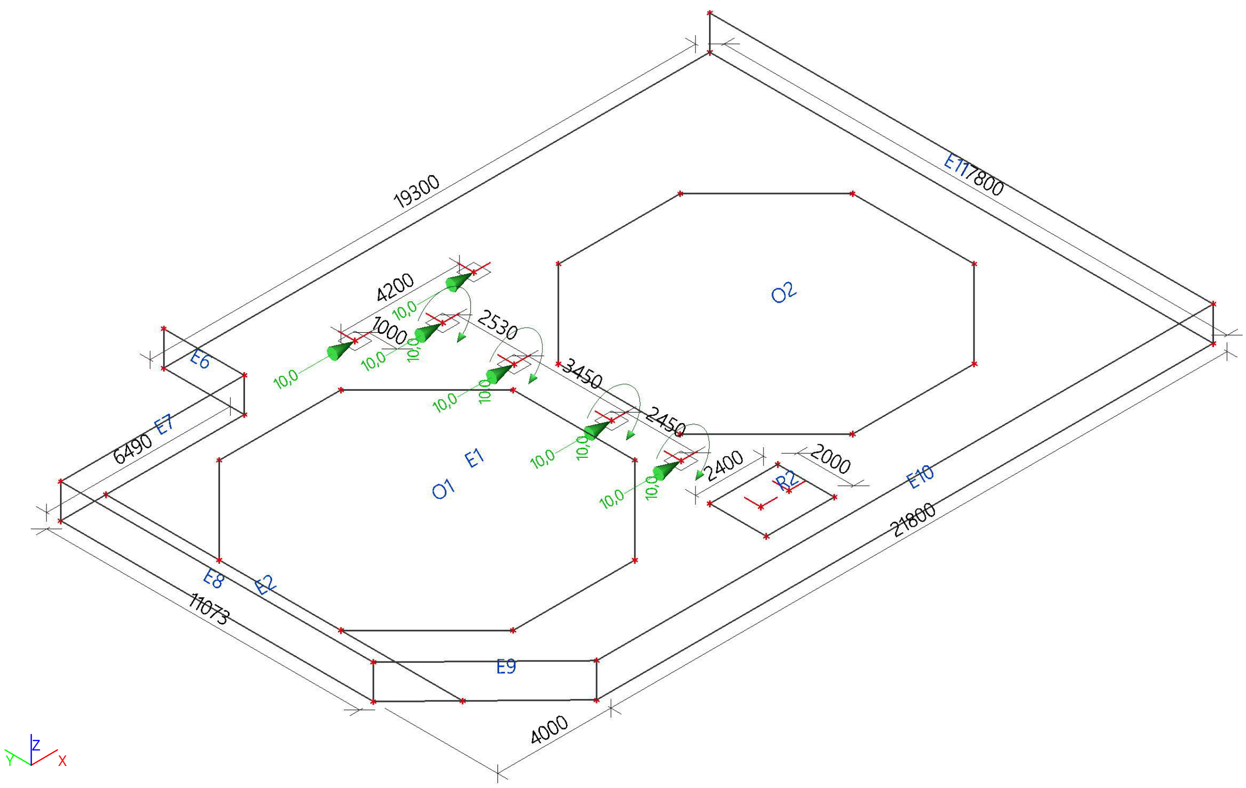
Name	Node	Load case	System	Dir	Type	Value - F [kN]
F36	N26	LC_13-4 - Do - Piping Load E-->W	GCS	X	Force	-10,0
F37	N27	LC_13-4 - Do - Piping Load E-->W	GCS	X	Force	-10,0
F38	N115	LC_13-4 - Do - Piping Load E-->W	GCS	X	Force	-10,0
F39	N116	LC_13-4 - Do - Piping Load E-->W	GCS	X	Force	-10,0
F40	N117	LC_13-4 - Do - Piping Load E-->W	GCS	X	Force	-10,0
F41	N118	LC_13-4 - Do - Piping Load E-->W	GCS	X	Force	-10,0

4.6.3. Momenten in knopen

Name	Node	Load case	System	Dir	Type	Value - M [kNm]
M1	N115	LC_13-4 - Do - Piping Load E-->W	GCS	My	Moment	-10,0
M2	N116	LC_13-4 - Do - Piping Load E-->W	GCS	My	Moment	-10,0
M3	N117	LC_13-4 - Do - Piping Load E-->W	GCS	My	Moment	-10,0
M4	N118	LC_13-4 - Do - Piping Load E-->W	GCS	My	Moment	-10,0

4.7. LC_13-5

4.7.1. LC_13-5 / Totale waarde



4.7.2. Puntlasten in knopen

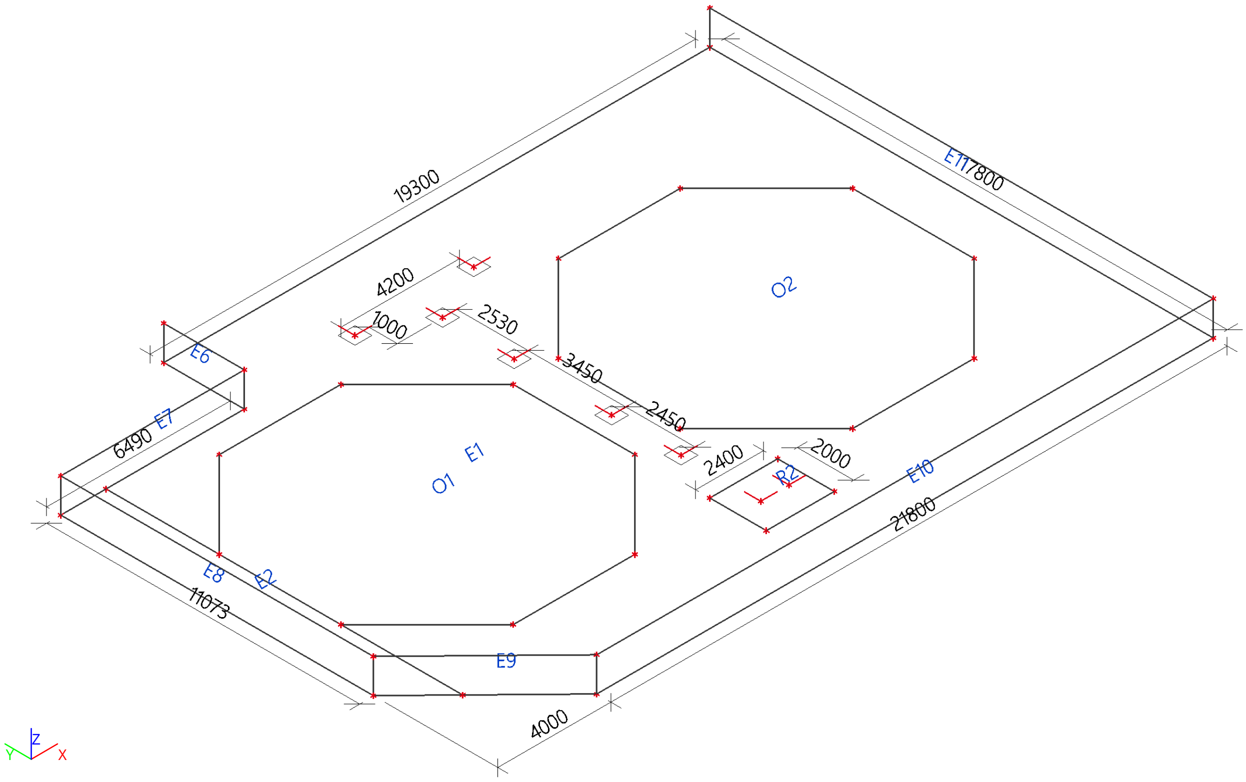
Name	Node	Load case	System	Dir	Type	Value - F [kN]
F42	N26	LC_13-5 - Do - Piping Load W-->E	GCS	X	Force	10,0
F43	N27	LC_13-5 - Do - Piping Load W-->E	GCS	X	Force	10,0
F44	N115	LC_13-5 - Do - Piping Load W-->E	GCS	X	Force	10,0
F45	N116	LC_13-5 - Do - Piping Load W-->E	GCS	X	Force	10,0
F46	N117	LC_13-5 - Do - Piping Load W-->E	GCS	X	Force	10,0
F47	N118	LC_13-5 - Do - Piping Load W-->E	GCS	X	Force	10,0

4.7.3. Momenten in knopen

Name	Node	Load case	System	Dir	Type	Value - M [kNm]
M5	N115	LC_13-5 - Do - Piping Load W-->E	GCS	My	Moment	10,0
M6	N116	LC_13-5 - Do - Piping Load W-->E	GCS	My	Moment	10,0
M7	N117	LC_13-5 - Do - Piping Load W-->E	GCS	My	Moment	10,0
M8	N118	LC_13-5 - Do - Piping Load W-->E	GCS	My	Moment	10,0

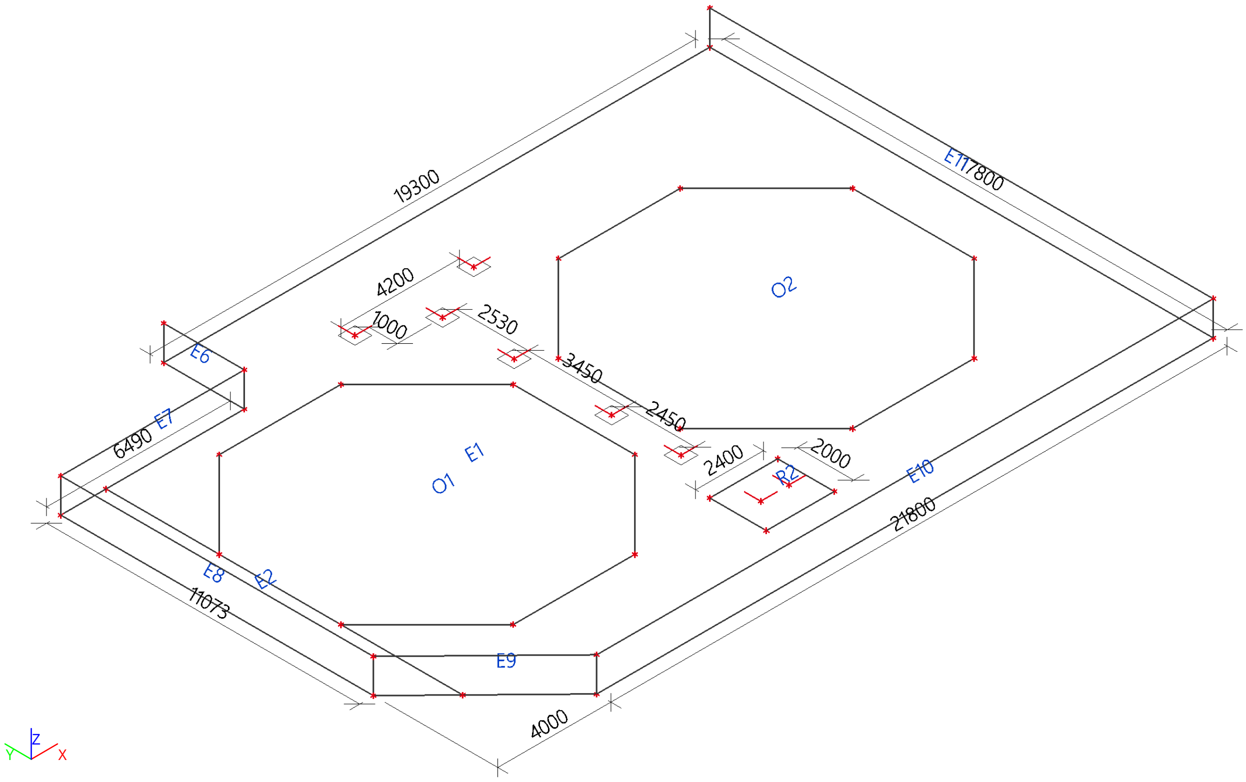
4.8. LC_14-1

4.8.1. LC_14-1 / Totale waarde



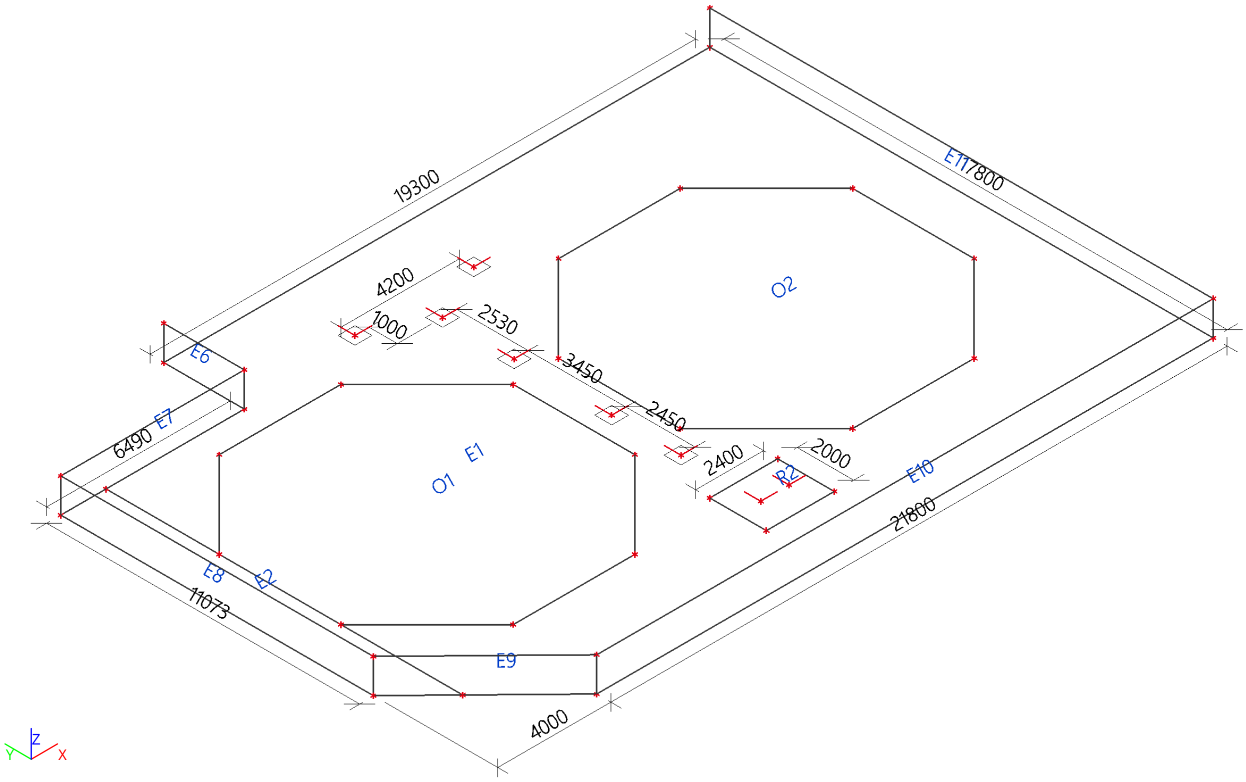
4.9. LC_14-2

4.9.1. LC_14-2 / Totale waarde



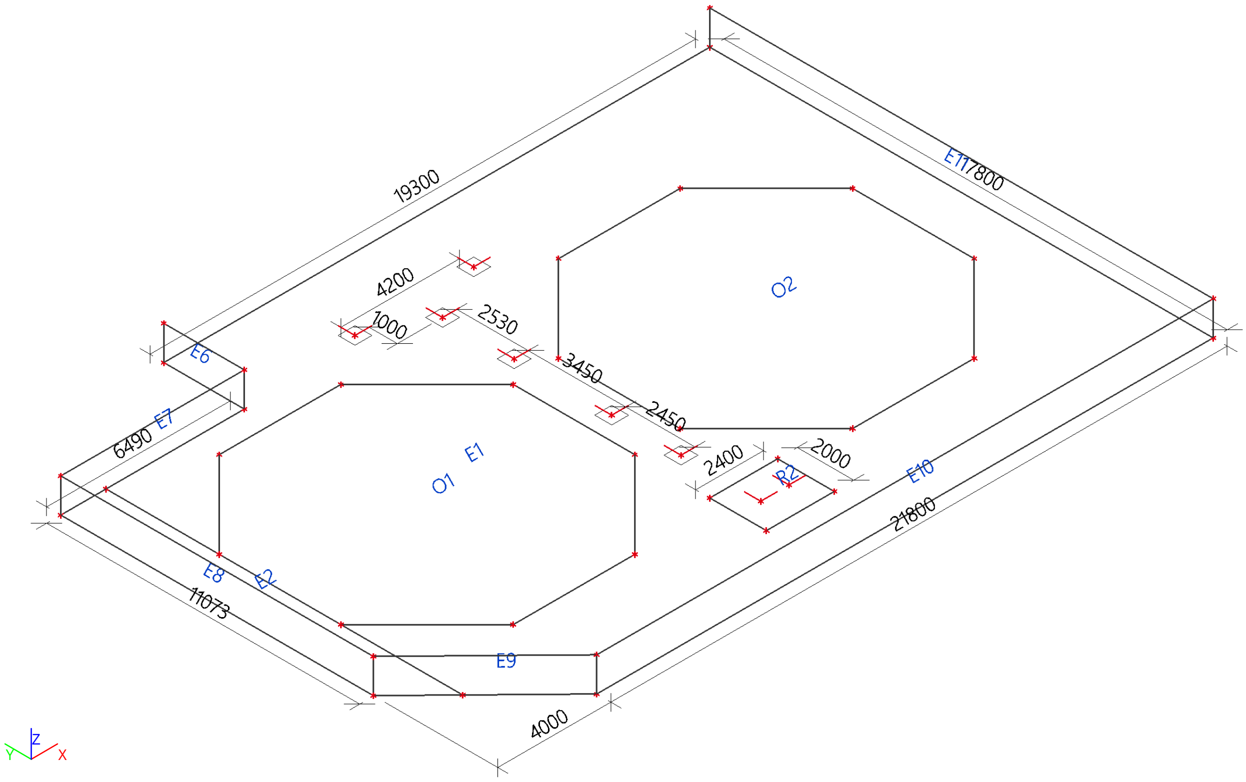
4.10. LC_14-3

4.10.1. LC_14-3 / Totale waarde



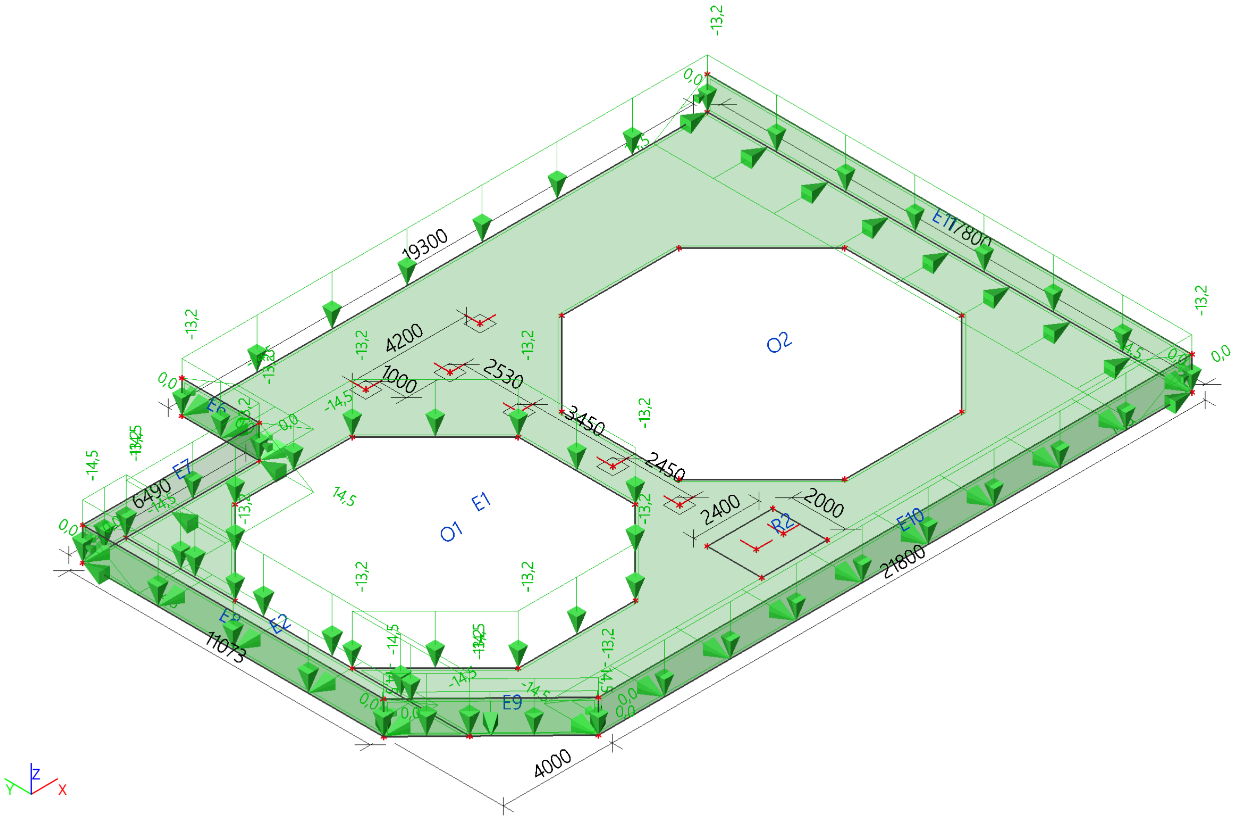
4.11. LC_14-4

4.11.1. LC_14-4 / Totale waarde



4.12. LC_15

4.12.1. LC_15 / Totale waarde



4.12.2. Lasten op oppervlak

Name	2D member	Load case	Dir	Type	Value [kN/m^2]	System	Loc
SF3	E1	LC_15 - AL - Calamity	Z	Force	-13,2	LCS	Length
SF4	E2	LC_15 - AL - Calamity	Z	Force	-14,5	LCS	Length

