

Preparation by	SFL	Verification by	BGU	Approval by	MIR
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Date	16-10-2020	Date	16-10-2020	Date	16-10-2020
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"FOR COMMENTS"

TAR VERLADING

Detail Calculation Concrete Loading Station

Client	Shin-Etsu	Client number	B2017-053
Project	TAR VERLADING	KH number	62596-106
Plant	BOTLEK		
Unit	2000	Revision	0A
Document Code	4.007.212	Date	16-10-2020

Revision	Description	Date
0A	For comments	16-10-2020

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Appendix	Title
A	SCIA engineer 3D calculation report
B	R1901326-03 Geotechnical advice
C	WLT Steel structure

1 INTRODUCTION

1.1 General

The location of the new TAR loading facility project is the Shin Etsu site in Botlek (Port of Rotterdam).

The construction is formed by the following parts:

- A steel structure supporting the loading arm (by third party);
- Foundation on piles for the steel structure;
- Concrete slab for the truck loading area.

The two foundation types have a separation joint to account for the difference in movement.

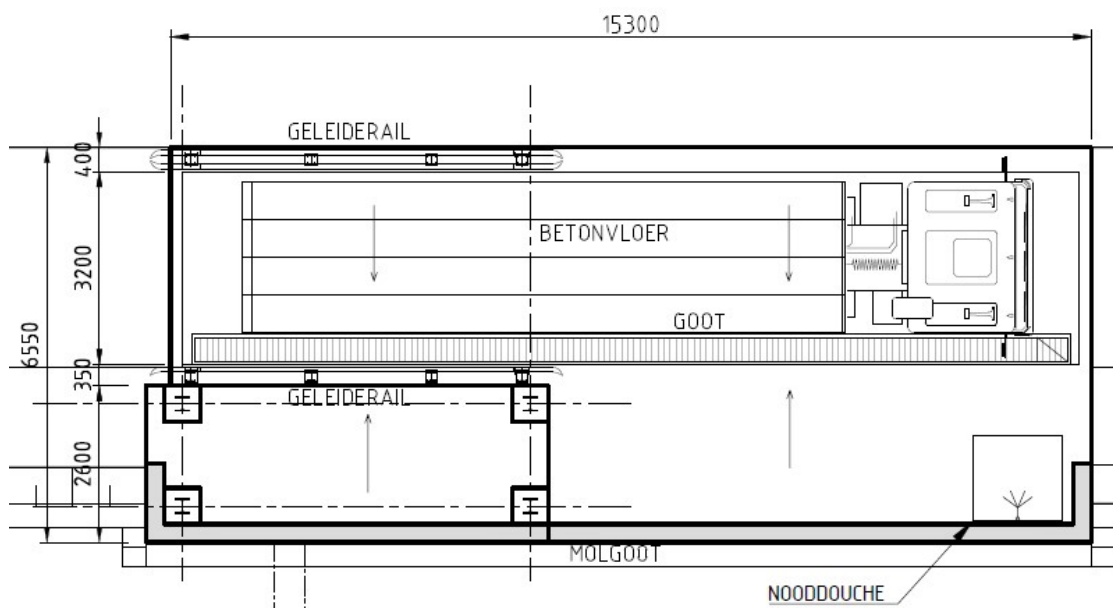


Figure 1. General dimensions of the foundations

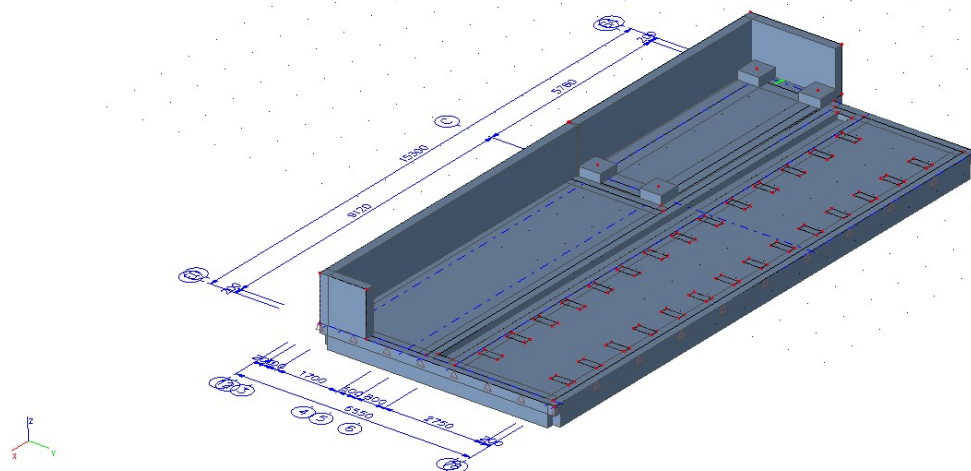


Figure 2. SCIA Model geometry

1.2 Location

SHIN ETSU.
Welplaatweg 12
3197 KS Botlek-Rotterdam
Havennummer 4150



Figure 3. Location SHIN ETSU (behind Akzo Nobel/Nureon) Welplaatweg 12 te Botlek-Rotterdam

 Location TAR loading station

1.3 Applicable Eurocodes and other standards

Number	Title
EN 1990	Eurocode 0 - Basis of structural design
EN 1991	Eurocode 1 - Actions on structures
EN 1992	Eurocode 2 - Design of concrete structures
EN 1993	Eurocode 3 - Design of steel structures
NEN-EN 1992 NA	Eurocode 2 - Ontwerp en berekening van betonconstructies
NEN-EN 1993 NA	Eurocode 3 - Ontwerp en berekening van staalconstructies
NEN-EN 1997 NA	Eurocode 7 - Geotechnical design
NEN 9997-1	Geotechnisch ontwerp van constructies - Deel 1: Algemene regels

1.4 Design working life, consequence class and reliability class

	Design working life	Consequence Class	Reliability Class
Permanent structures	50 years	CC3	RC3

1.5 Liquid-tight provisions in concrete

The concrete slab needs to be liquid-tight and the following minimum requirement according to CUR/PBV recommendation 65 the following criteria is imposed:

Elastically supported floors and surfacing, poured on site with minimum thickness $h = 180$ mm.

Maximum permissible mean crack width at the reinforcement $w = 0.15$ mm and maximum bar distance $s = 100$ mm.

The minimum reinforcement percentage at the drying side is $\omega_0 = 0.47\%$ at concrete strength class C35/45.

2 LOADS

2.1 Loads: General

The following loads are entered in SCIA as line loads, surface loads or point loads depending on the situation.

The loads introduced in the calculation can be found on Annex A. SCIA report. This document is a 3D PDF where the user can navigate through the model and get an accurate description of the loads used.

In this section, an overview of the assumptions, loads and combinations used is given. For more detail information see Appendix A. SCIA report.

2.2 Load Cases

The following basic load cases are used for the calculation:

BLC		TYPES OF LOAD
1. Self-Weight	GSW	Structure self-weight
2. Dead Load	GDL	Dead load of ground, grating, handrails, stairs etc...
3. Operation loads	GOP	Operation loads of piping and equipment
4. Wind loads	QWL	Wind loads on the structure
5. Live Load	QFL	Live load Floor
6. Traffic load	QTL	Truck traffic load

2.3 Load factors and classification of variable actions according NEN-EN 1990

- | | | |
|-------------------------------|------------------------------|-------------------|
| - Design (technical) lifespan | 50 year | |
| - Consequence class | CC3 | |
| - Load factors | ULS | SLS |
| - Permanent load | $\gamma_G = 1.5 / 1.3 / 0.9$ | $\gamma_G = 1.00$ |
| - Variable load | $\gamma_Q = 1.65$ | $\gamma_Q = 1.00$ |

BLC	Description	Category	ψ_0	ψ_1	ψ_2
QFL	Floor live load	E	1	0.9	0.8
QTL	Traffic load	G	0.7	0.5	0.3

2.4 BLC 1 GSW. Structural self-weight

Self-weight of structural elements is automatically introduced by the FEA software SCIA engineer. Material densities used for determination of structural self-weights are shown in the following table:

Material	Description	Self-Weight
Concrete	C35/45	25 kN/m ³

2.5 BLC 2 GDL. Dead load of ground

The soil pressure on the wall is calculated as follows:

Type of soil considered is Sand / Clean / Moderate - NEN 6740

Properties of soil:

$$\begin{aligned}\phi' &= 32,5^\circ \\ c' &= 0 \text{ MPa} \\ \gamma &= 1800 \text{ kg/m}^3\end{aligned}$$

Geometry considered:

$$\begin{aligned}h &= 1,5 \text{ m} && \text{Is the height of the wall} \\ \alpha &= 38^\circ && \text{Is the slope of the earth} \\ \beta &= 90^\circ && \text{Is the angle of the wall} \\ \delta &= 0^\circ && \text{Is the friction between the wall and soil}\end{aligned}$$

The soil pressure P_p is:

$$P_{p,0} = 1/2 K_A \gamma h^2 \text{ [kN/m]}$$

Where:

$$K_A = \frac{\sin^2(\beta + \phi)}{\sin^2(\beta) \cdot \sin(\beta - \delta) \cdot \left[1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha)}{\sin(\beta - \delta) \cdot \sin(\alpha + \beta)}} \right]^2}$$

$P_p = 14,4 \text{ kN/m}$

A triangular shaped force with minimum 0 kN/m at top of the wall and maximum 14.40 kN/m at the bottom of the wall is applied on the surface of the wall as a permanent action.

2.6 BLC 4 QWL. Wind loads

The reactions of the steel structure are considered as nodal forces on the foundation.

The forces resulting from the steel structure, maximal per column, are:

- 300 kN compression
- 300kN tension
- 20 kN horizontal force

The load cases designed in order to create different loading scenarios are:

- Case 1: 2 columns in tension and 2 columns in compression;
- Case 2: All columns in compression
- Case 3: Horizontal loads on all columns

The combinations criteria will allow to combine horizontal loads with the first two cases.

The information of the loads delivered by third party are presented in Appendix C - WLT Steel structure.

2.7 BLC 5 QFL. Floor live load

A 5 kN/m² surface load is introduced on the slab under the steel structure.
This is to simulate future pipes supported on the slab.

2.8 BLC 6 QTL. Traffic load

The concrete slab is loaded by a mobile load system. This simulates loading trucks crossing the slab. For this, a load system class 450 according to the old standards for bridges is used.

This concerns a system of 3 axes of 150 kN center to center, at an interval of 1.00 m resp. 4.00 and 2.50 m wide.

The wheel prints are 0.50 m long and 0.20 m wide.

The wheel load is: $150/2 = 75$ kN with $75 \text{ kN} / (0.20 \text{ m} \times 0.50 \text{ m}) = 750 \text{ kN} / \text{m}^2$

This load system is moved across the plate in 14 steps of 1.00 m for design ground pressures and forces.

In a different load case, a 15 kN/m² surface load is introduced on the loading area slab. This load is exclusive and does not combine with the mobile load.

Note: The load system for bridges with 2 axes is 300 kN according to NEN-EN-1991-2. This is not applicable for this concrete slab with predominantly stationary traffic.

3 CONCLUSION

3.1 Foundation loads

3.1.1 Pile loads

ULS – Maximal values (rounded) - Nonlinear calculation

Compression : 720 kN

Tension : 410 kN

Horizontal force: 56 kN

The foundation on piles corresponding to the pile loads results from SCIA are:

Ground-displacing concrete pile with permanent steel tube, screwed to depth
 Ø 324/ 450 [NAP + m] - 22,0

Pile dimensions $\varnothing_{\text{tube}} / \varnothing_{\text{end}}$ [mm × mm]	Pile level [NAP + m]	$R_{c;\text{net};d}$ [kN]	ULS R_c [kN]	Unity check	$R_{t;\text{net};1;d}$ [kN]	ULS R_t [kN]	Unity check	$R_{t;\text{net};\text{groep};d}$ [kN]	ULS R_t [kN]	Unity check
Ø 350/450	-22.0	1105	720	0.65	670	410	0.61	600	410	0.68

Vertical spring stiffness for pile : $k_{v;\text{langd};k} = 96 \text{ MN/m}$ with min $96 / 1.35$ and max 96×1.5 ;
 ULS = $k_{v;\text{langd};k} / 1.3$

Horizontal spring stiffness for pile : $k_{h;k} = 12.5 \text{ MN/m}$ with min $12.5 / 1.35$ and max 12.5×1.5 ;
 ULS = $k_{h;k} / 1.3$

The detail information regarding the geotechnical analysis are presented in Appendix B "R1901326-03 - FA Verladingsplaats".

3.1.2 Soil pressure

ULS soil pressure for soil bearing capacity calculation – Nonlinear calculation

Values between maximum 69 kN/m^2 and 22 kN/m^2

SLS quasi-permanent soil pressure for settlement calculation – Nonlinear calculation

Values between maximum 21 kN/m^2 and 13 kN/m^2

Soil stiffness for the slab 10 MN/m^3

The detail information regarding the geotechnical analysis are presented in Appendix B "R1901326-03 - FA Verladingsplaats".

3.2 Foundation details

The SCIA Engineer calculation in combination with CUR/PBV recommendation 65 gives the following results:

3.2.1 Concrete slab – Truck loading area

The concrete slab has the following characteristics:

- Concrete class C35/45
- Thickness 250 mm
- Concrete cover 45 mm
- Main reinforcement:
 - o Top reinforcement $\varnothing$ 12 mm at 100 mm in 2 directions
 - o Bottom reinforcement $\varnothing$ 12 mm at 100 mm in 2 directions

3.2.2 Concrete slab – Loading arm area

The concrete slab has the following characteristics:

- Concrete class C35/45
- Thickness 300 mm
- Concrete cover 45 mm
- Main reinforcement:
 - o Top reinforcement $\varnothing$ 12 mm at 100 mm in 2 directions
 - o Bottom reinforcement $\varnothing$ 12 mm at 100 mm in 2 directions

3.2.3 Beams and Pile caps

Pile caps 600 x 800 mm, and beams 400 x 600:

- Concrete class C35/45
- Concrete cover 45 mm
- Main reinforcement:
 - o Top reinforcement 4 $\varnothing$ 20 mm
 - o Bottom reinforcement 4 $\varnothing$ 20 mm
 - o Stirrups $\varnothing$ 10 mm at 150 mm

3.2.4 Wall

The concrete wall has the following characteristics:

- Concrete class C35/45
- Thickness 250 mm
- Concrete cover 45 mm
- Main reinforcement:
 - o Top reinforcement $\varnothing$ 12 mm at 100 mm in 2 directions
 - o Bottom reinforcement $\varnothing$ 12 mm at 100 mm in 2 directions

The detailed calculation of the results and unity checks can be found in Appendix A. SCIA Calculation

Appendix A. SCIA calculation

1. Project

Licence name	KH Engineering	
Project	SHIN ETSU VCM - Rotterdam Botlek	
Part	TAR VERLADING	
Description	4.007.212_0A_Detailberekening beton verlaadstation	
Author	SFL	
Date	16/10/2020	
Structure	General XYZ	
No. of nodes :		150
No. of beams :		15
No. of slabs :		6
No. of solids :		0
No. of used profiles :		3
No. of load cases :		22
No. of used materials :		3
Acceleration of gravity [m/s ²]		9,810
National code	EC - EN	

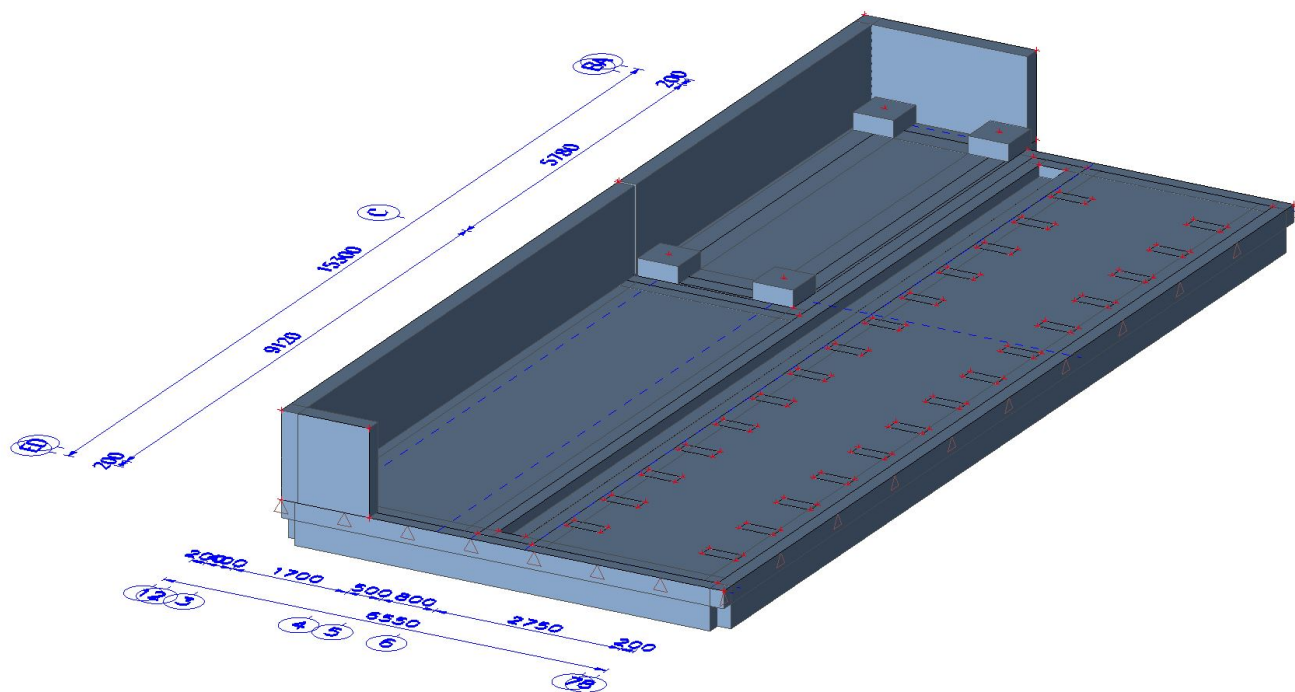
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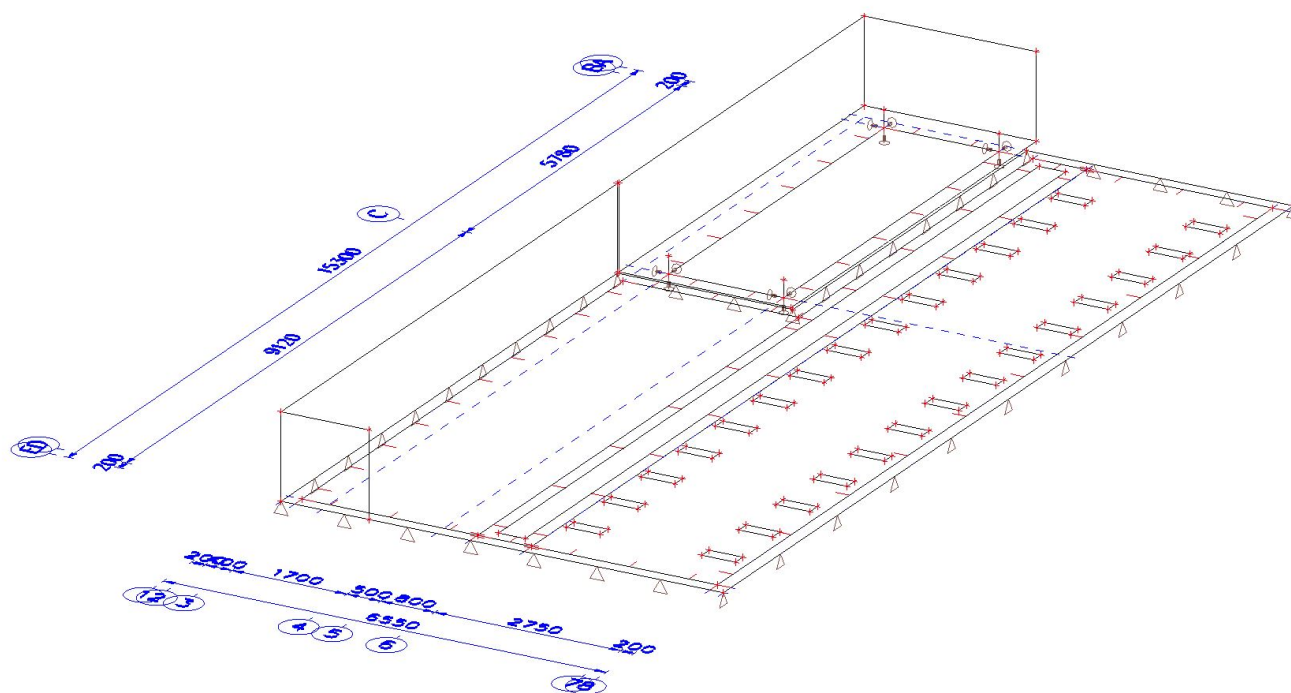
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3. Structure overview

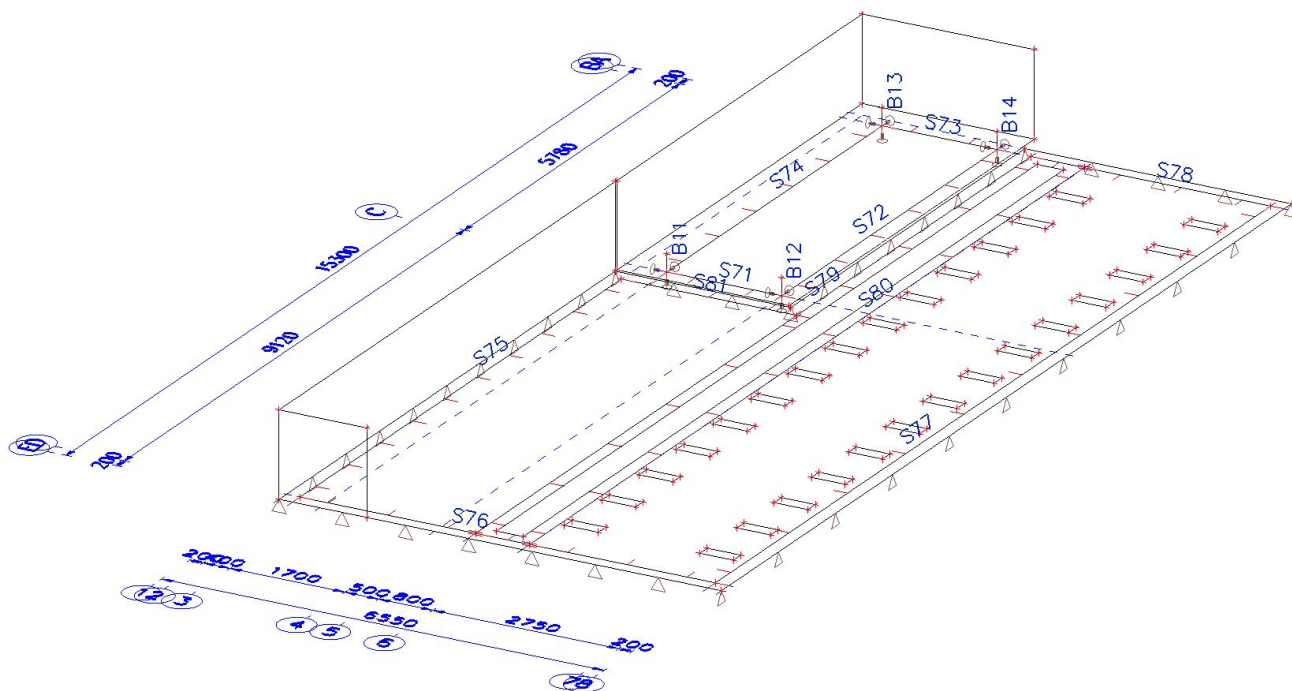
3.1. Analysis model



3.2. Structure mechanics

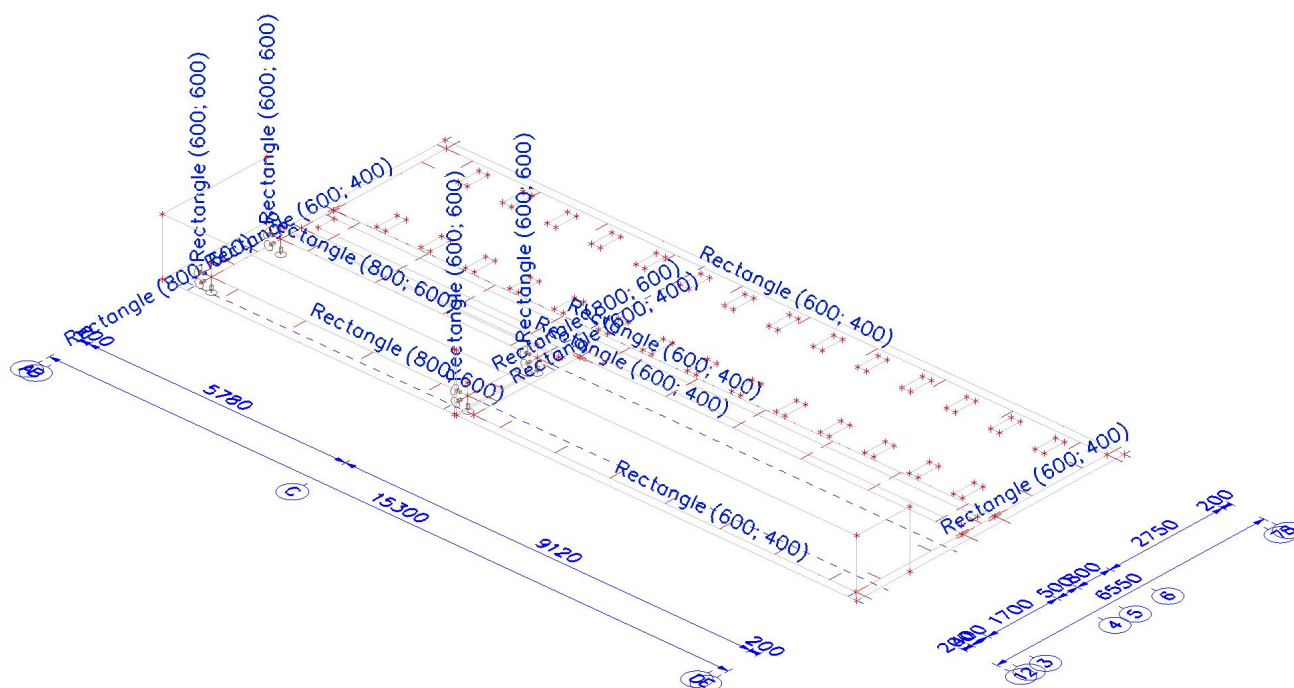


3.3. Beam labels

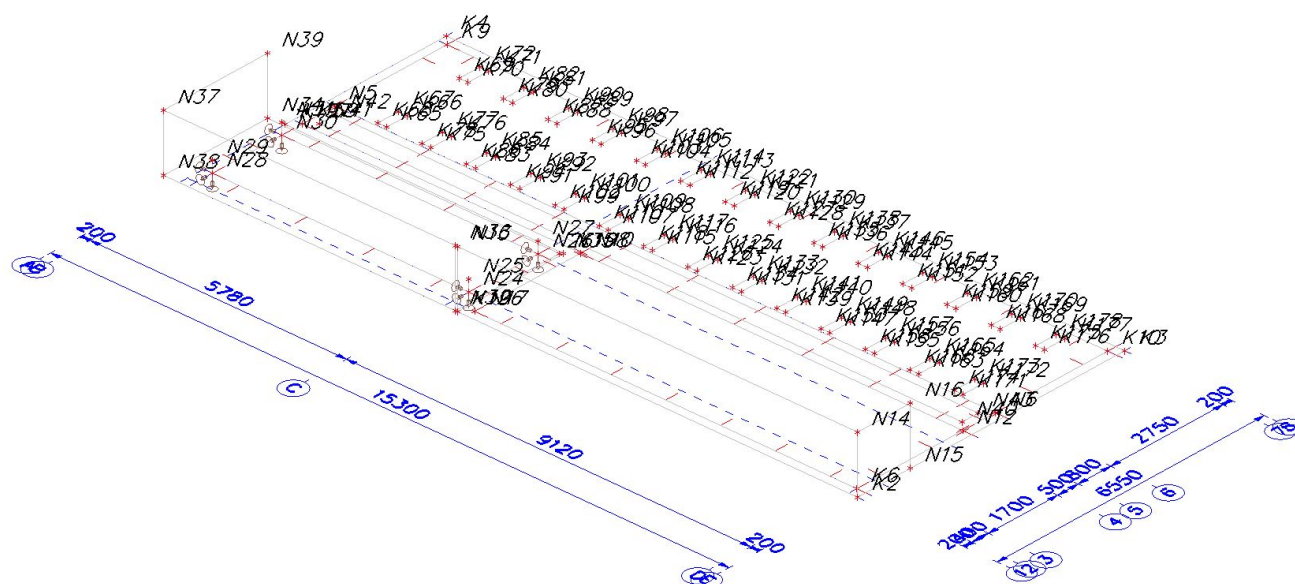


Name	Cross-section	Material	Length [m]	Beg. node	End node	Type
B11	FB3 - Rectangle (600; 600)	C35/45	0,250	N24	N25	column (100)
B12	FB3 - Rectangle (600; 600)	C35/45	0,250	N26	N27	column (100)
B13	FB3 - Rectangle (600; 600)	C35/45	0,250	N28	N29	column (100)
B14	FB3 - Rectangle (600; 600)	C35/45	0,250	N30	N31	column (100)
S71	FB2 - Rectangle (800; 600)	C35/45	1,700	N24	N26	beam (80)
S72	FB2 - Rectangle (800; 600)	C35/45	5,780	N26	N30	beam (80)
S73	FB2 - Rectangle (800; 600)	C35/45	1,700	N30	N28	beam (80)
S74	FB2 - Rectangle (800; 600)	C35/45	5,780	N28	N24	beam (80)
S75	FB1 - Rectangle (600; 400)	C35/45	8,620	N17	K6	beam (80)
S76	FB1 - Rectangle (600; 400)	C35/45	6,150	K6	K10	beam (80)
S77	FB1 - Rectangle (600; 400)	C35/45	14,900	K10	K9	beam (80)
S78	FB1 - Rectangle (600; 400)	C35/45	3,550	K9	K59	beam (80)
S79	FB1 - Rectangle (600; 400)	C35/45	14,900	K59	N12	beam (80)
S80	FB1 - Rectangle (600; 400)	C35/45	14,900	N5	N6	beam (80)
S81	FB1 - Rectangle (600; 400)	C35/45	2,600	N17	N10	beam (80)