4.12.3. Vrije oppervlakte last

Name	Selected 2D members	Load case	Dir	Type	Distribution	q1 [kN/m^2]	q2 [kN/m^2]
FF1	E6	LC_15 - AL - Calamity	X	Force	Dir Y	0,0	-14,5
FF2	E7	LC_15 - AL - Calamity	Y	Force	Dir Y	0,0	14,5
FF3	E8	LC_15 - AL - Calamity	X	Force	Dir Y	-14,5	0,0
FF4	E9	LC_15 - AL - Calamity	Z	Force	Dir Y	0,0	-14,5
FF5	E10	LC_15 - AL - Calamity	Y	Force	Dir Y	0,0	-14,5
FF6	E11	LC_15 - AL - Calamity	X	Force	Dir Y	0,0	14,5

5. Load combinations

5.1. Load cases

Name	Description	Action type	Load type	Load group	Direction	Duration
LC_01	DL - Self weight	Permanent	Self weight	LG1	-Z	
LC_11	LL - Live Load on the floor	Variable	Static	LG2 vloer		Short
LC_12	Do - Pumps	Variable	Static	LG2 vloer		Short
LC_13-1	Do - Piping Load	Variable	Static	LG2 vloer		Short
LC_13-2	Do - Piping Load N-->S	Variable	Static	LG2 vloer		Short
LC_13-3	Do - Piping Load S-->N	Variable	Static	LG2 vloer		Short
LC_13-4	Do - Piping Load E-->W	Variable	Static	LG2 vloer		Short
LC_13-5	Do - Piping Load W-->E	Variable	Static	LG2 vloer		Short
LC_14-1	W - Wind Load N-->S	Variable	Static	LG3 Wind		Short
LC_14-2	W - Wind Load S-->N	Variable	Static	LG3 Wind		Short
LC_14-3	W - Wind Load E-->W	Variable	Static	LG3 Wind		Short
LC_14-4	W - Wind Load W-->E	Variable	Static	LG3 Wind		Short
LC_15	AL - Calamity	Variable	Static	LG2 vloer		Short

5.2. Load groups

Name	Load	Relation	Type
LG1	Permanent		
LG2 vloer	Variable	Standard	Cat E : Storage
LG3 Wind	Variable	Standard	Wind

5.3. Combinations

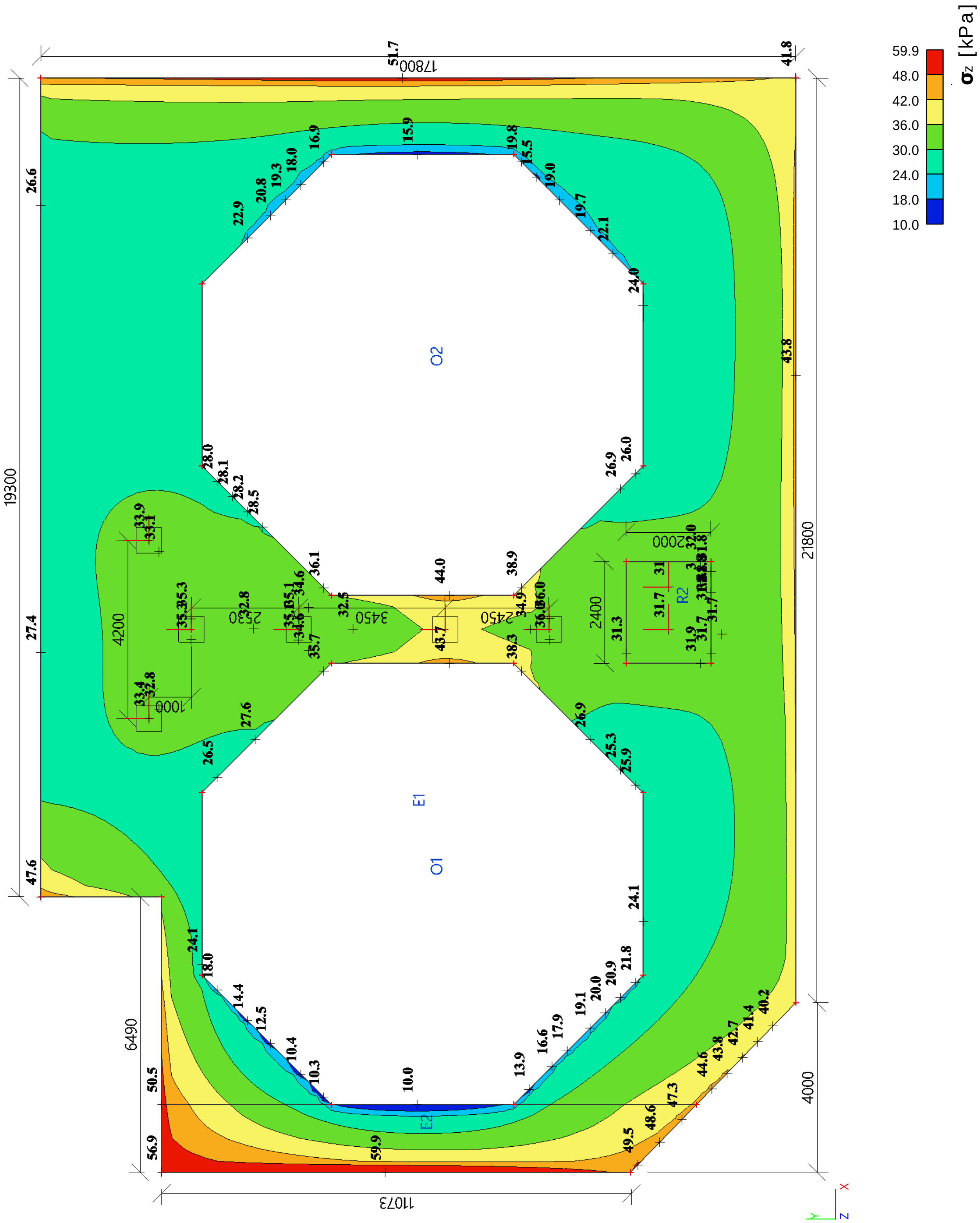
Name	Description	Type	Load cases	Coeff. [-]
ULS_01		Linear - ultimate	LC_01 - DL - Self weight	1,35
ULS_02		Linear - ultimate	LC_01 - DL - Self weight	1,50
			LC_13-1 - Do - Piping Load	1,65
			LC_13-2 - Do - Piping Load N-->S	1,65
			LC_14-1 - W - Wind Load N-->S	1,00
ULS_03		Linear - ultimate	LC_01 - DL - Self weight	1,50
			LC_13-1 - Do - Piping Load	1,65
			LC_13-3 - Do - Piping Load S-->N	1,65
			LC_14-2 - W - Wind Load S-->N	1,65
ULS_04		Linear - ultimate	LC_01 - DL - Self weight	1,50
			LC_13-1 - Do - Piping Load	1,65
			LC_13-4 - Do - Piping Load E-->W	1,65
			LC_14-3 - W - Wind Load E-->W	1,65
ULS_05		Linear - ultimate	LC_01 - DL - Self weight	1,50
			LC_11 - LL - Live Load on the floor	1,65
			LC_12 - Do - Pumps	1,65
			LC_13-1 - Do - Piping Load	1,65
			LC_13-5 - Do - Piping Load W-->E	1,65
			LC_14-4 - W - Wind Load W-->E	1,65
ULS_06		Linear - ultimate	LC_01 - DL - Self weight	1,50
			LC_11 - LL - Live Load on the floor	1,65
			LC_12 - Do - Pumps	1,65
			LC_13-1 - Do - Piping Load	1,65
			LC_13-2 - Do - Piping Load N-->S	1,65
			LC_14-1 - W - Wind Load N-->S	1,65
ULS_07		Linear - ultimate	LC_01 - DL - Self weight	1,50
			LC_11 - LL - Live Load on the floor	1,65
			LC_12 - Do - Pumps	1,65
			LC_13-1 - Do - Piping Load	1,65
			LC_13-3 - Do - Piping Load S-->N	1,65
			LC_14-2 - W - Wind Load S-->N	1,65
ULS_08		Linear - ultimate	LC_01 - DL - Self weight	1,50
			LC_11 - LL - Live Load on the floor	1,65
			LC_12 - Do - Pumps	1,65
			LC_13-1 - Do - Piping Load	1,65
			LC_13-4 - Do - Piping Load E-->W	1,65
			LC_14-3 - W - Wind Load E-->W	1,65
ULS_09		Linear - ultimate	LC_01 - DL - Self weight	1,50
			LC_11 - LL - Live Load on the floor	1,65
			LC_12 - Do - Pumps	1,65
			LC_13-1 - Do - Piping Load	1,65
			LC_13-5 - Do - Piping Load W-->E	1,65
			LC_14-4 - W - Wind Load W-->E	1,65
ULS_20	Calamity	Linear - ultimate	LC_01 - DL - Self weight	1,00
			LC_11 - LL - Live Load on the floor	0,90
			LC_12 - Do - Pumps	0,80
			LC_13-1 - Do - Piping Load	0,80
			LC_15 - AL - Calamity	1,00
SLS_01		Linear - serviceability	LC_01 - DL - Self weight	1,00
SLS_02		Linear - serviceability	LC_01 - DL - Self weight	1,00
			LC_13-1 - Do - Piping Load	1,00
			LC_13-2 - Do - Piping Load N-->S	1,00
			LC_14-1 - W - Wind Load N-->S	1,00
SLS_03		Linear - serviceability	LC_01 - DL - Self weight	1,00
			LC_13-1 - Do - Piping Load	1,00
			LC_13-3 - Do - Piping Load S-->N	1,00
			LC_14-2 - W - Wind Load S-->N	1,00
SLS_04		Linear - serviceability	LC_01 - DL - Self weight	1,00
			LC_13-1 - Do - Piping Load	1,00
			LC_13-4 - Do - Piping Load E-->W	1,00
			LC_14-3 - W - Wind Load E-->W	1,00
SLS_05		Linear - serviceability	LC_01 - DL - Self weight	1,00
			LC_13-1 - Do - Piping Load	1,00

Name	Description	Type	Load cases	Coeff. [-]
			LC_13-5 - Do - Piping Load W-->E	1,00
			LC_14-4 - W - Wind Load W-->E	1,00
SLS_06		Linear - serviceability	LC_01 - DL - Self weight	1,00
			LC_11 - LL - Live Load on the floor	1,00
			LC_12 - Do - Pumps	1,00
			LC_13-1 - Do - Piping Load	1,00
			LC_13-2 - Do - Piping Load N-->S	1,00
			LC_14-1 - W - Wind Load N-->S	1,00
SLS_07		Linear - serviceability	LC_01 - DL - Self weight	1,00
			LC_11 - LL - Live Load on the floor	1,00
			LC_12 - Do - Pumps	1,00
			LC_13-1 - Do - Piping Load	1,00
			LC_13-3 - Do - Piping Load S-->N	1,00
			LC_14-2 - W - Wind Load S-->N	1,00
SLS_08		Linear - serviceability	LC_01 - DL - Self weight	1,00
			LC_11 - LL - Live Load on the floor	1,00
			LC_12 - Do - Pumps	1,00
			LC_13-1 - Do - Piping Load	1,00
			LC_13-4 - Do - Piping Load E-->W	1,00
			LC_14-3 - W - Wind Load E-->W	1,00
SLS_09		Linear - serviceability	LC_01 - DL - Self weight	1,00
			LC_11 - LL - Live Load on the floor	1,00
			LC_12 - Do - Pumps	1,00
			LC_13-1 - Do - Piping Load	1,00
			LC_13-5 - Do - Piping Load W-->E	1,00
			LC_14-4 - W - Wind Load W-->E	1,00

6. Results floor

6.1. Reactions

6.1.1. 2D-contactspanningen; **σ**_z



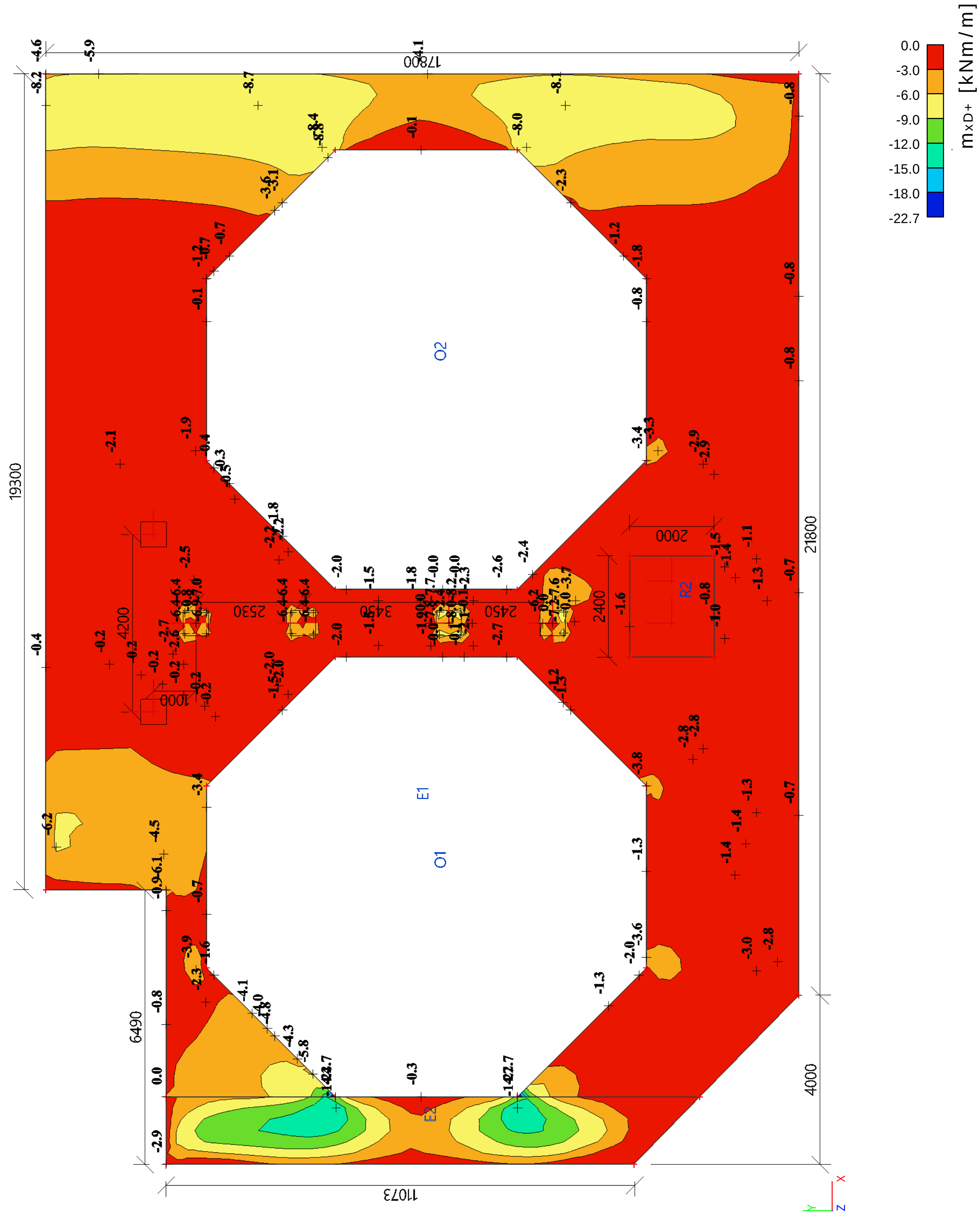
6.1.2. 2D contact stresses

Linear calculation
Class: ULS_All
Extreme: Global
Selection: All
Location: In nodes avg.. System: LCS mesh element
Nothing in selection to display as: Standard result