3.4. Structure profiles & sections



3.5. Nodes

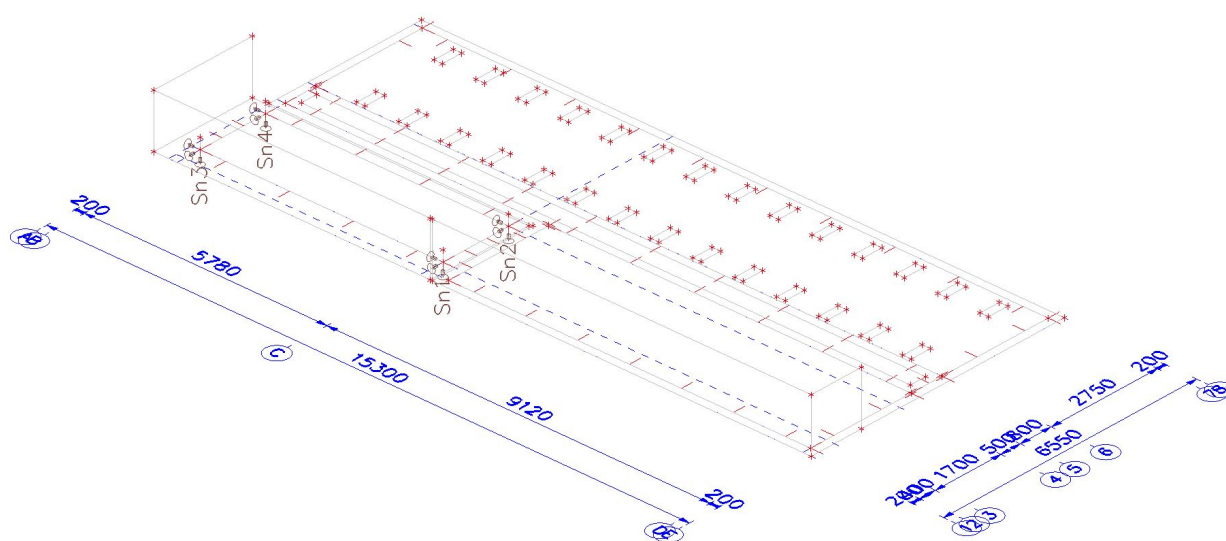


Name	Coord X [m]	Coord Y [m]	Coord Z [m]
K2	15,300	0,000	0,000
K3	15,300	6,550	0,000
K4	0,000	6,550	0,000
K6	15,100	0,200	0,000
K9	0,200	6,350	0,000
K10	15,100	6,350	0,000
K59	0,200	2,800	0,000
K65	1,300	3,675	0,000
K66	1,300	4,175	0,000
K67	1,100	4,175	0,000
K68	1,100	3,675	0,000
K69	1,100	5,675	0,000
K70	1,300	5,675	0,000
K71	1,300	6,175	0,000
K72	1,100	6,175	0,000
K75	2,300	3,675	0,000
K76	2,300	4,175	0,000
K77	2,100	4,175	0,000
K78	2,100	3,675	0,000
K79	2,100	5,675	0,000
K80	2,300	5,675	0,000
K81	2,300	6,175	0,000
K82	2,100	6,175	0,000
K83	3,300	3,675	0,000
K84	3,300	4,175	0,000
K85	3,100	4,175	0,000
K86	3,100	3,675	0,000
K87	3,100	5,675	0,000
K88	3,300	5,675	0,000
K89	3,300	6,175	0,000
K90	3,100	6,175	0,000
K91	4,300	3,675	0,000
K92	4,300	4,175	0,000
K93	4,100	4,175	0,000
K94	4,100	3,675	0,000
K95	4,100	5,675	0,000
K96	4,300	5,675	0,000
K97	4,300	6,175	0,000
K98	4,100	6,175	0,000
K99	5,300	3,675	0,000
K100	5,300	4,175	0,000
K101	5,100	4,175	0,000
K102	5,100	3,675	0,000
K103	5,100	5,675	0,000
K104	5,300	5,675	0,000
K105	5,300	6,175	0,000
K106	5,100	6,175	0,000
K107	6,300	3,675	0,000
K108	6,300	4,175	0,000
K109	6,100	4,175	0,000

Name	Coord X [m]	Coord Y [m]	Coord Z [m]
K110	6,100	3,675	0,000
K111	6,100	5,675	0,000
K112	6,300	5,675	0,000
K113	6,300	6,175	0,000
K114	6,100	6,175	0,000
K115	7,300	3,675	0,000
K116	7,300	4,175	0,000
K117	7,100	4,175	0,000
K118	7,100	3,675	0,000
K119	7,100	5,675	0,000
K120	7,300	5,675	0,000
K121	7,300	6,175	0,000
K122	7,100	6,175	0,000
K123	8,300	3,675	0,000
K124	8,300	4,175	0,000
K125	8,100	4,175	0,000
K126	8,100	3,675	0,000
K127	8,100	5,675	0,000
K128	8,300	5,675	0,000
K129	8,300	6,175	0,000
K130	8,100	6,175	0,000
K131	9,300	3,675	0,000
K132	9,300	4,175	0,000
K133	9,100	4,175	0,000
K134	9,100	3,675	0,000
K135	9,100	5,675	0,000
K136	9,300	5,675	0,000
K137	9,300	6,175	0,000
K138	9,100	6,175	0,000
K139	10,300	3,675	0,000
K140	10,300	4,175	0,000
K141	10,100	4,175	0,000
K142	10,100	3,675	0,000
K143	10,100	5,675	0,000
K144	10,300	5,675	0,000
K145	10,300	6,175	0,000
K146	10,100	6,175	0,000
K147	11,300	3,675	0,000
K148	11,300	4,175	0,000
K149	11,100	4,175	0,000
K150	11,100	3,675	0,000
K151	11,100	5,675	0,000
K152	11,300	5,675	0,000
K153	11,300	6,175	0,000
K154	11,100	6,175	0,000
K155	12,300	3,675	0,000
K156	12,300	4,175	0,000
K157	12,100	4,175	0,000
K158	12,100	3,675	0,000
K159	12,100	5,675	0,000

Name	Coord X [m]	Coord Y [m]	Coord Z [m]
K160	12,300	5,675	0,000
K161	12,300	6,175	0,000
K162	12,100	6,175	0,000
K163	13,300	3,675	0,000
K164	13,300	4,175	0,000
K165	13,100	4,175	0,000
K166	13,100	3,675	0,000
K167	13,100	5,675	0,000
K168	13,300	5,675	0,000
K169	13,300	6,175	0,000
K170	13,100	6,175	0,000
K171	14,300	3,675	0,000
K172	14,300	4,175	0,000
K173	14,100	4,175	0,000
K174	14,100	3,675	0,000
K175	14,100	5,675	0,000
K176	14,300	5,675	0,000
K177	14,300	6,175	0,000
K178	14,100	6,175	0,000
K196	6,280	0,000	0,000
K197	0,000	2,600	0,000
K198	6,280	2,600	0,000
N5	0,200	3,593	0,000
N6	15,100	3,600	0,000
N10	6,480	2,800	0,000
N12	15,100	2,800	0,000
N13	6,280	0,000	1,250
N14	15,300	0,000	1,250
N15	15,300	1,300	0,000
N16	15,300	1,300	1,250
N17	6,480	0,200	0,000
N24	5,980	0,600	0,000
N25	5,980	0,600	0,250
N26	5,980	2,300	0,000
N27	5,980	2,300	0,250
N28	0,200	0,600	0,000
N29	0,200	0,600	0,250
N30	0,200	2,300	0,000
N31	0,200	2,300	0,250
N32	6,230	0,000	0,000
N34	-0,350	2,550	0,000
N35	6,230	2,550	0,000
N36	6,230	0,000	1,250
N37	-0,350	0,000	1,250
N38	-0,350	0,000	0,000
N39	-0,350	2,550	1,250
N40	14,900	3,000	0,000
N41	0,400	3,000	0,000
N42	0,400	3,393	0,000
N43	14,900	3,393	0,000

3.6. Supports



3.7. Nodal supports

Name Node	System User UCS	Type Angle [deg]	X Stiffness X [MN/m]	Y Stiffness Y [MN/m]	Z Stiffness Z [MN/m]	Rx Stiffness Rx [MNm/rad]	Ry Stiffness Ry [MNm/rad]	Rz Stiffness Rz [MNm/rad]
Sn1 N24	GCS	Standard	Flexible 7,1225e+00	Flexible 7,1225e+00	Flexible 5,4701e+01	Free	Free	Free
Sn2 N26	GCS	Standard	Flexible 7,1225e+00	Flexible 7,1225e+00	Flexible 5,4701e+01	Free	Free	Free
Sn3 N28	GCS	Standard	Flexible 7,1225e+00	Flexible 7,1225e+00	Flexible 5,4701e+01	Free	Free	Free
Sn4 N30	GCS	Standard	Flexible 7,1225e+00	Flexible 7,1225e+00	Flexible 5,4701e+01	Free	Free	Free

3.8. 2D member supports

Name	Type	Subsoil	2D member
SS1	Individual	Sand/Clean/Moderate - NEN 6740	E1

3.9. Subsoils

Name	C1x [MN/m ³]	C1z	C1y [MN/m ³]	Stiffness [MN/m ³]	C2x [MN/m]	C2y [MN/m]
Sand/Clean/Moderate	2,0000e+00	Flexible	2,0000e+00	1,0000e+01	0,0000e+00	0,0000e+00

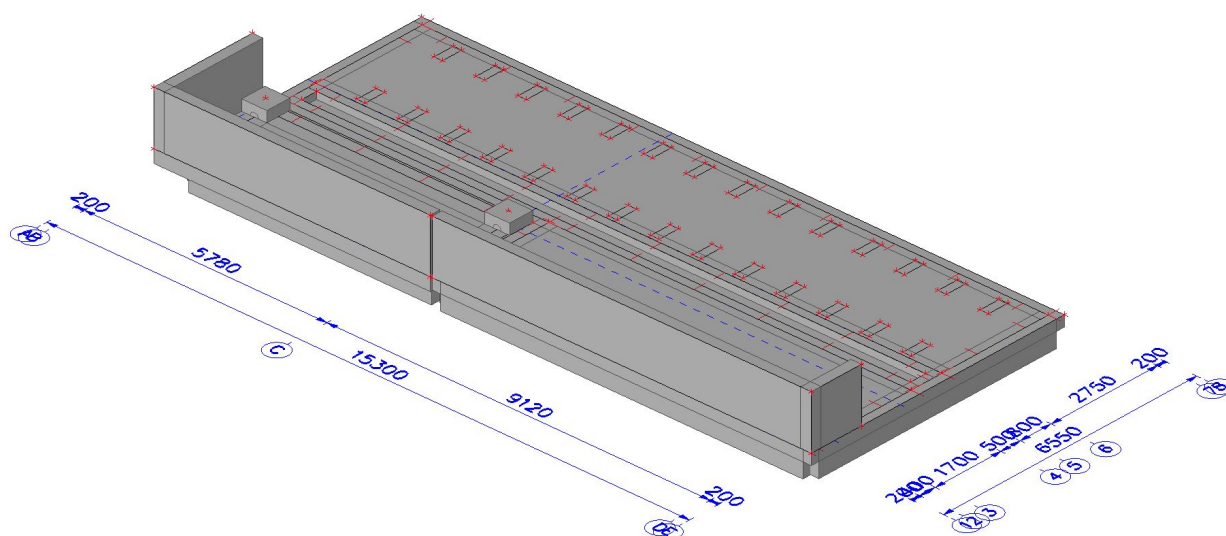
3.10. Materials

Concrete EC2

Name	Type	ρ [kg/m ³]	Density in fresh state [kg/m ³]	E_{mod} [MPa]	μ	α [m/mK]	$f_{c,k,28}$ [MPa]	Colour
C35/45	Concrete	2500,0	2600,0	3,4100e+04	0.2	0,00	35,00	■

Reinforcement EC2

Name	Type	ρ [kg/m ³]	E_{mod} [MPa]	G_{mod} [MPa]	α [m/mK]	$f_{y,k}$ [MPa]
B 500B	Reinforcement steel	7850,0	2,0000e+05	8,3333e+04	0,00	500,0



4. Loads and Load combinations

4.1. Load cases

Name	Description	Action type	Load group	Direction	Duration	Master load case
	Spec	Load type				
GSW00	Structure Self-Weight	Permanent Self weight	LG1	-Z		
GDL00	Earth pressure	Permanent Standard	LG1			
QTL00	Traffic Load pos 0 a = 0,0 m Standard	Variable Static	LG4		Short	None
QTL01	Traffic Load pos 1 a = 1,0 m Standard	Variable Static	LG4		Short	None
QTL02	Traffic Load pos 2 a = 2,0 m Standard	Variable Static	LG4		Short	None
QTL03	Traffic Load pos 3 a = 3,0 m Standard	Variable Static	LG4		Short	None
QTL04	Traffic Load pos 4 a = 4,0 m Standard	Variable Static	LG4		Short	None
QTL05	Traffic Load pos 5 a = 5,0 m Standard	Variable Static	LG4		Short	None
QTL06	Traffic Load pos 6 a = 6,0 m Standard	Variable Static	LG4		Short	None
QTL07	Traffic Load pos 7 a = 7,0 m Standard	Variable Static	LG4		Short	None
QTL08	Traffic Load pos 8 a = 8,0 m Standard	Variable Static	LG4		Short	None
QTL09	Traffic Load pos 9 a = 9,0 m Standard	Variable Static	LG4		Short	None
QTL10	Traffic Load pos 10 a = 10,0 m Standard	Variable Static	LG4		Short	None
QTL11	Traffic Load pos 11 a = 11,0 m Standard	Variable Static	LG4		Short	None
QTL12	Traffic Load pos 12 a = 12,0 m Standard	Variable Static	LG4		Short	None
QTL13	Traffic Load pos 13 a = 13,0 m Standard	Variable Static	LG4		Short	None
QTL14	Distributed Standard	Variable Static	LG4		Short	None
BLC1.1	-NB3 -NC3 +NB4 +NC4 Standard	Variable Static	LG5		Short	None
BLC1.2	-NB3 -NC3 +NB4 +NC4 Standard	Variable Static	LG5		Short	None
BLC1.3	-NB3 -NC3 -NB4 -NC4 Standard	Variable Static	LG5		Short	None
BLC2.1	VX Standard	Variable Static	LG6		Short	None
BLC2.2	VY Standard	Variable Static	LG6		Short	None

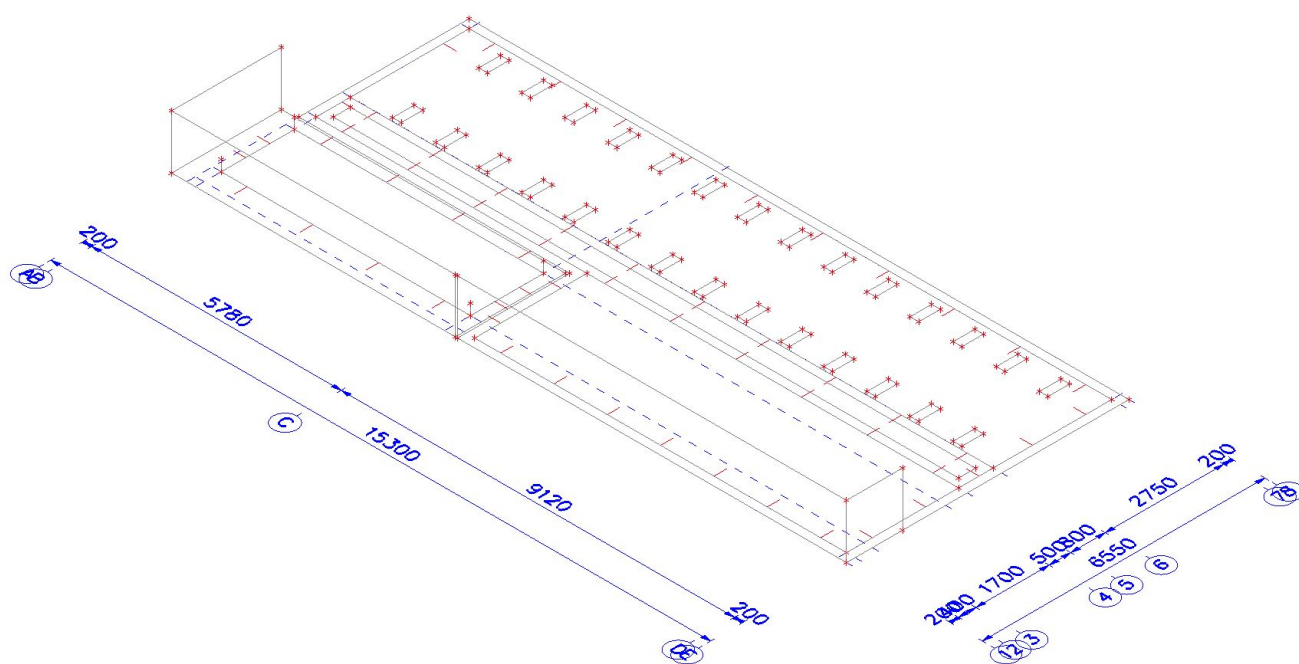
4.2. Load groups

Name	Load	Relation	Type
LG1	Permanent		
LG2	Variable	Standard	Cat E : Storage
LG3	Variable	Exclusive	Wind
LG4	Variable	Exclusive	Cat G : Vehicle >30kN
LG5	Variable	Exclusive	Cat E : Storage
LG6	Variable	Exclusive	Cat E : Storage

4.3. Loads per load case

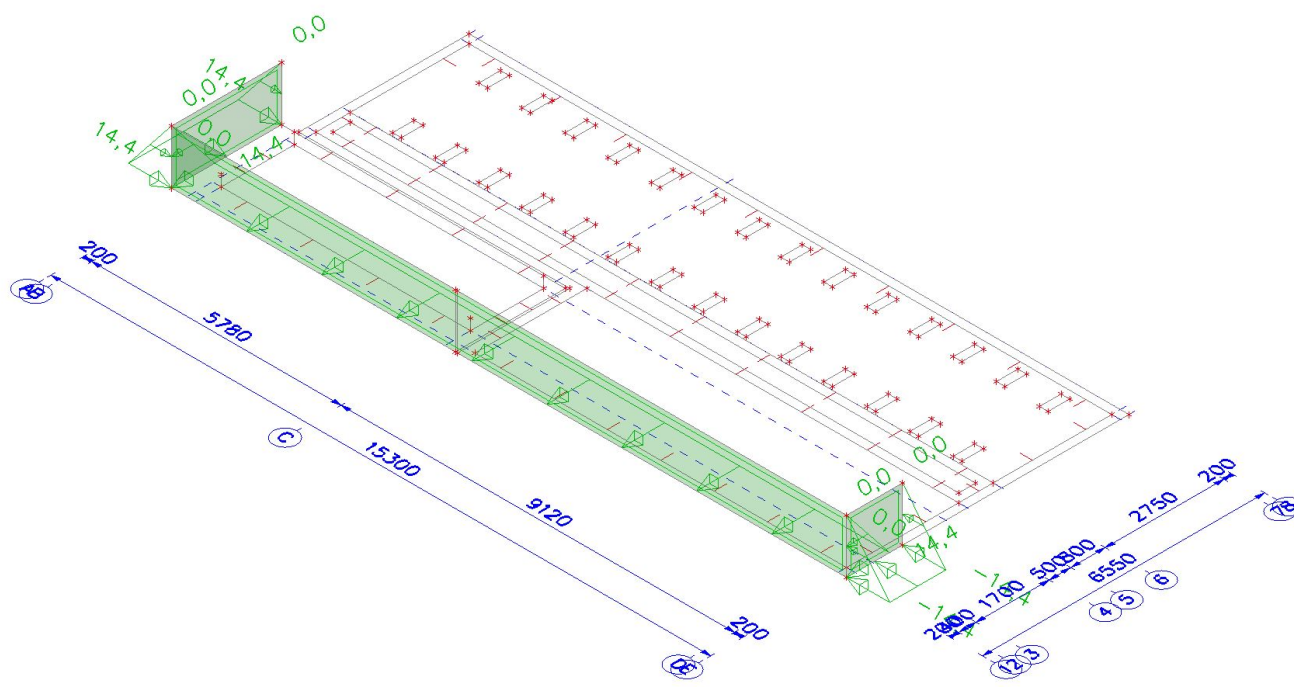
4.3.1. Loads per load case - GSW00

Name	Description	Action type	Load group	Load type	Direction
GSW00	Structure Self-Weight	Permanent	LG1	Self weight	-Z



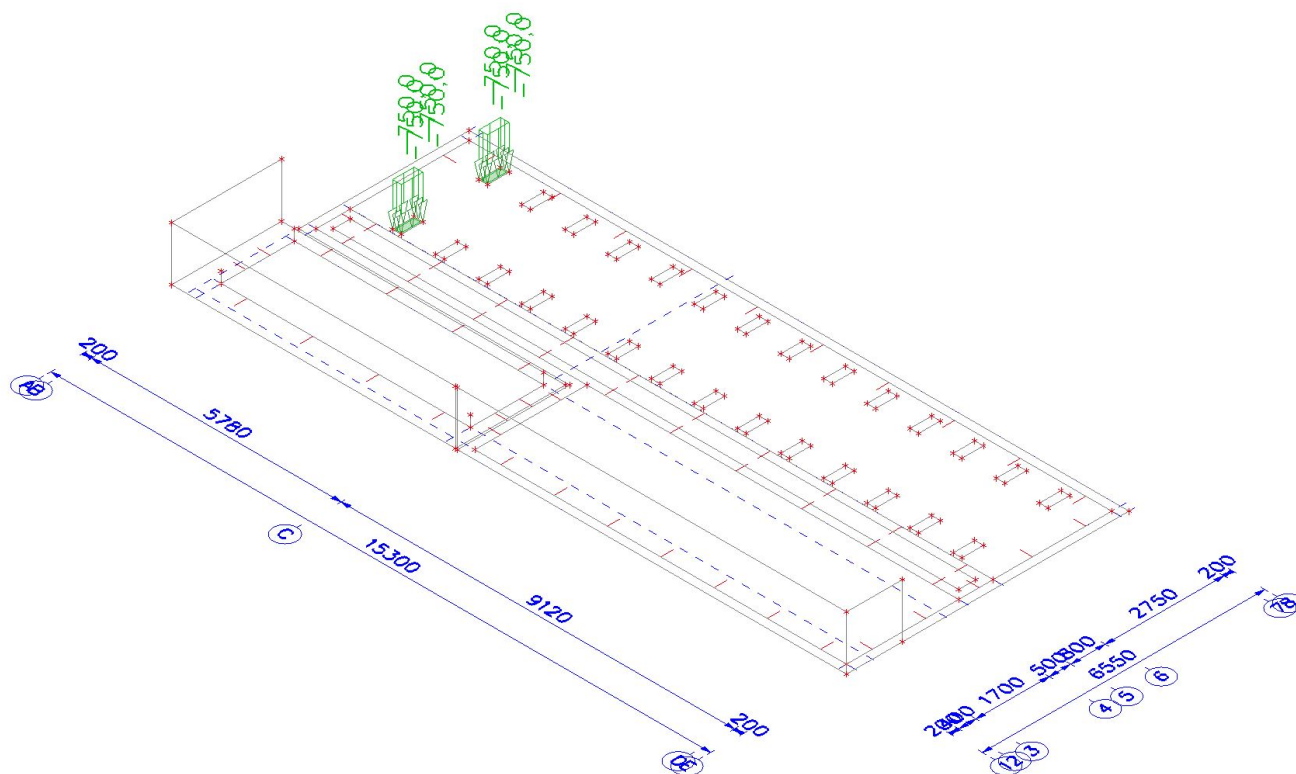
4.3.2. Loads per load case - GDL00

Name	Description	Action type	Load group	Load type
GDL00	Earth pressure	Permanent	LG1	Standard



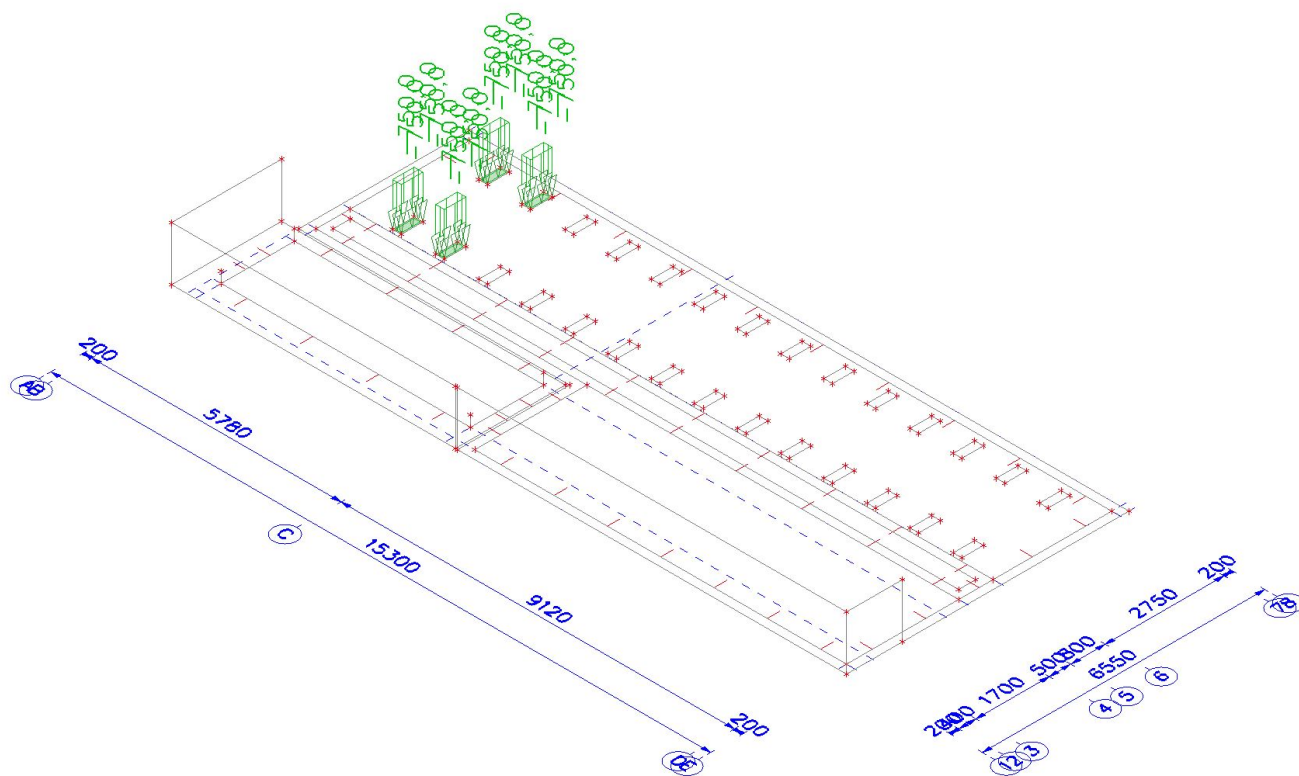
4.3.3. Loads per load case - QTL00

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL00	Traffic Load pos 0 a = 0,0 m	Variable	LG4	Static	Standard	Short	None



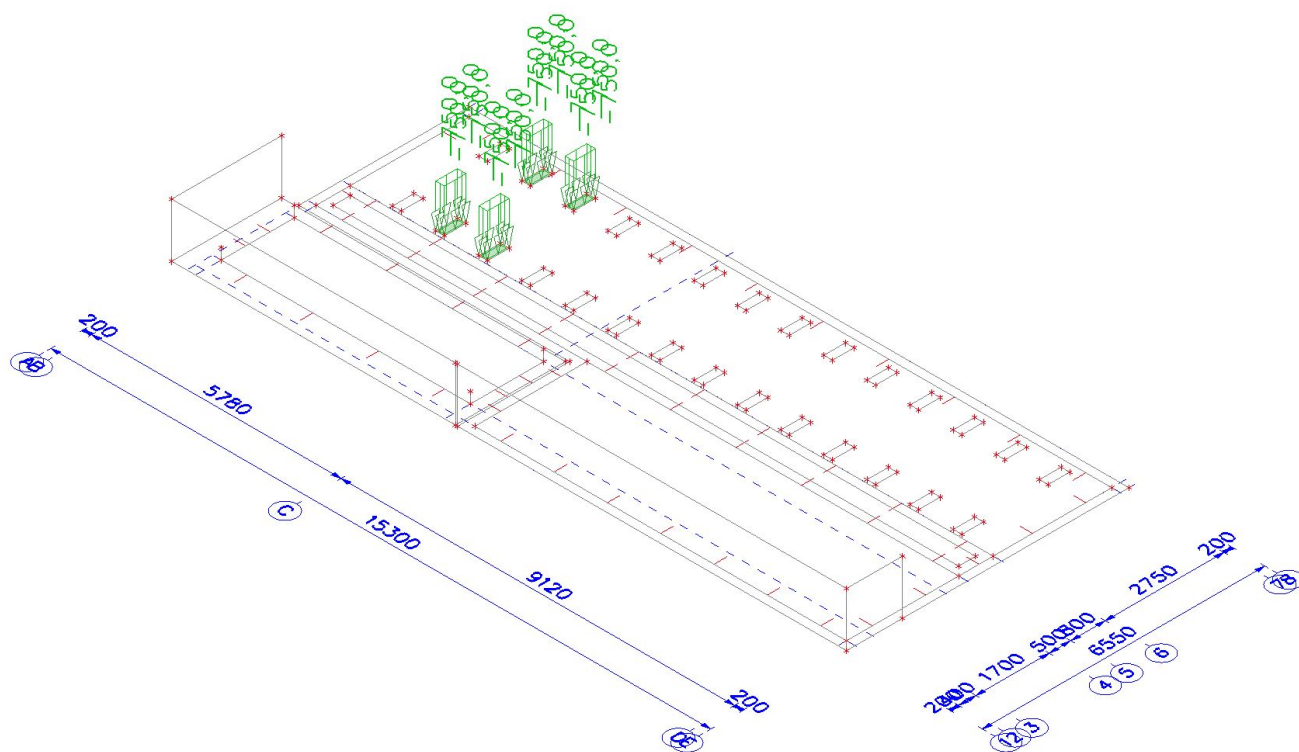
4.3.4. Loads per load case - QTL01

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL01	Traffic Load pos 1 a = 1,0 m	Variable	LG4	Static	Standard	Short	None