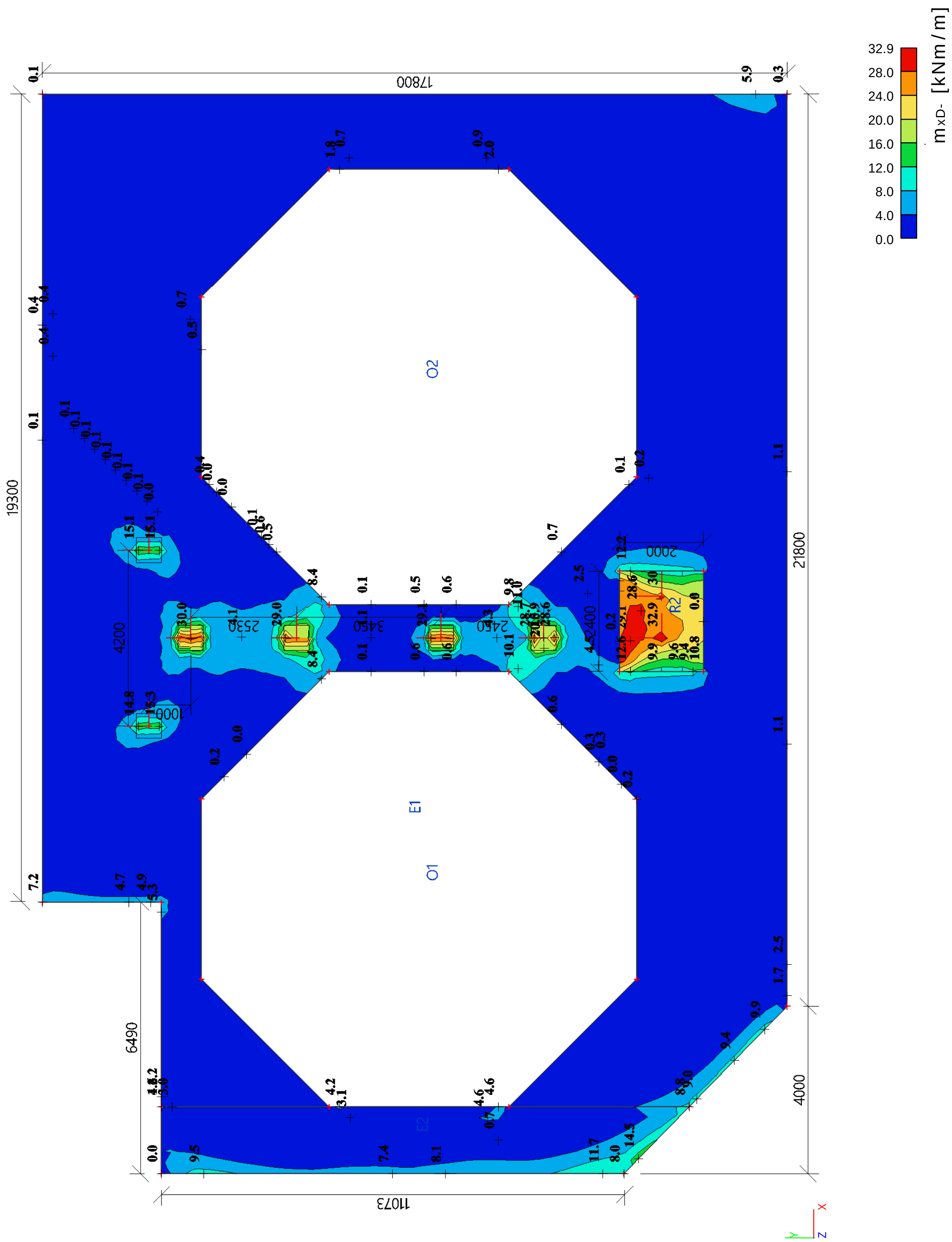
6.2. Internal Forces

6.2.1. LIN-ULS

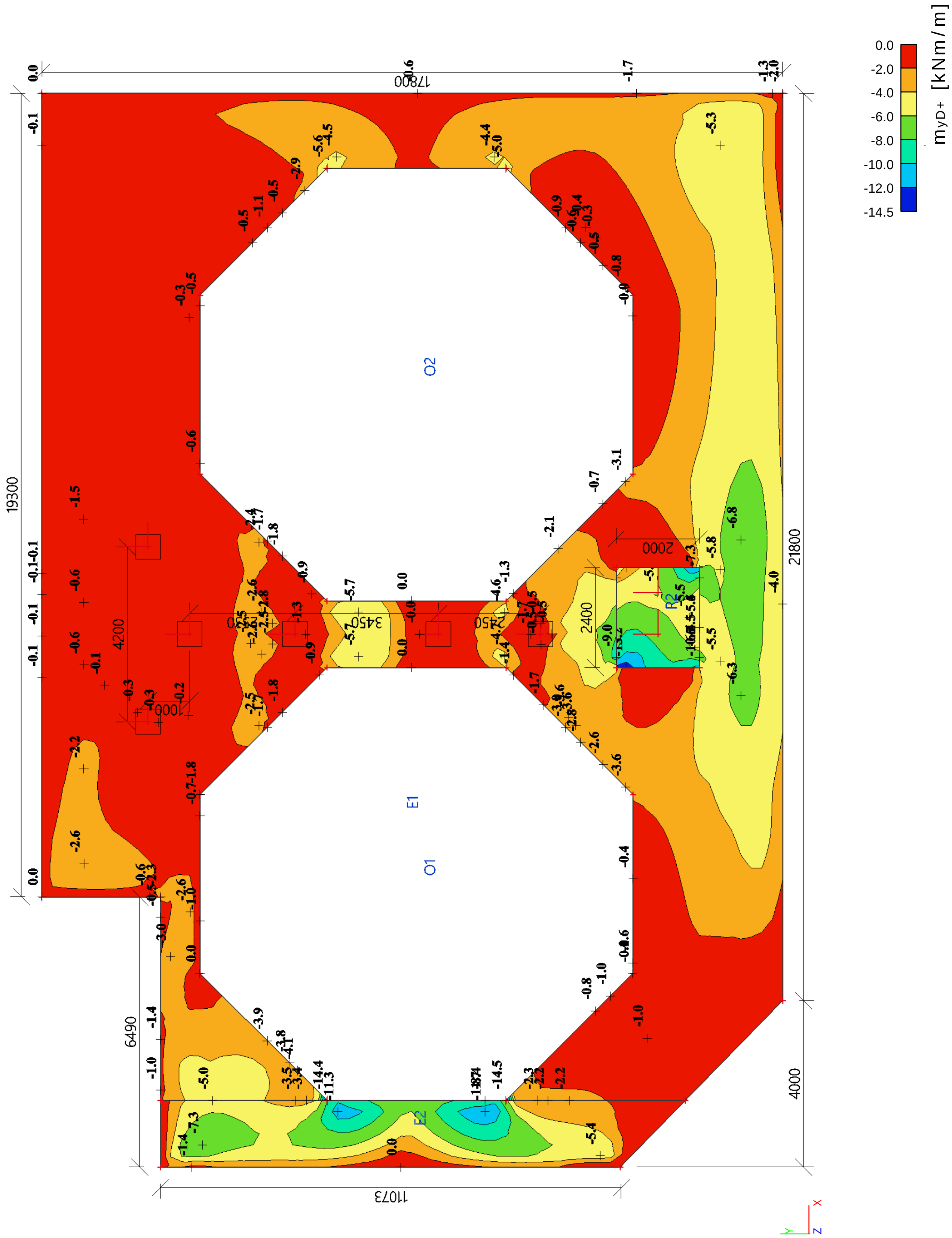
6.2.1.1. LIN-ULS m_xD+



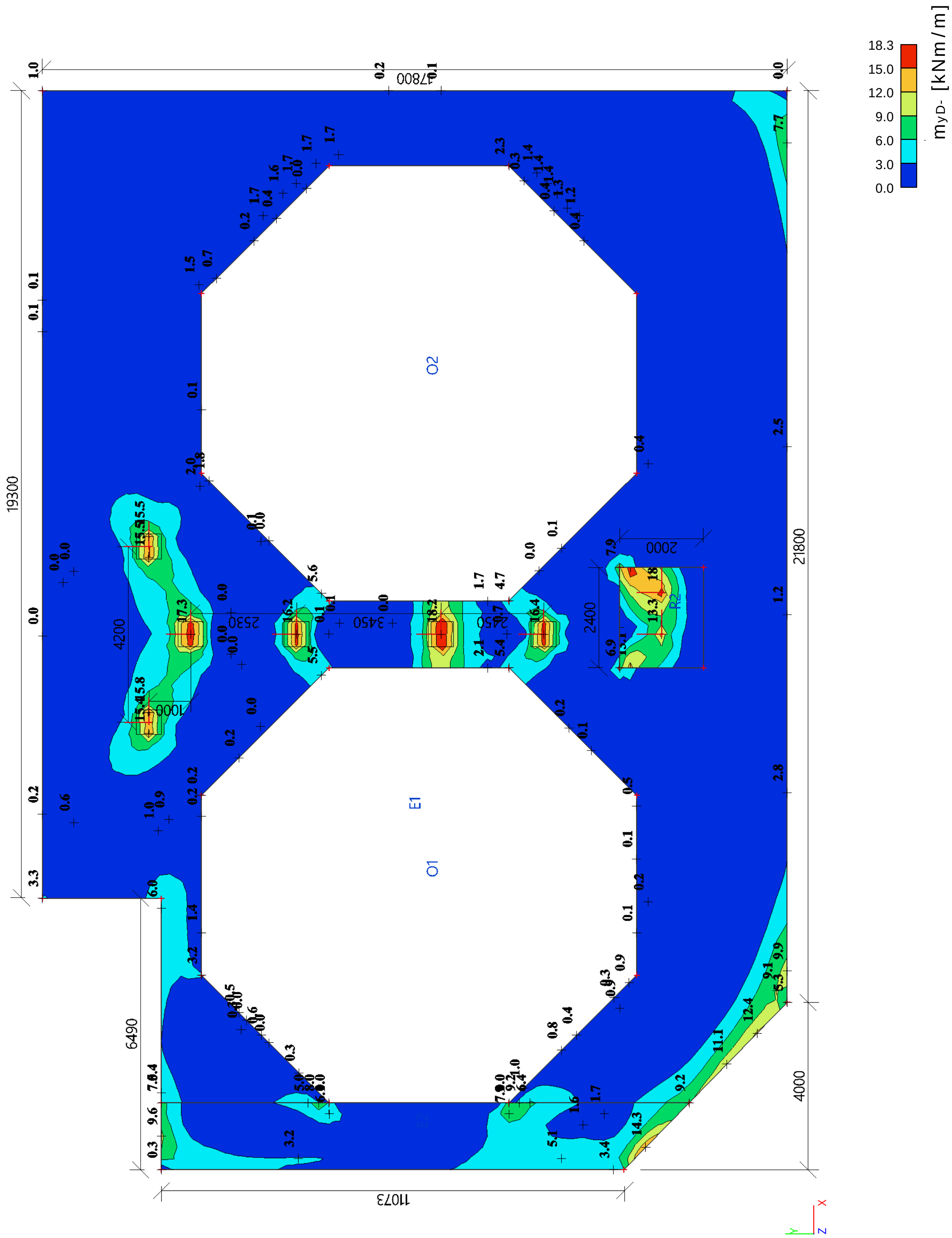
6.2.1.2. LIN-ULS m_xD-



6.2.1.3. LIN-ULS m_yD+



6.2.1.4. LIN-ULS m_yD-



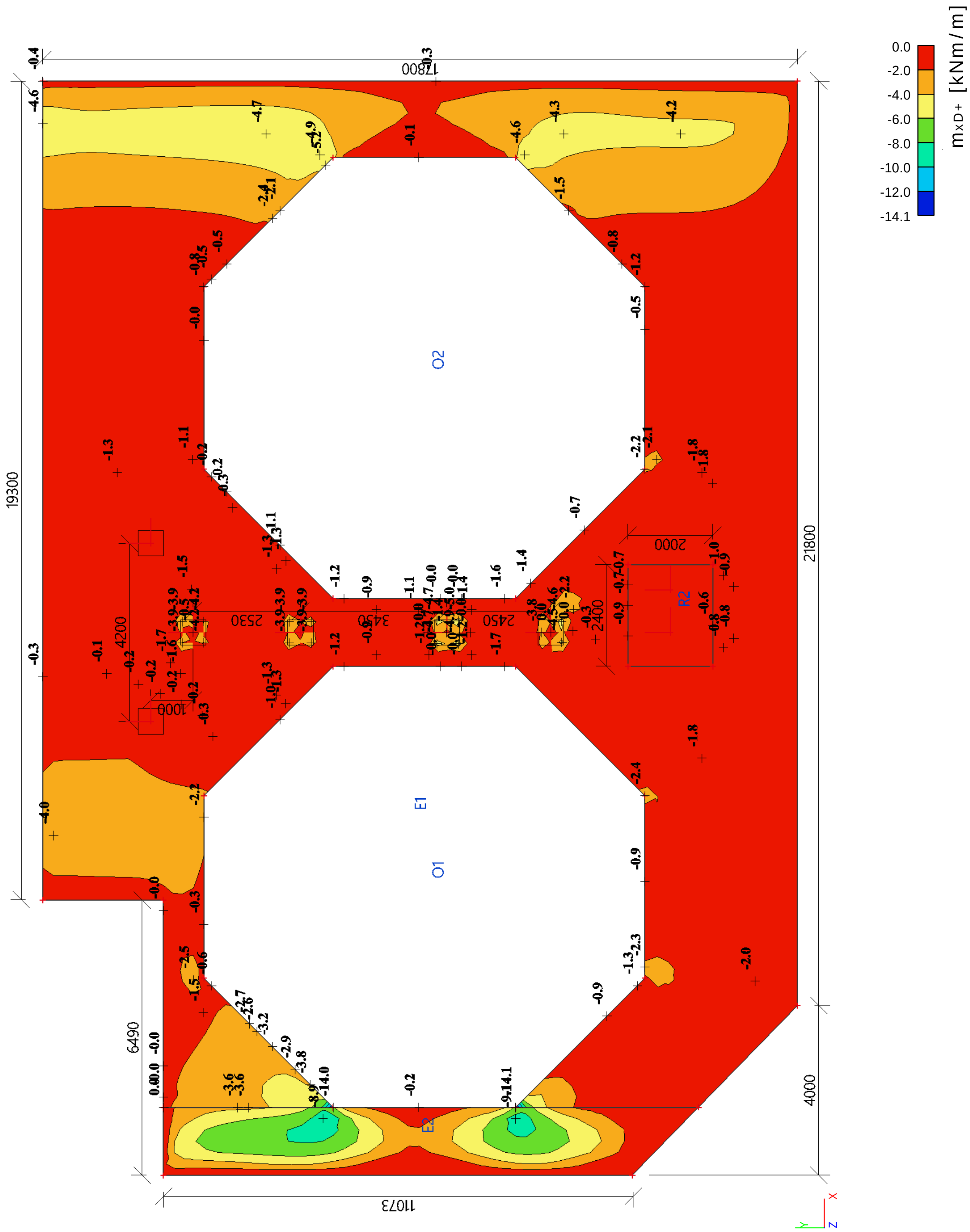
6.2.1.5. LIN-ULS internal forces

Linear calculation
Class: ULS_All
Extreme: Global
Selection: E1, E2
Location: In nodes avg. on macro. System: LCS mesh element
Elementary design magnitudes

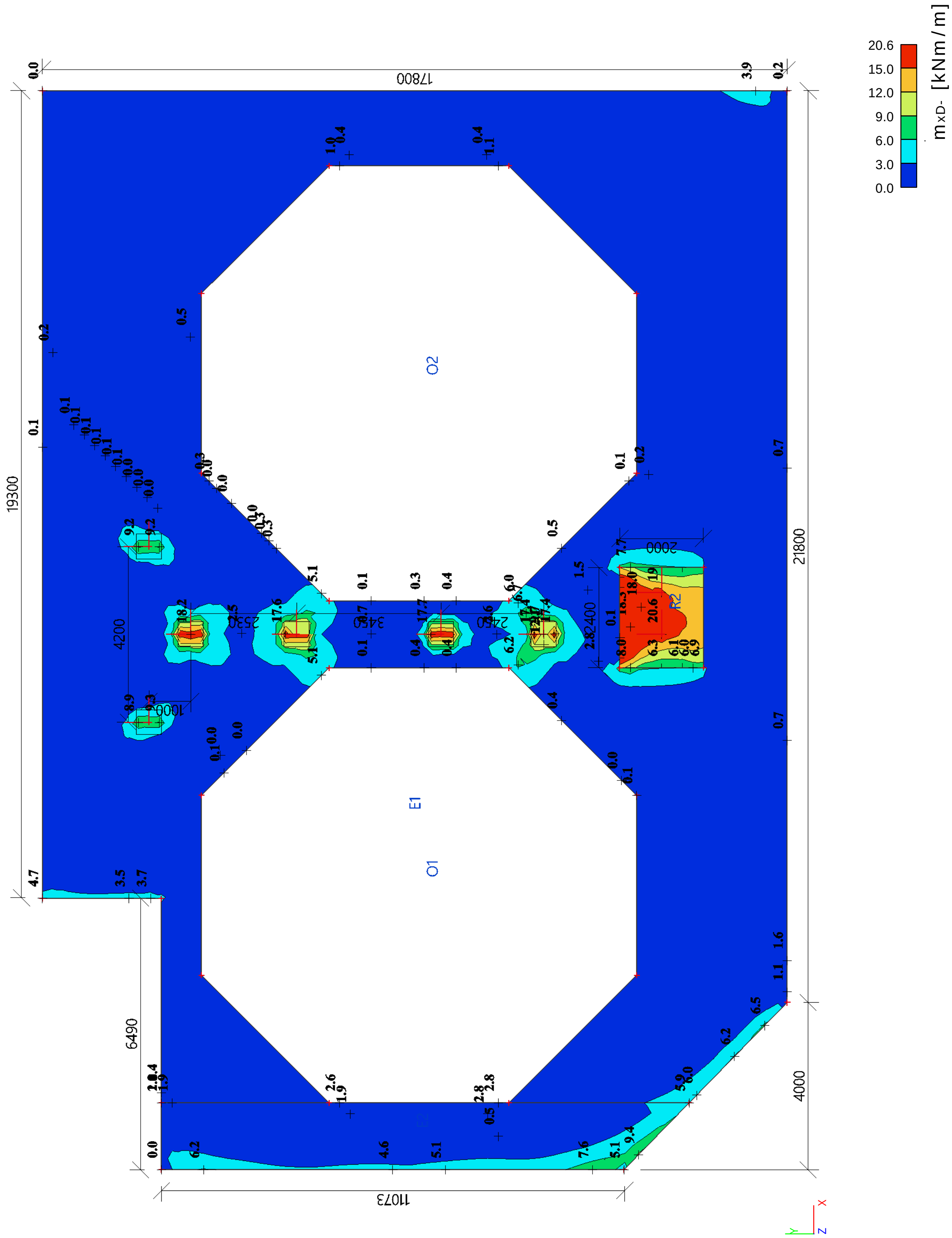
Name	Mesh	Position [m]	Case	m_{xD+} [kNm/m] m_{xD-} [kNm/m]	m_{yD+} [kNm/m] m_{yD-} [kNm/m]	n_{xD} [kN/m]	n_{yD} [kN/m]
E1	Element: 3792 Node: 34	8,800 3,000 0,000	ULS_08/1	0,0 32,9	0,0 12,7	0,6	6,1
E1	Element: 235 Node: 9	-2,400 6,650 0,000	ULS_06/2	-22,7 0,0	-14,5 0,0	-10,0	0,0
E1	Element: 1 Node: 1	-2,400 10,950 0,000	ULS_05/3	-22,7 0,0	-14,4 0,0	-10,8	0,0
E1	Element: 3801 Node: 35	9,800 3,000 0,000	ULS_08/1	0,0 26,4	0,0 18,3	5,4	10,7
E2	Element: 3874 Node: 37	-4,000 3,900 0,000	ULS_07/4	0,0 8,0	0,0 6,0	-47,4	0,0
E1	Element: 36 Node: 3	2,490 14,953 0,000	ULS_20/5	-6,1 1,8	-2,3 5,5	197,4	120,4
E1	Element: 207 Node: 7	0,000 0,000 0,000	ULS_08/1	-0,3 2,4	0,0 5,3	0,0	-37,0
E1	Element: 36 Node: 3	2,490 14,953 0,000	ULS_07/4	-1,5 2,3	0,0 5,9	136,0	127,3

6.2.2. LIN-SLS

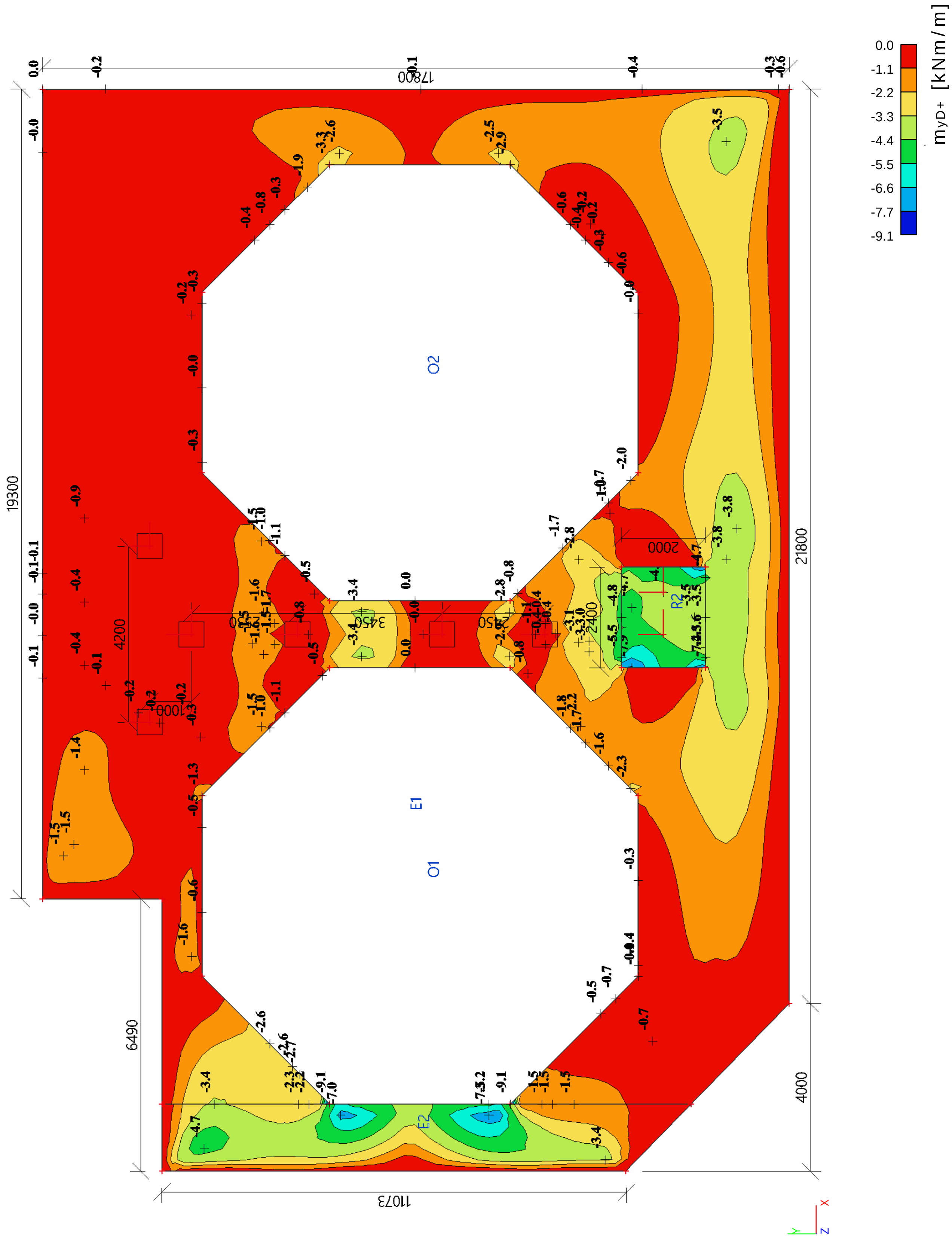
6.2.2.1. LIN-SLS m_xD+



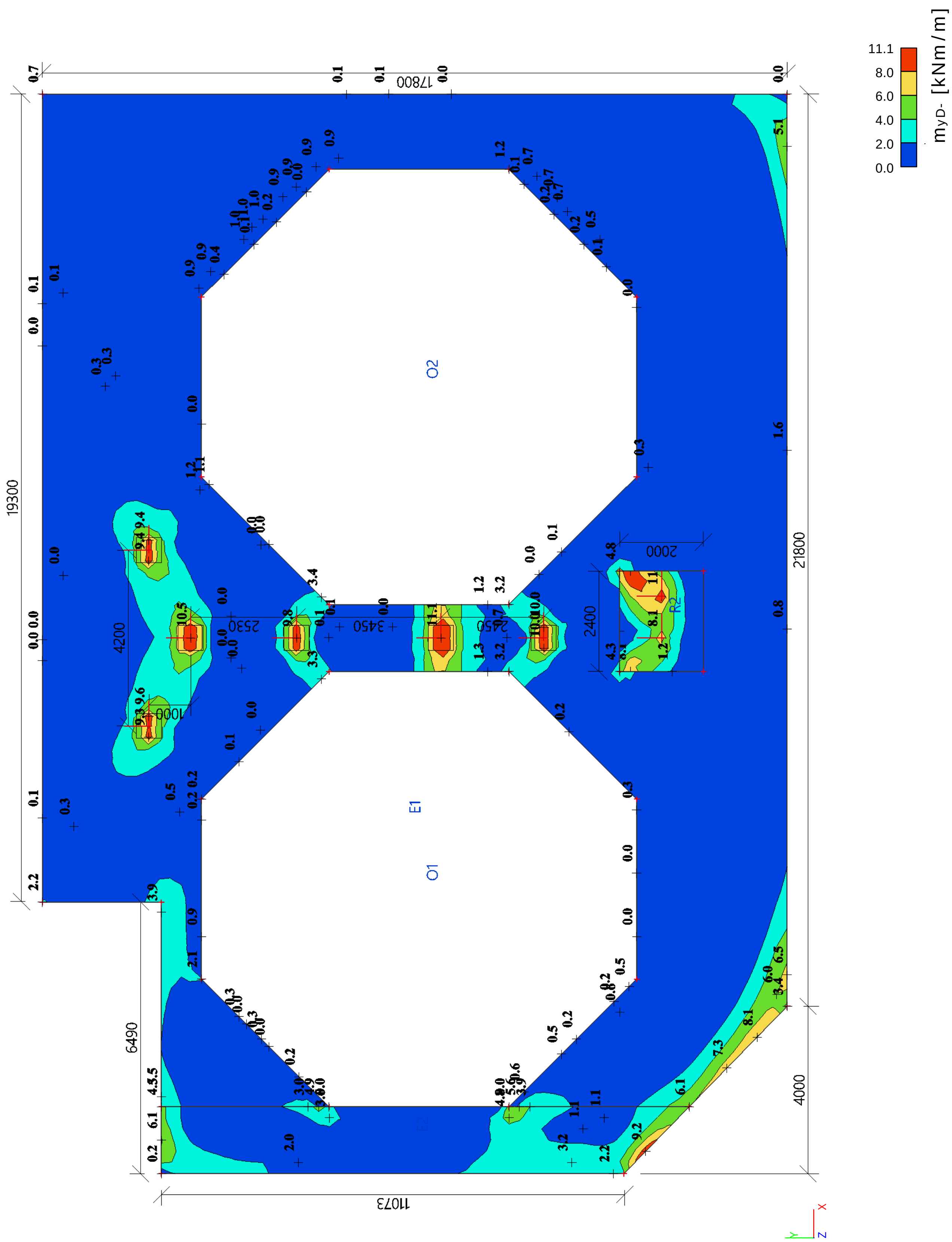
6.2.2.2. LIN-SLS m_xD-



6.2.2.3. LIN-SLS m_yD+



6.2.2.4. *LIN-SLS m_yD-*



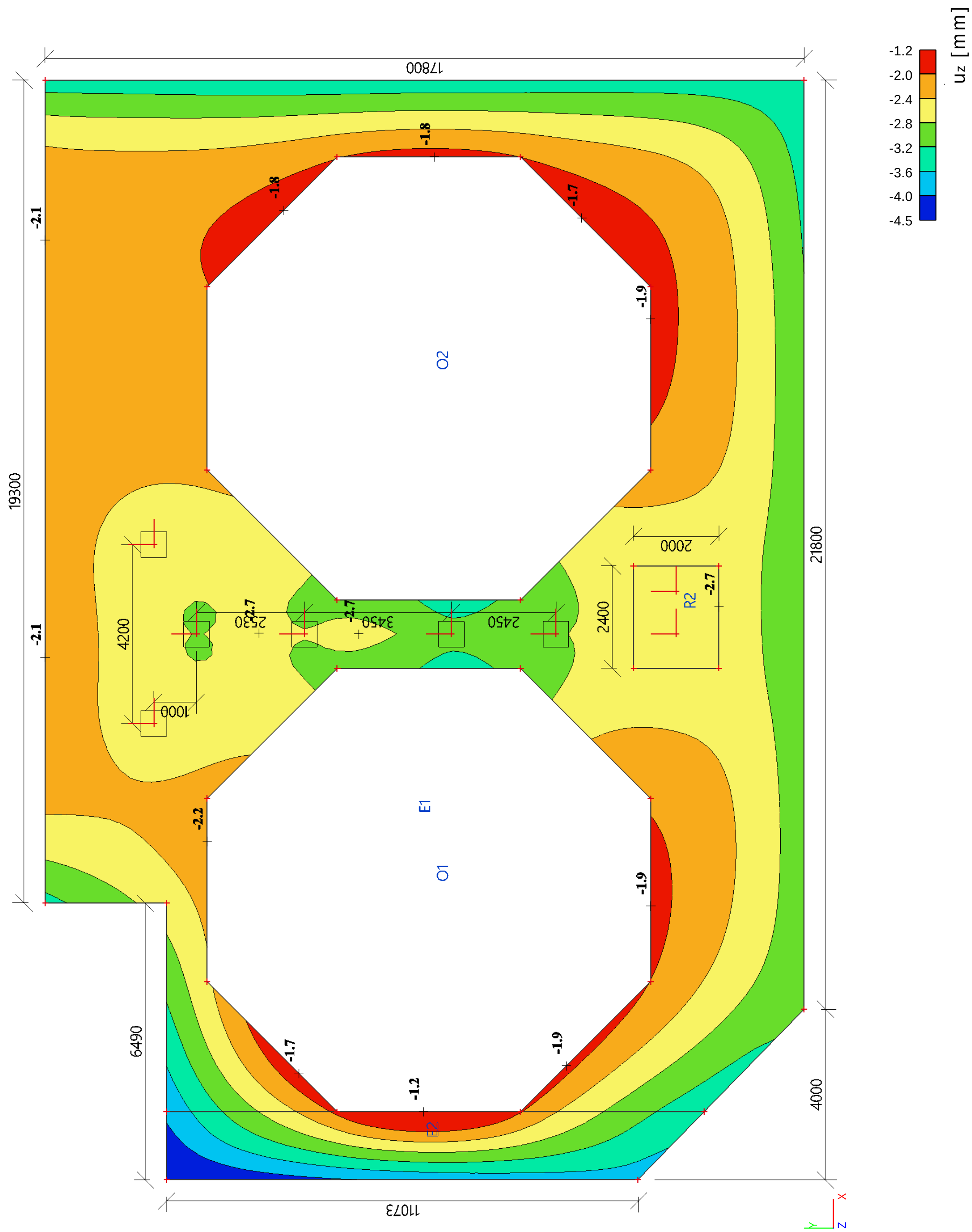
6.2.2.5. LIN-SLS internal forces

Linear calculation
Class: SLS_All
Extreme: Global
Selection: E1, E2
Location: In nodes avg. on macro. System: LCS mesh element
Elementary design magnitudes

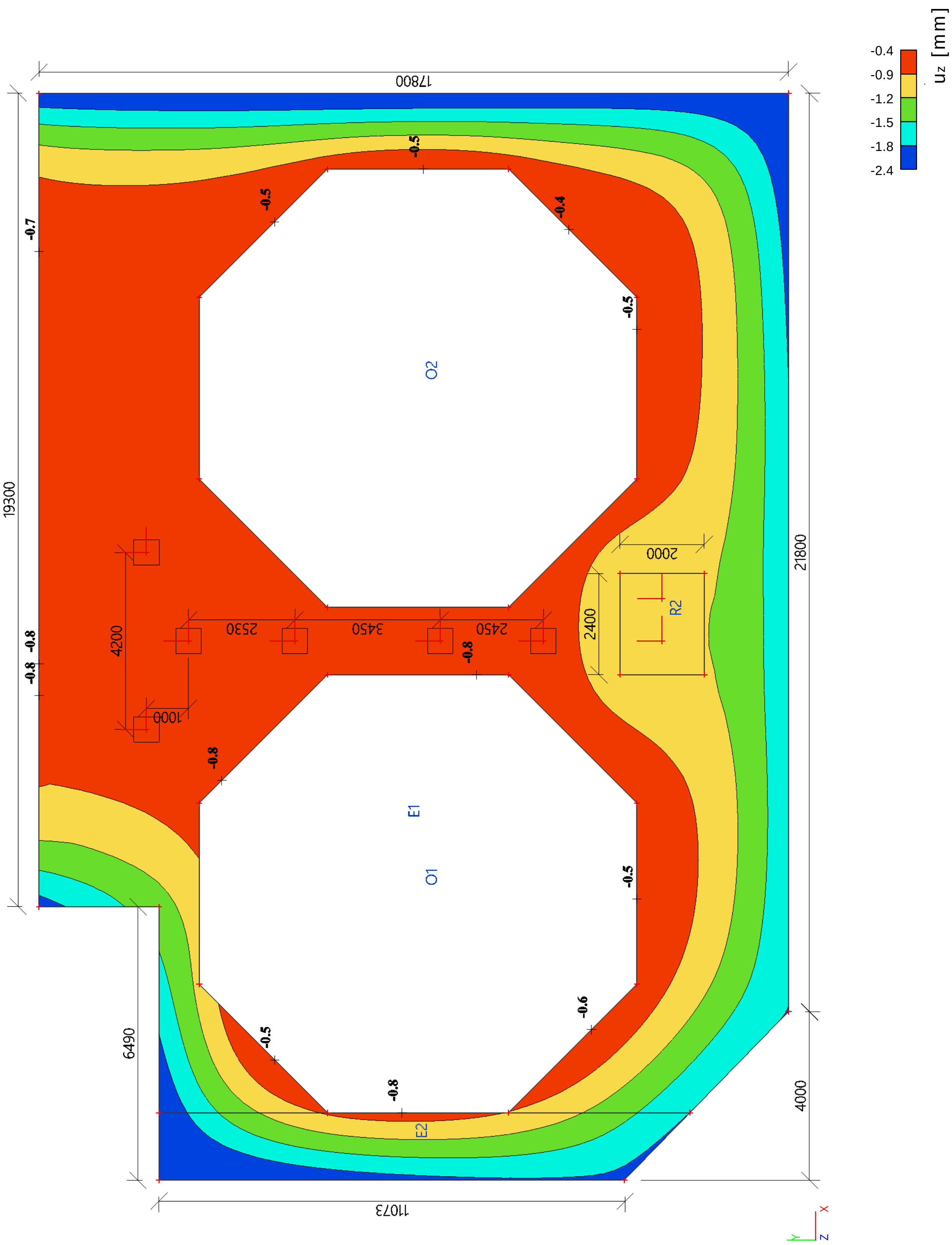
Name	Mesh	Position [m]	Case	m_{xD+} [kNm/m] m_{xD-} [kNm/m]	m_{yD+} [kNm/m] m_{yD-} [kNm/m]	n_{xD} [kN/m]	n_{yD} [kN/m]
E1	Element: 3792 Node: 34	8,800 3,000 0,000	SLS_08/1	0,0 20,6	0,0 7,7	0,2	3,8
E1	Element: 235 Node: 9	-2,400 6,650 0,000	SLS_06/2	-14,1 0,0	-9,1 0,0	-6,9	0,0
E1	Element: 3801 Node: 35	9,800 3,000 0,000	SLS_08/1	0,0 16,6	0,0 11,1	3,2	6,7
E2	Element: 3874 Node: 37	-4,000 3,900 0,000	SLS_07/3	0,0 5,1	0,0 3,9	-30,9	0,0
E1	Element: 207 Node: 7	0,000 0,000 0,000	SLS_08/1	-0,2 1,6	0,0 3,4	0,0	-23,9
E1	Element: 36 Node: 3	2,490 14,953 0,000	SLS_07/3	-0,6 1,7	0,0 3,8	86,9	81,0

6.3. Settlements_SLS

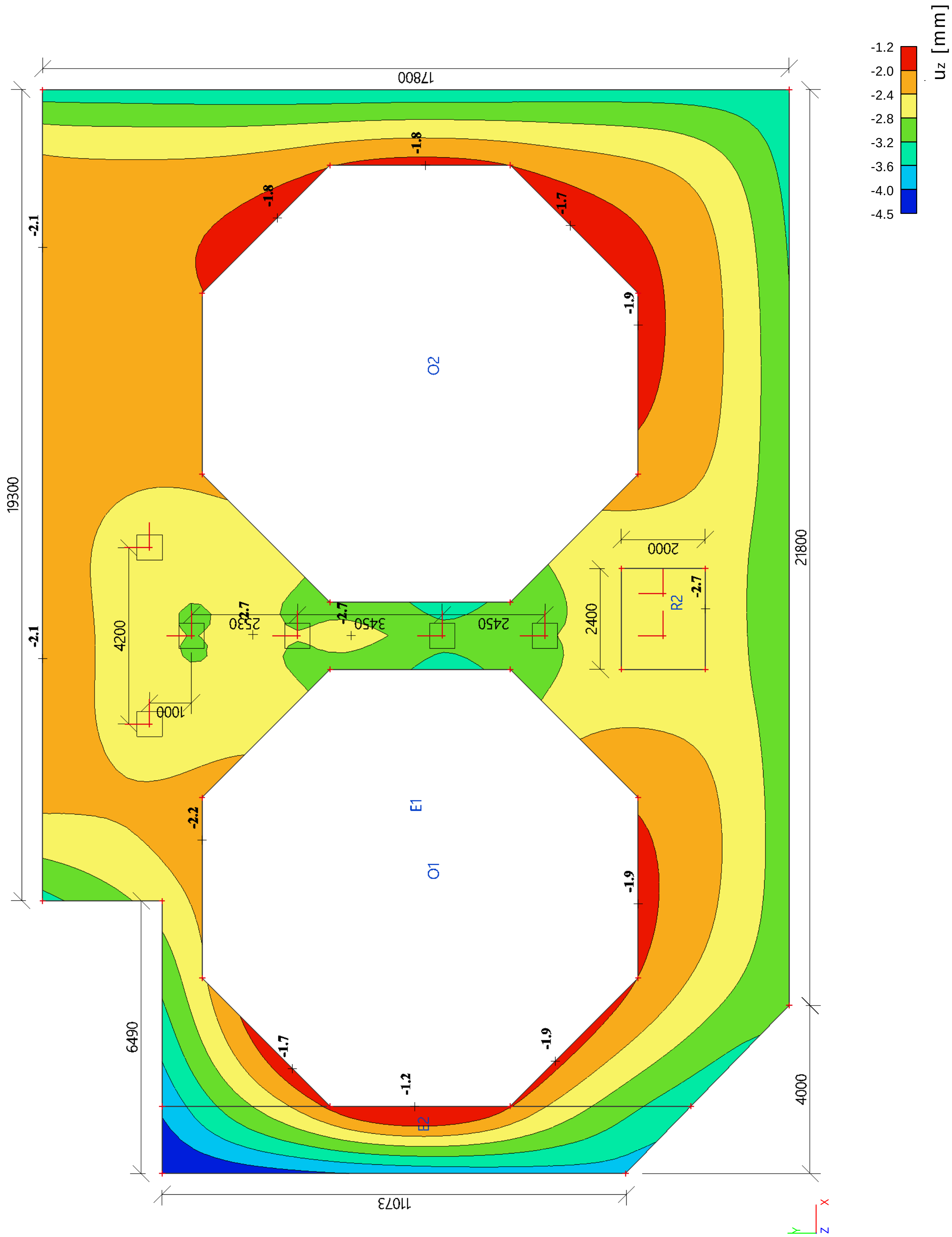
6.3.1. 2D-verplaatsing; u_z minimum



6.3.2. 2D-verplaatsing; u_z maximum



6.3.3. 2D-verplaatsing; u_z



6.3.4. 2D displacement

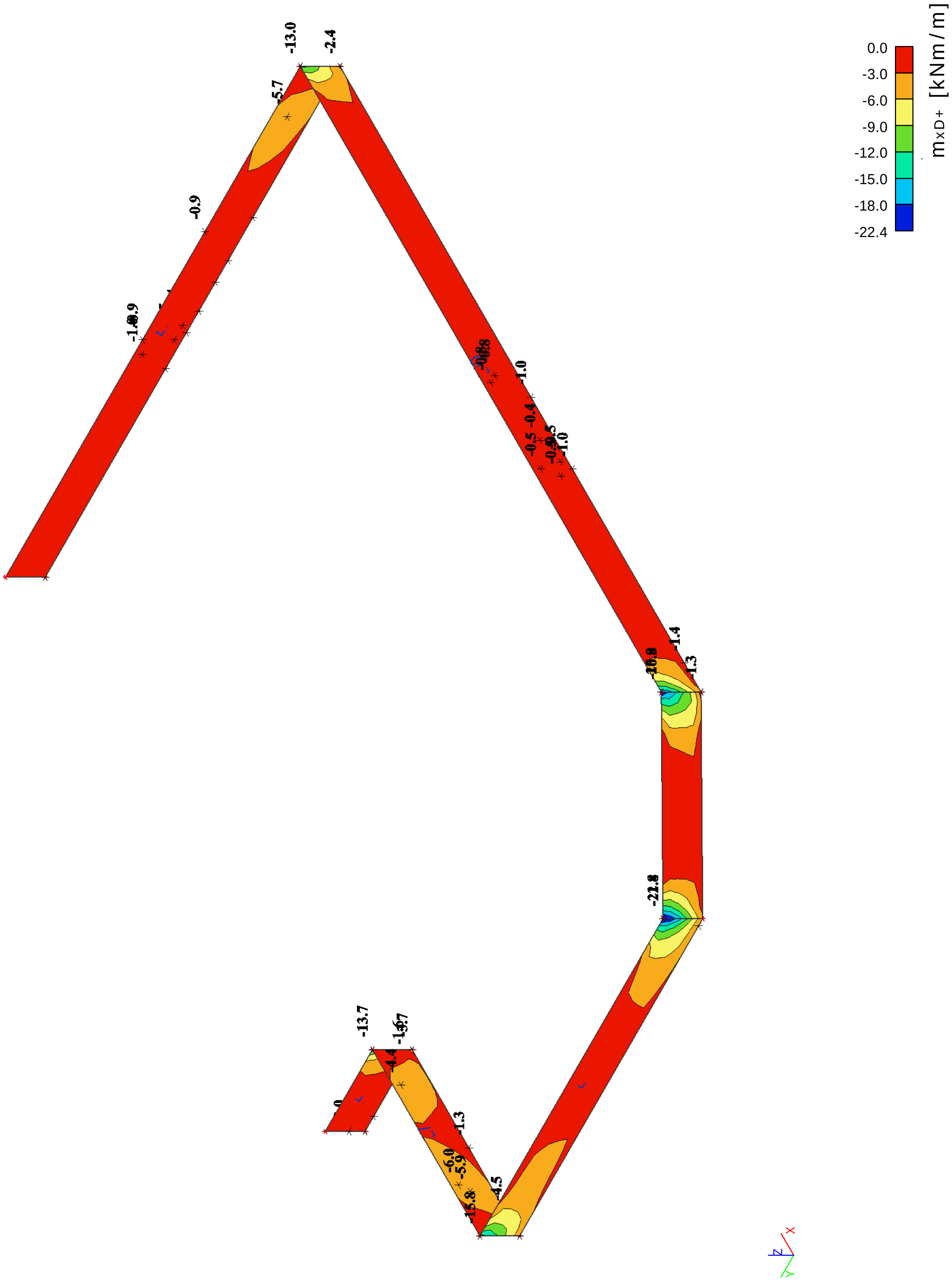
Linear calculation
Class: SLS_All
Extreme: Global
Selection:
Location: In nodes avg. on macro. System: LCS mesh element
Nothing in selection to display as: Standard result