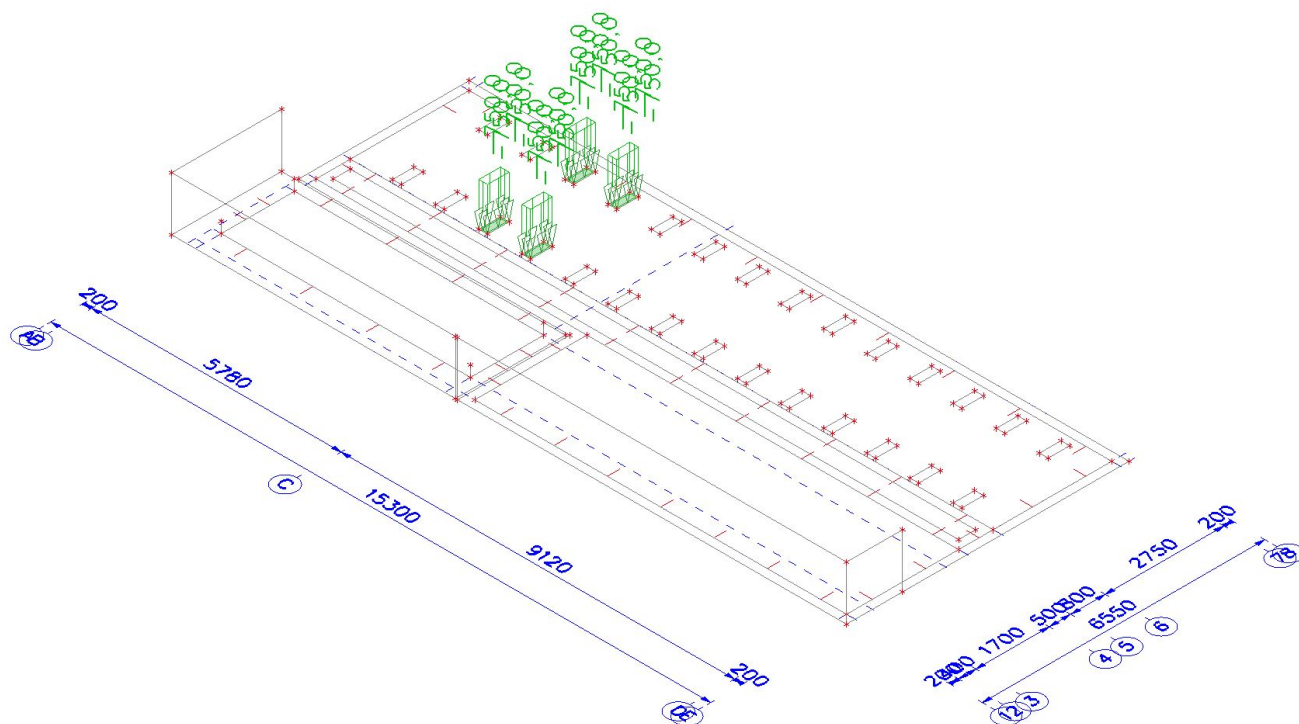
4.3.5. Loads per load case - QTL02

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL02	Traffic Load pos 2 a = 2,0 m	Variable	LG4	Static	Standard	Short	None



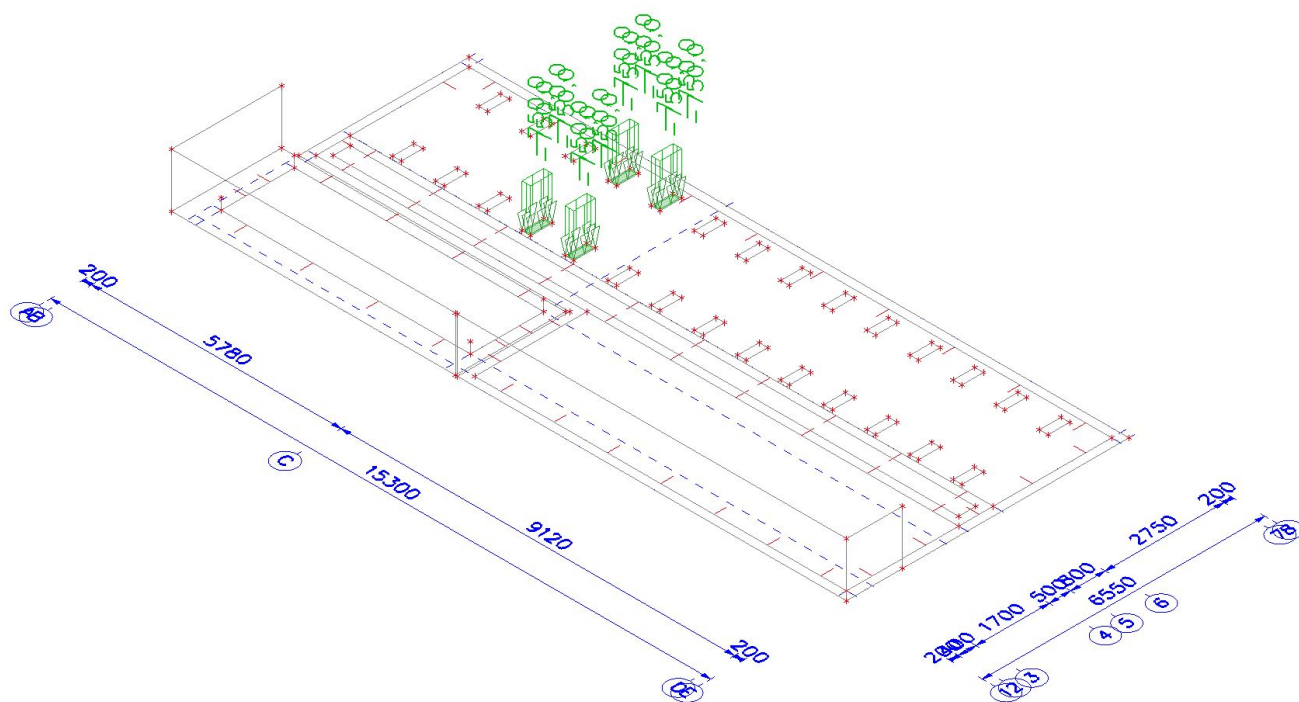
4.3.6. Loads per load case - QTL03

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL03	Traffic Load pos 3 a = 3,0 m	Variable	LG4	Static	Standard	Short	None



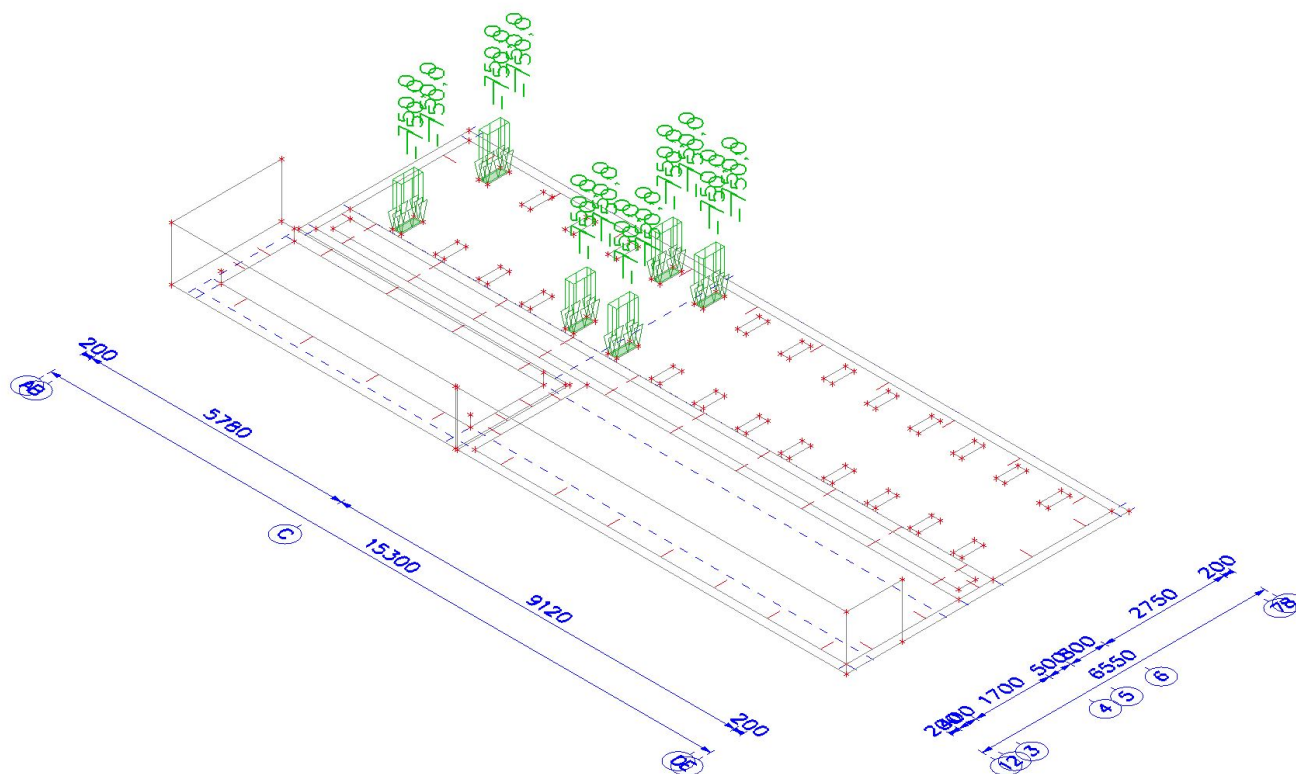
4.3.7. Loads per load case - QTL04

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL04	Traffic Load pos 4 a = 4,0 m	Variable	LG4	Static	Standard	Short	None



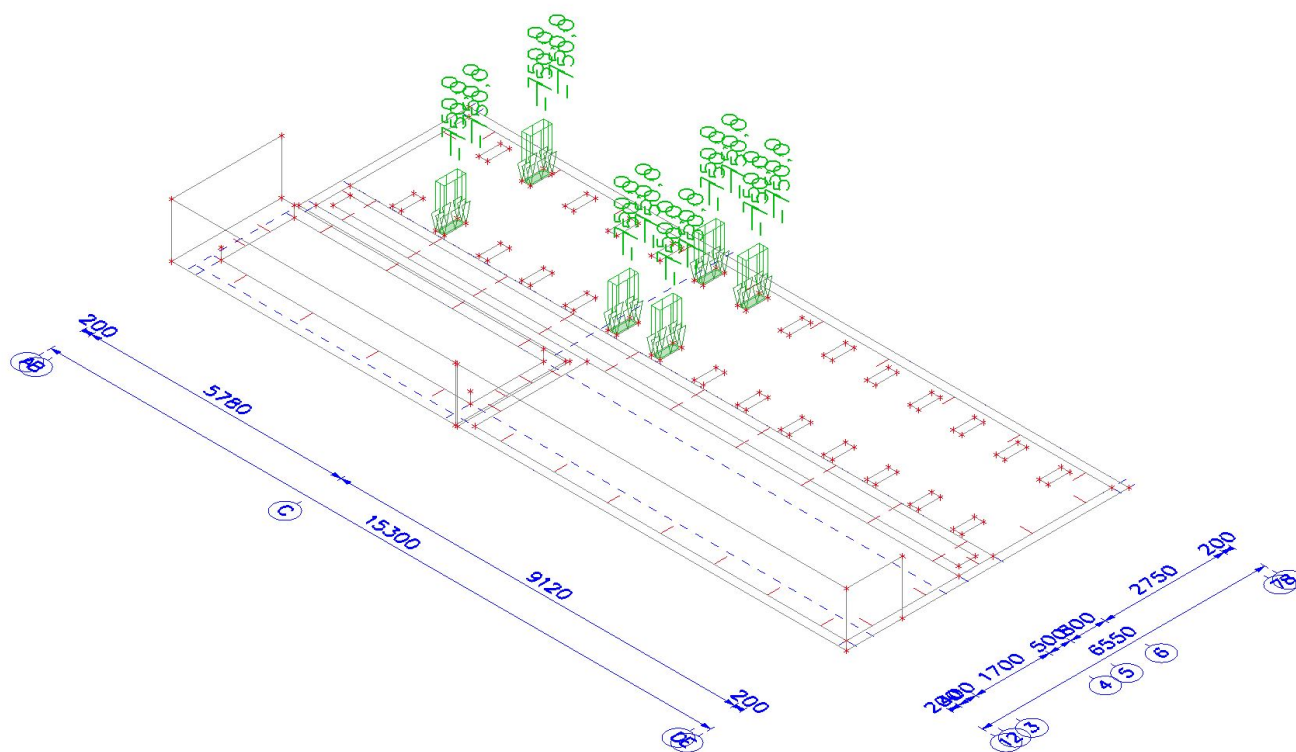
4.3.8. Loads per load case - QTL05

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL05	Traffic Load pos 5 a = 5,0 m	Variable	LG4	Static	Standard	Short	None



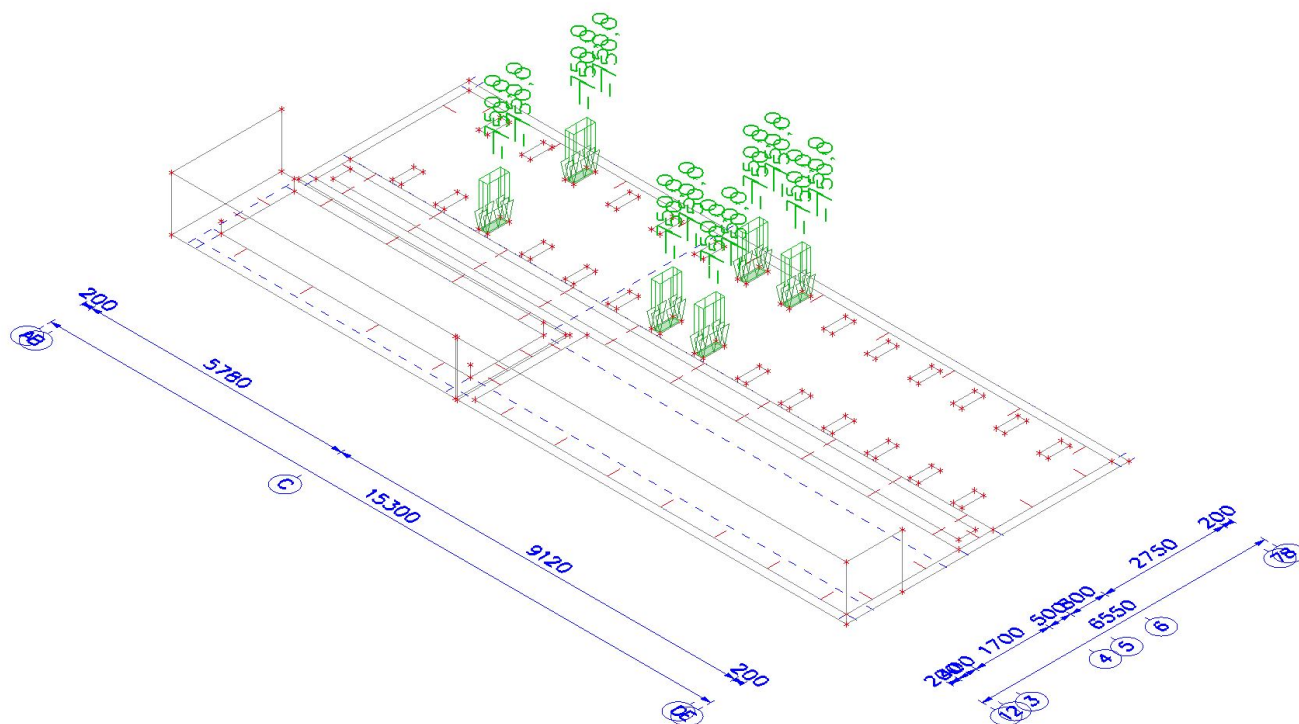
4.3.9. Loads per load case - QTL06

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL06	Traffic Load pos 6 a = 6,0 m	Variable	LG4	Static	Standard	Short	None



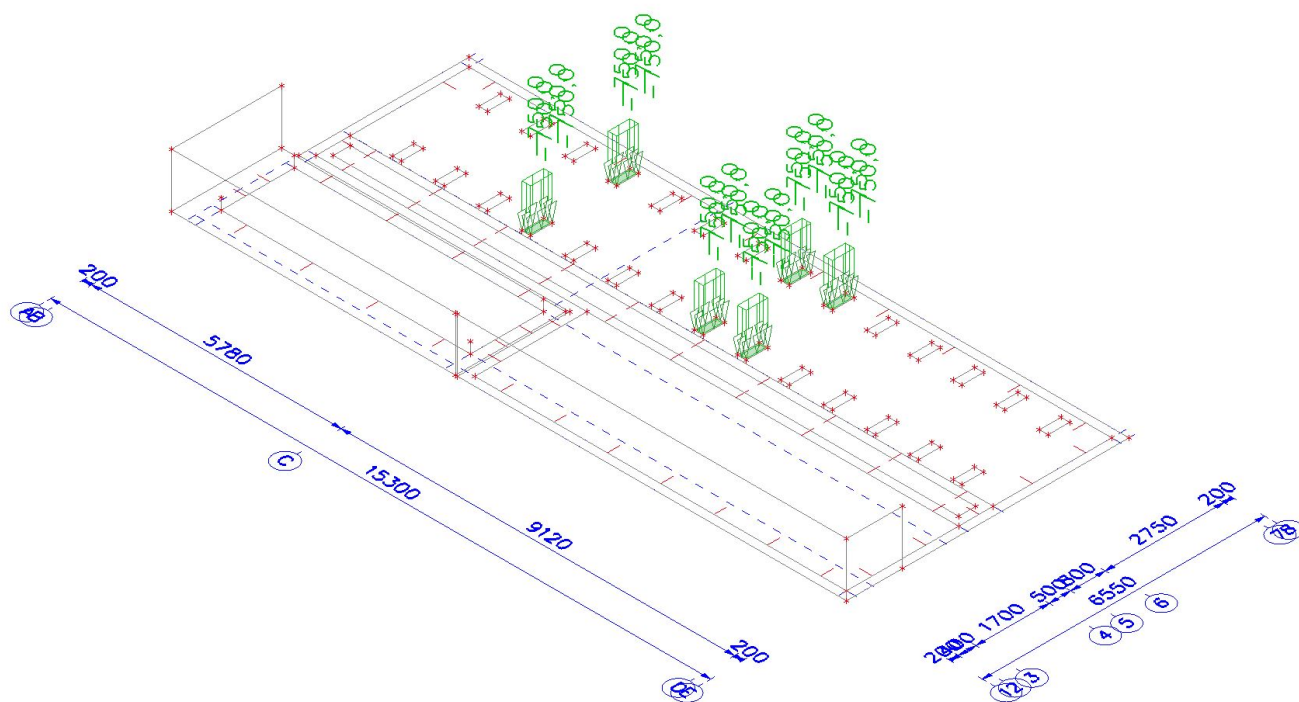
4.3.10. Loads per load case - QTL07

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL07	Traffic Load pos 7 a = 7,0 m	Variable	LG4	Static	Standard	Short	None



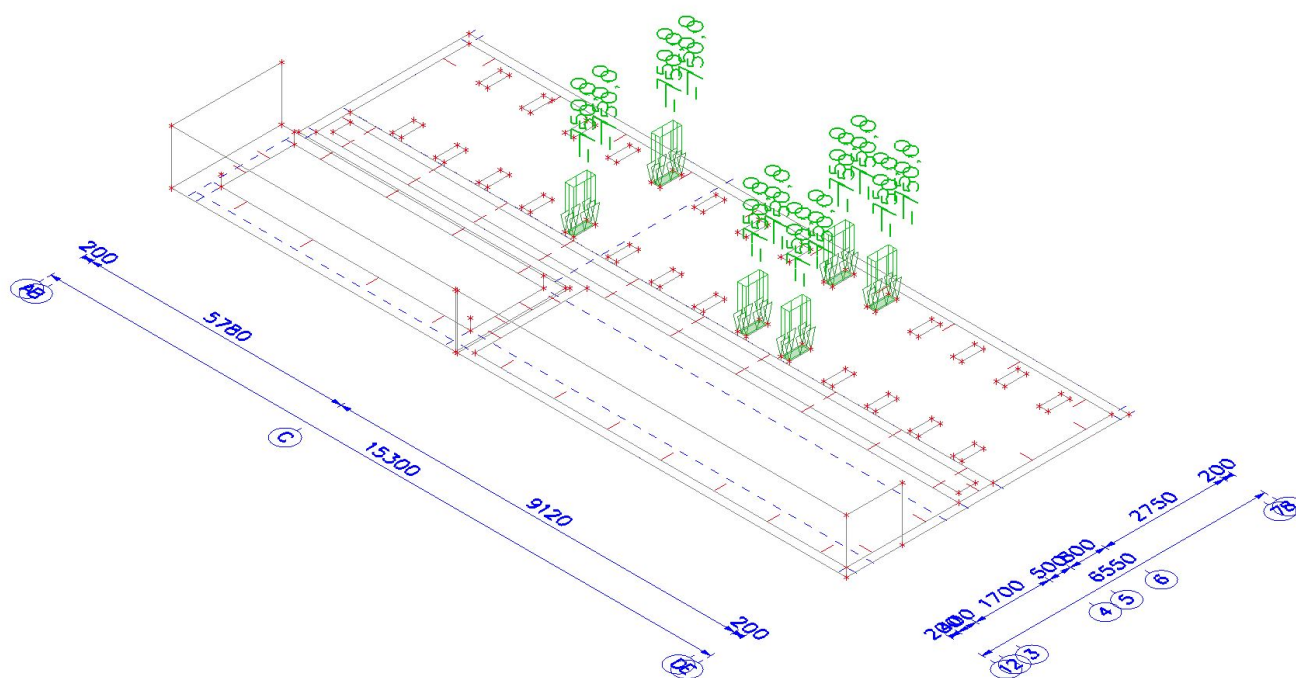
4.3.11. Loads per load case - QTL08

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL08	Traffic Load pos 8 a = 8,0 m	Variable	LG4	Static	Standard	Short	None



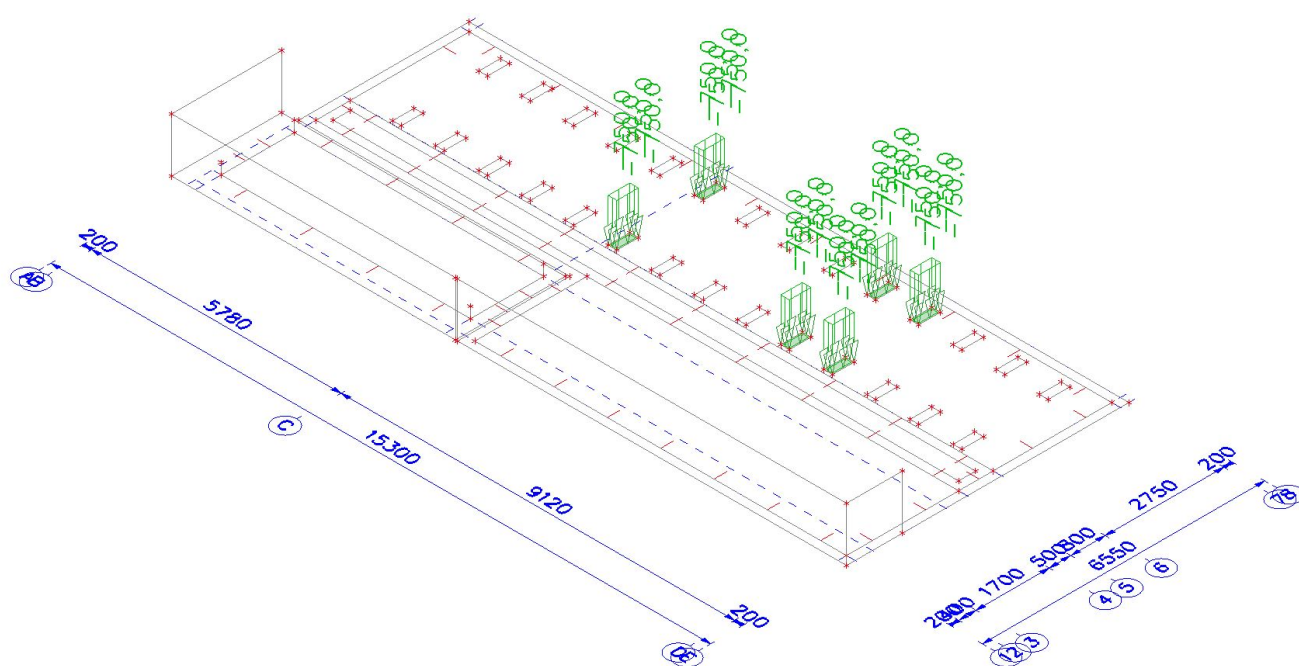
4.3.12. Loads per load case - QTL09

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL09	Traffic Load pos 9 a = 9,0 m	Variable	LG4	Static	Standard	Short	None



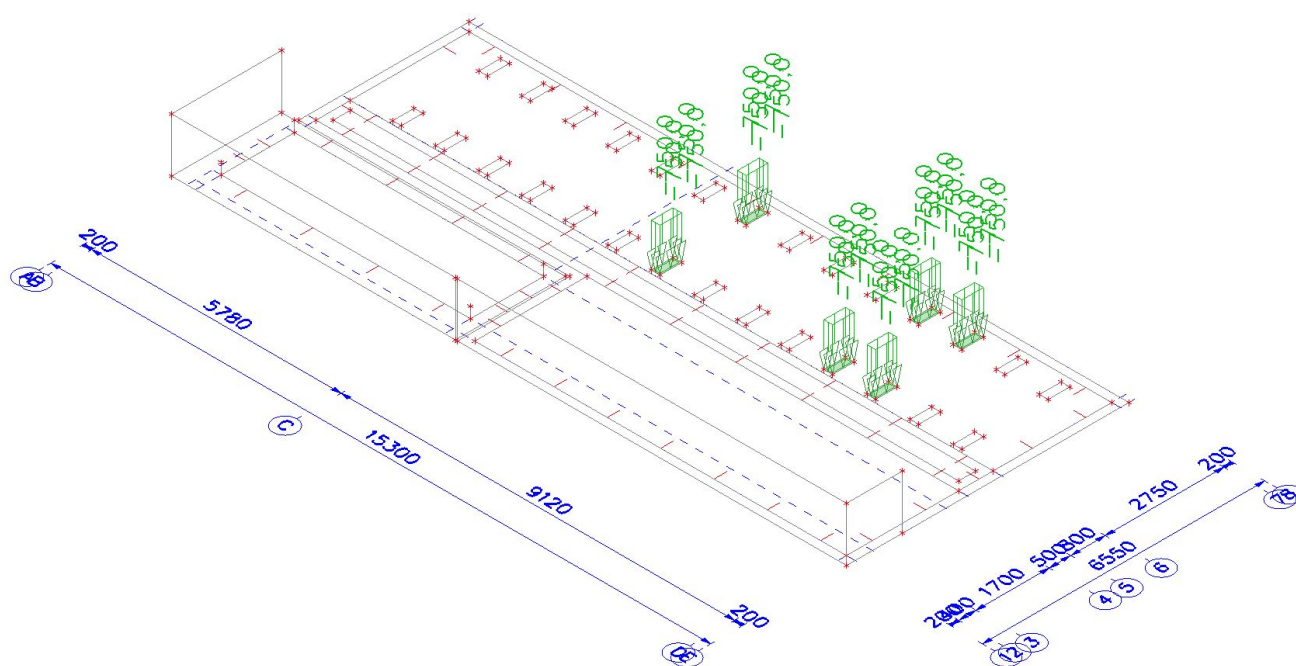
4.3.13. Loads per load case - QTL10

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL10	Traffic Load pos 10 a = 10,0 m	Variable	LG4	Static	Standard	Short	None



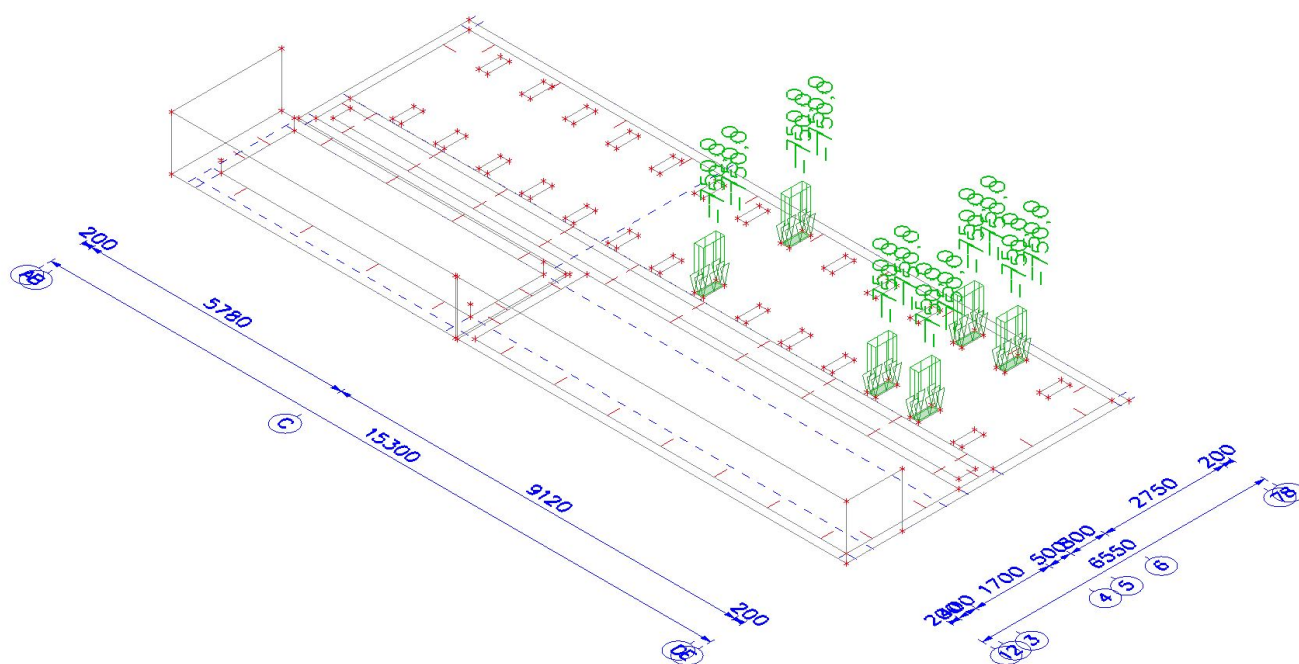
4.3.14. Loads per load case - QTL11

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL11	Traffic Load pos 11 a = 11,0 m	Variable	LG4	Static	Standard	Short	None



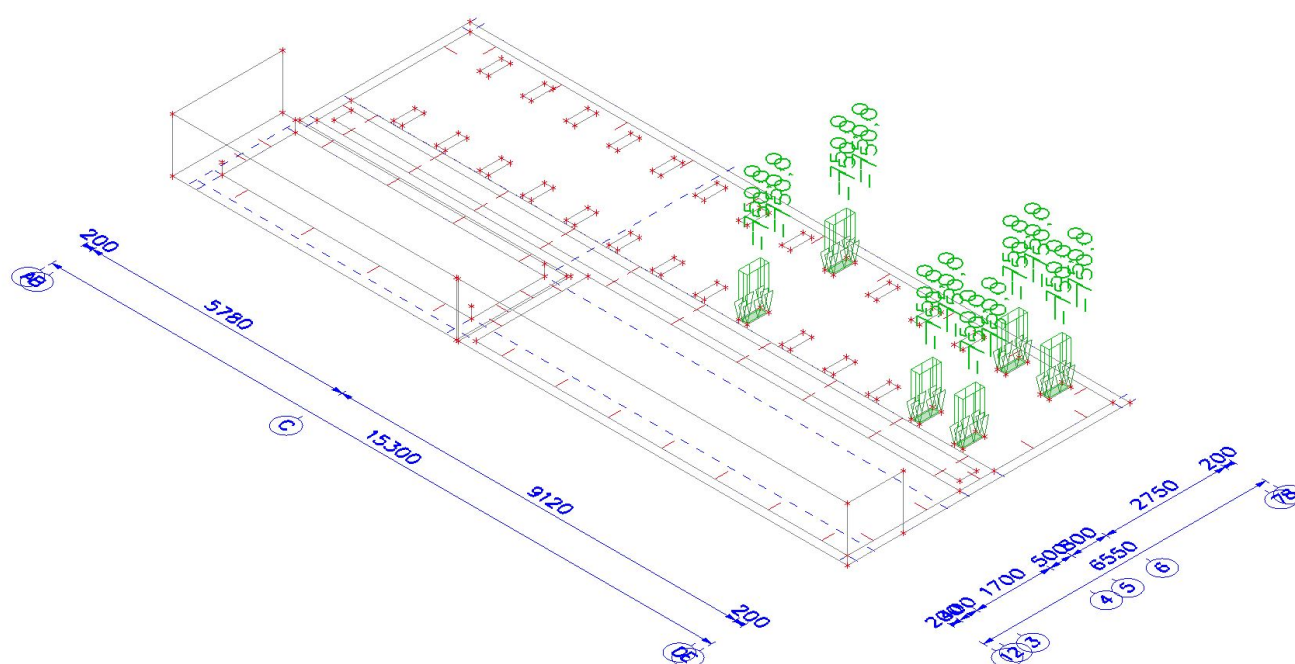
4.3.15. Loads per load case - QTL12

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL12	Traffic Load pos 12 a = 12,0 m	Variable	LG4	Static	Standard	Short	None



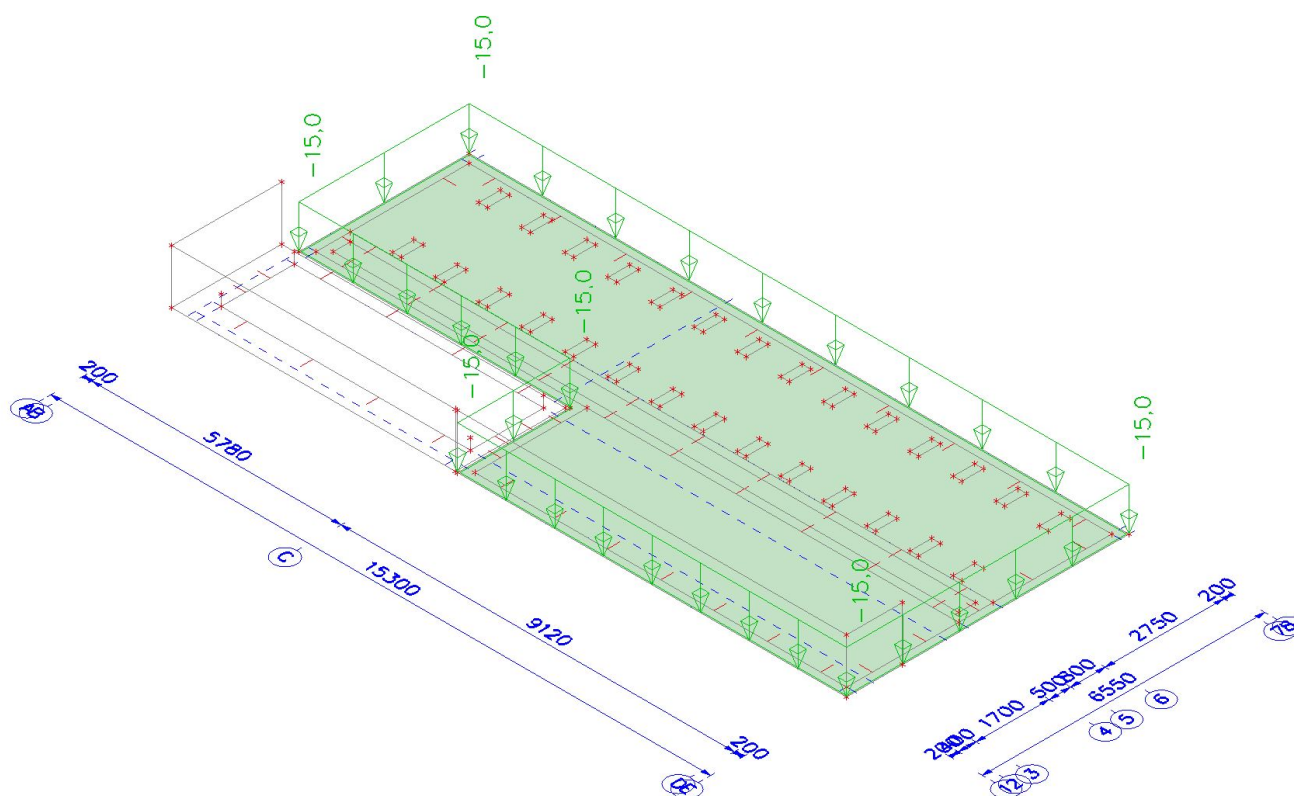
4.3.16. Loads per load case - QTL13

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL13	Traffic Load pos 13 a = 13,0 m	Variable	LG4	Static	Standard	Short	None



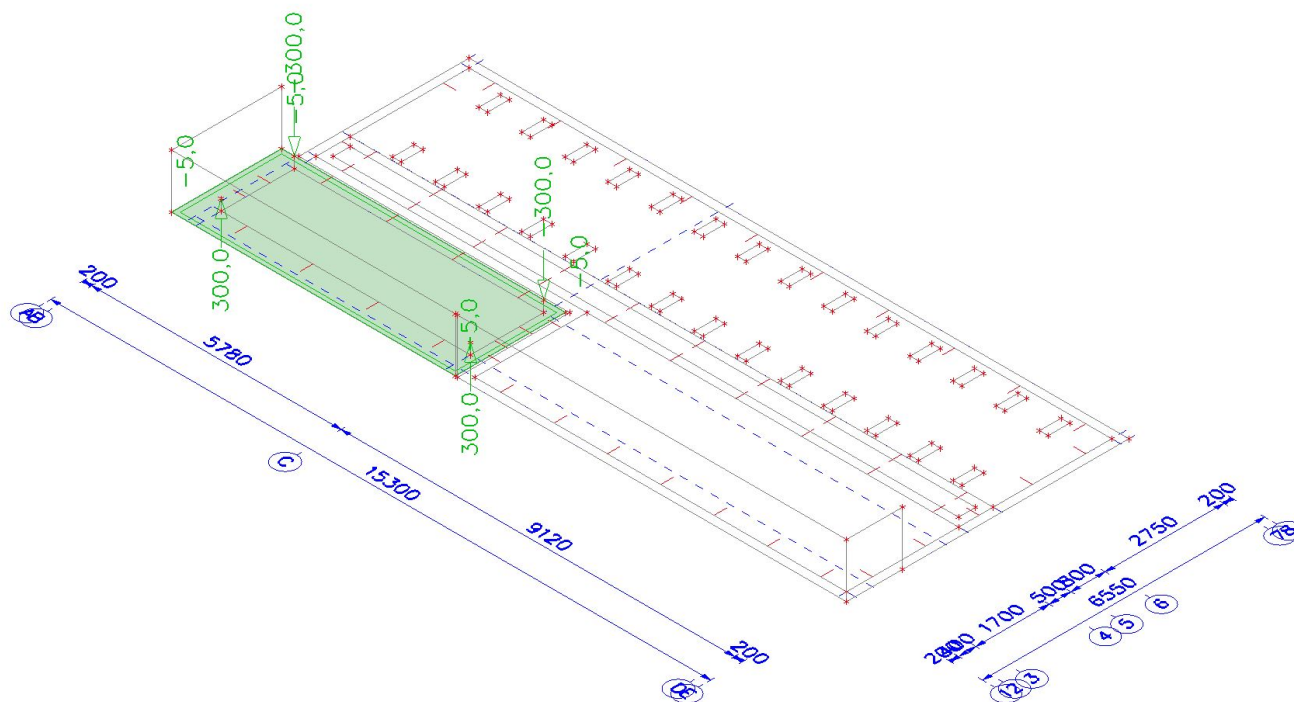
4.3.17. Loads per load case - QTL14

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
QTL14	Distributed	Variable	LG4	Static	Standard	Short	None



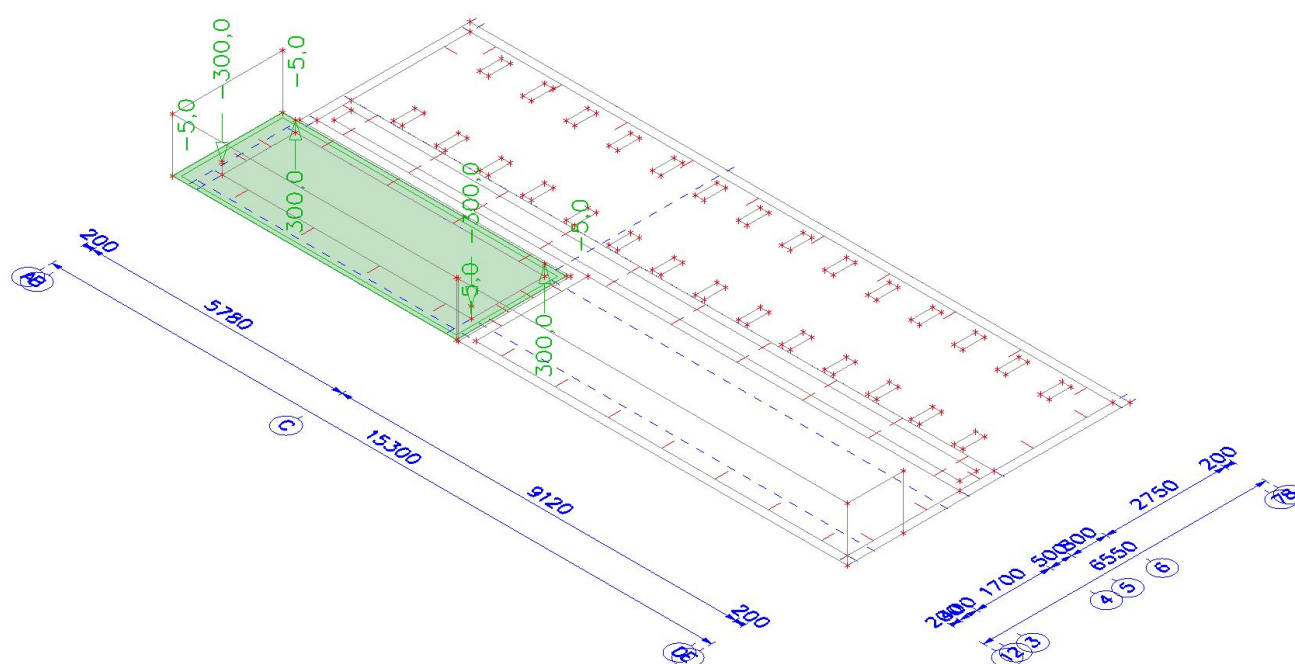
4.3.18. Loads per load case - BLC1.1

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
BLC1.1	-NB3 -NC3 +NB4 +NC4	Variable	LG5	Static	Standard	Short	None



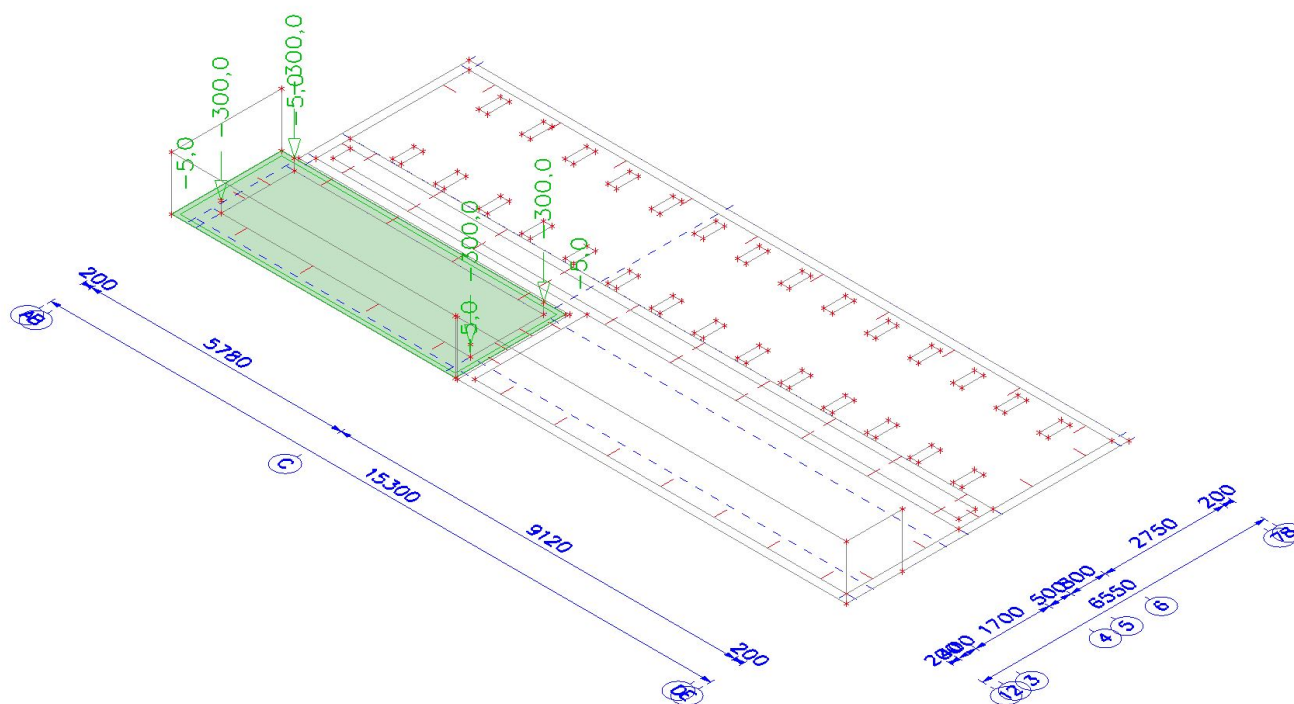
4.3.19. Loads per load case - BLC1.2

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
BLC1.2	-NB3 -NC3 +NB4 +NC4	Variable	LG5	Static	Standard	Short	None



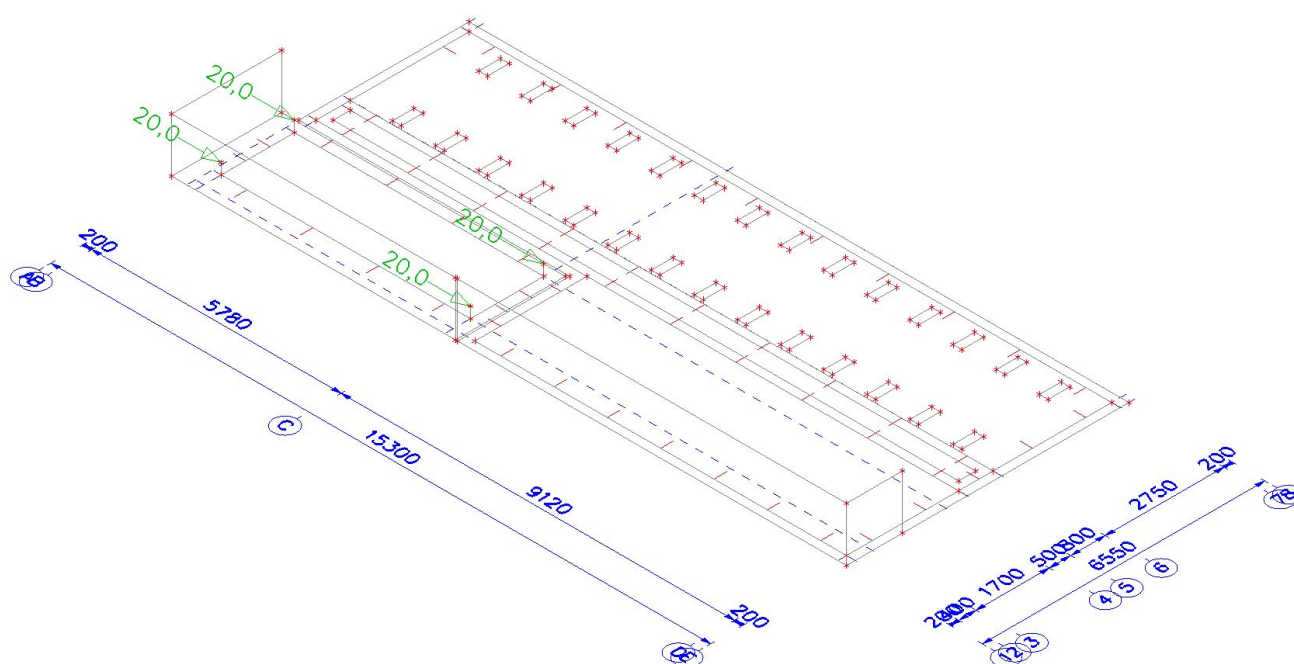
4.3.20. Loads per load case - BLC1.3

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
BLC1.3	-NB3 -NC3 -NB4 -NC4	Variable	LG5	Static	Standard	Short	None



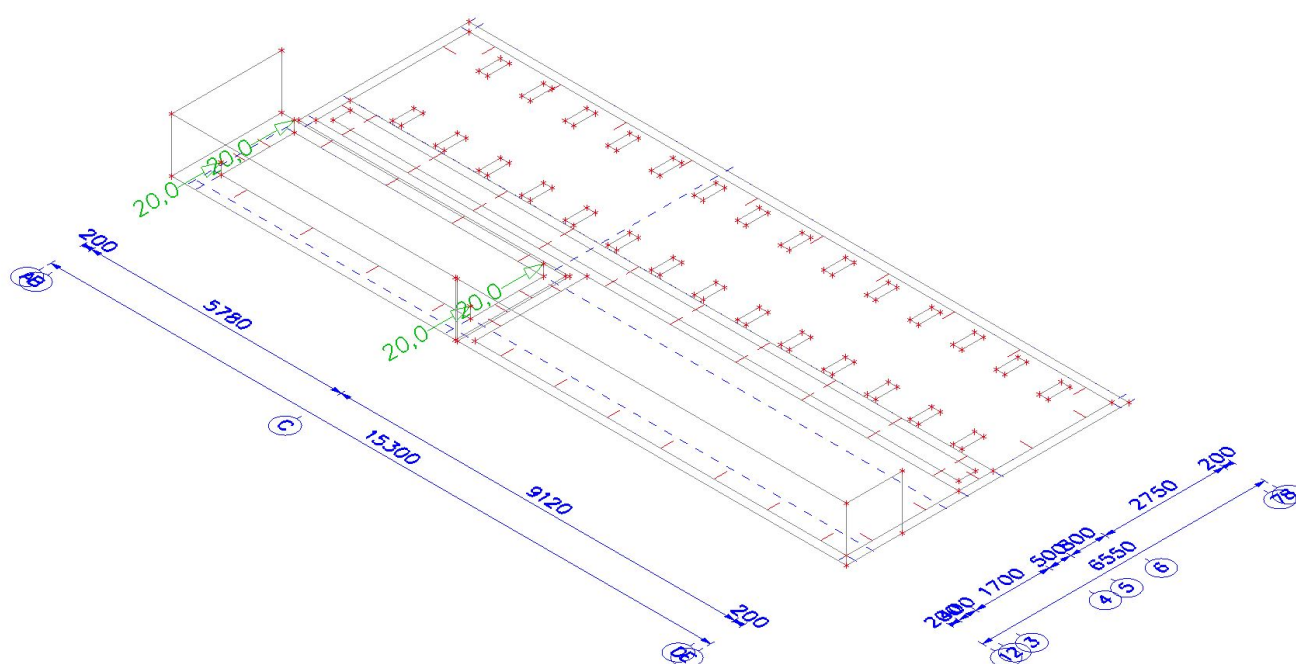
4.3.21. Loads per load case - BLC2.1

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
BLC2.1	VX	Variable	LG6	Static	Standard	Short	None



4.3.22. Loads per load case - BLC2.2

Name	Description	Action type	Load group	Load type	Spec	Duration	Master load case
BLC2.2	VY	Variable	LG6	Static	Standard	Short	None



4.4. Load combinations

Name	Type	Load cases	Coeff. [-]
NC_ULS - Set B (automatisch).1	Ultimate	GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).2	Ultimate	QTL13 - Traffic Load pos 13 a = 13,0 m	1,65
		GSW00 - Structure Self-Weight	1,32
NC_ULS - Set B (automatisch).3	Ultimate	GDL00 - Earth pressure	1,32
		QTL05 - Traffic Load pos 5 a = 5,0 m	1,65
NC_ULS - Set B (automatisch).4	Ultimate	GSW00 - Structure Self-Weight	1,32
		GDL00 - Earth pressure	1,32
NC_ULS - Set B (automatisch).5	Ultimate	QTL13 - Traffic Load pos 13 a = 13,0 m	1,65
		GSW00 - Structure Self-Weight	0,90
NC_ULS - Set B (automatisch).6	Ultimate	GDL00 - Earth pressure	0,90
		QTL09 - Traffic Load pos 9 a = 9,0 m	1,65
NC_ULS - Set B (automatisch).7	Ultimate	GSW00 - Structure Self-Weight	1,32
		GDL00 - Earth pressure	1,32
NC_ULS - Set B (automatisch).8	Ultimate	QTL09 - Traffic Load pos 9 a = 9,0 m	1,65
		GSW00 - Structure Self-Weight	0,90
NC_ULS - Set B (automatisch).9	Ultimate	GDL00 - Earth pressure	0,90
		QTL10 - Traffic Load pos 10 a = 10,0 m	1,65
NC_ULS - Set B (automatisch).10	Ultimate	GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).11	Ultimate	QTL08 - Traffic Load pos 8 a = 8,0 m	1,65
		GSW00 - Structure Self-Weight	1,32
NC_ULS - Set B (automatisch).12	Ultimate	GDL00 - Earth pressure	1,32
		QTL06 - Traffic Load pos 6 a = 6,0 m	1,65
NC_ULS - Set B (automatisch).13	Ultimate	GSW00 - Structure Self-Weight	1,32
		GDL00 - Earth pressure	1,32
NC_ULS - Set B (automatisch).14	Ultimate	QTL01 - Traffic Load pos 1 a = 1,0 m	1,65
		GSW00 - Structure Self-Weight	0,90
NC_ULS - Set B (automatisch).15	Ultimate	GDL00 - Earth pressure	0,90
		QTL10 - Traffic Load pos 10 a = 10,0 m	1,65
NC_ULS - Set B (automatisch).16	Ultimate	GSW00 - Structure Self-Weight	1,32
		GDL00 - Earth pressure	1,32
NC_ULS - Set B (automatisch).17	Ultimate	QTL11 - Traffic Load pos 11 a = 11,0 m	1,65
		GSW00 - Structure Self-Weight	0,90
NC_ULS - Set B (automatisch).18	Ultimate	GDL00 - Earth pressure	0,90
		QTL08 - Traffic Load pos 8 a = 8,0 m	1,65
NC_ULS - Set B (automatisch).19	Ultimate	GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).20	Ultimate	QTL01 - Traffic Load pos 1 a = 1,0 m	1,65
		GSW00 - Structure Self-Weight	1,32
NC_ULS - Set B (automatisch).21	Ultimate	GDL00 - Earth pressure	1,32
		QTL07 - Traffic Load pos 7 a = 7,0 m	1,65
NC_ULS - Set B (automatisch).22	Ultimate	GSW00 - Structure Self-Weight	1,32
		GDL00 - Earth pressure	1,32
NC_ULS - Set B (automatisch).23	Ultimate	QTL07 - Traffic Load pos 7 a = 7,0 m	1,65
		GSW00 - Structure Self-Weight	0,90
NC_ULS - Set B (automatisch).24	Ultimate	GDL00 - Earth pressure	0,90
		QTL06 - Traffic Load pos 6 a = 6,0 m	1,65

Name	Type	Load cases	Coeff. [-]
(automatisch).17			
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).18	Ultimate	QTL11 - Traffic Load pos 11 a = 11,0 m	1,65
		GSW00 - Structure Self-Weight	1,32
		GDL00 - Earth pressure	1,32
NC_ULS - Set B (automatisch).19	Ultimate	GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).20	Ultimate	QTL05 - Traffic Load pos 5 a = 5,0 m	1,65
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).21	Ultimate	QTL02 - Traffic Load pos 2 a = 2,0 m	1,65
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).22	Ultimate	QTL03 - Traffic Load pos 3 a = 3,0 m	1,65
		GSW00 - Structure Self-Weight	1,32
		GDL00 - Earth pressure	1,32
NC_ULS - Set B (automatisch).23	Ultimate	QTL12 - Traffic Load pos 12 a = 12,0 m	1,65
		GSW00 - Structure Self-Weight	1,32
		GDL00 - Earth pressure	1,32
NC_ULS - Set B (automatisch).24	Ultimate	QTL12 - Traffic Load pos 12 a = 12,0 m	1,65
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).25	Ultimate	QTL03 - Traffic Load pos 3 a = 3,0 m	1,65
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).26	Ultimate	QTL02 - Traffic Load pos 2 a = 2,0 m	1,65
		GSW00 - Structure Self-Weight	1,32
		GDL00 - Earth pressure	1,32
NC_ULS - Set B (automatisch).27	Ultimate	QTL04 - Traffic Load pos 4 a = 4,0 m	1,65
		GSW00 - Structure Self-Weight	1,32
		GDL00 - Earth pressure	1,32
NC_ULS - Set B (automatisch).28	Ultimate	BLC1.1 - -NB3 -NC3 +NB4 +NC4	1,65
		BLC2.1 - VX	1,65
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).29	Ultimate	BLC2.2 - VY	1,65
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).30	Ultimate	QTL04 - Traffic Load pos 4 a = 4,0 m	1,65
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).31	Ultimate	BLC2.1 - VX	1,65
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).32	Ultimate	BLC1.1 - -NB3 -NC3 +NB4 +NC4	1,65
		BLC2.2 - VY	1,65
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).33	Ultimate	BLC1.1 - -NB3 -NC3 +NB4 +NC4	1,65

Name	Type	Load cases	Coeff. [-]
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).34	Ultimate	QTL13 - Traffic Load pos 13 a = 13,0 m	1,15
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).35	Ultimate	QTL00 - Traffic Load pos 0 a = 0,0 m	1,65
		GSW00 - Structure Self-Weight	1,32
		GDL00 - Earth pressure	1,32
NC_ULS - Set B (automatisch).36	Ultimate	QTL00 - Traffic Load pos 0 a = 0,0 m	1,65
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).37	Ultimate	QTL01 - Traffic Load pos 1 a = 1,0 m	1,15
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).38	Ultimate	BLC1.1 - -NB3 -NC3 +NB4 +NC4	1,65
		BLC2.1 - VX	1,65
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).39	Ultimate	QTL02 - Traffic Load pos 2 a = 2,0 m	1,15
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).40	Ultimate	BLC2.1 - VX	1,65
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).41	Ultimate	BLC2.2 - VY	1,65
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).42	Ultimate	QTL00 - Traffic Load pos 0 a = 0,0 m	1,15
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).43	Ultimate	QTL03 - Traffic Load pos 3 a = 3,0 m	1,15
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).44	Ultimate	BLC1.1 - -NB3 -NC3 +NB4 +NC4	1,65
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).45	Ultimate	BLC1.1 - -NB3 -NC3 +NB4 +NC4	1,65
		BLC2.2 - VY	1,65
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).46	Ultimate	QTL12 - Traffic Load pos 12 a = 12,0 m	1,15
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).47	Ultimate	QTL11 - Traffic Load pos 11 a = 11,0 m	1,15
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).48	Ultimate	QTL05 - Traffic Load pos 5 a = 5,0 m	1,15
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).49	Ultimate	QTL10 - Traffic Load pos 10 a = 10,0 m	1,15

Name	Type	Load cases	Coeff. [-]
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).50	Ultimate	QTL04 - Traffic Load pos 4 a = 4,0 m	1,15
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).51	Ultimate	QTL09 - Traffic Load pos 9 a = 9,0 m	1,15
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).52	Ultimate	QTL08 - Traffic Load pos 8 a = 8,0 m	1,15
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).53	Ultimate	QTL06 - Traffic Load pos 6 a = 6,0 m	1,15
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).54	Ultimate	QTL07 - Traffic Load pos 7 a = 7,0 m	1,15
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).55	Ultimate	BLC1.2 - -NB3 -NC3 +NB4 +NC4	1,65
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).56	Ultimate	BLC1.2 - -NB3 -NC3 +NB4 +NC4	1,65
		BLC2.1 - VX	1,65
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).57	Ultimate	BLC1.2 - -NB3 -NC3 +NB4 +NC4	1,65
		BLC2.2 - VY	1,65
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).58	Ultimate	BLC1.2 - -NB3 -NC3 +NB4 +NC4	1,65
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).59	Ultimate	BLC1.2 - -NB3 -NC3 +NB4 +NC4	1,65
		BLC2.1 - VX	1,65
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).60	Ultimate	BLC1.2 - -NB3 -NC3 +NB4 +NC4	1,65
		BLC2.2 - VY	1,65
		GSW00 - Structure Self-Weight	0,90
		GDL00 - Earth pressure	0,90
NC_ULS - Set B (automatisch).61	Ultimate	BLC1.3 - -NB3 -NC3 -NB4 -NC4	1,65
		BLC2.1 - VX	1,65
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_ULS - Set B (automatisch).62	Ultimate	BLC1.3 - -NB3 -NC3 -NB4 -NC4	1,65
		BLC2.2 - VY	1,65
		GSW00 - Structure Self-Weight	1,49
		GDL00 - Earth pressure	1,49
NC_SLS - Characteristic (automatisch).1	Serviceability	GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic	Serviceability	QTL09 - Traffic Load pos 9 a = 9,0 m	1,00