7. Results walls

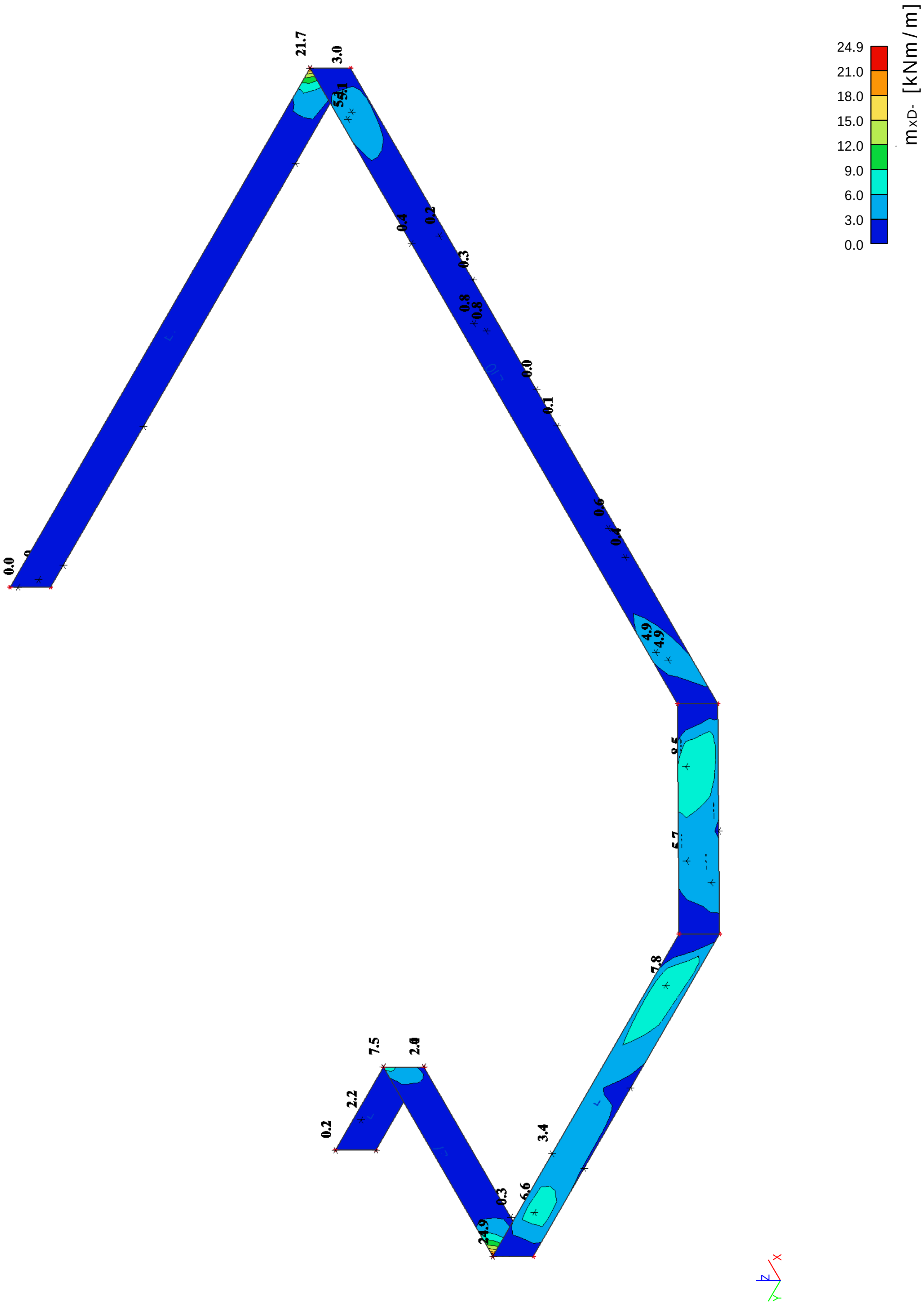
7.1. Internal forces

7.1.1. LIN-ULS

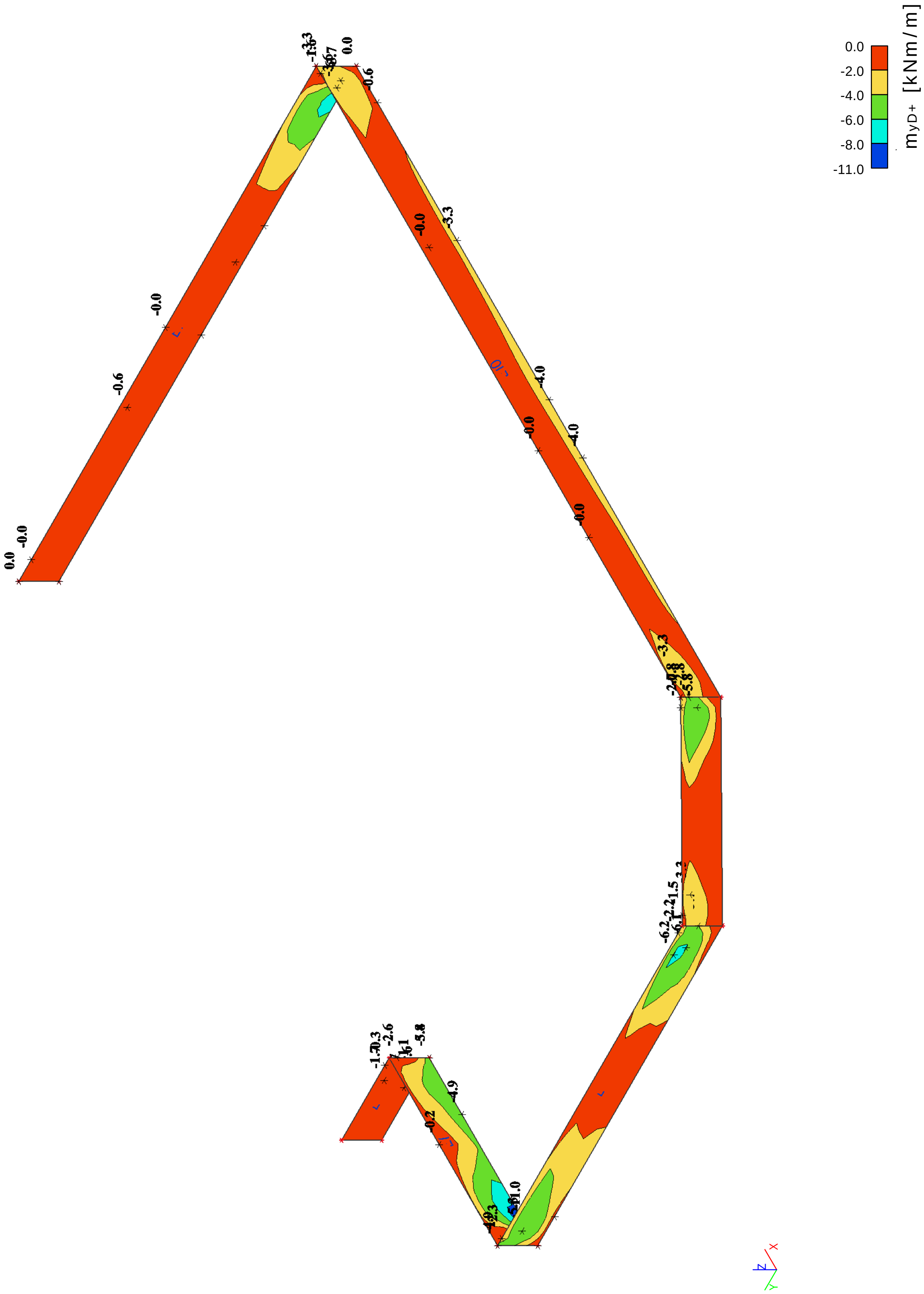
7.1.1.1. LIN-ULS m_xD+



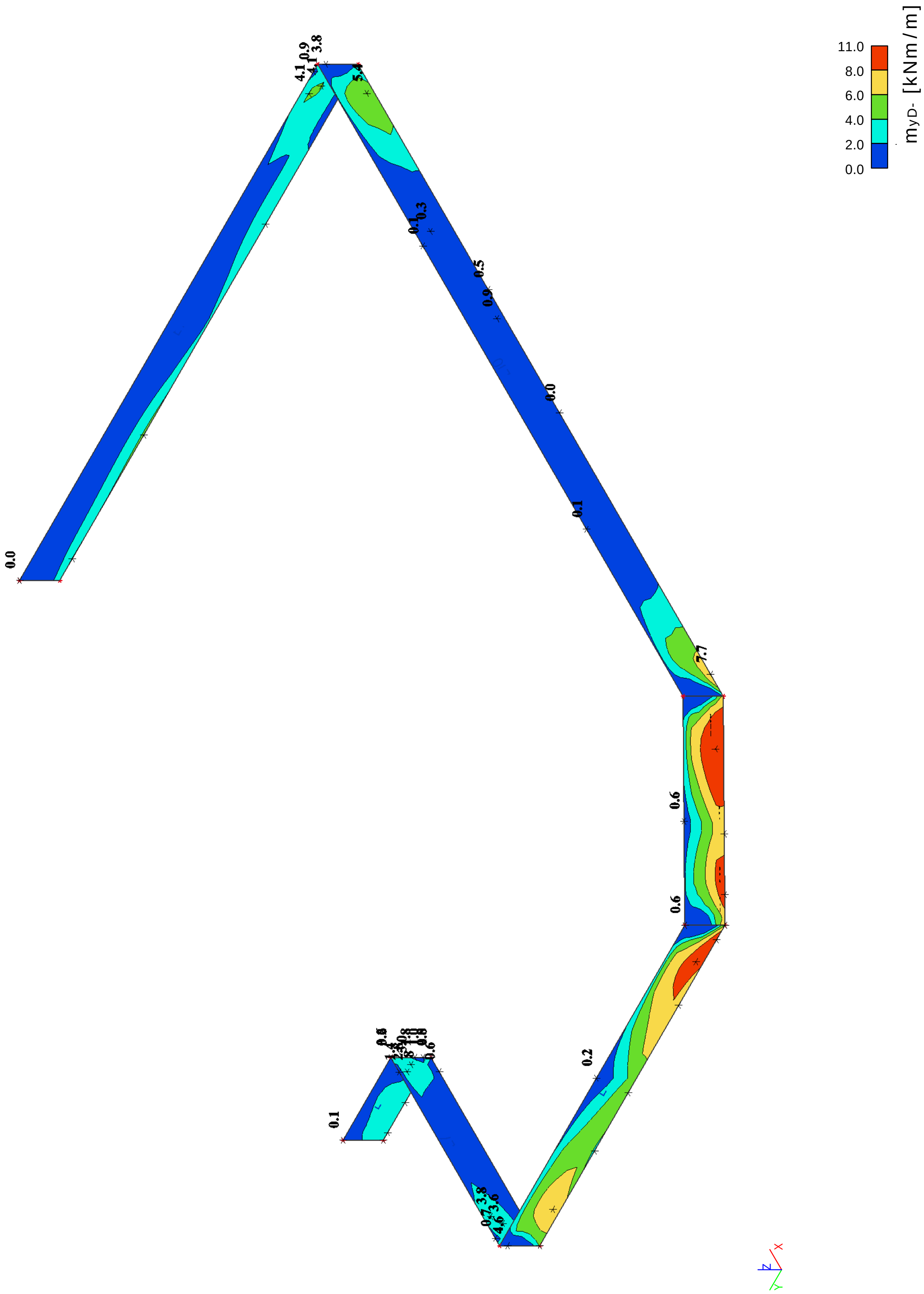
7.1.1.2. LIN-ULS m_xD-



7.1.1.3. LIN-ULS m_yD+



7.1.1.4. LIN-ULS m_yD-



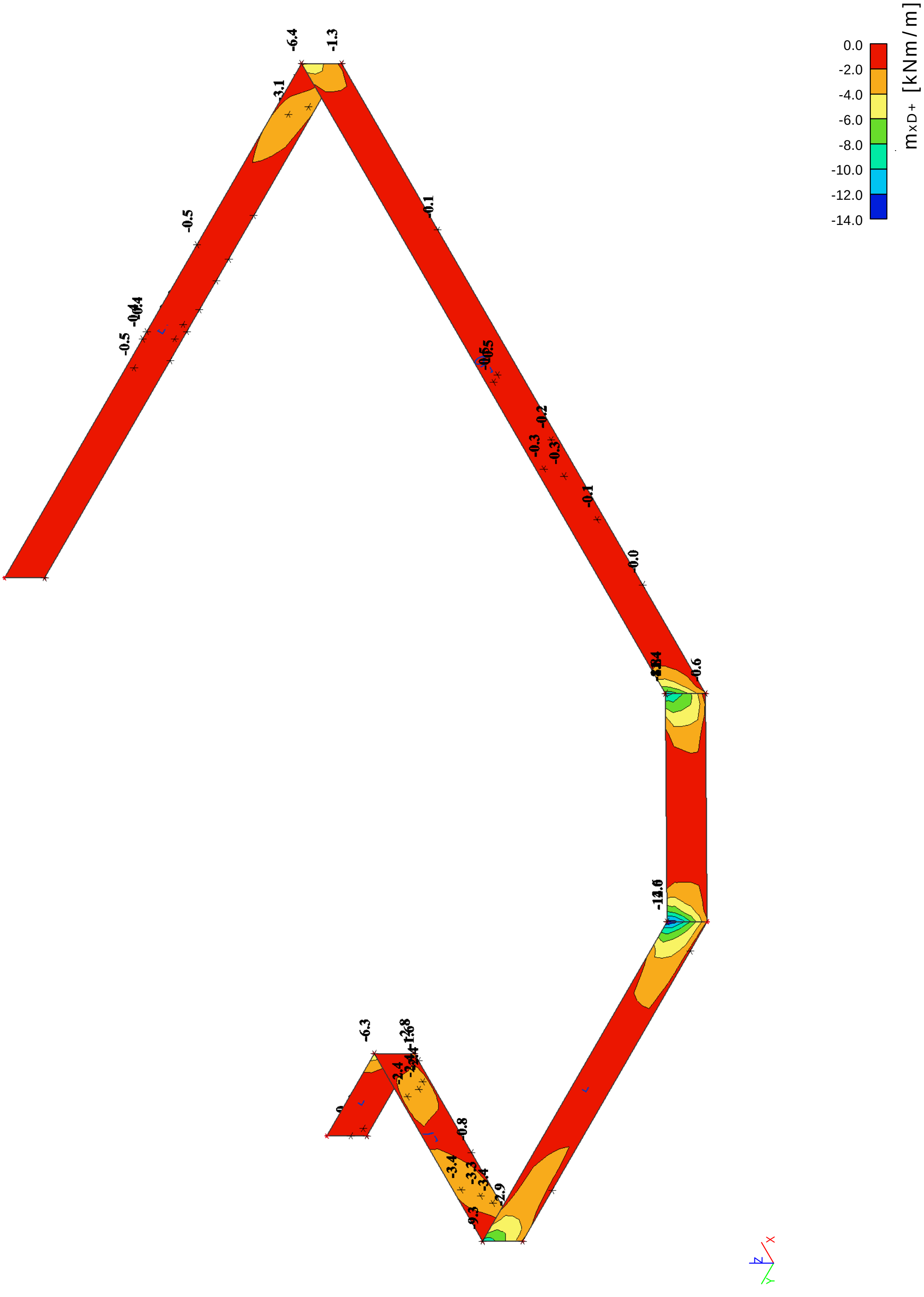
7.1.1.5. LIN-ULS internal forces

Linear calculation
Class: ULS_All
Extreme: Global
Selection: All
Location: In nodes avg. on macro. System: LCS mesh element
Elementary design magnitudes

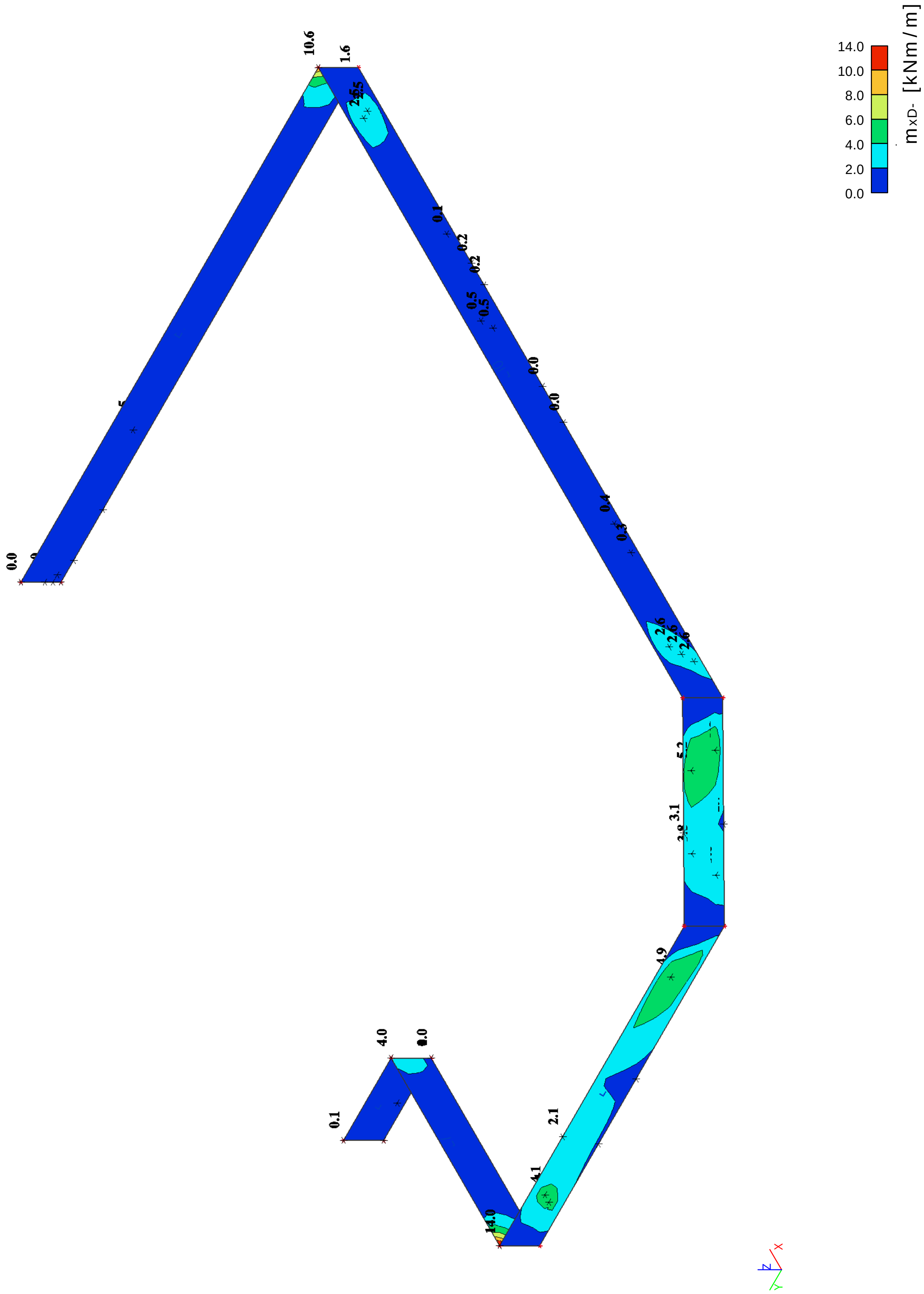
Name	Mesh	Position [m]	Case	m_{xD+} [kNm/m] m_{xD-} [kNm/m]	m_{yD+} [kNm/m] m_{yD-} [kNm/m]	n_{xD} [kN/m]	n_{yD} [kN/m]
E8	Element: 4510 Node: 41	-4,000 3,900 1,200	ULS_20/1	-22,4 0,0	-2,5 0,0	110,3	15,6
E7	Element: 4290 Node: 40	-4,000 14,953 1,200	ULS_20/1	0,0 24,9	0,0 3,1	79,1	38,5
E7	Element: 4183 Node: 4058	-3,200 14,953 0,000	ULS_06/2	-4,5 0,3	-11,0 0,0	-26,1	0,0
E9	Element: 4527 Node: 4785	-0,920 0,897 0,240	ULS_08/3	-3,8 7,9	-0,7 11,0	0,0	-12,4
E9	Element: 4511 Node: 4084	-3,822 3,727 0,000	ULS_06/2	-1,0 0,0	0,0 6,8	-37,7	0,0
E9	Element: 4610 Node: 4868	-1,818 1,773 1,200	ULS_20/1	0,0 6,1	-0,1 1,2	188,3	0,3
E9	Element: 4512 Node: 4083	-3,644 3,553 0,000	ULS_08/3	-0,5 1,3	0,0 8,4	0,0	-41,3
E9	Element: 4511 Node: 37	-4,000 3,900 0,000	ULS_08/3	-3,9 0,0	0,0 8,3	38,5	110,3

7.1.2. LIN-SLS

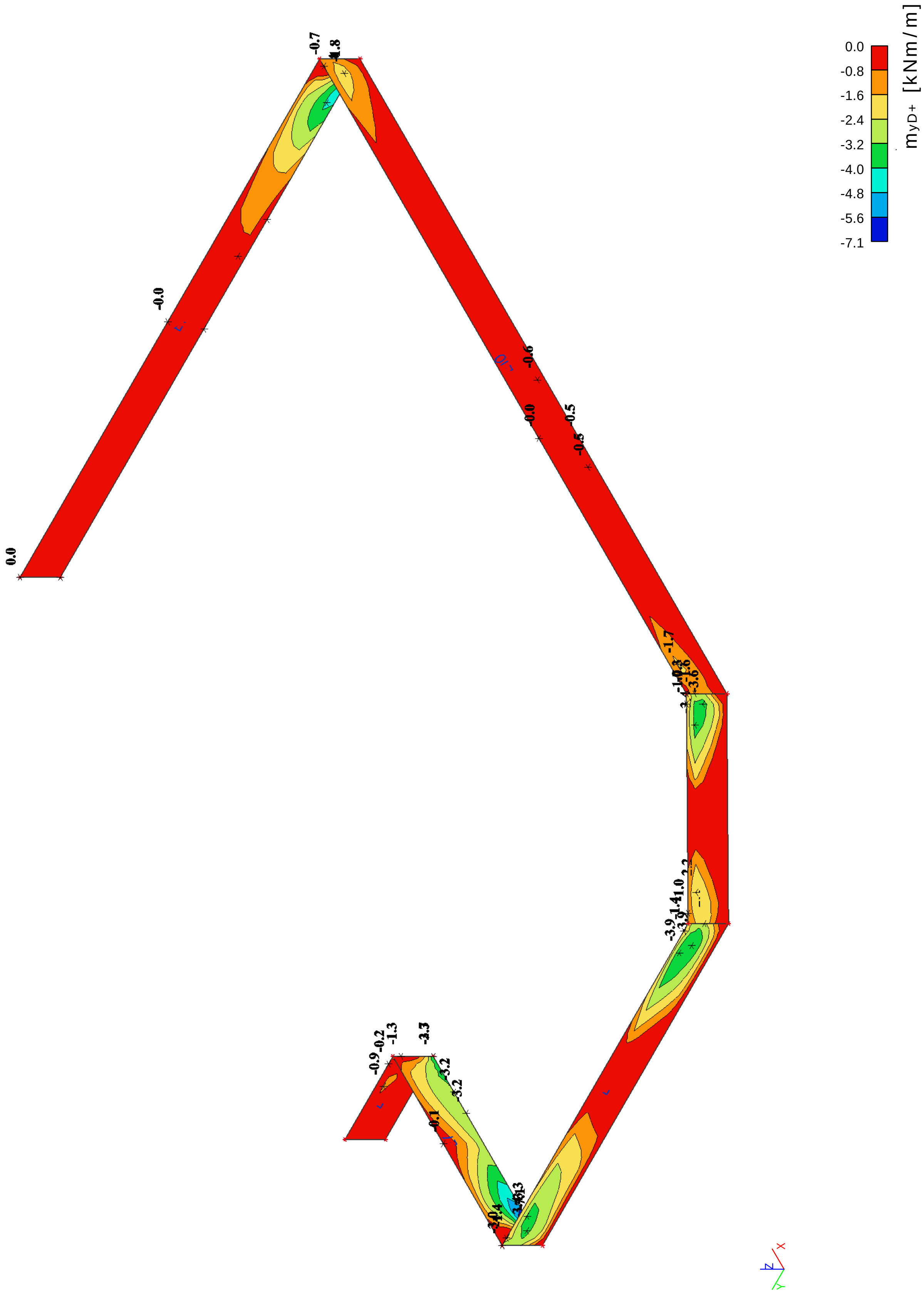
7.1.2.1. LIN-SLS m_xD+



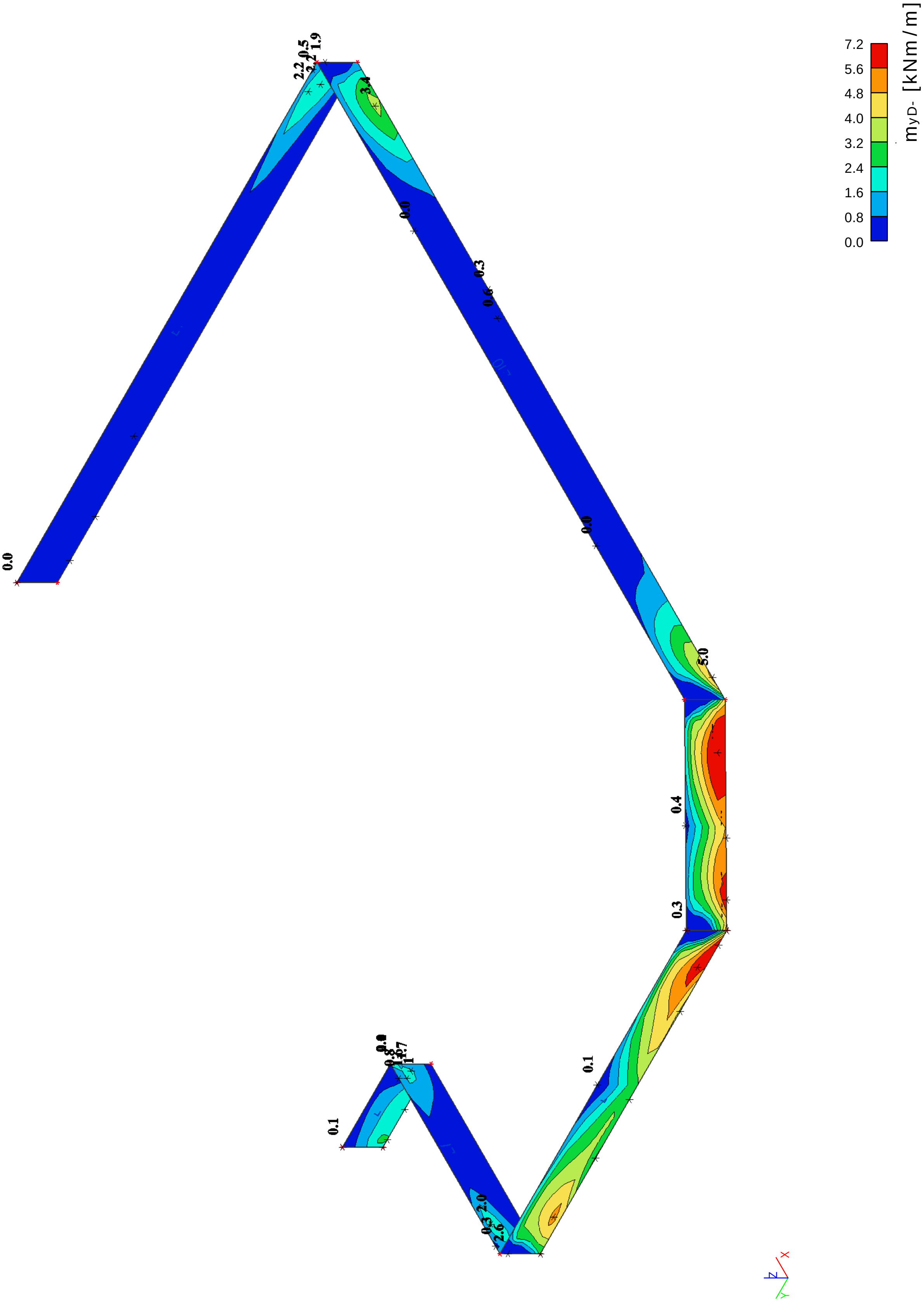
7.1.2.2. LIN-SLS m_xD-



7.1.2.3. LIN-SLS m_yD+



7.1.2.4. LIN-SLS m_yD-



7.1.2.5. 2D internal forces

Linear calculation
Class: SLS_All
Extreme: Global
Selection: All
Location: In nodes avg. on macro. System: LCS mesh element
Elementary design magnitudes

Name	Mesh	Position [m]	Case	m_{xD+} [kNm/m] m_{xD-} [kNm/m]	m_{yD+} [kNm/m] m_{yD-} [kNm/m]	n_{xD} [kN/m]	n_{yD} [kN/m]
E8	Element: 4510 Node: 41	-4,000 3,900 1,200	SLS_07/1	-14,0 0,0	-1,8 0,0	56,1	7,7
E7	Element: 4290 Node: 40	-4,000 14,953 1,200	SLS_06/2	0,0 14,0	0,0 1,7	46,1	22,1
E7	Element: 4183 Node: 4058	-3,200 14,953 0,000	SLS_06/2	-2,9 0,2	-7,1 0,0	-16,1	0,0
E9	Element: 4527 Node: 4785	-0,920 0,897 0,240	SLS_08/3	-2,4 5,1	-0,3 7,2	0,0	-8,2
E9	Element: 4511 Node: 4084	-3,822 3,727 0,000	SLS_06/2	-0,7 0,0	0,0 4,5	-23,5	0,0
E9	Element: 4610 Node: 4868	-1,818 1,773 1,200	SLS_06/2	0,0 3,6	-0,2 0,9	114,5	0,3
E9	Element: 4512 Node: 4083	-3,644 3,553 0,000	SLS_08/3	-0,4 1,0	0,0 5,5	0,0	-26,2
E9	Element: 4511 Node: 37	-4,000 3,900 0,000	SLS_08/3	-2,4 0,0	0,0 5,3	24,6	70,2

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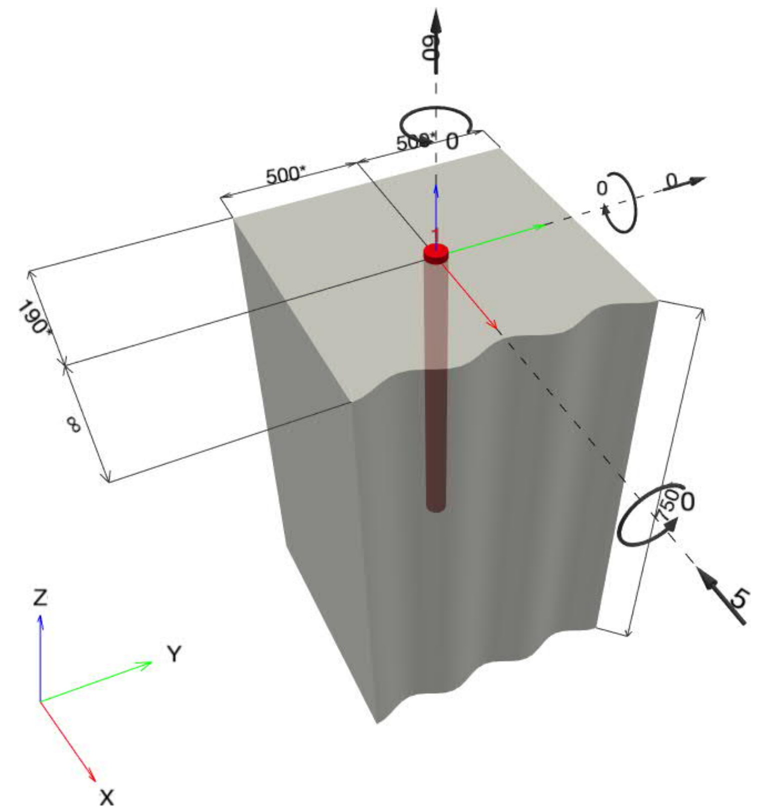
Adres:	Spoorstraat 7, Schiedam	Constructeur:	
Tel. I Fax:	|	E-mail:	
berekening:	Ankers tankfundering	Datum:	05-10-2020
Sub-Project I Pos. Nr.:	Ankers Tankfundering		

Opmerkingen van de constructeur:

1 Invoergegevens

Ankertype en -afmeting:	**HIT-RE 500 V3 + HAS-U 5.8 M30**
Retourperiode (levensduur in jaren):	50
Artikelnummer:	niet beschikbaar
Effectieve verankeringsdiepte:	$h_{ef,act}$ = 450,0 mm ($h_{ef,limit}$ = - mm)
Materiaal:	5.8
Goedkeuring nr.:	ETA 16/0143
Uitgegeven I Geldig:	14-05-2019 | -
Aantoning:	rekenmethode ETAG methode voor lijmankers; EOTA TR 029
Afstandsmontage:	
Staalprofiel:	
Ondergrond:	ongescheurd beton, C30/37, $f_{c,cube}$ = 37,00 N/mm^2; h = 750,0 mm, Temp. kort/lang: 40/24 °C
Plaatsing:	**diamant-geboord gat, plaatsingsconditie: vochtig (verzadigd met water)**
Wapening:	staafafstand wapening < 150 mm (elke Ø) of <100 (Ø <= 10mm) met rechte randwapening d>= 12,0 [mm] Wapening tegen splijten volgens EOTA, TR 029, 5.2.2.6 is aanwezig.

Geometrie [mm] & Belastingen [kN, kNm]



1.1 Belastingscombinatie

Geval	Omschrijving	Lasten [kN] / Momenten [kNm]	Seismisch	Brand	Max. uitnutting Anker [%]
1	Combinatie 1	N = 60,000; V_x = -5,000; V_y = 0,000; M_x = 0,000; M_y = 0,000; M_z = 0,000;	Nee	nee	61

2 Belastingsituatie/Resulterende ankerlasten

Ankerreacties [kN]
Trekkracht: (+ Trek, - Druk)

Anker	Trekkracht	Afschuifkracht	Afschuifkracht x	Afschuifkracht y
1	60,000	5,000	-5,000	0,000

max. stuik van het beton: - [‰]
max. betondrukspanning: - [N/mm^2]
resulterende trekkracht in (x/y)=(0,0/0,0): 0,000 [kN]
resulterende drukkracht in (x/y)=(0,0/0,0): 0,000 [kN]

3 Treklast (EOTA TR 029, paragraaf 5.2.2)

Trekbelasting ankers 60kN uit maximale belastingcombinatie lege tank met windzuiging

	Belasting [kN]	Capaciteit [kN]	Benutting β_N [%]	Status
Staalbreuk*	60,000	187,000	33	OK
Gecombineerd bezwijken door uittrekken en betonkegelbreuk**	60,000	160,790	38	OK
Betonkegelbreuk**	60,000	99,999	61	OK
Splijten**	60,000	115,875	52	OK

* ongunstigste anker **ankergroep (ankers onder trekbelasting)

3.1 Staalbreuk

$N_{Sd} \leq N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{M,s}}$ EOTA TR 029, tabel 5.2.2.1

$N_{Rk,s}$ [kN]	$\gamma_{M,s}$	$N_{Rd,s}$ [kN]	N_{Sd} [kN]
280,500	1,500	187,000	60,000

3.2 Gecombineerd bezwijken door uittrekken en betonkegelbreuk

$N_{Sd} \leq N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{M,p}}$ EOTA TR 029, tabel 5.2.2.1

$N_{Rk,p} = N^0_{Rk,p} \cdot \frac{A_{p,N}}{A^0_{p,N}} \cdot \psi_{s,Np} \cdot \psi_{g,Np} \cdot \psi_{ec1,Np} \cdot \psi_{ec2,Np} \cdot \psi_{re,Np}$ EOTA TR 029, Eq. (5.2)

$N^0_{Rk,p} = \pi \cdot d \cdot h_{ef} \cdot \tau_{Rk}$ EOTA TR 029, Eq. (5.2a)

$A^0_{p,N} = s_{cr,Np} \cdot s_{cr,Np}$ EOTA TR 029, Eq. (5.2b)

$s_{cr,Np} = 20 \cdot d \cdot \left(\frac{\tau_{Rk,ucr}}{7,5}\right)^{0,5} \leq 3 \cdot h_{ef}$ EOTA TR 029, Eq. (5.2c)

$c_{cr,Np} = \frac{s_{cr,Np}}{2}$ EOTA TR 029, Eq. (5.2d)

$\psi_{s,Np} = 0,7 + 0,3 \cdot \frac{c}{c_{cr,Np}} \leq 1,00$ EOTA TR 029, Eq. (5.2e)

$\psi_{g,Np} = \psi^0_{g,Np} - \left(\frac{s}{s_{cr,Np}}\right)^{0,5} \cdot \left(\psi^0_{g,Np} - 1\right) \geq 1,00$ EOTA TR 029, Eq. (5.2f)

$\psi^0_{g,Np} = \sqrt{n} - (\sqrt{n} - 1) \cdot \left(\frac{d \cdot \tau_{Rk}}{k \cdot \sqrt{h_{ef} \cdot f_{ck,cube}}}\right)^{1,5} \geq 1,00$ EOTA TR 029, Eq. (5.2g)

$\psi_{ec1,Np} = \frac{1}{1 + \frac{2 \cdot e_{c1,N}}{s_{cr,Np}}} \leq 1,00$ EOTA TR 029, Eq. (5.2h)

$\psi_{ec2,Np} = \frac{1}{1 + \frac{2 \cdot e_{c2,N}}{s_{cr,Np}}} \leq 1,00$ EOTA TR 029, Eq. (5.2h)

$\psi_{re,Np} = 0,5 + \frac{h_{ef}}{200} \leq 1,00$ EOTA TR 029, Eq. (5.2i)

$A_{p,N}$ [mm^2]	$A^0_{p,N}$ [mm^2]	$\tau_{Rk,ucr,25}$ [N/mm^2]	$s_{cr,Np}$ [mm]	$c_{cr,Np}$ [mm]	c_{min} [mm]
432.200	576.000	12,00	758,9	379,5	190,0

ψ_c	$\tau_{Rk,ucr}$ [N/mm^2]	k	$\psi^0_{g,Np}$	$\psi_{g,Np}$
1,040	12,48	3,200	1,000	1,000

$e_{c1,N}$ [mm]	$\psi_{ec1,Np}$	$e_{c2,N}$ [mm]	$\psi_{ec2,Np}$	$\psi_{s,Np}$	$\psi_{re,Np}$
0,0	1,000	0,0	1,000	0,850	1,000

$N^0_{Rk,p}$ [kN]	$N_{Rk,p}$ [kN]	$\gamma_{M,p}$	$N_{Rd,p}$ [kN]	N_{Sd} [kN]
529,287	337,659	2,100	160,790	60,000

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3.3 Betonkegelbreuk

$N_{Sd} \leq N_{Rd,c} = \dfrac{N_{Rk,c}}{\gamma_{M,c}}$	EOTA TR 029, tabel 5.2.2.1
$N_{Rk,c} = N^0_{Rk,c} \cdot \dfrac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec1,N} \cdot \psi_{ec2,N}$	EOTA TR 029, Eq. (5.3)
$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1,5}$	EOTA TR 029, Eq. (5.3a)
$A^0_{c,N} = s_{cr,N} \cdot s_{cr,N}$	EOTA TR 029, Eq. (5.3b)
$\psi_{s,N} = 0,7 + 0,3 \cdot \dfrac{c}{c_{cr,N}} \leq 1,00$	EOTA TR 029, Eq. (5.3c)
$\psi_{re,N} = 0,5 + \dfrac{h_{ef}}{200} \leq 1,00$	EOTA TR 029, Eq. (5.3d)
$\psi_{ec1,N} = \dfrac{1}{1 + \dfrac{2 \cdot e_{c1,N}}{s_{cr,N}}} \leq 1,00$	EOTA TR 029, Eq. (5.3e)
$\psi_{ec2,N} = \dfrac{1}{1 + \dfrac{2 \cdot e_{c2,N}}{s_{cr,N}}} \leq 1,00$	EOTA TR 029, Eq. (5.3e)
$h'_{ef} = \max\left(\dfrac{c_{max}}{c_{cr,N}}, \dfrac{s_{max}}{s_{cr,N}}\right) \cdot h_{ef}$	

$A_{c,N}$ [mm^2]	$A^0_{c,N}$ [mm^2]	$c_{cr,N}$ [mm]	$s_{cr,N}$ [mm]
690.000	1.000.000	675,0	1.350,0

h'_{ef} [mm]	$c'_{cr,N}$ [mm]	$s'_{cr,N}$ [mm]
333,3	500,0	1.000,0

$e_{c1,N}$ [mm]	$\psi_{ec1,N}$	$e_{c2,N}$ [mm]	$\psi_{ec2,N}$	$\psi_{s,N}$	$\psi_{re,N}$
0,0	1,000	0,0	1,000	0,814	1,000

k_1	$N^0_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Sd} [kN]
10,100	373,887	2,100	99,999	60,000

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3.4 Splijten

$N_{Sd} \leq N_{Rd,sp} = \frac{N_{Rk,sp}}{\gamma_{M,sp}}$	EOTA TR 029, tabel 5.2.2.1
$N_{Rk,sp} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec1,N} \cdot \psi_{ec2,N} \cdot \psi_{h,sp}$	EOTA TR 029, Eq. (5.4)
$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1,5}$	EOTA TR 029, Eq. (5.3a)
$A^0_{c,N} = s_{cr,sp} \cdot s_{cr,sp}$	EOTA TR 029, Eq. (5.3b)
$\psi_{s,N} = 0,7 + 0,3 \cdot \frac{c}{c_{cr,sp}} \leq 1,00$	EOTA TR 029, Eq. (5.3c)
$\psi_{ec1,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{c1,N}}{s_{cr,sp}}\right)} \leq 1,00$	EOTA TR 029, Eq. (5.3e)
$\psi_{ec2,N} = \frac{1}{1 + \left(\frac{2 \cdot e_{c2,N}}{s_{cr,sp}}\right)} \leq 1,00$	EOTA TR 029, Eq. (5.3e)
$\psi_{h,sp} = \left(\frac{h}{h_{min}}\right)^{2/3}$	EOTA TR 029, Eq. (5.4a)
$1 \leq \psi_{h,sp} = \left(\frac{2 \cdot h_{ef}}{h_{min}}\right)^{2/3}$	EOTA TR 029, Eq. (5.4b)
$h'_{ef} = \max\left(\frac{c_{max}}{c_{cr,sp}}, \frac{s_{max}}{s_{cr,sp}}\right) \cdot h_{ef}$	

$A_{c,N}$ [mm²]	$A^0_{c,N}$ [mm²]	$c_{cr,sp}$ [mm]	$s_{cr,sp}$ [mm]	$\psi_{h,sp}$
690.000	1.000.000	720,0	1.440,0	1,277

h'_{ef} [mm]	$c'_{cr,sp}$ [mm]	$s'_{cr,sp}$ [mm]
312,5	500,0	1.000,0

$e_{c1,N}$ [mm]	$\psi_{ec1,N}$	$e_{c2,N}$ [mm]	$\psi_{ec2,N}$	$\psi_{s,N}$	$\psi_{re,N}$	k_1
0,0	1,000	0,0	1,000	0,814	1,000	10,100

$N^0_{Rk,c}$ [kN]	$\gamma_{M,sp}$	$N_{Rd,sp}$ [kN]	N_{Sd} [kN]
339,389	2,100	115,875	60,000

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Adres:	Spoorstraat 7, Schiedam	Constructeur:	
Tel. I Fax:	|	E-mail:	
berekening:	Ankers tankfundering	Datum:	05-10-2020
Sub-Project I Pos. Nr.:	Ankers Tankfundering		

4 Afschuifbelasting (EOTA TR 029, paragraaf 5.2.3)

	Belasting [kN]	Capaciteit [kN]	Benutting β_V [%]	Status
Staalbreuk (zonder hefboomsarm)*	5,000	112,240	5	OK
Staalbreuk (met hefboomsarm)*	N.V.T.	N.V.T.	N.V.T.	N.V.T.
Betonachteruitbreken**	5,000	279,996	2	OK
Betonrandbreuk in richting x-**	5,000	61,150	9	OK

* ongunstigste anker **ankergroep (geactiveerde ankers)

4.1 Staalbreuk (zonder hefboomsarm)

$V_{Sd} \leq V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{M,s}}$ EOTA TR 029, tabel 5.2.3.1

$V_{Rk,s}$ [kN]	$\gamma_{M,s}$	$V_{Rd,s}$ [kN]	V_{Sd} [kN]
140,300	1,250	112,240	5,000