Name	Type	Load cases	Coeff. [-]
(automatisch).2			
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).3	Serviceability	QTL13 - Traffic Load pos 13 a = 13,0 m	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).4	Serviceability	QTL05 - Traffic Load pos 5 a = 5,0 m	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).5	Serviceability	QTL10 - Traffic Load pos 10 a = 10,0 m	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).6	Serviceability	QTL01 - Traffic Load pos 1 a = 1,0 m	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).7	Serviceability	QTL08 - Traffic Load pos 8 a = 8,0 m	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).8	Serviceability	QTL06 - Traffic Load pos 6 a = 6,0 m	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).9	Serviceability	QTL11 - Traffic Load pos 11 a = 11,0 m	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).10	Serviceability	QTL07 - Traffic Load pos 7 a = 7,0 m	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).11	Serviceability	QTL02 - Traffic Load pos 2 a = 2,0 m	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).12	Serviceability	QTL03 - Traffic Load pos 3 a = 3,0 m	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).13	Serviceability	QTL12 - Traffic Load pos 12 a = 12,0 m	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).14	Serviceability	QTL04 - Traffic Load pos 4 a = 4,0 m	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).15	Serviceability	QTL00 - Traffic Load pos 0 a = 0,0 m	1,00

Name	Type	Load cases	Coeff. [-]
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).16	Serviceability	BLC1.1 - -NB3 -NC3 +NB4 +NC4	1,00
		BLC2.1 - VX	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).17	Serviceability	BLC2.2 - VY	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).18	Serviceability	BLC2.1 - VX	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).19	Serviceability	BLC1.1 - -NB3 -NC3 +NB4 +NC4	1,00
		BLC2.2 - VY	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).20	Serviceability	BLC1.1 - -NB3 -NC3 +NB4 +NC4	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).21	Serviceability	BLC1.2 - -NB3 -NC3 +NB4 +NC4	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).22	Serviceability	BLC1.2 - -NB3 -NC3 +NB4 +NC4	1,00
		BLC2.1 - VX	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).23	Serviceability	BLC1.2 - -NB3 -NC3 +NB4 +NC4	1,00
		BLC2.2 - VY	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).24	Serviceability	BLC1.3 - -NB3 -NC3 -NB4 -NC4	1,00
		BLC2.1 - VX	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Characteristic (automatisch).25	Serviceability	BLC1.3 - -NB3 -NC3 -NB4 -NC4	1,00
		BLC2.2 - VY	1,00
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).1	Serviceability	GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).2	Serviceability	QTL09 - Traffic Load pos 9 a = 9,0 m	0,30
		GSW00 - Structure Self-Weight	1,00

Name	Type	Load cases	Coeff. [-]
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).3	Serviceability	QTL13 - Traffic Load pos 13 a = 13,0 m	0,30
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).4	Serviceability	QTL05 - Traffic Load pos 5 a = 5,0 m	0,30
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).5	Serviceability	QTL10 - Traffic Load pos 10 a = 10,0 m	0,30
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).6	Serviceability	QTL01 - Traffic Load pos 1 a = 1,0 m	0,30
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).7	Serviceability	QTL08 - Traffic Load pos 8 a = 8,0 m	0,30
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).8	Serviceability	QTL06 - Traffic Load pos 6 a = 6,0 m	0,30
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).9	Serviceability	QTL11 - Traffic Load pos 11 a = 11,0 m	0,30
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).10	Serviceability	QTL07 - Traffic Load pos 7 a = 7,0 m	0,30
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).11	Serviceability	QTL02 - Traffic Load pos 2 a = 2,0 m	0,30
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).12	Serviceability	QTL03 - Traffic Load pos 3 a = 3,0 m	0,30
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).13	Serviceability	QTL12 - Traffic Load pos 12 a = 12,0 m	0,30
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).14	Serviceability	QTL04 - Traffic Load pos 4 a = 4,0 m	0,30
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).15	Serviceability	QTL00 - Traffic Load pos 0 a = 0,0 m	0,30
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00

Name	Type	Load cases	Coeff. [-]
NC_SLS - Quasi-permanent (automatisch).16	Serviceability	BLC1.1 - -NB3 -NC3 +NB4 +NC4	0,80
		BLC2.1 - VX	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).17	Serviceability	BLC2.2 - VY	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).18	Serviceability	BLC2.1 - VX	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).19	Serviceability	BLC1.1 - -NB3 -NC3 +NB4 +NC4	0,80
		BLC2.2 - VY	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).20	Serviceability	BLC1.1 - -NB3 -NC3 +NB4 +NC4	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).21	Serviceability	BLC1.2 - -NB3 -NC3 +NB4 +NC4	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).22	Serviceability	BLC1.2 - -NB3 -NC3 +NB4 +NC4	0,80
		BLC2.1 - VX	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).23	Serviceability	BLC1.2 - -NB3 -NC3 +NB4 +NC4	0,80
		BLC2.2 - VY	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).24	Serviceability	BLC1.3 - -NB3 -NC3 -NB4 -NC4	0,80
		BLC2.1 - VX	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Quasi-permanent (automatisch).25	Serviceability	BLC1.3 - -NB3 -NC3 -NB4 -NC4	0,80
		BLC2.2 - VY	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).1	Serviceability	GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).2	Serviceability	QTL09 - Traffic Load pos 9 a = 9,0 m	0,50
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).3	Serviceability	QTL13 - Traffic Load pos 13 a = 13,0 m	0,50
		GSW00 - Structure Self-Weight	1,00

Name	Type	Load cases	Coeff. [-]
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).4	Serviceability	QTL05 - Traffic Load pos 5 a = 5,0 m	0,50
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).5	Serviceability	QTL10 - Traffic Load pos 10 a = 10,0 m	0,50
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).6	Serviceability	QTL01 - Traffic Load pos 1 a = 1,0 m	0,50
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).7	Serviceability	QTL08 - Traffic Load pos 8 a = 8,0 m	0,50
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).8	Serviceability	QTL06 - Traffic Load pos 6 a = 6,0 m	0,50
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).9	Serviceability	QTL11 - Traffic Load pos 11 a = 11,0 m	0,50
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).10	Serviceability	QTL07 - Traffic Load pos 7 a = 7,0 m	0,50
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).11	Serviceability	QTL02 - Traffic Load pos 2 a = 2,0 m	0,50
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).12	Serviceability	QTL03 - Traffic Load pos 3 a = 3,0 m	0,50
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).13	Serviceability	QTL12 - Traffic Load pos 12 a = 12,0 m	0,50
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).14	Serviceability	QTL04 - Traffic Load pos 4 a = 4,0 m	0,50
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).15	Serviceability	QTL00 - Traffic Load pos 0 a = 0,0 m	0,50
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).16	Serviceability	BLC1.1 - -NB3 -NC3 +NB4 +NC4	0,90
		BLC2.1 - VX	0,80
		GSW00 - Structure Self-Weight	1,00
NC_SLS - Frequent (automatisch).17	Serviceability	GDL00 - Earth pressure	1,00
		BLC2.2 - VY	0,90
		GSW00 - Structure Self-Weight	1,00
NC_SLS - Frequent (automatisch).18	Serviceability	GDL00 - Earth pressure	1,00
		BLC2.1 - VX	0,90
		GSW00 - Structure Self-Weight	1,00
NC_SLS - Frequent (automatisch).19	Serviceability	GDL00 - Earth pressure	1,00
		BLC1.1 - -NB3 -NC3 +NB4 +NC4	0,90
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00

Name	Type	Load cases	Coeff. [-]
NC_SLS - Frequent (automatisch).20	Serviceability	BLC1.1 - -NB3 -NC3 +NB4 +NC4	0,90
		BLC2.2 - VY	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).21	Serviceability	BLC1.1 - -NB3 -NC3 +NB4 +NC4	0,80
		BLC2.1 - VX	0,90
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).22	Serviceability	BLC1.1 - -NB3 -NC3 +NB4 +NC4	0,80
		BLC2.2 - VY	0,90
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).23	Serviceability	BLC1.2 - -NB3 -NC3 +NB4 +NC4	0,90
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).24	Serviceability	BLC1.2 - -NB3 -NC3 +NB4 +NC4	0,90
		BLC2.1 - VX	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).25	Serviceability	BLC1.2 - -NB3 -NC3 +NB4 +NC4	0,90
		BLC2.2 - VY	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).26	Serviceability	BLC1.2 - -NB3 -NC3 +NB4 +NC4	0,80
		BLC2.2 - VY	0,90
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).27	Serviceability	BLC1.3 - -NB3 -NC3 -NB4 -NC4	0,90
		BLC2.1 - VX	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00
NC_SLS - Frequent (automatisch).28	Serviceability	BLC1.3 - -NB3 -NC3 -NB4 -NC4	0,90
		BLC2.2 - VY	0,80
		GSW00 - Structure Self-Weight	1,00
		GDL00 - Earth pressure	1,00

5. Internal forces for foundation check

5.1. ULS internal forces

5.1.1. 1D Elements Global results per section

5.1.1.1. Summary

Nonlinear calculation

Class: RC_NC_ULS - Set B (automatisch)

Coordinate system: Principal

Extreme 1D: Global

Selection: S71..S81

Name	dx [m]	Case	N [kN]	V _y [kN]	V _z [kN]	M _x [kNm]	M _y [kNm]	M _z [kNm]
S77	9,437-	NC_ULS - Set B (automatisch).14	-140,2	-0,5	-1,4	-0,9	-40,4	0,0
S77	10,430-	NC_ULS - Set B (automatisch).30	232,7	0,3	0,4	0,0	73,4	2,1
S79	6,280-	NC_ULS - Set B (automatisch).20	15,1	-27,5	-12,0	-1,9	11,7	-6,2
S71	0,000	NC_ULS - Set B (automatisch).33	0,2	26,7	39,6	1,2	-10,2	-14,5
S74	5,780	NC_ULS - Set B (automatisch).28	22,6	-1,6	-108,6	0,3	-7,3	-14,5
S74	0,000	NC_ULS - Set B (automatisch).33	22,4	3,2	94,6	0,2	-12,5	-10,8
S74	4,775-	NC_ULS - Set B (automatisch).33	121,5	-19,1	-34,9	-3,9	41,9	-0,2
S74	1,005-	NC_ULS - Set B (automatisch).56	118,3	15,8	38,8	3,5	34,9	0,9
S77	9,685-	NC_ULS - Set B (automatisch).14	-140,1	-0,6	0,8	-0,9	-40,6	-0,2
S72	2,764-	NC_ULS - Set B (automatisch).32	153,7	-0,5	2,0	-0,1	95,4	-4,9
S74	5,780	NC_ULS - Set B (automatisch).33	28,4	-2,1	-104,8	0,3	-0,9	-14,7
S74	3,016-	NC_ULS - Set B (automatisch).33	184,1	-0,3	0,1	-0,3	54,1	10,2

5.1.1.2. 1D internal forces; N

Values: **N**

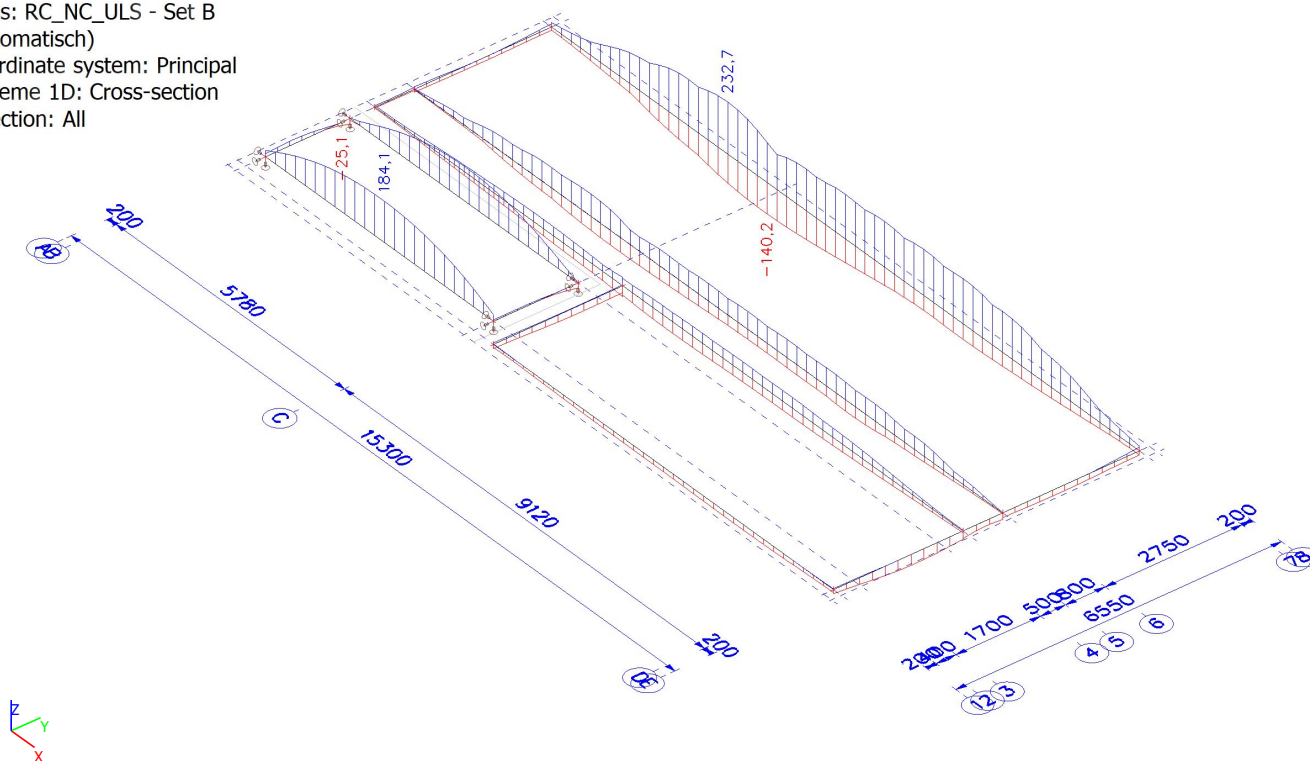
Nonlinear calculation

Class: RC_NC_ULS - Set B
(automatisch)

Coordinate system: Principal

Extreme 1D: Cross-section

Selection: All



5.1.1.3. 1D internal forces; M_y

Values: **M_y**

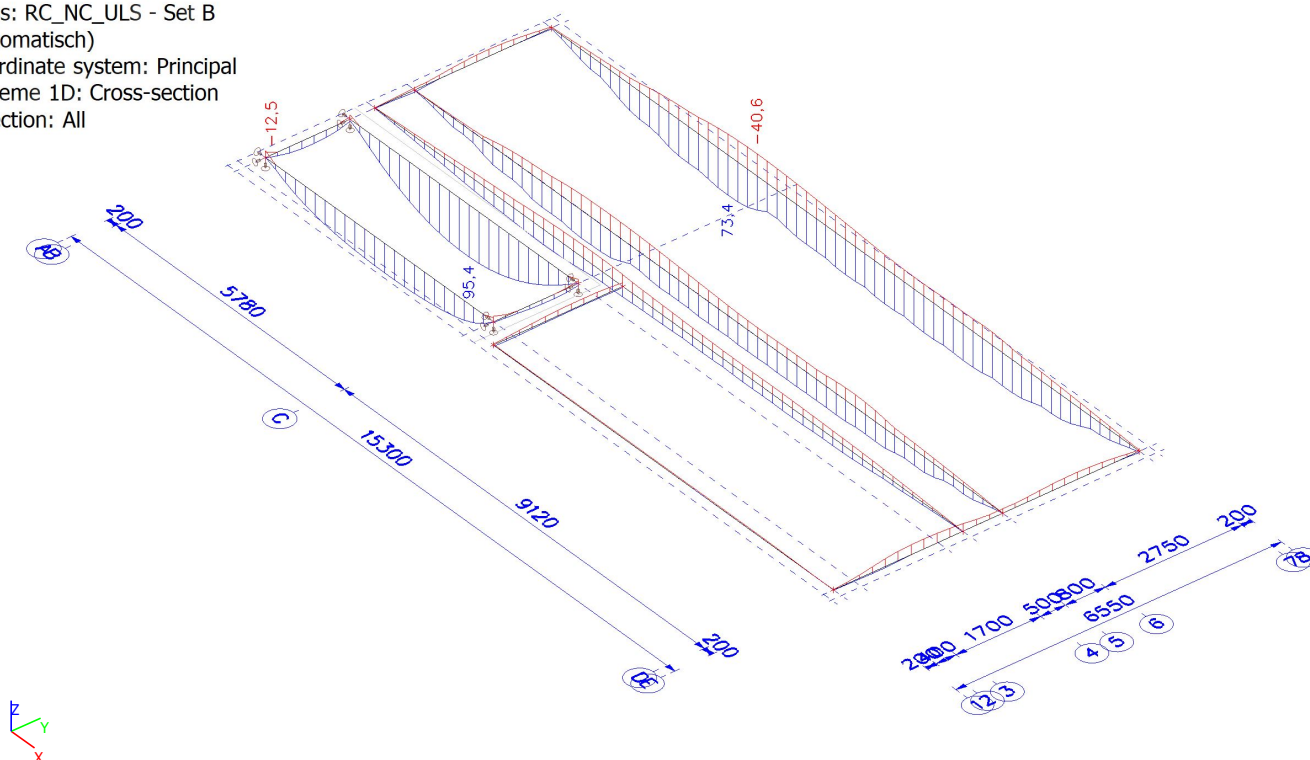
Nonlinear calculation

Class: RC_NC_ULS - Set B
(automatisch)

Coordinate system: Principal

Extreme 1D: Cross-section

Selection: All



5.1.1.4. 1D internal forces; V_z

Values: V_z

Nonlinear calculation

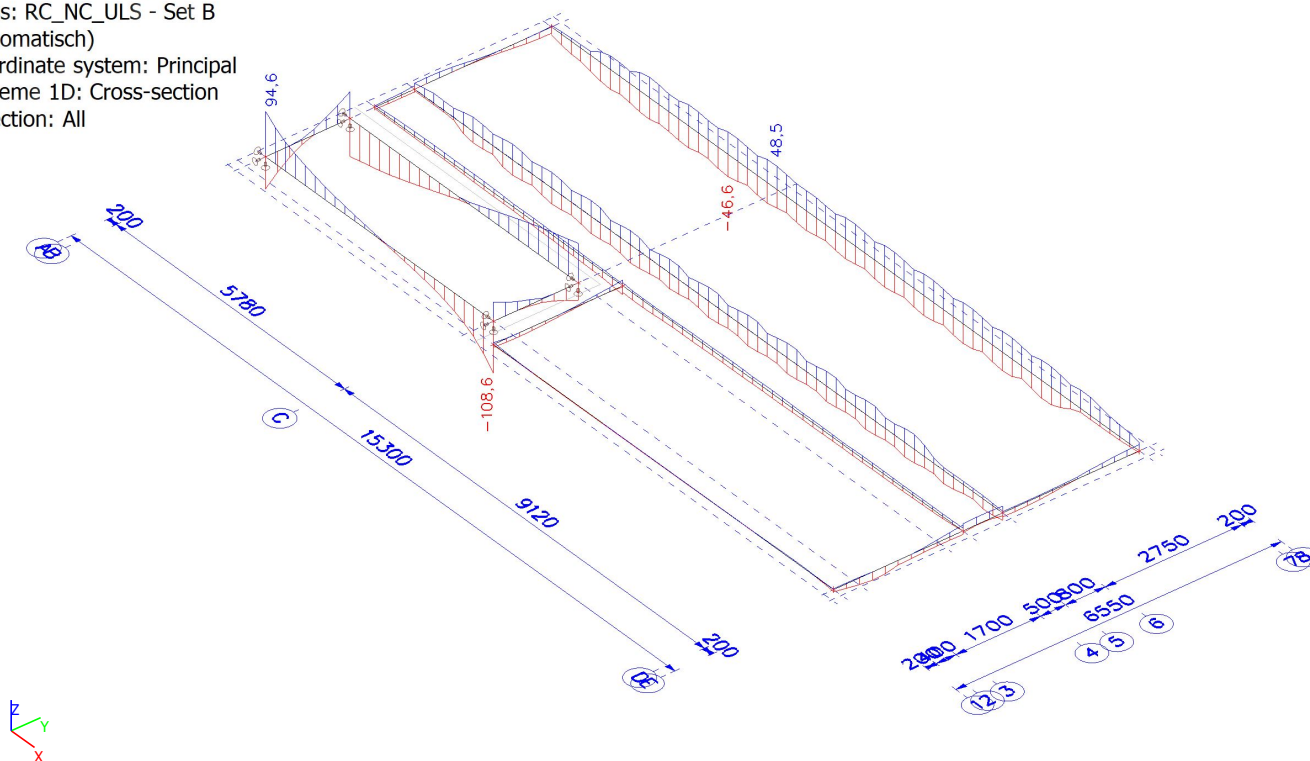
Class: RC_NC_ULS - Set B

(automatisch)

Coordinate system: Principal

Extreme 1D: Cross-section

Selection: All



5.1.2. 2D Elements Global results

5.1.2.1. Summary

Nonlinear calculation

Class: RC_NC_ULS - Set B (automatisch)

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]	m _{cD+} [kNm/m] m _{cD-} [kNm/m]	n _{xD} [kN/m]	n _{yD} [kN/m]	n _{cD} [kN/m]
E1	Element: 1443 Node: 1517	4,150 3,197 0,000	NC_ULS - Set B (automatisch).14	-39,4 0,0	-14,3 15,0	-33,6 -35,1	0,0	2,4	-173,1
E1	Element: 1444 Node: 461	4,150 3,393 0,000	NC_ULS - Set B (automatisch).30	0,0 44,7	-4,0 4,1	-39,0 -13,7	226,4	13,0	-35,2
E3	Element: 1659 Node: 134	15,300 1,300 0,000	NC_ULS - Set B (automatisch).2	-11,2 0,0	-22,9 0,0	-12,2 -19,0	101,8	126,4	-91,0
E4	Element: 1841 Node: 1935	5,977 0,000 0,000	NC_ULS - Set B (automatisch).33	0,0 8,9	0,0 36,3	-31,0 -13,5	35,8	3,1	-70,6
E1	Element: 434 Node: 441	1,150 3,000 0,000	NC_ULS - Set B (automatisch).18	-0,2 0,0	-0,1 0,0	0,0 -0,2	0,9	2,3	-4,2
E1	Element: 1453 Node: 1522	2,900 3,197 0,000	NC_ULS - Set B (automatisch).14	-30,8 13,9	-21,3 23,4	-44,6 -44,6	0,0	4,4	-71,4
E2	Element: 1583 Node: 1644	15,300 0,000 1,000	NC_ULS - Set B (automatisch).10	0,0 0,4	0,0 0,1	-0,4 0,0	0,0	-0,9	-2,8
E6	Element: 2100 Node: 1963	-0,350 0,765 0,000	NC_ULS - Set B (automatisch).28	-2,6 2,8	-1,7 3,7	-5,4 -5,4	-36,7	0,0	-59,9
E1	Element: 1439 Node: 427	4,650 3,000 0,000	NC_ULS - Set B (automatisch).30	0,0 35,4	-2,0 0,0	-35,3 -2,0	360,4	2,9	-0,2
E1	Element: 1359 Node: 119	14,900 3,000 0,000	NC_ULS - Set B (automatisch).12	-5,6 11,5	-6,8 10,4	-17,2 -17,2	0,0	-50,4	-85,0
E3	Element: 1659 Node: 134	15,300 1,300 0,000	NC_ULS - Set B (automatisch).4	-10,4 0,0	-20,2 0,0	-11,3 -16,7	104,2	134,7	-93,2
E5	Element: 2004 Node: 2108	2,940 0,000 1,250	NC_ULS - Set B (automatisch).61	-3,1 0,0	-0,4 0,0	-0,7 -2,8	0,0	-1,5	-262,4
E2	Element: 1636 Node: 1698	10,790 0,000 1,250	NC_ULS - Set B (automatisch).37	0,0 0,8	0,0 0,1	-0,7 -0,2	51,5	0,1	0,0

5.1.2.2. 2D internal forces; m_{xD+}

Values: m_{xD+}

Nonlinear calculation

Class: RC_NC_ULS - Set B
(automatisch)

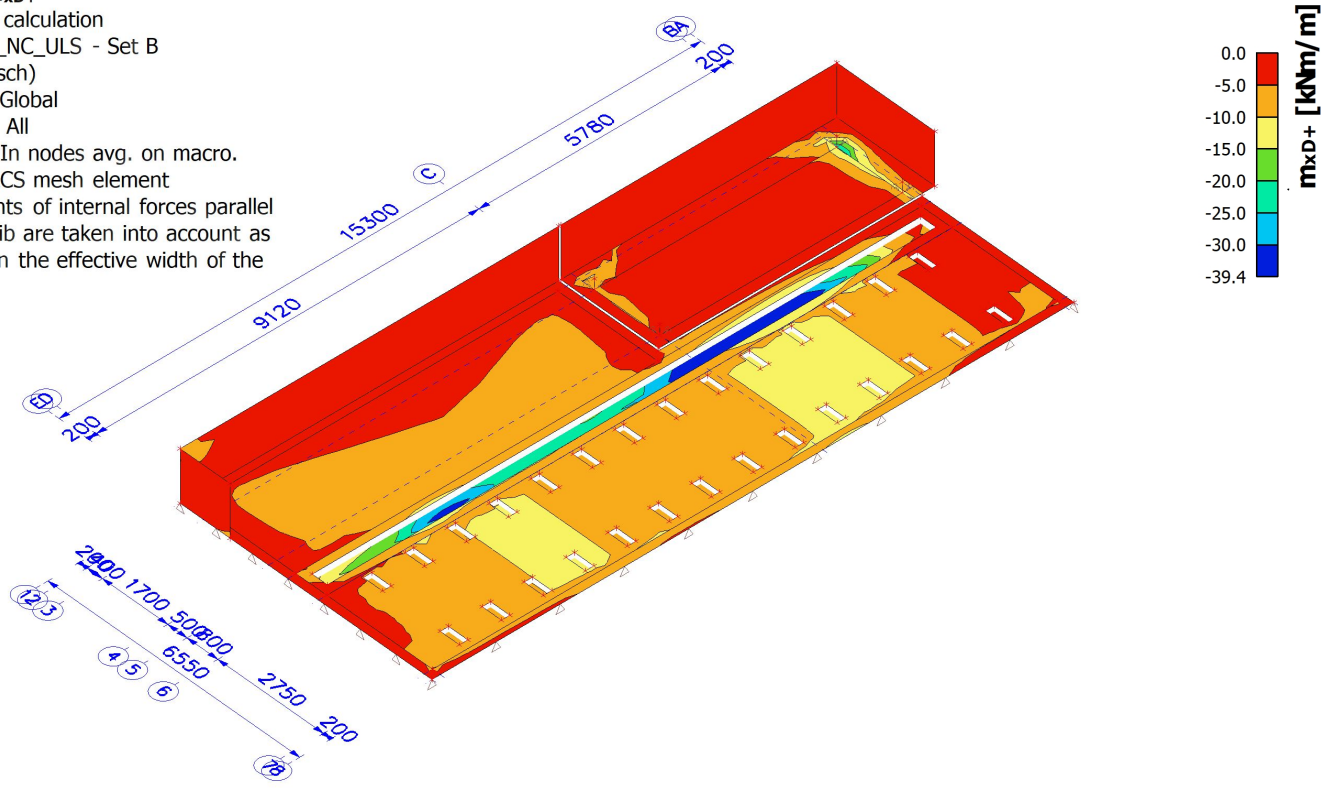
Extreme: Global

Selection: All

Location: In nodes avg. on macro.

System: LCS mesh element

Components of internal forces parallel with the rib are taken into account as zero within the effective width of the rib.



5.1.2.3. 2D internal forces; m_{xD-}

Values: m_{xD-}

Nonlinear calculation

Class: RC_NC_ULS - Set B
(automatisch)

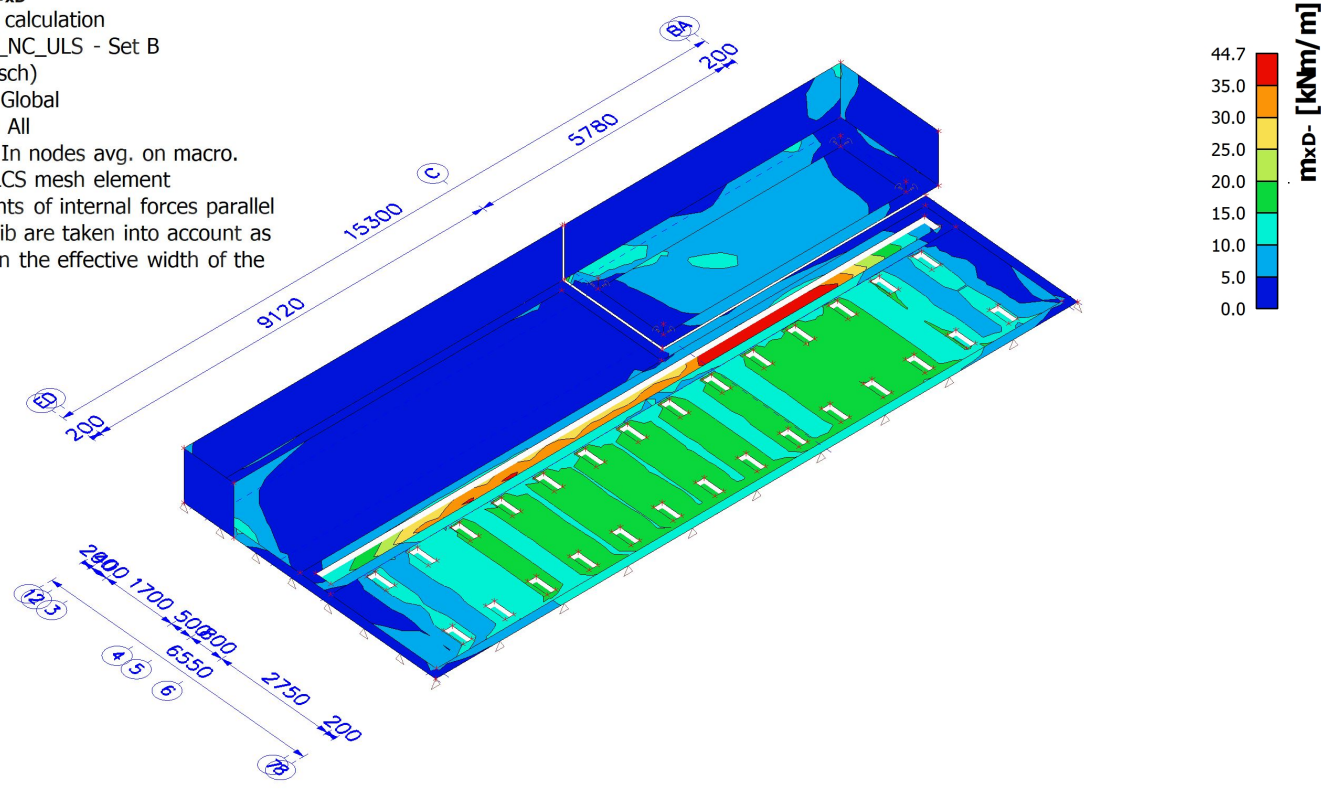
Extreme: Global

Selection: All

Location: In nodes avg. on macro.