4.2 Betonachteruitbreken (door betonkegelbreuk)

$V_{Sd} \leq V_{Rd,cp} = \dfrac{V_{Rk,cp}}{\gamma_{M,c,p}}$	EOTA TR 029, tabel 5.2.3.1
$V_{Rk,cp} = k \cdot \min(N_{Rk,p}; N_{Rk,c})$	EOTA TR 029, Eq. (5.7), (5.7a)
$N_{Rk,c} = N^0_{Rk,c} \cdot \dfrac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec1,N} \cdot \psi_{ec2,N}$	EOTA TR 029, Eq. (5.3)
$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1,5}$	EOTA TR 029, Eq. (5.3a)
$A^0_{c,N} = s_{cr,N} \cdot s_{cr,N}$	EOTA TR 029, Eq. (5.3b)
$\psi_{s,N} = 0{,}7 + 0{,}3 \cdot \dfrac{c}{c_{cr,N}} \leq 1{,}00$	EOTA TR 029, Eq. (5.3c)
$\psi_{re,N} = 0{,}5 + \dfrac{h_{ef}}{200} \leq 1{,}00$	EOTA TR 029, Eq. (5.3d)
$\psi_{ec1,N} = \dfrac{1}{1 + \dfrac{2 \cdot e_{c1,V}}{s_{cr,N}}} \leq 1{,}00$	EOTA TR 029, Eq. (5.3e)
$\psi_{ec2,N} = \dfrac{1}{1 + \dfrac{2 \cdot e_{c2,V}}{s_{cr,N}}} \leq 1{,}00$	EOTA TR 029, Eq. (5.3e)
$h'_{ef} = \max\left(\dfrac{c_{max}}{c_{cr,N}}, \dfrac{s_{max}}{s_{cr,N}}\right) \cdot h_{ef}$	

$A_{c,N}$ [mm²]	$A^0_{c,N}$ [mm²]	$c_{cr,N}$ [mm]	$s_{cr,N}$ [mm]	k-factor	k_1
690.000	1.000.000	675,0	1.350,0	2,000	10,100

h'_{ef} [mm]	$c'_{cr,N}$ [mm]	$s'_{cr,N}$ [mm]
333,3	500,0	1.000,0

$e_{c1,V}$ [mm]	$\psi_{ec1,N}$	$e_{c2,V}$ [mm]	$\psi_{ec2,N}$	$\psi_{s,N}$	$\psi_{re,N}$
0,0	1,000	0,0	1,000	0,814	1,000

$N^0_{Rk,c}$ [kN]	$\gamma_{M,c,p}$	$V_{Rd,cp}$ [kN]	V_{Sd} [kN]
373,887	1,500	279,996	5,000

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4.3 Betonrandbreuk in richting x-

$V_{Sd} \le V_{Rd,c} = \dfrac{V_{Rk,c}}{\gamma_{M,c}}$	EOTA TR 029, tabel 5.2.3.1
$V_{Rk,c} = V^0_{Rk,c} \cdot \dfrac{A_{c,V}}{A^0_{c,V}} \cdot \psi_{s,V} \cdot \psi_{h,V} \cdot \psi_{\alpha,V} \cdot \psi_{ec,V} \cdot \psi_{re,V}$	EOTA TR 029, Eq. (5.8)
$V^0_{Rk,c} = k_1 \cdot d^{\alpha}_{nom} \cdot h^{\beta}_{ef} \cdot \sqrt{f_{ck,cube}} \cdot c_1^{1,5}$	EOTA TR 029, Eq. (5.8a)
$\alpha = 0,1 \cdot \left(\dfrac{h_{ef}}{c_1}\right)^{0,5}$	EOTA TR 029, Eq. (5.8b)
$\beta = 0,1 \cdot \left(\dfrac{d_{nom}}{c_1}\right)^{0,2}$	EOTA TR 029, Eq. (5.8c)
$A^0_{c,V} = 4,5 \cdot c_1^2$	EOTA TR 029, Eq. (5.8d)
$\psi_{s,V} = 0,7 + 0,3 \cdot \dfrac{c_2}{1,5 \cdot c_1} \le 1,00$	EOTA TR 029, Eq. (5.8e)
$\psi_{h,V} = \left(\dfrac{1,5 \cdot c_1}{h}\right)^{0,5} \ge 1,00$	EOTA TR 029, Eq. (5.8f)
$\psi_{\alpha,V} = \sqrt{\dfrac{1}{(\cos \alpha_V)^2 + \left(\dfrac{\sin \alpha_V}{2,5}\right)^2}} \ge 1,00$	EOTA TR 029, Eq. (5.8g)
$\psi_{ec,V} = \dfrac{1}{1 + \dfrac{2 \cdot e_{c,V}}{3 \cdot c_1}} \le 1,00$	EOTA TR 029, Eq. (5.8h)

h_{ef} [mm]	d_{nom} [mm]	k_1	α	β
360,0	30,00	2,400	0,138	0,069

c_1 [mm]	$A_{c,V}$ [mm^2]	$A^0_{c,V}$ [mm^2]
190,0	162.450	162.450

$\psi_{s,V}$	$\psi_{h,V}$	$\psi_{\alpha,V}$	$e_{c,V}$ [mm]	$\psi_{ec,V}$	$\psi_{re,V}$
1,000	1,000	1,000	0,0	1,000	1,000

$V^0_{Rk,c}$ [kN]	$\gamma_{M,c}$	$V_{Rd,c}$ [kN]	V_{Sd} [kN]
91,725	1,500	61,150	5,000

Firma:	Bilfinger Tebodin Netherlands B.V.	Bladzijde:	10
Adres:	Spoorstraat 7, Schiedam	Constructeur:	
Tel. I Fax:	|	E-mail:	
berekening:	Ankers tankfundering	Datum:	05-10-2020
Sub-Project I Pos. Nr.:	Ankers Tankfundering		

5 Gecombineerde trek- en afschuifbelasting (EOTA TR 029, paragraaf 5.2.4)

Staal bezwijken

β_N	β_V	α	Benutting $\beta_{N,V}$ [%]	Status
0,600	0,082	1,500	49	OK

$\beta_N^\alpha + \beta_V^\alpha \leq 1{,}0$

6 Verplaatsingen (hoogst belaste anker)

Kortdurende belastingen

N_{Sk} = 44,444 [kN] δ_N = 0,0838 [mm]

V_{Sk} = 3,704 [kN] δ_V = 0,1111 [mm]

δ_{NV} = 0,1392 [mm]

Langeduur-belastingen

N_{Sk} = 44,444 [kN] δ_N = 0,1991 [mm]

V_{Sk} = 3,704 [kN] δ_V = 0,1852 [mm]

δ_{NV} = 0,2719 [mm]

NB: Verplaatsingen t.g.v. trekbelasting zijn gebaseerd op de helft van het vereiste aandraaimoment voor ongescheurd beton! Verplaatsingen t. g. v. afschuiving zijn bepaald zonder inachtneming van wrijving tussen beton en voetplaat! De speling als gevolg van toleranties in boorgatdiameter en gatdiameter in voetplaat wordt niet beschouwd in deze berekening!

Hoeveel verplaatsing toelaatbaar is, hangt af van de verbinding en dient door de constructeur te worden bepaald!

7 Waarschuwingen

- De ankerberekeningsmethoden in PROFIS Engineering vereisen rigide voetplaten volgens de huidige regelgeving (AS 5216:2018, ETAG 001/Annex C, EOTA TR029, etc.). Dit betekend dat herverdeling van de belasting op de ankers als gevolg van elastische deformatie van de voetplaat niet wordt meegenomen - De voetplaat wordt stijf verondersteld, en dus niet vervormd wanneer onderhevig aan een belasting. PROFIS Engineering berekent de minimaal benodigde voetplaatdikte met EEM om de spanning in de voetplaat te minimaliseren, gebaseerd op de aannames zoals hierboven gesteld. Het bewijs dat de aanname correct is dat de voetplaat rigide is wordt niet door PROFIS engineering geleverd. Ingevoerde data en resultaten moeten worden gecontroleerd of deze in overeenstemming zijn met de bestaande voorwaarden en op geloofwaardigheid!
- De overdracht van de belastingen in de ondergrond moet worden gecontroleerd volgens EOTA TR 029 paragraaf 7!
- De berekening is enkel geldig indien het boutgat in de voetplaat niet groter is dan de waarde die is opgegeven in Tabel 4.1 van EOTA TR 029! Voor grotere boutgatdiameters zie Hoofdstuk 1.1 van EOTA TR029!
- De lijst van benodigdheden is slechts ter informatie voor de gebruiker. In elk geval, dienen de gebruiksinstructies behorende bij het produkt opgevolgd te worden om een juiste installatie te bewerkstelligen.
- Boorgatreiniging moet volgens de gebruiksaanwijzigingen worden uitgevoerd (2x blazen met olievrije perslucht (min. 6 bar), 2x borstelen, 2x blazen met olievrije perslucht (min. 6 bar)).
- Karakteristieke hechtspanningen zijn afhankelijk van korte en lange termijn temperaturen.
- Er is geen randwapening vereist om splijten te voorkomen
- De karakteristieke aanhechtsterkten zijn afhankelijk van de retourperiode (levensduur in jaren): 50

Verbinding is VEILIG!

8 Plaatsingsgegevens

Voetplaat staal: -

Staalprofiel: -

Gatdiameter in voetplaat: -

Voetplaatdikte (invoer): -

Boormethode: Diamant geboord

Boorgatreiniging: Premium boorgatreiniging is vereist

Ankertype en -afmeting: HIT-RE 500 V3 + HAS-U 5.8 M30

Artikelnummer: niet beschikbaar

Aandraaimoment: 300 Nm

Boorgatdiameter in het basismateriaal: 35,0 mm

Boorgatdiepte in ondergrond: 450,0 mm

Minimale dikte van de ondergrond: 520,0 mm

Hilti HAS-U draadeinde met HIT-RE 500 V3 injectiemortel met 450 mm verankeringsdiepte h_ef, M30, Verzinkt staal, Diamantboren installatie volgens ETA 16/0143

8.1 Vereiste toebehoren

Boren	Boorgatreiniging	Plaatsing
• Diamantboorstatief	• Perslucht met benodigde toebehoren om van onder in het gat te blazen. • Juiste borstel voor diameter	• Dispenser inclusief cassette en mixtuit • Momentsleutel

Ankercoördinaten [mm]

Anker	x	y	c_{-x}	c_{+x}	c_{-y}	c_{+y}
1	0,0	0,0	190,0	-	500,0	500,0

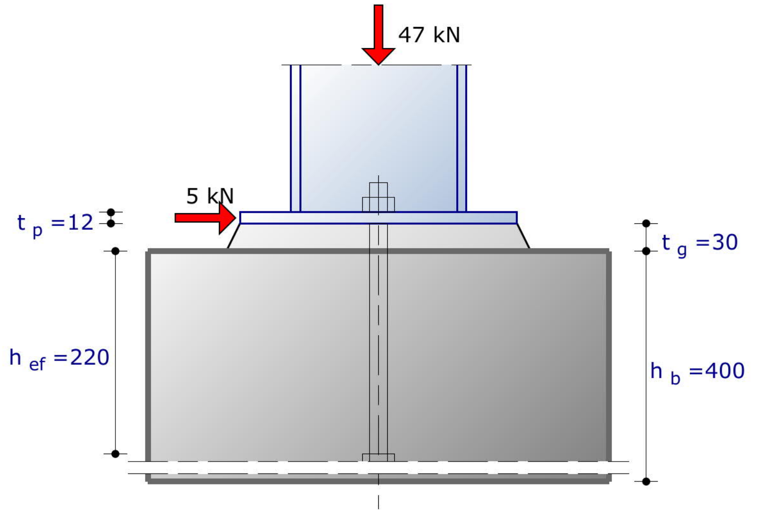
9 Opmerkingen

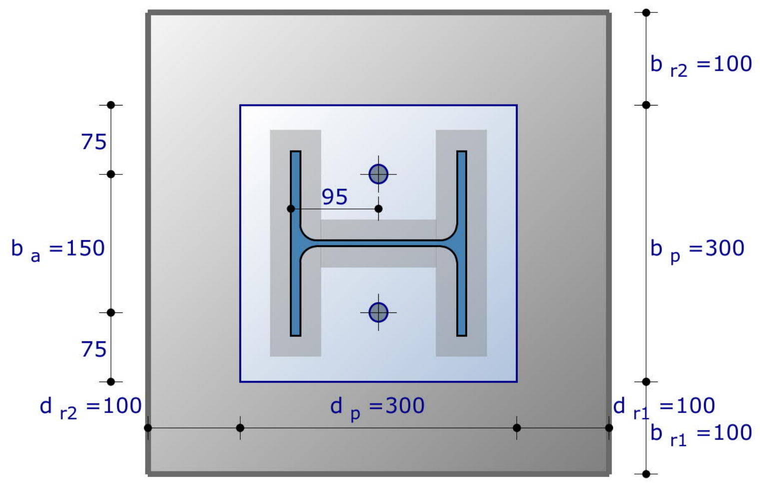
- Alle informatie en data die deel uitmaken van de Software hebben uitsluitend betrekking op het gebruik van Hilti producten en zijn gebaseerd op de principes, formules en beveiligingsregels zoals die van kracht zijn op technische richtlijnen die Hilti hanteert en de instructies voor gebruik, montage, assemblage enz. die strikt dienen te worden nageleefd door de gebruiker. Alle in die informatie genoemde cijfers zijn gemiddelden, wat wil zeggen dat op de specifieke toepassing toegesneden tests nodig kunnen zijn voordat een product van Hilti daadwerkelijk in gebruik wordt genomen. De uitkomsten van met behulp van de Software uitgevoerde berekeningen zijn in essentie niet los te zien van de door u als gebruiker ingevoerde gegevens. Eventuele fouten in die berekeningen zijn dan ook niet aan de Software toe te schrijven, maar, waar van toepassing, het gevolg van mogelijke onvolledigheid of irrelevantie van de door u ingevoerde gegevens. Daarnaast bent u ook als enige verantwoordelijk voor het laten controleren en bevestigen van zulke berekeningen en de uitkomsten daarvan door een terzake deskundige, met name waar het gaat om conformering aan geldende normen en voorschriften, voordat u deze toepast binnen uw organisatie. De Software is uitsluitend bedoeld als hulpmiddel bij de interpretatie van zulke normen en voorschriften, zonder dat garanties worden verleend ten aanzien van volledige correctheid en relevantie van de resultaten, noch ten aanzien van geschiktheid voor een specifieke toepassing.
- U bent persoonlijk verantwoordelijk voor binnen de grenzen van het redelijke te nemen stappen en maatregelen ter voorkoming van schade die het gevolg kan zijn van gebruik van de Software. Dat wil onder meer zeggen dat u zorg dient te dragen voor regelmatige backups van programmatuur en gegevens, en implementatie van updates op de Software die door Hilti ter beschikking worden gesteld. Als u ervoor kiest geen gebruik te maken van de AutoUpdate functie die in de Software beschikbaar is, dient u zeker te stellen dat u in alle gevallen met de actuele, op dat moment nieuwste versie van de Software werkt door middel van handmatige updates via de Hilti Website. Hilti is niet aansprakelijk voor schadelijke gevolgen, bijvoorbeeld in de vorm van gegevensverlies, gegevenscorruptie of schade aan programmatuur, van het op de genoemde punten in gebreke blijven door de gebruiker.

Toetsing kolomvoetplaatverbinding volgens CUR/BmS-rapport 10
Aanbevelingen voor de berekening volgens Eurocodes. De Eurocode voor staalconstructies (NEN-EN 1993-1-8), de Eurocode voor betonconstructies (NEN-EN 1992-1-1) en de Europese Technische specificatie voor ankerbevestingen (CEN/TS 1992-4-1)

XColumnBase 1.16.04
Bestand : ....53591-01-1334001 REV.1 Steel column anchor check.xcob

INVOERGEGEVENS





Profiel:	HEA200, sterkteklasse S235
Ankers:	M 20, ankerbout, klasse 8.8 gerolde draad normale gatspeling h_{ef} = 220 mm
Grout:	zand-cement mortel, t_g = 30 mm
Fundering:	betonsterkteklasse C30/37, gescheurd, betonstaalsoort B500B h_b = 400 mm, c_{min} =30 mm
Afmetingen voetplaat:	b_p = 300 mm, d_p = 300 mm, t_p = 12 mm
Las:	dubbele hoeklas a = 5 mm
Afstanden van de ankers:	b_a = 150 mm, d_a = 0 mm
Randafstanden van de ankers:	r_2 = 75 mm, r_1 = 150 mm
Belastingen:	N_{Ed} = 47 kN, V_{Ed} = 5 kN, M_{Ed} = 0 kNm

BEREKENING

Centrische belaste verbinding

Randcondities

$d_{r,2} = 100$ mm < $d_p = 300$ mm → voor druk randeffect

$d_{r,1} = 100$ mm < $d_p = 300$ mm → voor druk randeffect

$b_{r,1} = 100$ mm < $b_p = 300$ mm → voor druk randeffect

$b_{r,2} = 100$ mm < $b_p = 300$ mm → voor druk randeffect

$h = 400$ mm < $2\,d_p = 600$ mm → voor druk randeffect

$h = 400$ mm < $2\,b_p = 600$ mm → voor druk randeffect

Druksterkte beton

$b_1 = d_p = 300$ mm

$d_1 = b_p = 300$ mm

$b_2 = b_1 + 2\,d_{r,min} = 300 + 2 \times 100 = 500$ mm

$d_2 = d_1 + 2\,b_{r,min} = 300 + 2 \times 100 = 500$ mm

$A_{c0} = b_1\,d_1 = 300 \times 300 = 90000 \text{ mm}^2$

$A_{c1} = b_2\,d_2 = 500 \times 500 = 250000 \text{ mm}^2$

$$k_d = \sqrt{\frac{A_{c1}}{A_{c0}}} = \sqrt{\frac{250000}{90000}} = 1{,}67$$

C30/37: $f_{cd} = \alpha_{cc}\,f_{ck} / \gamma_c = 1{,}0 \times 30 / 1{,}5 = 20 \text{ N/mm}^2$ ...NEN-EN 1992-1-1 (3.15)

$F_{Rdu} = A_{c0}\,f_{cd}\,k_d = 90000 \times 20 \times 1{,}67 \times 10^{-3} = 3000$ kN ...NEN-EN 1992-1-1 (6.63)

$$f_{jd} = \frac{\beta_j\,F_{Rdu}}{A_{c0}} = \frac{2/3 \times 3000 \times 10^3}{90000} = 22{,}22 \text{ N/mm}^2$$ ...NEN-EN 1993-1-8 (6.6)

Voorwaarde voegmateriaal:

$t_g \leq 0{,}2 \min[\,b_p\,;\,d_p\,] = 0{,}2 \times \min[\,300\,;\,300\,] = 60$ mm → OK ...NEN-EN 1993-1-8; 6.2.5(7)

De karakteristieke sterkte van de grout moet ten minste gelijk zijn aan:

$f_{gr,k} \geq 0{,}2\,f_{ck} = 0{,}20 \times 30 = 6 \text{ N/mm}^2$ ...NEN-EN 1993-1-8; 6.2.5(7)

Bijkomende stuikbreedte

$$c = t\sqrt{\frac{f_{yd}}{3\,f_{jd}}} = 12 \times \sqrt{\frac{235}{3 \times 22{,}22}} = 22{,}5 \text{ mm}$$ ...NEN-EN 1993-1-8 (6.5)

Afmetingen drukprent

T-stuk 1 en T-stuk 3:

$b_{eff} = t_f + 2\,c = 10 + 2 \times 22{,}5 = 55{,}1$ mm

$l_{eff} = b + 2c = 200 + 2 \times 22{,}5 = 245{,}1$ mm

$A_{pr,1} = A_{pr,3} = b_{eff}\ l_{eff} = 55{,}1 \times 245{,}1 = 13493\ mm^2$

T-stuk 2:

$b_{eff} = t_w + 2c = 6{,}5 + 2 \times 22{,}5 = 51{,}6$ mm

$l_{eff} = h_a - 2t_f - 2c = 190 - 2 \times 10 - 2 \times 22{,}5 = 124{,}9$ mm

$A_{pr,2} = b_{eff}\ l_{eff} = 51{,}6 \times 124{,}9 = 6442\ mm^2$

$A_{prent} = A_{pr,1} + A_{pr,2} + A_{pr,3} = 13493 + 6442 + 13493 = 33428\ mm^2$

Toetsing

$N_{Rd} = f_{jd}\ A_{prent} = 22{,}22 \times 33428 = 742{,}8$ kN

$$\frac{N_{Ed}}{N_{Rd}} = \frac{47}{742{,}8} = 0{,}06 \rightarrow \text{OK}$$

Splijtwapening drukzijde

$$\frac{N_{Ed}}{A_{prent}} = \frac{47 \times 10^3}{33428} = 1{,}41\ N/mm^2 < f_{c,d} = 20\ N/mm^2$$

$$\frac{N_{Ed}}{A_{c1}} = \frac{47 \times 10^3}{250000} = 0{,}19\ N/mm^2 < 5\ N/mm^2$$

→ Geen splijtwapening nodig.

Afschuiving

Door ankers:

$$k_1 = \min[\ 2{,}8\ \frac{e_2}{d_0} - 1{,}7\ ;\ 2{,}5\ ] = \min[\ 2{,}8 \times \frac{75}{22} - 1{,}7\ ;\ 2{,}5\ ] = 2{,}5$$

$$\alpha_d = \frac{e_1}{3\ d_0} = \frac{150}{3 \times 22} = 2{,}273$$

$$\alpha_b = \min[\ \alpha_d\ ;\ \frac{f_{ub}}{f_u}\ ;\ 1{,}0\ ] = \min[\ 2{,}273\ ;\ \frac{800}{360}\ ;\ 1{,}0\ ] = 1$$

$$F_{1,vb,Rd} = \frac{k_1\ \alpha_b\ f_u\ d\ t}{\gamma_{M2}} = \frac{2{,}5 \times 1 \times 360 \times 20 \times 12}{1{,}25 \times 10^3} = 172{,}8 \text{ kN}$$ ...NEN-EN 1993-1-8; tabel 3.4

$\alpha_b = 0{,}44 - 0{,}0003\ f_{yb} = 0{,}44 - 0{,}0003 \times 640 = 0{,}248$

$$F_{2,vb,Rd} = \frac{\alpha_b\ f_{ub}\ A_s}{\gamma_{Mb}} = \frac{0{,}248 \times 800 \times 245}{1{,}25 \times 10^3} = 38{,}9 \text{ kN}$$ ...NEN-EN 1993-1-8; 6.2.2(7)

$F_{v,Rd} = F_{f,Rd} + n\ F_{vb,Rd} = 0 + 2 \times 38{,}9 = 77{,}8$ kN ...NEN-EN 1993-1-8 (6.3)

$$\frac{V_{Ed}}{F_{v,Rd}} = \frac{5}{77{,}8} = 0{,}06 \rightarrow \text{OK}$$

Randcondities afschuiving

$c_{dr,2} = 250$ mm $< 60\ d = 60 \times 20 = 1200$ mm → voor afschuiving randeffect

$c_{dr,1}$ = 250 mm < 60 d = 60 x 20 = 1200 mm → voor afschuiving randeffect

$c_{br,1}$ = 175 mm < 60 d = 60 x 20 = 1200 mm → voor afschuiving randeffect

$c_{br,2}$ = 175 mm < 60 d = 60 x 20 = 1200 mm → voor afschuiving randeffect

Wapening voor opnemen afschuifkracht

$e_s = t_p / 2 + t_g + c + Ø / 2 = 12 / 2 + 30 + 30 + 12 / 2 = 72$ mm

$d = h_b - c - Ø / 2 = 400 - 30 - 12 / 2 = 364$ mm $\qquad z = 0{,}8\ d = 0{,}8 \times 364 = 291$ mm

$$N_{Ed,re} = (\frac{e_s}{z} + 1)\ V_{Ed} = (\frac{72}{291} + 1) \times 5 = 6{,}24 \text{ kN}$$

$$A_{ben} = \frac{N_{Ed,re}}{f_{yd}} = \frac{6{,}2}{435} = 14 \text{ mm}^2$$

→ Om de afschuifkracht via wrijving in te leiden moet wapening worden toegepast!

De verankeringslengte in de uitbreekkegel moet minimaal 4 Ø = 4 x 12 = 48 mm zijn.

Beschikbare verankering uitgaande van 1,5 c_d: l_1 = 143 mm

Bepaling van de hoeklassen voor flens en lijf

$$F_{t,max,Ed} = \frac{|N_{Ed}|}{2} + \frac{|M_{Ed}|}{h - t} = \frac{|47|}{2} + \frac{|0 \times 10^3|}{190 - 10} = 23{,}5 \text{ kN}$$

$$\text{statisch bepaald} \rightarrow \sigma_{Ed} = \frac{F_{t,max,Ed}}{A_f} = \frac{23{,}5 \times 10^3}{2000} = 11{,}8 \text{ N/mm}^2$$

$$\tau_{f,Ed} = \frac{V_{y,Ed}}{2\ A_f} = 0 \text{ N/mm}^2 \qquad \tau_{w,Ed} = \frac{V_{z,Ed}}{A_w} = \frac{5 \times 10^3}{1105} = 4{,}5 \text{ N/mm}^2$$

$$a_f \geq \beta_w\ \gamma_{M2} \frac{\sqrt{2\ \sigma_{Ed}^2 + 3\ \tau_{f,Ed}^2}}{f_u} \frac{t_f}{2} = 0{,}8 \times 1{,}25 \times \frac{\sqrt{2 \times 11{,}8^2 + 3 \times 0^2}}{360} \frac{10}{2} = 0{,}2 \text{ mm}$$

$\rightarrow a_f = 3$ mm ...NEN-EN 1993-1-8; 4.5.2(2)

$$a_w \geq \beta_w\ \gamma_{M2} \frac{\sqrt{2\ \sigma_{Ed}^2 + 3\ \tau_{w,Ed}^2}}{f_u} \frac{t_w}{2} = 0{,}8 \times 1{,}25 \times \frac{\sqrt{2 \times 11{,}8^2 + 3 \times 4{,}5^2}}{360} \frac{7}{2} = 0{,}2 \text{ mm}$$

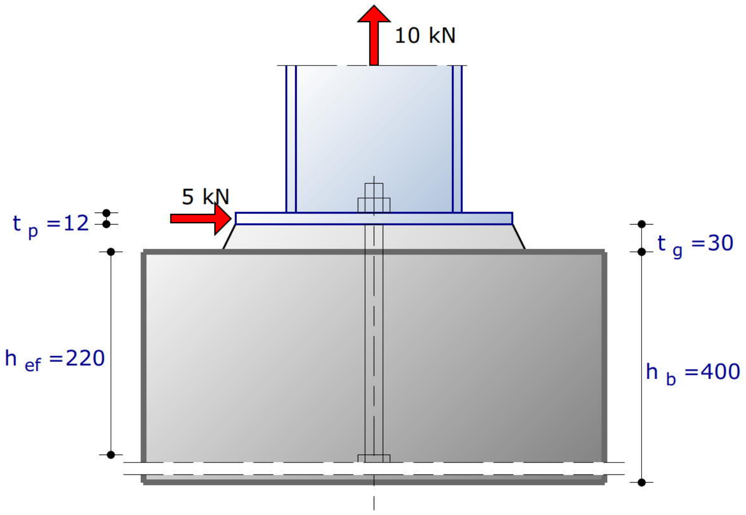
$\rightarrow a_w = 3$ mm ...NEN-EN 1993-1-8; 4.5.2(2)

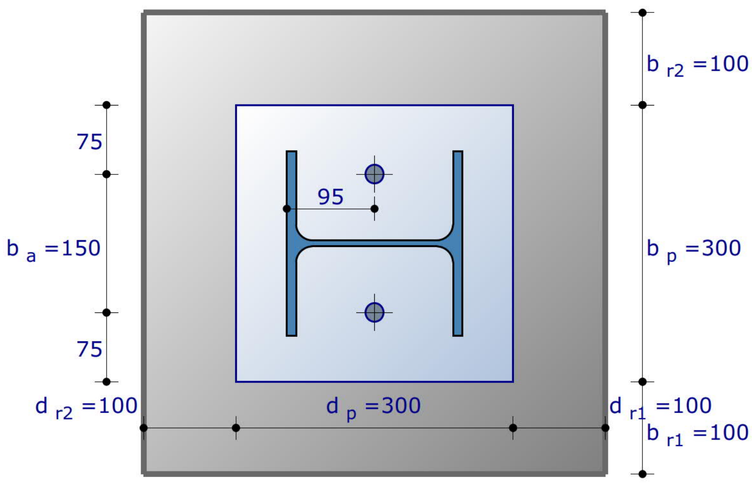
Conclusie : Kolomvoetplaatverbinding voldoet.

Toetsing kolomvoetplaatverbinding volgens CUR/BmS-rapport 10
Aanbevelingen voor de berekening volgens Eurocodes. De Eurocode voor staalconstructies (NEN-EN 1993-1-8), de Eurocode voor betonconstructies (NEN-EN 1992-1-1) en de Europese Technische specificatie voor ankerbevestingen (CEN/TS 1992-4-1)

XColumnBase 1.16.04
Bestand : ....53591-01-1334001 REV.1 Steel column anchor check TREK.xcob

INVOERGEGEVENS





Profiel:	HEA200, sterkteklasse S235
Ankers:	M 20, ankerbout, klasse 8.8 gerolde draad
	normale gatspeling
	h_{ef} = 220 mm
Grout:	zand-cement mortel, t_g = 30 mm
Fundering:	betonsterkteklasse C30/37, gescheurd, betonstaalsoort B500B
	h_b = 400 mm, c_{min} =30 mm
Afmetingen voetplaat:	b_p = 300 mm, d_p = 300 mm, t_p = 12 mm
Las:	dubbele hoeklas a = 5 mm
Afstanden van de ankers:	b_a = 150 mm, d_a = 0 mm
Randafstanden van de ankers:	r_2 = 75 mm, r_1 = 150 mm
Belastingen:	N_{Ed} = 10 kN, V_{Ed} = 5 kN, M_{Ed} = 0 kNm

BEREKENING

Verbinding belast op druk, buiging en afschuiving

Randcondities

$d_{r,2} = 100$ mm < $1{,}2\,c_{cr,sp} = 1{,}2\,(4\,h_{eff}) = 1056$ mm → voor trek randeffect

$d_{r,1} = 100$ mm < $1{,}2\,c_{cr,sp} = 1{,}2\,(4\,h_{eff}) = 1056$ mm → voor trek randeffect

$b_{r,1} = 100$ mm < $1{,}2\,c_{cr,sp} = 1{,}2\,(4\,h_{eff}) = 1056$ mm → voor trek randeffect

$b_{r,2} = 100$ mm < $1{,}2\,c_{cr,sp} = 1{,}2\,(4\,h_{eff}) = 1056$ mm → voor trek randeffect

Type spanningsverdeling

$e = M_{Ed} / N_{Ed} = 0 / -10 = 0$ m

$z_l = h_a - t_f = 190 - 10 = 180$ mm

$e = 0$ mm < $z_T = 0$ mm → Spanningsverdeling type III

Trekkracht F_T

$z_T = 0$ mm $\quad z_{III} = 2\,z_T = 2 \times 0 = 0$ mm

Toetsing voetplaat trekzijde

Ankers binnen de kolomflens

$m_2 = 79{,}3$ mm $\quad m = 66{,}1$ mm $\quad e = 75$ mm

$$\lambda_1 = \frac{m}{m+e} = \frac{66{,}1}{66{,}1+75} = 0{,}468 \qquad \lambda_2 = \frac{m_2}{m+e} = \frac{79{,}3}{66{,}1+75} = 0{,}562 \qquad \alpha = 5{,}714$$

$m_2 < 2\,m + 0{,}625\,e$ en $p > 4\,m + 1{,}25\,e \rightarrow l_{eff,nc} = \alpha\ m = 5{,}714 \times 66{,}1 = 377{,}7$ mm

$p > 2\,\pi\ m \rightarrow l_{eff,cp} = 2\,\pi\ m = 415{,}3$ mm

$M_{pl,Rd} = ¼\,l_{eff,1}\,t^2\,f_{yd} = ¼ \times 377{,}7 \times 12^2 \times 235 \times 10^{-6} = 3{,}195$ kNm

$$F_{T,Rd} = \frac{2\,M_{pl,Rd}}{m} = \frac{2 \times 3{,}195 \times 10^3}{66{,}1} = 96{,}7 \text{ kN}$$

$$\frac{T}{F_{T,Rd}} = \frac{10}{96{,}7} = 0{,}1 \rightarrow \text{OK}$$

Sterkte ankers

Trek

$T = 10$ kN → per anker $\quad F_{t,Ed} = 10 / 2 = 5$ kN

$$F_{t,Rd} = \frac{k_2\,f_{ub}\,A_s}{\gamma_{M2}} = \frac{0{,}9 \times 800 \times 245}{1{,}25} \times 10^{-3} = 141{,}1 \text{ kN}$$ ...NEN-EN 1993-1-8; tabel 3.4

$$\frac{F_{t,Ed}}{F_{t,Rd}} = \frac{5}{141{,}1} = 0{,}04 \rightarrow \text{OK}$$

Splijten ten gevolge van trekkracht op ankers

Splijtkracht in de richting loodrecht op de twee op trek belaste ankers:

$F_s = 0{,}5\ T = 0{,}5 \times 10 = 5$ kN $\qquad A_{ben} = \dfrac{F_s}{f_{yd}} = \dfrac{5000}{435} = 12\ mm^2$

$1Ø12 \rightarrow A_s = 113\ mm^2$

De splijtwapening kan door middel van beugels worden aangebracht.

Splijtkracht in de richting evenwijdig op de twee op trek belaste ankers:

$F_s = 0{,}5\ F_{t,Ed} = 0{,}5 \times 5 = 2{,}5$ kN $\qquad A_{ben} = \dfrac{F_s}{f_{yd}} = \dfrac{2500}{435} = 6\ mm^2$

Deze wapeningsdoorsnede moet worden gesuperponeerd bij de doorsnede die al om andere redenen in de lengterichting moet worden aangebracht.

Uittrekken anker

$A_h = (\pi/4)\,[d_h^2 - d^2] = (\pi/4) \times [32^2 - 20^2] = 490\ mm^2$

$$N_{Rd,p} = \frac{A_h\ 5\ f_{ck}\ \psi_{ucr,N}}{\gamma_{Mc}} = \frac{490 \times 5 \times 30 \times 1{,}0}{1{,}5} \times 10^{-3} = 49\ kN$$ ...CEN/TS 1992-4-2; 6.2.4

Toetsing

$$\frac{0{,}5\ T}{N_{Rd,p} / 1{,}7} = \frac{5}{49 / 1{,}7} = 0{,}17 \rightarrow OK$$ ...CEN/TS 1992-4-1; B.1.3.2.1

Betonkegelbreuk

$$N^0_{Rk,c} = 9{,}5 \sqrt{f_{ck}} \sqrt{h_{ef}^3} = 9{,}5 \times \sqrt{30} \times \sqrt{220^3} \times 10^{-3} = 169{,}8\ kN$$

$s_{cr,N} = 3{,}0\ h_{eff} = 3{,}0 \times 220 = 660$ mm

$c_{cr,N} = 1{,}5\ h_{eff} = 1{,}5 \times 220 = 330$ mm

$A_{cN} = [(b_{r,1} + g) + b_a + (g + b_{r,2})]\ [(d_{r,2} + g) + d_a + (g + d_{r,1})] =$

$= [(100 + 75) + 150 + (75 + 100)] \times [(100 + 150) + 0 + (150 + 100)] = 250000\ mm^2$

$A^0_{cN} = 4\ c_{cr,N}^2 = 4 \times 330^2 = 435600\ mm^2$

$$\psi_{ec,N} = \frac{1}{1 + 2\ e_N / 2\ h_{ef}} = \frac{1}{1 + 2 \times 0 / (3 \times 220)} = 1$$

$$N^g_{Rd,c} = \frac{\frac{A_{cN}}{A^0_{cN}} N^0_{Rk,c}\ \psi_{ec,N}\ \psi_{ucr,N}}{\gamma_{Mc}} = \frac{\frac{250000}{435600} \times 169{,}8 \times 1{,}00 \times 1{,}00}{1{,}5} = 65\ kN$$

Toetsing

$$\frac{T}{N^g_{Rd,c} / 1{,}7} = \frac{10}{65 / 1{,}7} = 0{,}26 \rightarrow OK$$ ...CEN/TS 1992-4-1; B.1.3.2.1

Randcondities zijdelings uitbreken

$c_{dr,2}$ = 250 mm ≥ 6 d = 6 x 20 = 120 mm → voldoet

$c_{dr,1}$ = 250 mm ≥ 6 d = 6 x 20 = 120 mm → voldoet

$c_{br,1}$ = 175 mm ≥ 6 d = 6 x 20 = 120 mm → voldoet

$c_{br,2}$ = 175 mm ≥ 6 d = 6 x 20 = 120 mm → voldoet

Afschuiving

Door ankers:

$$k_1 = \min[\,2{,}8\,\frac{e_2}{d_0} - 1{,}7\,;\,2{,}5\,] = \min[\,2{,}8 \times \frac{75}{22} - 1{,}7\,;\,2{,}5\,] = 2{,}5$$

$$\alpha_d = \frac{e_1}{3\,d_0} = \frac{150}{3 \times 22} = 2{,}273$$

$$\alpha_b = \min[\,\alpha_d\,;\,\frac{f_{ub}}{f_u}\,;\,1{,}0\,] = \min[\,2{,}273\,;\,\frac{800}{360}\,;\,1{,}0\,] = 1$$

$$F_{1,vb,Rd} = \frac{k_1\,\alpha_b\,f_u\,d\,t}{\gamma_{M2}} = \frac{2{,}5 \times 1 \times 360 \times 20 \times 12}{1{,}25 \times 10^{3}} = 172{,}8 \text{ kN}$$ ...NEN-EN 1993-1-8; tabel 3.4

$$\alpha_b = 0{,}44 - 0{,}0003\,f_{yb} = 0{,}44 - 0{,}0003 \times 640 = 0{,}248$$

$$F_{2,vb,Rd} = \frac{\alpha_b\,f_{ub}\,A_s}{\gamma_{Mb}} = \frac{0{,}248 \times 800 \times 245}{1{,}25 \times 10^{3}} = 38{,}9 \text{ kN}$$ ...NEN-EN 1993-1-8; 6.2.2(7)

$$F_{v,Rd} = F_{f,Rd} + n\,F_{vb,Rd} = 0 + 2 \times 38{,}9 = 77{,}8 \text{ kN}$$ ...NEN-EN 1993-1-8 (6.3)

$$\frac{V_{Ed}}{F_{v,Rd}} = \frac{5}{77{,}8} = 0{,}06 \rightarrow \text{OK}$$

Randcondities afschuiving

$c_{dr,2}$ = 250 mm < 60 d = 60 x 20 = 1200 mm → voor afschuiving randeffect

$c_{dr,1}$ = 250 mm < 60 d = 60 x 20 = 1200 mm → voor afschuiving randeffect

$c_{br,1}$ = 175 mm < 60 d = 60 x 20 = 1200 mm → voor afschuiving randeffect

$c_{br,2}$ = 175 mm < 60 d = 60 x 20 = 1200 mm → voor afschuiving randeffect

Wapening voor opnemen afschuifkracht

$e_s = t_p / 2 + t_g + c + Ø / 2 = 12 / 2 + 30 + 30 + 12 / 2 = 72$ mm

$d = h_b - c - Ø / 2 = 400 - 30 - 12 / 2 = 364$ mm $z = 0{,}8\,d = 0{,}8 \times 364 = 291$ mm

$$N_{Ed,re} = (\frac{e_s}{z} + 1)\,V_{Ed} = (\frac{72}{291} + 1) \times 5 = 6{,}24 \text{ kN}$$

$$A_{ben} = \frac{N_{Ed,re}}{f_{yd}} = \frac{6{,}2}{435} = 14 \text{ mm}^2$$

→ Om de afschuifkracht in te leiden moet t.p.v. de ankers ophangwapening worden toegepast!

De ophangwapening kan door middel van haarspelden worden aangebracht.

haarspelden 1Ø12 → A_s = 226 mm ^{2}

$$\alpha_2 = 1 - \frac{0,15\,(c - Ø)}{Ø} = 1 - \frac{0,15\,(30 - 12)}{12} = 0,78$$

$$l_{b,rqd} = \frac{\alpha_1\ \alpha_2\ 0,77\ Ø\ \sigma_{sd}}{f_{ck}^{\ 2/3}} = \frac{1 \times 0,78 \times 0,77 \times 12 \times 28}{30^{\ 2/3}} = 20\text{ mm}$$ ...NEN-EN 1992-1-1 (8.3)

Als alternatief kan voor de ophangwapening de aanwezige oppervlaktewapening worden gebruikt, waarbij geldt:

1) Alleen wapening op een afstand ≤ 0,75 c_1 = 0,75 x 250 = 188 mm van de ankers mag worden meegerekend.

2) De verankeringslengte in de uitbreekkegel moet minimaal 4 Ø = 4 x 12 = 48 mm zijn.

Beschikbare verankeringslengte uitgaande van 1,5 c_d : l_1 = 55 mm

Bepaling van de hoeklassen voor flens en lijf

$$F_{t,max,Ed} = \frac{|N_{Ed}|}{2} + \frac{|M_{Ed}|}{h - t} = \frac{|-10|}{2} + \frac{|0 \times 10^{3}|}{190 - 10} = 5\text{ kN}$$

statisch bepaald → $\sigma_{Ed} = \dfrac{F_{t,max,Ed}}{A_f} = \dfrac{5 \times 10^{3}}{2000} = 2,5\text{ N/mm}^2$

$$\tau_{f,Ed} = \frac{V_{y,Ed}}{2\,A_f} = 0\text{ N/mm}^2 \qquad \tau_{w,Ed} = \frac{V_{z,Ed}}{A_w} = \frac{5 \times 10^{3}}{1105} = 4,5\text{ N/mm}^2$$

$$a_f \geq \beta_w\ \gamma_{M2}\ \frac{\sqrt{2\,\sigma_{Ed}^{\ 2} + 3\,\tau_{f,Ed}^{\ 2}}}{f_u}\ \frac{t_f}{2} = 0,8 \times\ 1,25 \times \frac{\sqrt{2 \times 2,5^{\ 2} + 3 \times 0^{\ 2}}}{360}\ \frac{10}{2} = 0\text{ mm}$$

→ a_f = 3 mm ...NEN-EN 1993-1-8; 4.5.2(2)

$$a_w \geq \beta_w\ \gamma_{M2}\ \frac{\sqrt{2\,\sigma_{Ed}^{\ 2} + 3\,\tau_{w,Ed}^{\ 2}}}{f_u}\ \frac{t_w}{2} = 0,8 \times\ 1,25 \times \frac{\sqrt{2 \times 2,5^{\ 2} + 3 \times 4,5^{\ 2}}}{360}\ \frac{7}{2} = 0\text{ mm}$$

→ a_w = 3 mm ...NEN-EN 1993-1-8; 4.5.2(2)

Conclusie : Kolomvoetplaatverbinding voldoet.