System: LCS mesh element

Components of internal forces parallel with the rib are taken into account as zero within the effective width of the rib.



5.1.2.4. 2D internal forces; m_{yD+}

Values: m_{yD+}

Nonlinear calculation

Class: RC_NC_ULS - Set B
(automatisch)

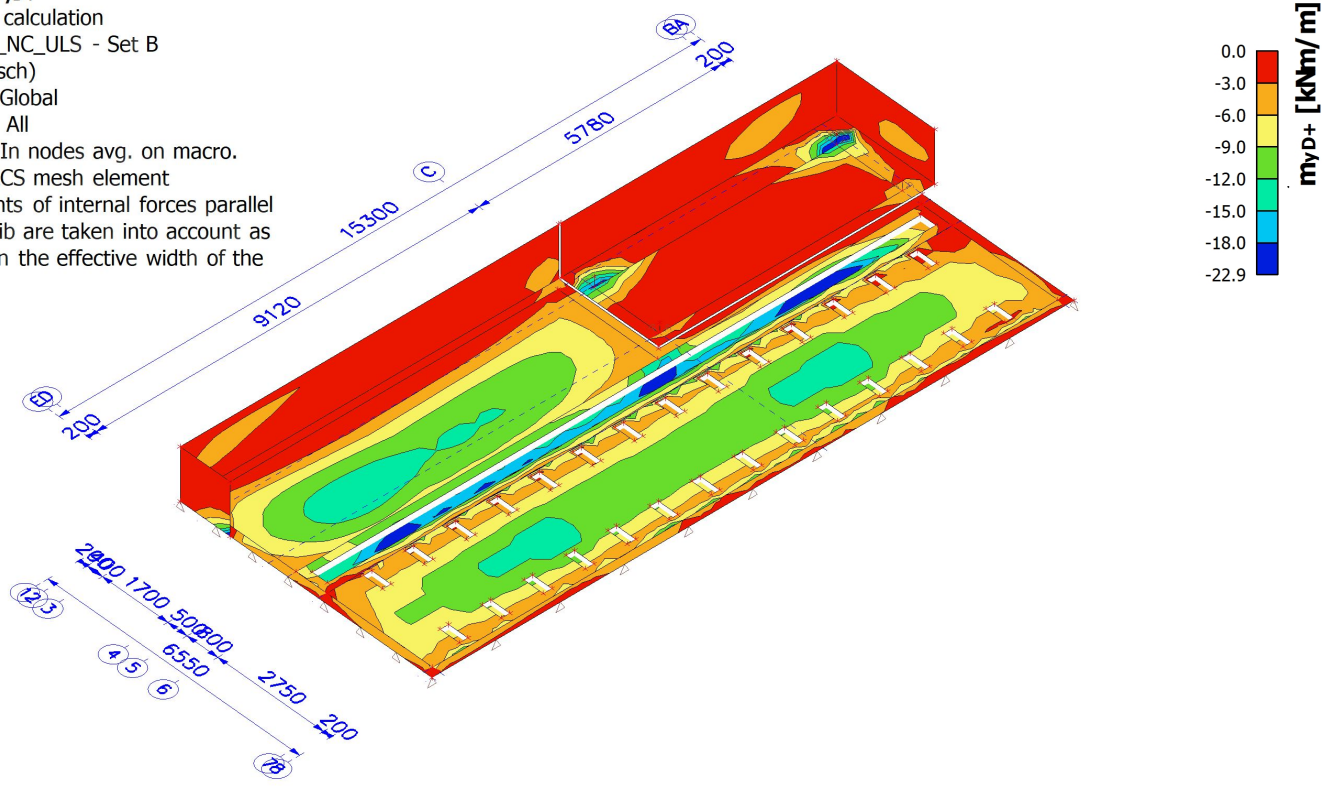
Extreme: Global

Selection: All

Location: In nodes avg. on macro.

System: LCS mesh element

Components of internal forces parallel with the rib are taken into account as zero within the effective width of the rib.



5.1.2.5. 2D internal forces; m_{yD-}

Values: m_{yD-}

Nonlinear calculation

Class: RC_NC_ULS - Set B
(automatisch)

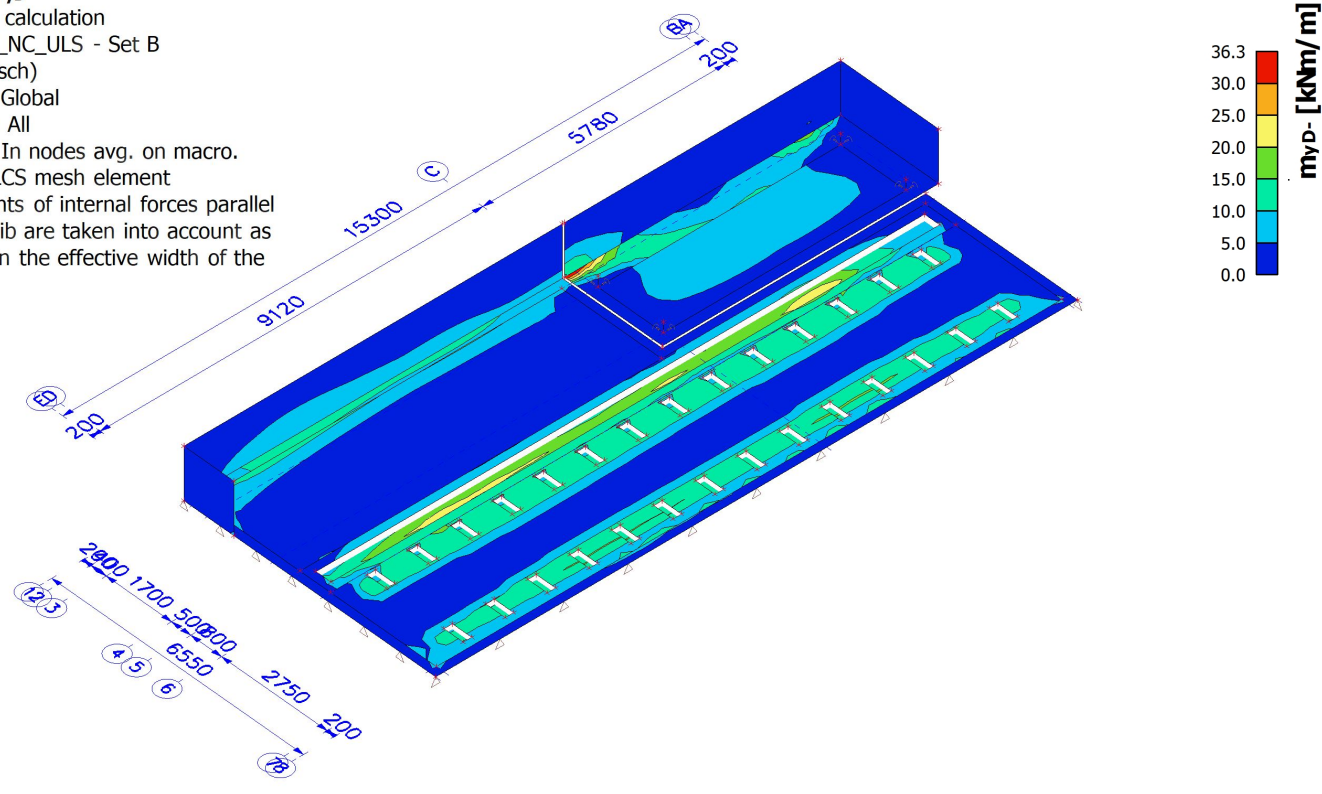
Extreme: Global

Selection: All

Location: In nodes avg. on macro.

System: LCS mesh element

Components of internal forces parallel with the rib are taken into account as zero within the effective width of the rib.



5.1.2.6. 2D internal forces; n_{xD}

Values: n_{xD}

Nonlinear calculation

Class: RC_NC_ULS - Set B
(automatisch)

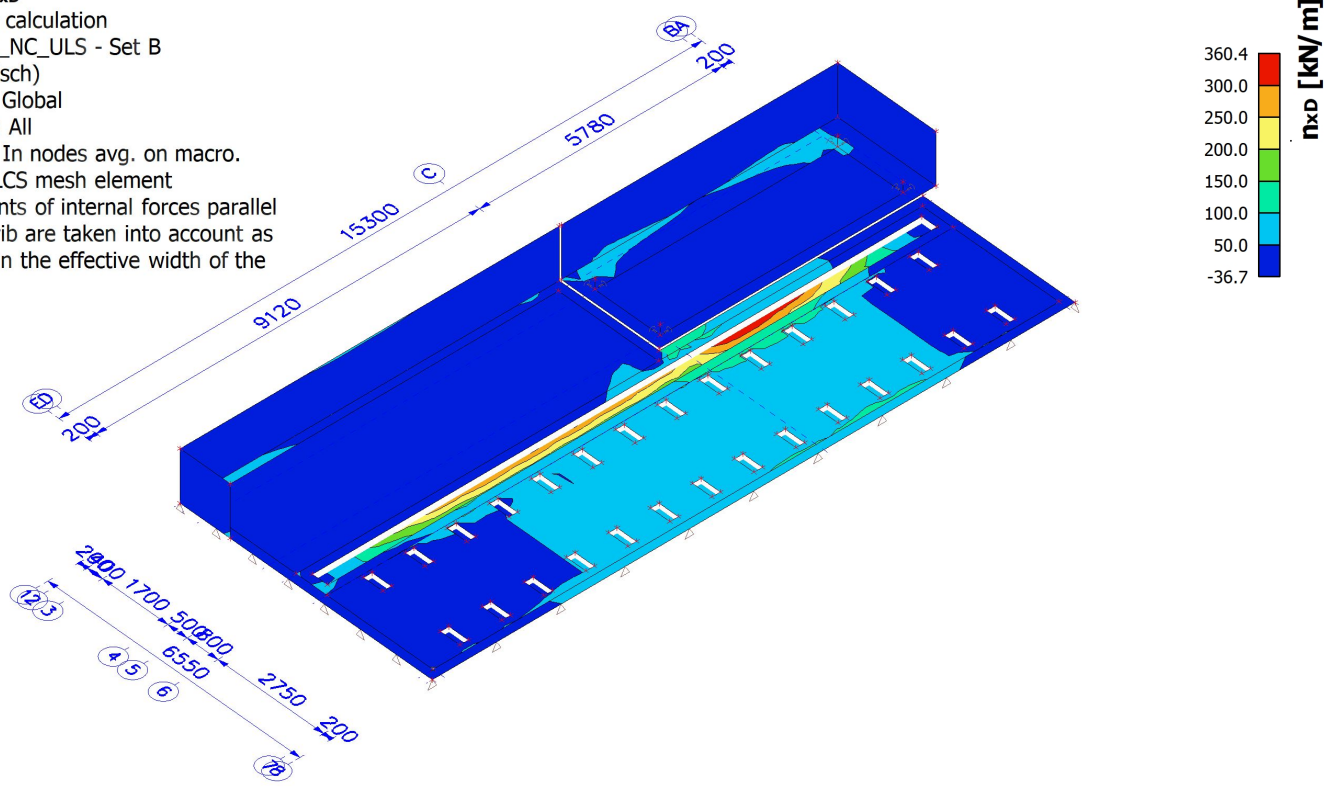
Extreme: Global

Selection: All

Location: In nodes avg. on macro.

System: LCS mesh element

Components of internal forces parallel with the rib are taken into account as zero within the effective width of the rib.



5.1.2.7. 2D internal forces; n_{yD}

Values: n_{yD}

Nonlinear calculation

Class: RC_NC_ULS - Set B
(automatisch)

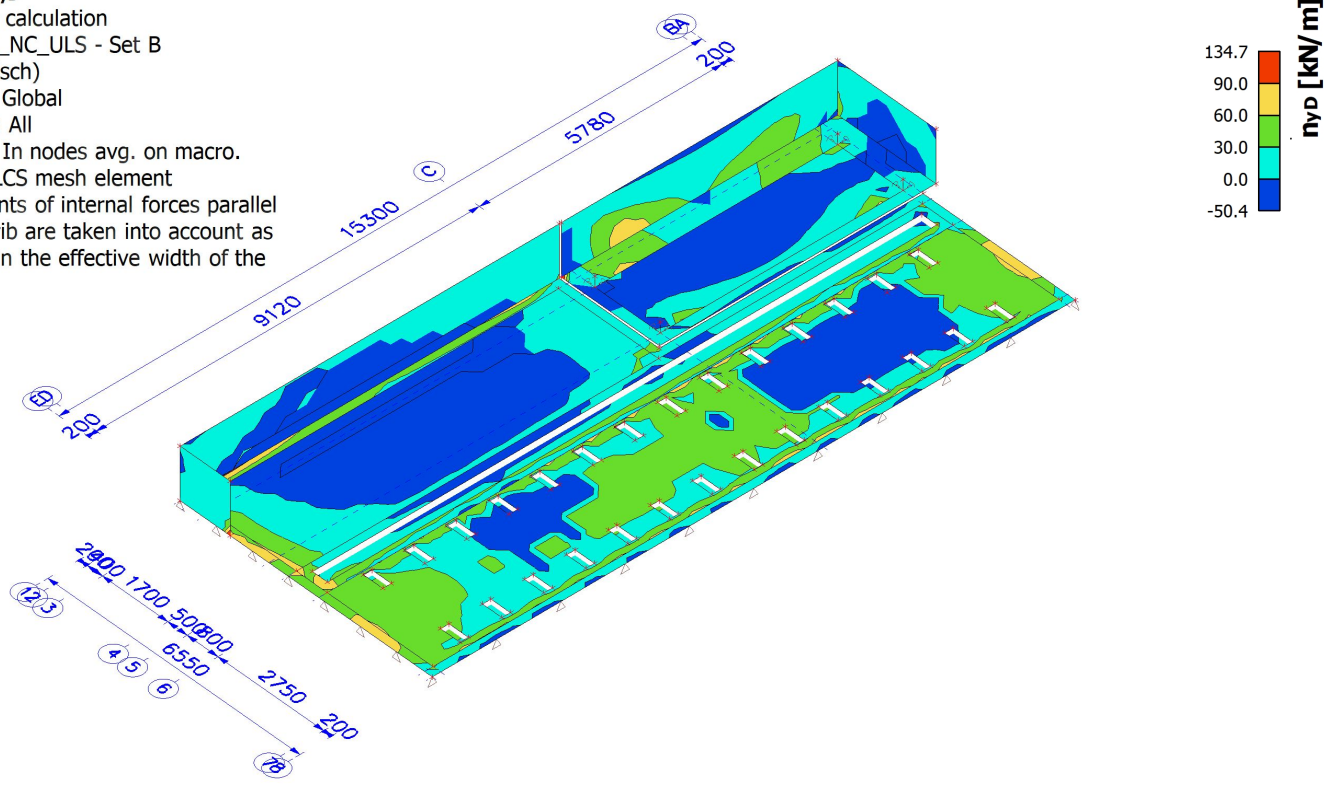
Extreme: Global

Selection: All

Location: In nodes avg. on macro.

System: LCS mesh element

Components of internal forces parallel with the rib are taken into account as zero within the effective width of the rib.



5.2. SLS internal forces for crack width check

5.2.1. 1D Elements Global results per section

5.2.1.1. Summary

Nonlinear calculation

Class: RC_NC_SLS - Frequent (automatisch)

Coordinate system: Principal

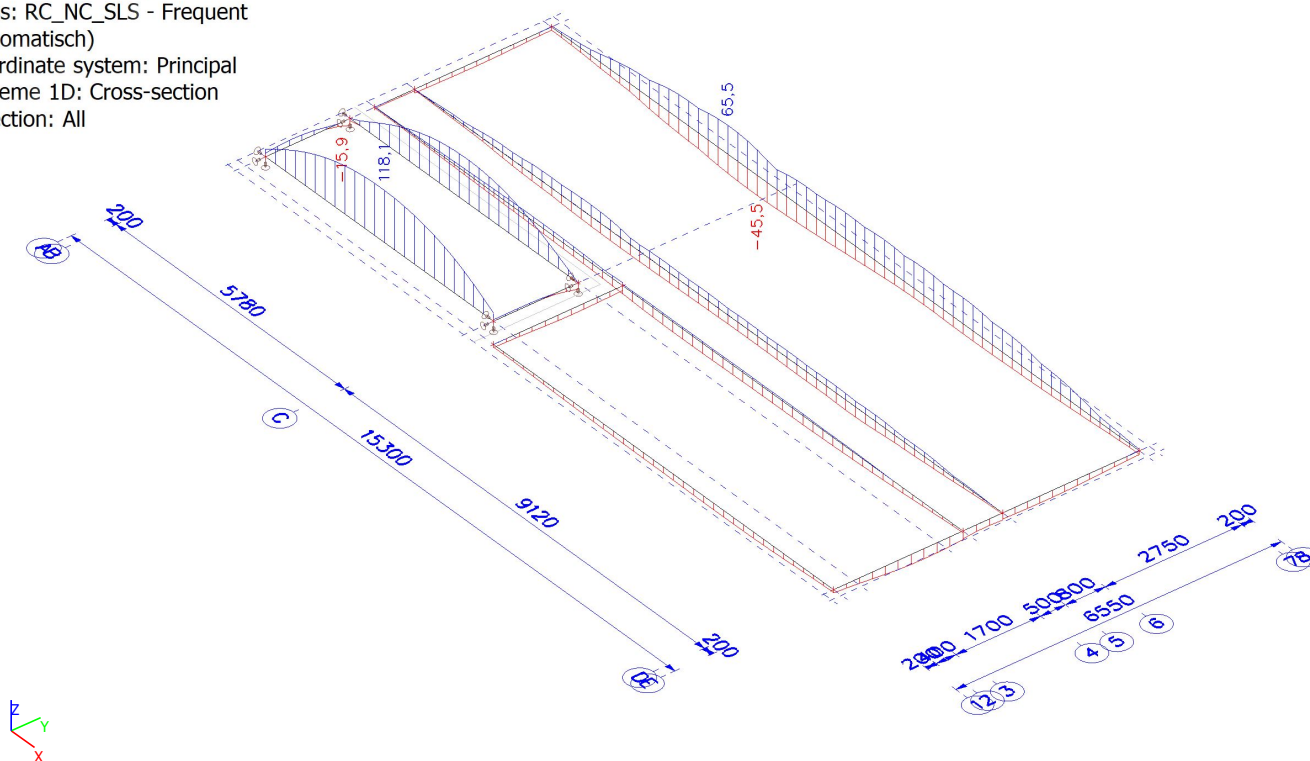
Extreme 1D: Global

Selection: S71..S81

Name	dx [m]	Case	N [kN]	V _y [kN]	V _z [kN]	M _x [kNm]	M _y [kNm]	M _z [kNm]
S74	5,026-	NC_SLS - Frequent (automatisch).19	65,5	-13,9	-29,0	-2,4	23,3	-2,9
S71	0,000	NC_SLS - Frequent (automatisch).19	0,3	17,1	25,7	0,8	-6,7	-9,3
S74	5,780	NC_SLS - Frequent (automatisch).16	15,3	-1,0	-69,4	0,2	-3,7	-9,3
S74	0,000	NC_SLS - Frequent (automatisch).19	14,4	1,8	61,1	0,1	-8,1	-6,9
S74	4,775-	NC_SLS - Frequent (automatisch).19	78,0	-12,2	-22,4	-2,5	27,0	-0,1
S74	1,005-	NC_SLS - Frequent (automatisch).24	75,1	10,1	25,4	2,2	22,1	0,5
S77	9,685-	NC_SLS - Frequent (automatisch).6	-45,5	-0,2	-0,2	-0,2	-13,4	-0,1
S72	2,764-	NC_SLS - Frequent (automatisch).20	99,2	-0,3	1,2	-0,1	61,3	-3,2
S74	5,780	NC_SLS - Frequent (automatisch).19	18,1	-1,3	-67,5	0,2	-0,5	-9,4
S74	3,016-	NC_SLS - Frequent (automatisch).19	118,1	-0,2	0,1	-0,2	34,8	6,6

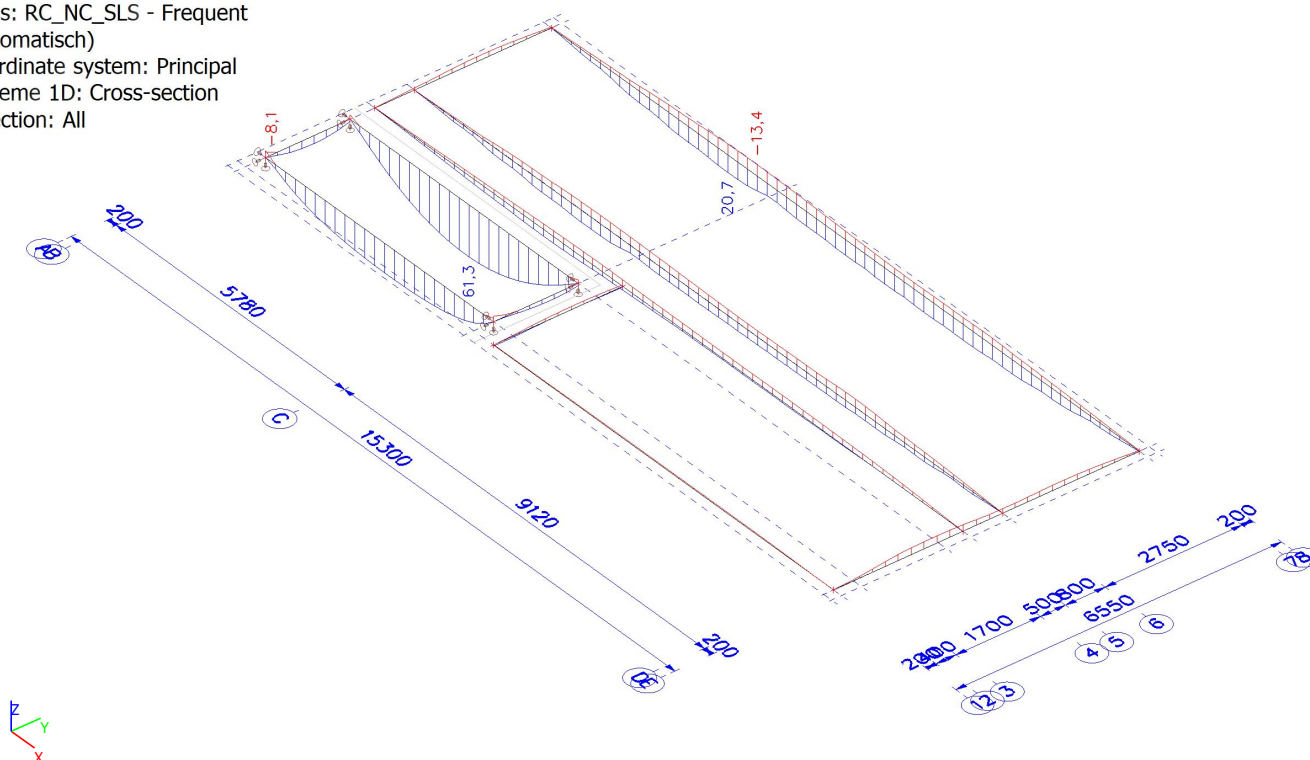
5.2.1.2. 1D internal forces; N

Values: **N**
Nonlinear calculation
Class: RC_NC_SLS - Frequent
(automatisch)
Coordinate system: Principal
Extreme 1D: Cross-section
Selection: All



5.2.1.3. 1D internal forces; M_y

Values: **M_y**
Nonlinear calculation
Class: RC_NC_SLS - Frequent
(automatisch)
Coordinate system: Principal
Extreme 1D: Cross-section
Selection: All



5.2.1.4. 1D internal forces; V_z

Values: V_z

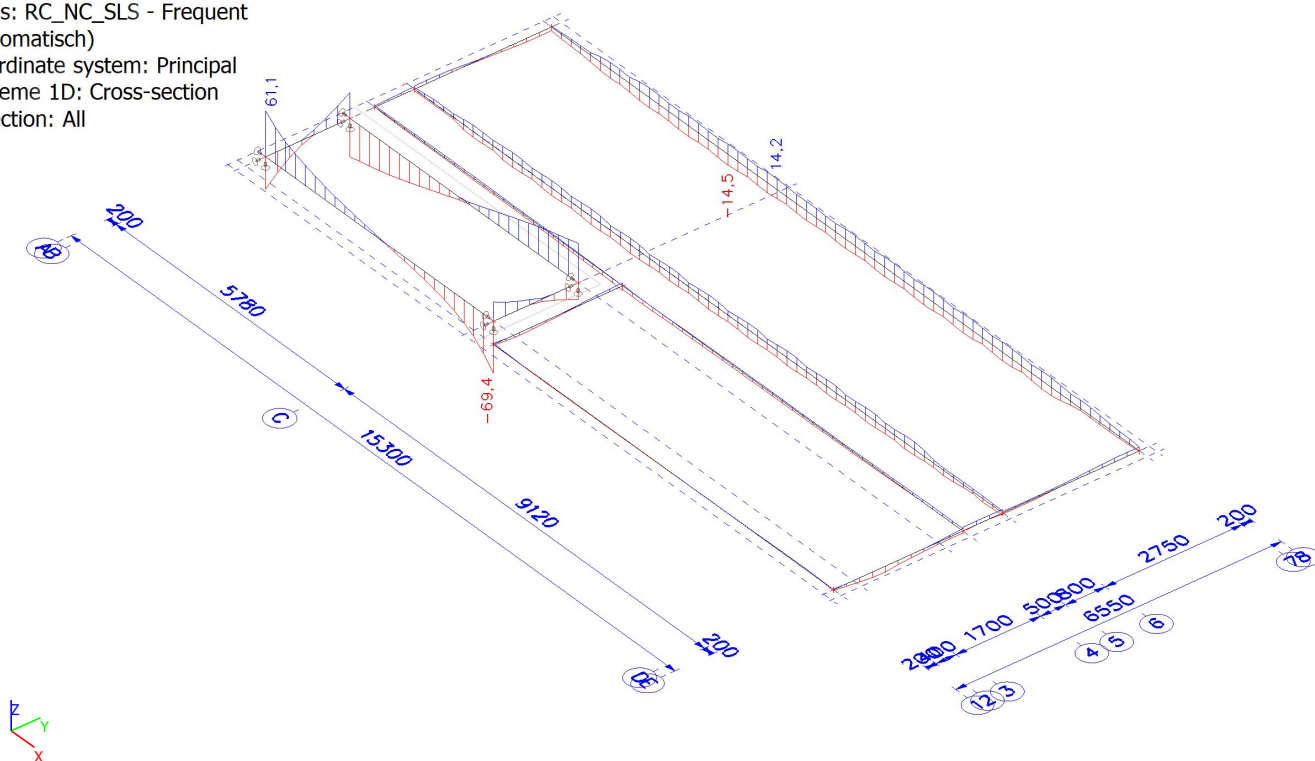
Nonlinear calculation

Class: RC_NC_SLS - Frequent
(automatisch)

Coordinate system: Principal

Extreme 1D: Cross-section

Selection: All



5.2.2. 2D Elements Global results

5.2.2.1. Summary

Nonlinear calculation

Class: RC_NC_SLS - Frequent (automatisch)

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]	m _{cD+} [kNm/m] m _{cD-} [kNm/m]	n _{xD} [kN/m]	n _{yD} [kN/m]	n _{cD} [kN/m]
E4	Element: 1914 Node: 1932	0,200 0,843 0,000	NC_SLS - Frequent (automatisch).16	-15,6 0,0	-5,0 0,0	-6,3 -13,2	39,2	14,7	-40,5
E4	Element: 1841 Node: 136	6,230 0,000 0,000	NC_SLS - Frequent (automatisch).25	0,0 14,5	0,0 23,5	-20,0 -9,7	38,2	82,4	-54,4
E4	Element: 1867 Node: 2031	-0,078 0,546 0,000	NC_SLS - Frequent (automatisch).20	-6,9 0,0	-14,5 0,0	-6,2 -12,3	24,4	0,0	-37,1
E4	Element: 1841 Node: 1935	5,977 0,000 0,000	NC_SLS - Frequent (automatisch).19	0,0 5,8	0,0 23,6	-20,2 -8,7	23,0	1,8	-45,5
E2	Element: 1549 Node: 1609	14,548 0,000 0,750	NC_SLS - Frequent (automatisch).6	-0,5 0,0	-0,2 0,0	0,0 -0,5	5,2	2,6	-9,5
E4	Element: 1842 Node: 2007	5,726 0,297 0,000	NC_SLS - Frequent (automatisch).19	-6,7 7,2	-6,0 7,8	-13,9 -13,9	41,4	22,3	-84,7
E1	Element: 1154 Node: 1325	12,293 0,000 0,000	NC_SLS - Frequent (automatisch).8	0,0 1,2	0,0 6,7	-6,7 0,0	0,0	-7,5	-13,6
E6	Element: 2100 Node: 1963	-0,350 0,765 0,000	NC_SLS - Frequent (automatisch).16	-1,7 1,8	-1,1 2,4	-3,5 -3,5	-23,5	0,0	-38,6
E1	Element: 1439 Node: 427	4,650 3,000 0,000	NC_SLS - Frequent (automatisch).14	0,0 10,9	-1,0 0,2	-10,0 -2,1	96,4	1,5	-0,8
E6	Element: 2090 Node: 1965	-0,350 1,275 0,000	NC_SLS - Frequent (automatisch).16	-1,5 1,5	-1,2 1,8	-3,0 -3,0	0,0	-13,3	-13,6
E4	Element: 1841 Node: 136	6,230 0,000 0,000	NC_SLS - Frequent (automatisch).20	0,0 14,5	0,0 23,5	-20,0 -9,7	38,2	82,4	-54,4
E5	Element: 2004 Node: 2108	2,940 0,000 1,250	NC_SLS - Frequent (automatisch).27	-2,0 0,0	-0,3 0,0	-0,5 -1,8	0,0	-1,0	-168,9
E2	Element: 1636 Node: 1698	10,790 0,000 1,250	NC_SLS - Frequent (automatisch).7	0,0 0,5	-0,3 0,3	-0,6 -0,6	25,6	0,1	0,0

5.2.2.2. 2D internal forces; m_{xD+}

Values: m_{xD+}

Nonlinear calculation

Class: RC_NC_SLS - Frequent
(automatisch)

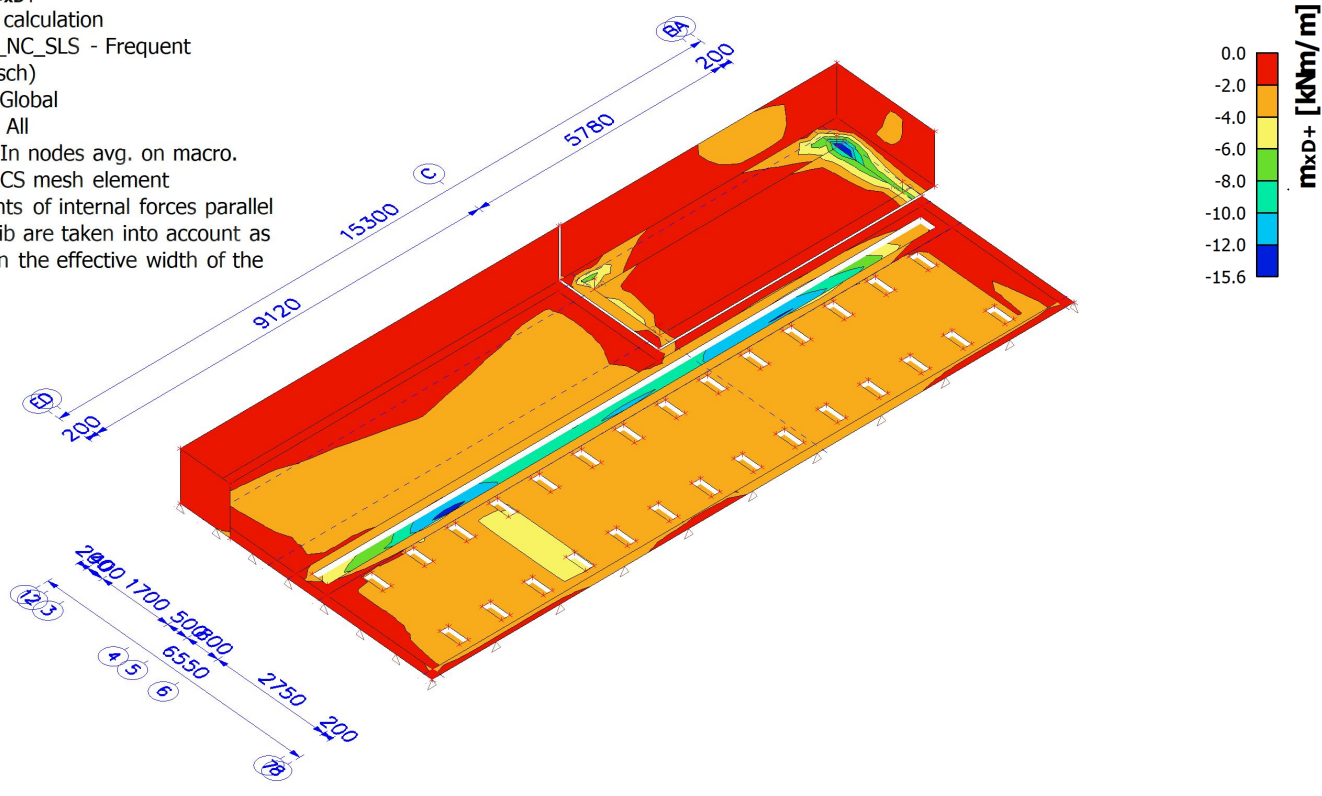
Extreme: Global

Selection: All

Location: In nodes avg. on macro.

System: LCS mesh element

Components of internal forces parallel with the rib are taken into account as zero within the effective width of the rib.



5.2.2.3. 2D internal forces; m_{xD-}

Values: m_{xD-}

Nonlinear calculation

Class: RC_NC_SLS - Frequent
(automatisch)

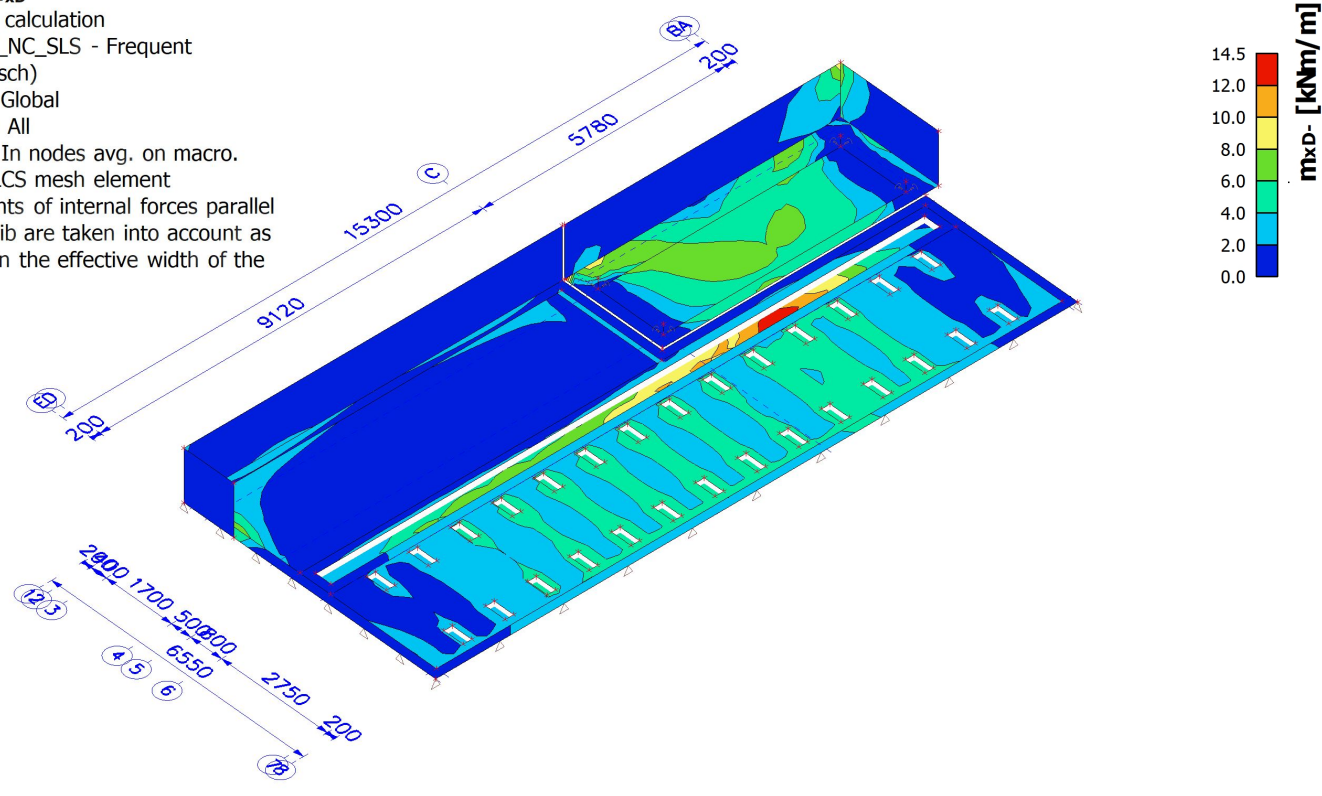
Extreme: Global

Selection: All

Location: In nodes avg. on macro.

System: LCS mesh element

Components of internal forces parallel with the rib are taken into account as zero within the effective width of the rib.



5.2.2.4. 2D internal forces; m_{yD+}

Values: m_{yD+}

Nonlinear calculation

Class: RC_NC_SLS - Frequent
(automatisch)

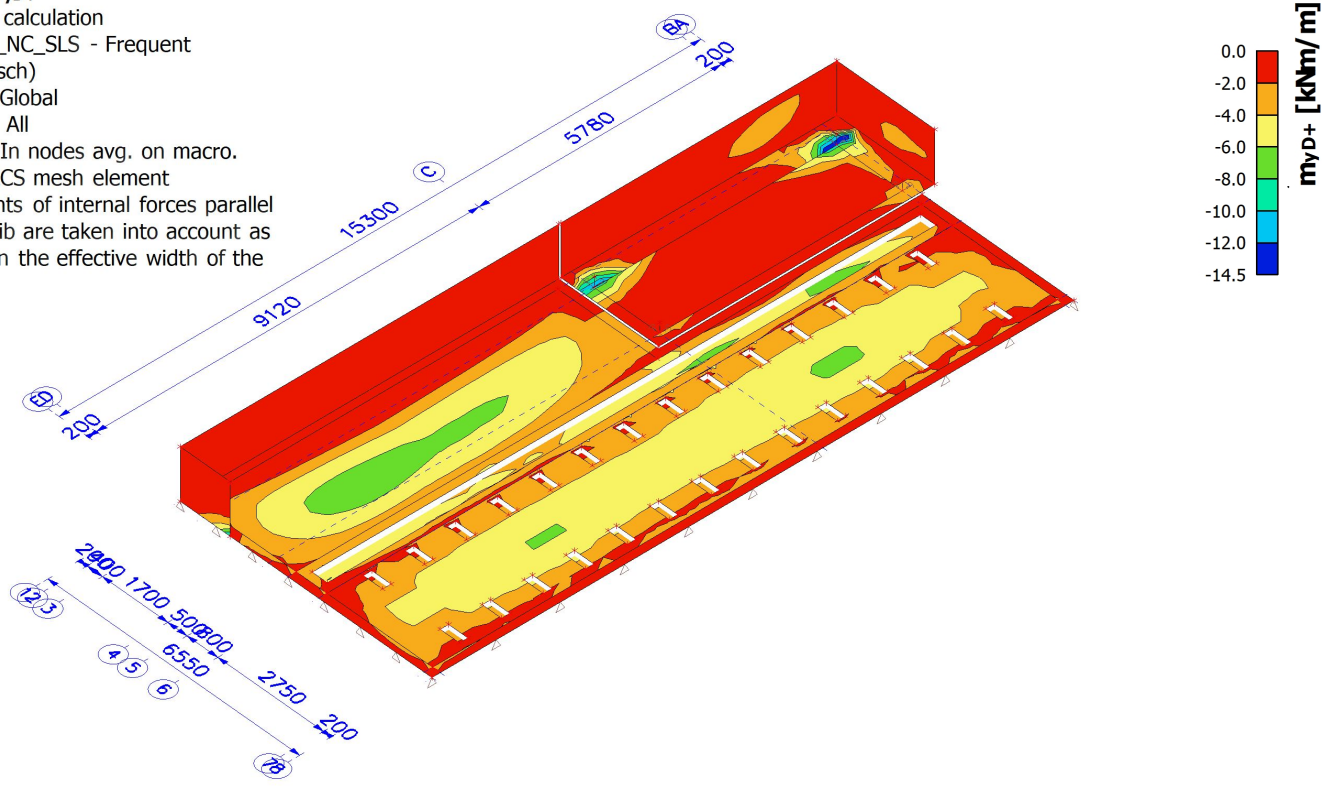
Extreme: Global

Selection: All

Location: In nodes avg. on macro.

System: LCS mesh element

Components of internal forces parallel with the rib are taken into account as zero within the effective width of the rib.



5.2.2.5. 2D internal forces; m_{yD-}

Values: m_{yD-}

Nonlinear calculation

Class: RC_NC_SLS - Frequent
(automatisch)

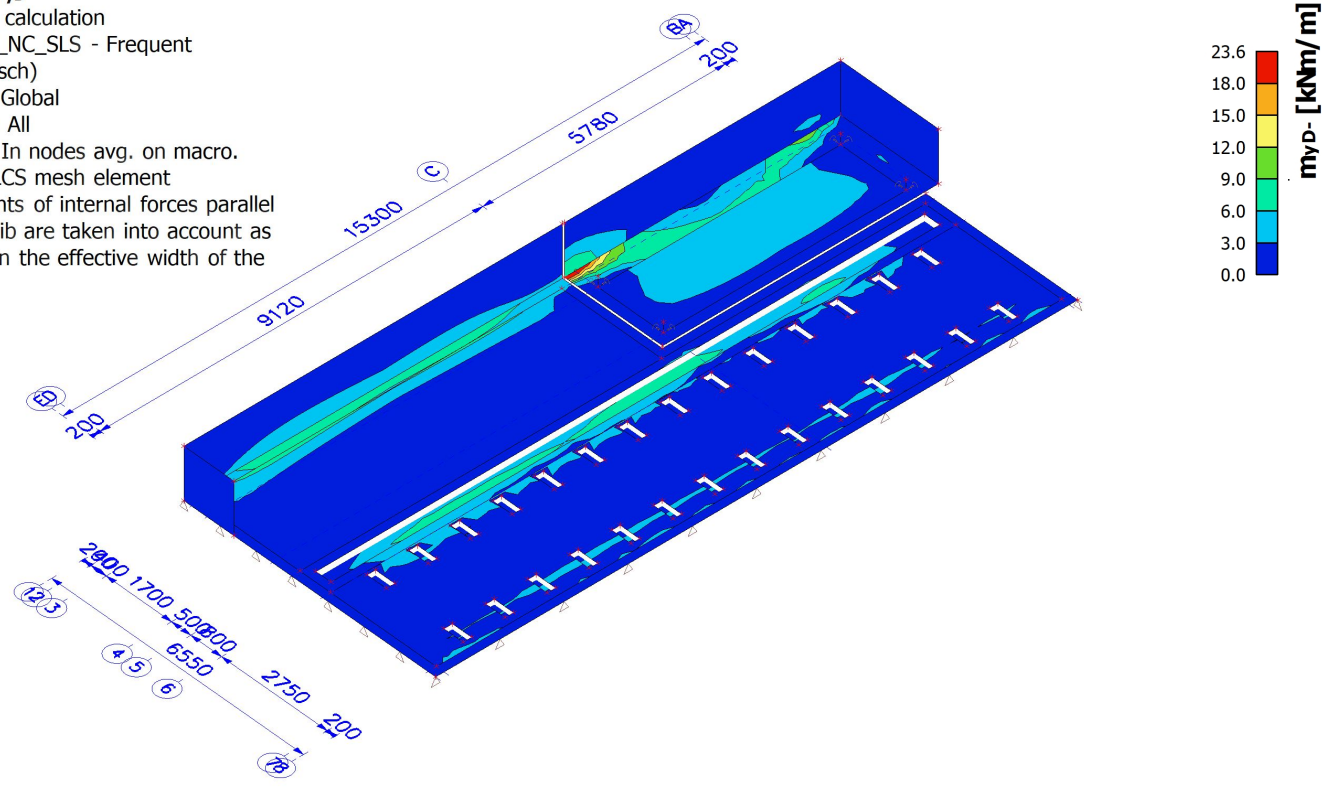
Extreme: Global

Selection: All

Location: In nodes avg. on macro.

System: LCS mesh element

Components of internal forces parallel with the rib are taken into account as zero within the effective width of the rib.



5.2.2.6. 2D internal forces; n_{xD}

Values: n_{xD}

Nonlinear calculation

Class: RC_NC_SLS - Frequent
(automatisch)

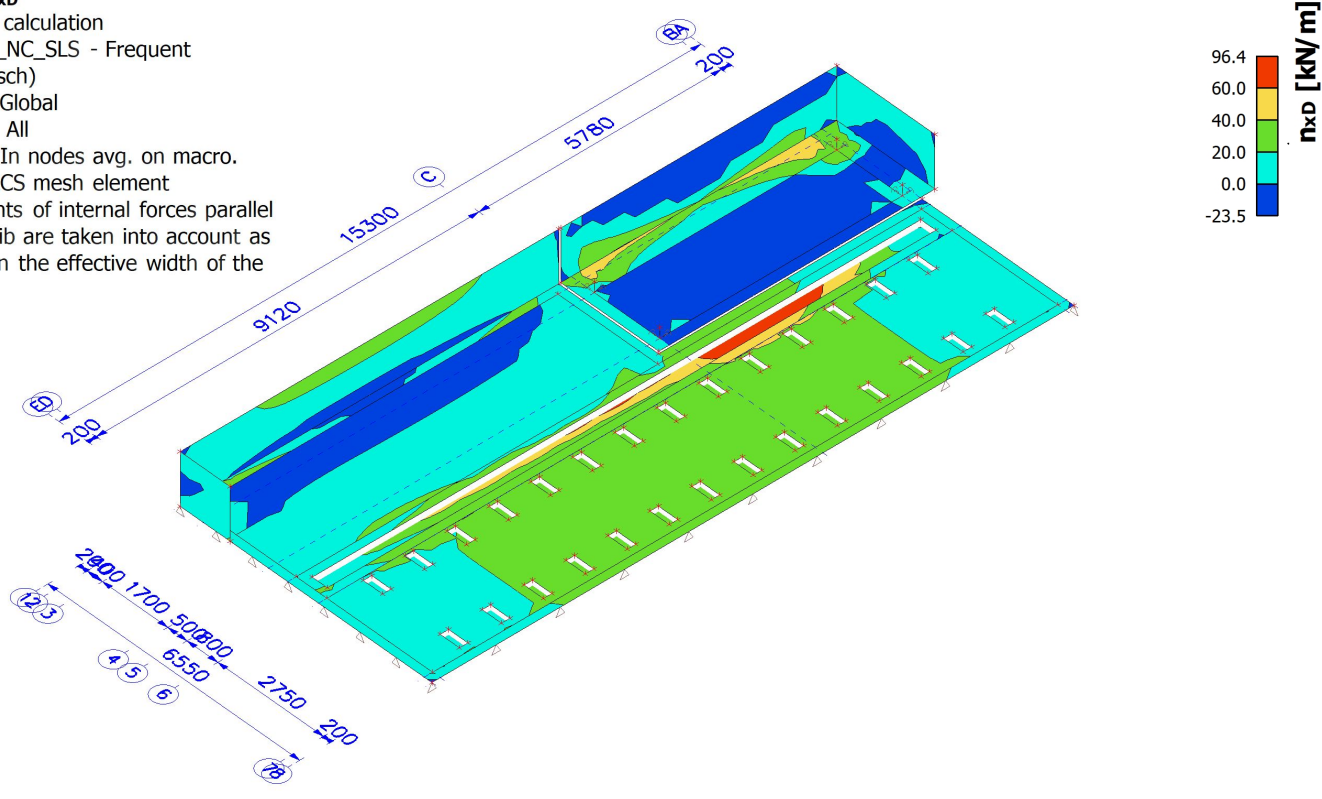
Extreme: Global

Selection: All

Location: In nodes avg. on macro.

System: LCS mesh element

Components of internal forces parallel with the rib are taken into account as zero within the effective width of the rib.



5.2.2.7. 2D internal forces; n_{yD}

Values: n_{yD}

Nonlinear calculation

Class: RC_NC_SLS - Frequent
(automatisch)

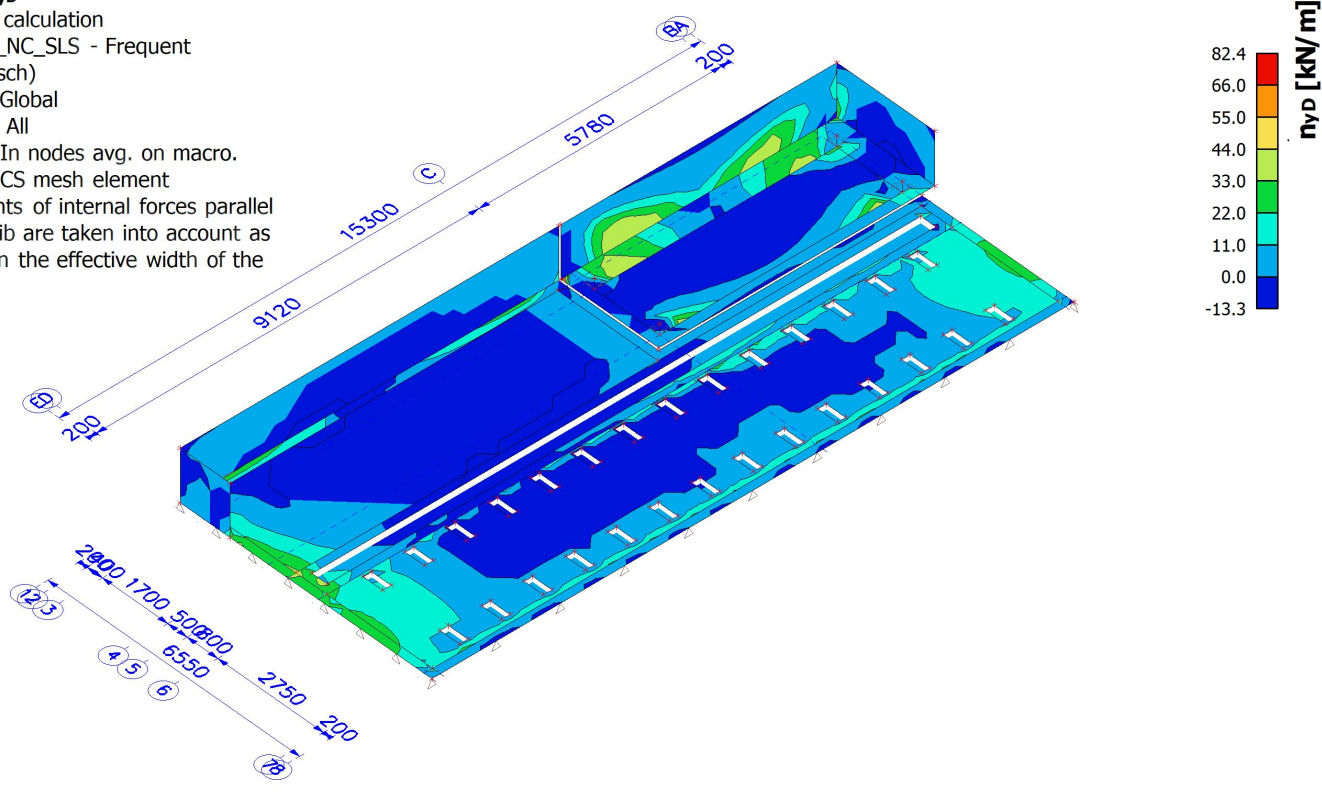
Extreme: Global

Selection: All

Location: In nodes avg. on macro.

System: LCS mesh element

Components of internal forces parallel with the rib are taken into account as zero within the effective width of the rib.



6. Column reactions for anchor bolt check

6.1. Internal forces on member

Nonlinear calculation, Extreme : Global, System : Principal

Selection : B11..B14

Class : RC_NC_ULS - Set B (automatisch)

Member	css	dx [m]	Case	N [kN]	Vy [kN]	Vz [kN]
B11	FB3 - Rectangle	0,000	NC_ULS - Set B (automatisch).55	-498,3	0,0	0,0
B11	FB3 - Rectangle	0,250	NC_ULS - Set B (automatisch).28	495,0	0,0	33,0
B11	FB3 - Rectangle	0,000	NC_ULS - Set B (automatisch).29	-2,0	-33,0	0,0
B11	FB3 - Rectangle	0,000	NC_ULS - Set B (automatisch).58	-497,0	0,0	0,0
B11	FB3 - Rectangle	0,000	NC_ULS - Set B (automatisch).23	-2,9	0,0	0,0
B11	FB3 - Rectangle	0,000	NC_ULS - Set B (automatisch).28	491,7	0,0	33,0

6.2. 1D internal forces; N

Values: **N**

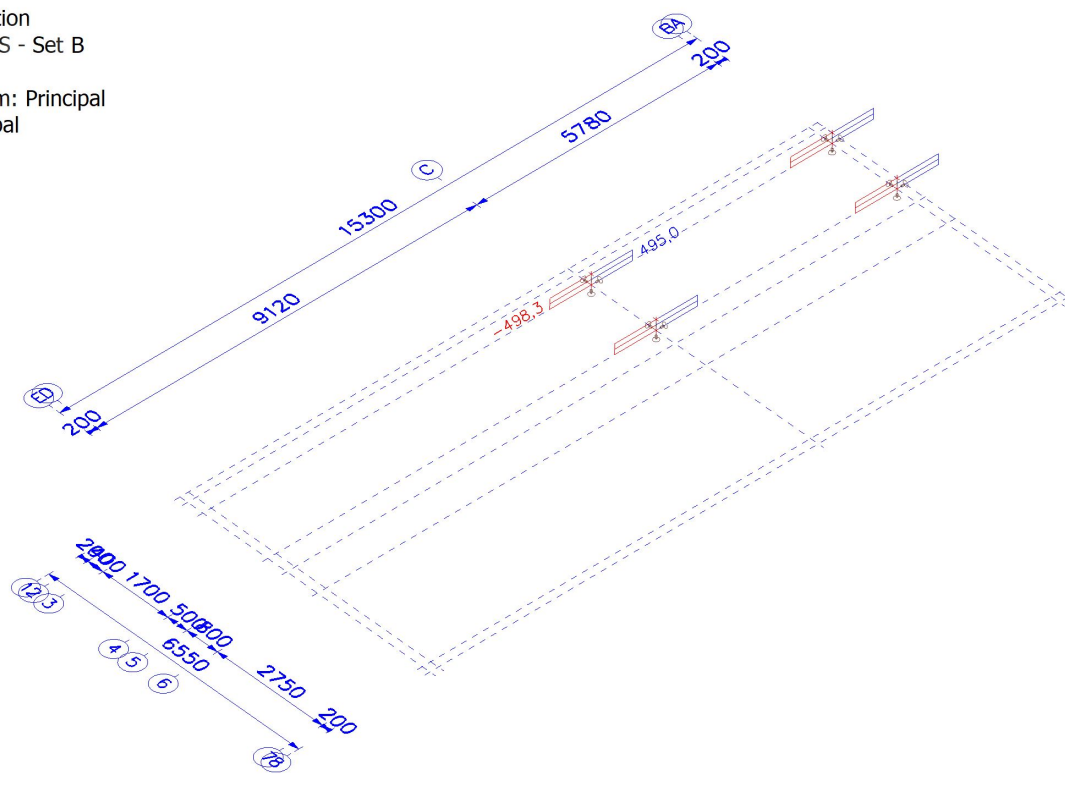
Nonlinear calculation

Class: RC_NC_ULS - Set B
(automatisch)

Coordinate system: Principal

Extreme 1D: Global

Selection: All



6.3. 1D internal forces; V_z

Values: V_z

Nonlinear calculation

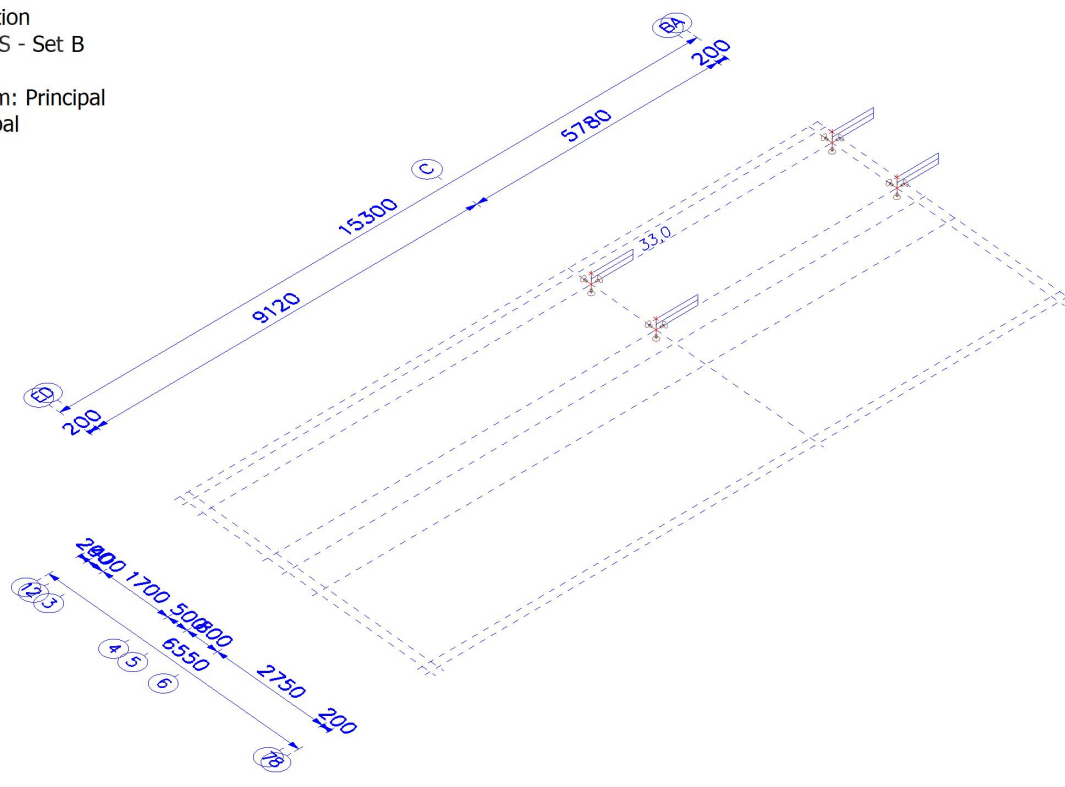
Class: RC_NC_ULS - Set B

(automatisch)

Coordinate system: Principal

Extreme 1D: Global

Selection: All



6.4. 1D internal forces; V_y

Values: V_y

Nonlinear calculation

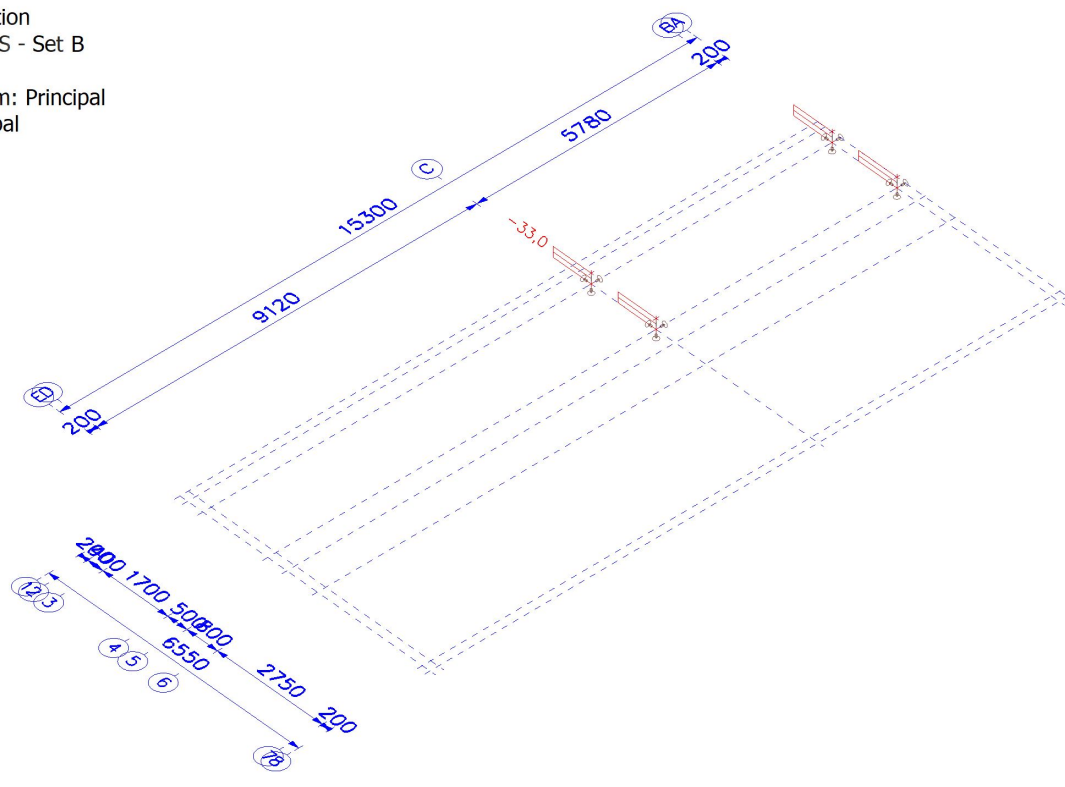
Class: RC_NC_ULS - Set B

(automatisch)

Coordinate system: Principal

Extreme 1D: Global

Selection: All



7. Pile reactions

7.1. ULS - Nonlinear calculation

7.1.1. Summary

Nonlinear calculation

Class: RC_NC_ULS - Set B (automatisch)

System: Global

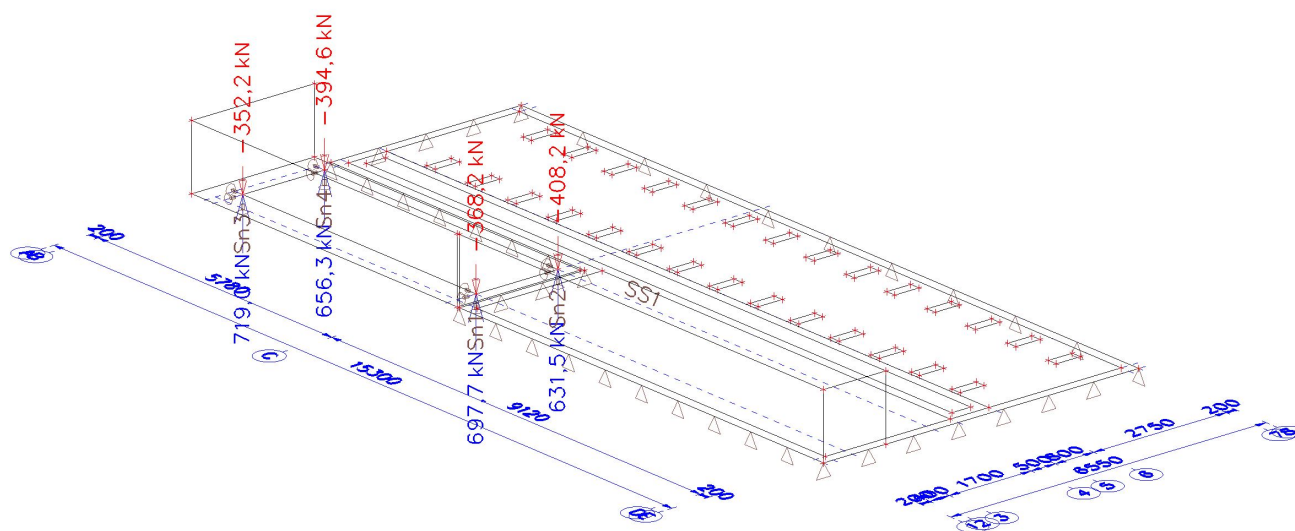
Extreme: Member

Selection: All

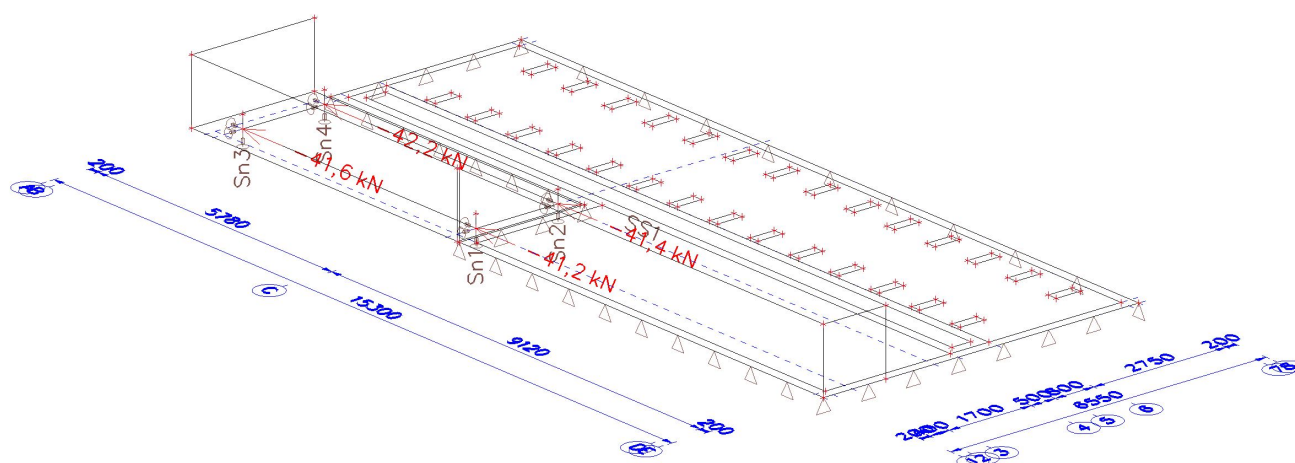
Nodal reactions

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]
Sn1/N24	NC_ULS - Set B (automatisch).44	-4,9	-13,0	-358,5	0,0	0,0	0,0	0,0	0,0
Sn1/N24	NC_ULS - Set B (automatisch).32	-8,2	-54,5	-304,9	0,0	0,0	0,0	0,0	0,0
Sn1/N24	NC_ULS - Set B (automatisch).1	-5,0	-13,0	96,6	0,0	0,0	0,0	0,0	0,0
Sn1/N24	NC_ULS - Set B (automatisch).45	-4,9	-46,0	-368,2	0,0	0,0	0,0	0,0	0,0
Sn1/N24	NC_ULS - Set B (automatisch).56	-41,2	-21,5	697,7	0,0	0,0	0,0	0,0	0,0
Sn1/N24	NC_ULS - Set B (automatisch).40	-41,2	-21,5	162,8	0,0	0,0	0,0	0,0	0,0
Sn2/N26	NC_ULS - Set B (automatisch).45	-5,0	-46,0	591,5	0,0	0,0	0,0	0,0	0,0
Sn2/N26	NC_ULS - Set B (automatisch).41	-8,4	-54,5	110,8	0,0	0,0	0,0	0,0	0,0
Sn2/N26	NC_ULS - Set B (automatisch).58	-5,0	-13,0	-408,2	0,0	0,0	0,0	0,0	0,0
Sn2/N26	NC_ULS - Set B (automatisch).32	-8,3	-54,5	631,5	0,0	0,0	0,0	0,0	0,0
Sn2/N26	NC_ULS - Set B (automatisch).40	-41,4	-21,5	103,9	0,0	0,0	0,0	0,0	0,0
Sn3/N28	NC_ULS - Set B (automatisch).29	-5,2	-46,7	99,3	0,0	0,0	0,0	0,0	0,0
Sn3/N28	NC_ULS - Set B (automatisch).32	-8,6	-55,7	-280,7	0,0	0,0	0,0	0,0	0,0
Sn3/N28	NC_ULS - Set B (automatisch).31	-38,2	-13,7	106,1	0,0	0,0	0,0	0,0	0,0
Sn3/N28	NC_ULS - Set B (automatisch).45	-5,2	-46,7	-352,2	0,0	0,0	0,0	0,0	0,0
Sn3/N28	NC_ULS - Set B (automatisch).55	-8,6	-22,7	719,0	0,0	0,0	0,0	0,0	0,0
Sn3/N28	NC_ULS - Set B (automatisch).28	-41,6	-22,7	-273,9	0,0	0,0	0,0	0,0	0,0
Sn4/N30	NC_ULS - Set B (automatisch).1	-5,5	-13,7	73,9	0,0	0,0	0,0	0,0	0,0
Sn4/N30	NC_ULS - Set B (automatisch).41	-9,1	-55,6	132,1	0,0	0,0	0,0	0,0	0,0
Sn4/N30	NC_ULS - Set B (automatisch).59	-38,6	-13,7	-394,6	0,0	0,0	0,0	0,0	0,0
Sn4/N30	NC_ULS - Set B (automatisch).32	-9,2	-55,6	656,3	0,0	0,0	0,0	0,0	0,0
Sn4/N30	NC_ULS - Set B (automatisch).28	-42,2	-22,6	643,8	0,0	0,0	0,0	0,0	0,0

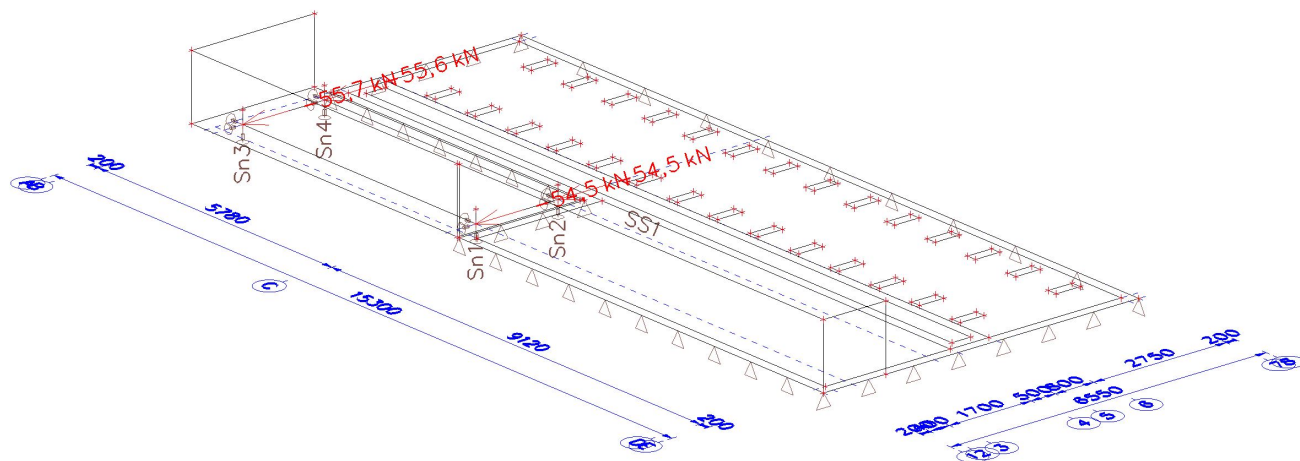
7.1.2. Reactions; R_z



7.1.3. Reactions; R_x



7.1.4. Reactions; R_y



8. 2D Contact stresses

8.1. ULS - 2D Contact stresses

8.1.1. Summary - ULS

Linear calculation

Class: ULS - Set B

Extreme: Global

Selection: All

Location: In nodes avg.. System: LCS mesh element

Name	Mesh	Position [m]	Case	T _{zx} [kN/m ²]	T _{yz} [kN/m ²]	σ _z [kN/m ²]
E1	Node: 1303	6,781 0,000 0,000	ULS - Set B (automatisch)/1	0	-1	24
E1	Node: 1413	2,759 6,550 0,000	ULS - Set B (automatisch)/1	1	-1	37
E1	Node: 1362	15,300 6,300 0,000	ULS - Set B (automatisch)/2	1	-2	29
E1	Node: 1531	0,650 3,197 0,000	ULS - Set B (automatisch)/3	0	0	40
E1	Node: 3	15,300 6,550 0,000	ULS - Set B (automatisch)/4	0	-1	6
E1	Node: 3	15,300 6,550 0,000	ULS - Set B (automatisch)/5	0	-2	69

Name	Combination key
ULS - Set B (automatisch)/1	1.49*GSW00 + 1.15*QTL01 + 1.49*GDL00
ULS - Set B (automatisch)/2	1.49*GSW00 + 1.15*QTL11 + 1.49*GDL00
ULS - Set B (automatisch)/3	0.90*GSW00 + 1.65*QTL01 + 0.90*GDL00
ULS - Set B (automatisch)/4	0.90*GSW00 + 1.65*QTL06 + 0.90*GDL00
ULS - Set B (automatisch)/5	1.32*GSW00 + 1.65*QTL13 + 1.32*GDL00

8.1.2. 2D contact stresses; σ_z

Values: σ_z

Nonlinear calculation

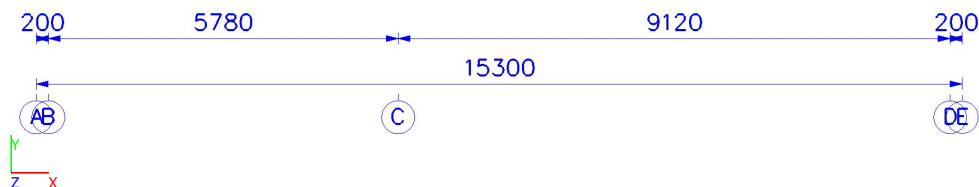
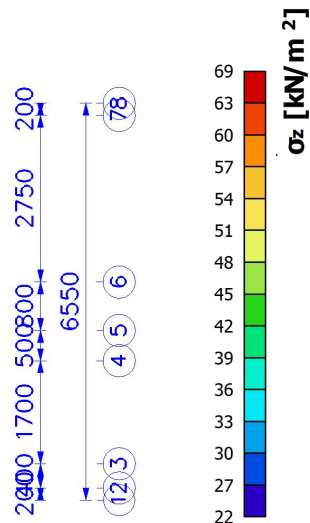
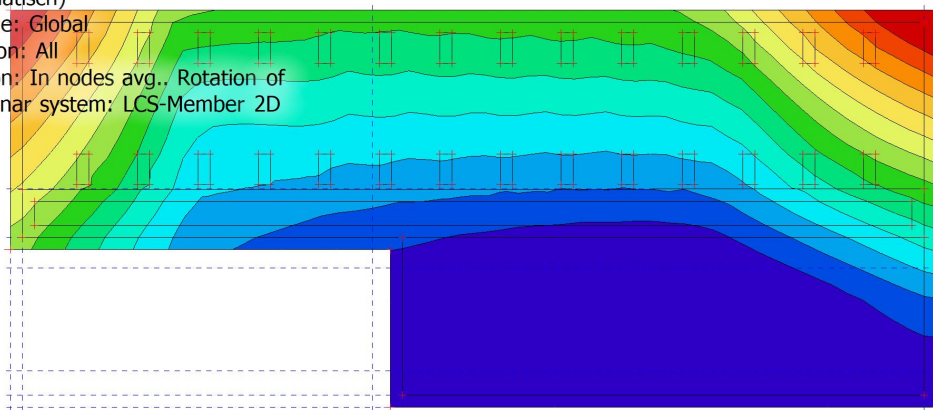
Class: RC_NC_ULS - Set B

(automatisch)

Extreme: Global

Selection: All

Location: In nodes avg., Rotation of
the planar system: LCS-Member 2D



8.2. SLS Characteristic - 2D Contact stresses

8.2.1. Summary - SLS Char

Nonlinear calculation

Class: RC_NC_SLS - Characteristic (automatisch)

Extreme: Global

Selection: All

Location: In nodes avg.. System: LCS mesh element

Name	Mesh	Position [m]	Case	T_{zx} [kN/m ²]	T_{yz} [kN/m ²]	σ_z [kN/m ²]
E1	Node: 1303	6,781 0,000 0,000	NC_SLS - Characteristic (automatisch).6	0	-1	16
E1	Node: 1412	3,010 6,550 0,000	NC_SLS - Characteristic (automatisch).6	0	-1	28
E1	Node: 1362	15,300 6,300 0,000	NC_SLS - Characteristic (automatisch).9	0	-2	22
E1	Node: 1531	0,650 3,197 0,000	NC_SLS - Characteristic (automatisch).6	0	0	31
E1	Node: 3	15,300 6,550 0,000	NC_SLS - Characteristic (automatisch).8	0	-2	8
E1	Node: 3	15,300 6,550 0,000	NC_SLS - Characteristic (automatisch).3	0	-2	44

8.2.2. 2D contact stresses; σ_z

Values: σ_z

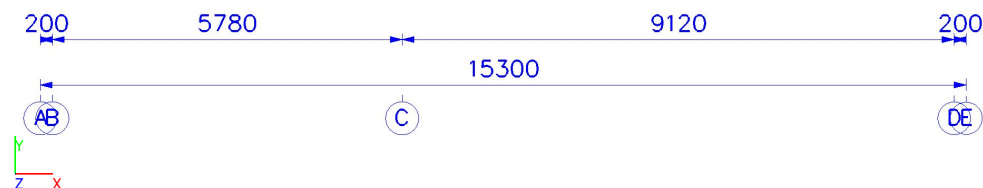
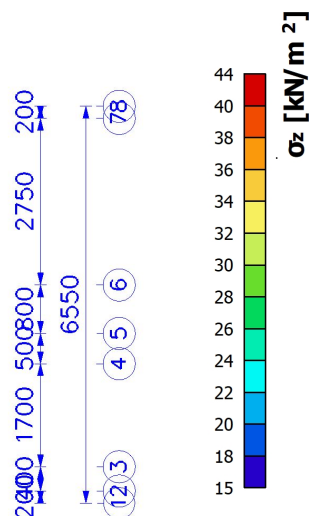
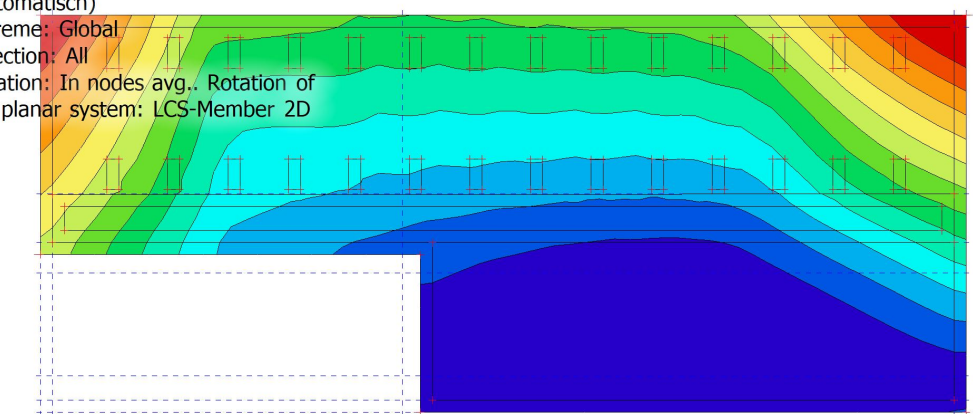
Nonlinear calculation

Class: RC_NC_SLS - Characteristic
(automatisch)

Extreme: Global

Selection: All

Location: In nodes avg.. Rotation of
the planar system: LCS-Member 2D



8.3. SLS Quasi permanent - 2D Contact stresses

8.3.1. Summary - SLS Quasi

Nonlinear calculation

Class: RC_NC_SLS - Quasi-permanent (automatisch)

Extreme: Global

Selection: All

Location: In nodes avg.. System: LCS mesh element

Name	Mesh	Position [m]	Case	T_{zx} [kN/m ²]	T_{yz} [kN/m ²]	σ_z [kN/m ²]
E1	Node: 1303	6,781 0,000 0,000	NC_SLS - Quasi-permanent (automatisch).6	0	-1	16
E1	Node: 1413	2,759 6,550 0,000	NC_SLS - Quasi-permanent (automatisch).6	0	0	16
E1	Node: 1362	15,300 6,300 0,000	NC_SLS - Quasi-permanent (automatisch).9	0	-2	14
E1	Node: 1438	0,000 3,094 0,000	NC_SLS - Quasi-permanent (automatisch).3	0	0	15
E1	Node: 699	9,100 5,925 0,000	NC_SLS - Quasi-permanent (automatisch).15	0	-1	9
E1	Node: 3	15,300 6,550 0,000	NC_SLS - Quasi-permanent (automatisch).3	0	-2	21

8.3.2. 2D contact stresses; σ_z

Values: σ_z

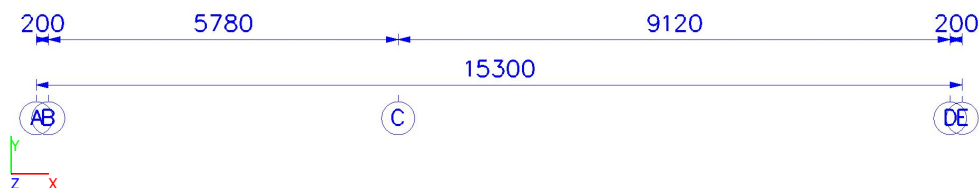
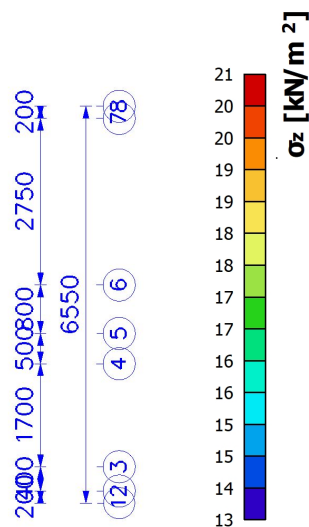
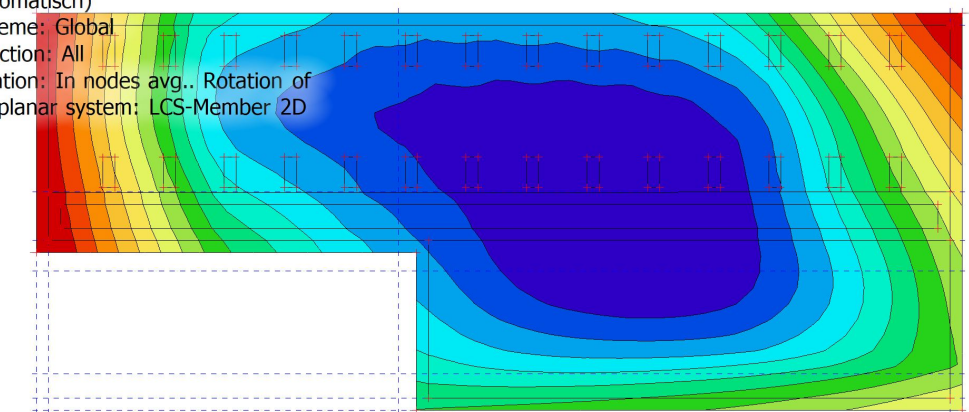
Nonlinear calculation

Class: RC_NC_SLS - Quasi-permanent
(automatisch)

Extreme: Global

Selection: All

Location: In nodes avg.. Rotation of
the planar system: LCS-Member 2D



10. Reinforcement Calculation

10.1. 1D Members

10.1.1. Concrete cover 1D

Linear calculation

Combination: ULS - Set B (automatisch)

Coordinate system: Member

Extreme 1D: Global

Selection: All

Name	dx [m]	Case	C _{nom,l} [mm]	C _{nom,u} [mm]	C _{nom,s} [mm]	C _{nom,m} [mm]
S71	0,000	ULS - Set B (automatisch)/1	45	45	45	0
B11	0,000	ULS - Set B (automatisch)/2	0	0	0	45

Name	Combination key
ULS - Set B (automatisch)/1	1.49*GSW00 + 1.65*BLC2.2 + 1.49*GDL00
ULS - Set B (automatisch)/2	0.90*GSW00 + 1.65*BLC1.1 + 0.90*GDL00

10.1.2. Section 400 x 600 mm Overall Design (ULS)

Nonlinear calculation

Class: RC_NC_ULS - Set B (automatisch)

Coordinate system: Member

Extreme 1D: Global

Selection: All

Filter: Cross-section = FB1 - Rectangle (600; 400)

Note: Longitudinal reinforcement is designed in the centre of the edges of the cross-section. Checks use the real position of the reinforcement.

Beam S79	Rectangle (600; 400)
NEN EN 1992-1-1+C2:2011/NB:2016	Section 46 [dx = 5.78 m]

Member length Ld = 14.9 m

Buckling length y Ly = 5.59 m

Buckling length z Lz = 3.19 m

Materials

Concrete C35/45

Reinforcement B 500B

Longitudinal reinforcement

upper: $\phi_{up} = 20$ mm, $c_{up} = 45$ mm

lower: $\phi_{lo} = 20$ mm, $c_{lo} = 45$ mm

side: $c_{side} = 45$ mm

Shear reinforcement

$n_{s.req} = 2$, $\phi_{s.req} = 10$ mm, $\alpha_{s.req} = 90^\circ$

Design shear reinforcement

Content of combination: NC_ULS-SetB(automatisch).42

$V_{Ed} = 0.406$ kN $V_{Rdmax} = 211$ kN $V_{Rdc} = 150$ kN $T_{Ed} = -0.0994$ kNm $T_{Rdc} = 48.5$ kNm $T_{Rdmax} = 137$ kNm

Required shear reinforcement: $\phi 10/152$ mm ($n_{s.req} = 2$) => (A_{sw}/s_l) = 1033 mm²/m

Provided shear reinforcement: $\phi 10/150$ mm ($n_{s.prov} = 2$) => (A_{sw}/s_l) = 1047 mm²/m

$A_{swm.req}$ [mm ² /m]	$A_{swm.prov}$ [mm ² /m]	$A_{swm.add.req}$ [mm ² /m]	Check $A_{swm.prov} > A_{swm.req}$
1033	1047	0	YES (0,99)

$A_{s.z+}$: NC_ULS-SetB(automatisch).10 : $N_{Ed} = -39$ kN, $M_{Edy} = -23$ kNm, $M_{Edz} = -1$ kNm

$A_{s.z-}$: NC_ULS-SetB(automatisch).30 : $N_{Ed} = 30$ kN, $M_{Edy} = 24$ kNm, $M_{Edz} = 1$ kNm

$A_{s.y+}$: NC_ULS-SetB(automatisch).30 : $N_{Ed} = 30$ kN, $M_{Edy} = 24$ kNm, $M_{Edz} = 1$ kNm

$A_{s.y-}$: NC_ULS-SetB(automatisch).30 : $N_{Ed} = 30$ kN, $M_{Edy} = 24$ kNm, $M_{Edz} = 1$ kNm

$\Delta A\sigma$: NC_ULS-SetB(automatisch).25: $T_{Ed} = -1$ kNm, $F_{ds.max} = 21$ kN

Required

Edge	y [m]	z [m]	$A_{s.stat}$ [mm ²]	$A_{s.det.min}$ [mm ²]	$A_{s.det.max}$ [mm ²]	$\Delta A_{s.tor}$ [mm ²]	$A_{s.req}$ [mm ²]	$A_{s.req.bar}$ [mm ²]	Reinf
1	0	-0.235	127	159	1792	8.97	159	628	2 ϕ 20
2	0.14	0	5.5	105	3008	13.5	105	78.5	1 ϕ 10+2 ϕ 20
3	0	0.235	60.3	75.4	1792	8.97	75.4	628	2 ϕ 20
4	-0.14	0	36.2	105	3008	13.5	105	78.5	1 ϕ 10+2 ϕ 20

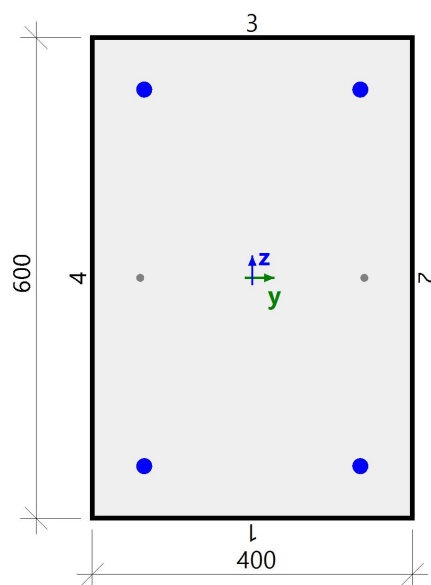
Provided

Edge	$A_{s,req}$ [mm ²]	$A_{s,bas,prov}$ [mm ²]	$A_{s,add,prov}$ [mm ²]	$A_{s,det,prov}$ [mm ²]	$A_{s,prov}$ [mm ²]	$A_{s,add,req}$ [mm ²]	Check $A_{s,prov} > A_{s,req}$	Reinf Prov.
1	159	1257	0	0	1257	0	YES (0,13)	4 ϕ 20
2	105	785	0	0	785	0	YES (0,13)	2 ϕ 10+2 ϕ 20
3	75.4	1257	0	0	1257	0	YES (0,06)	4 ϕ 20
4	105	785	0	0	785	0	YES (0,13)	2 ϕ 10+2 ϕ 20

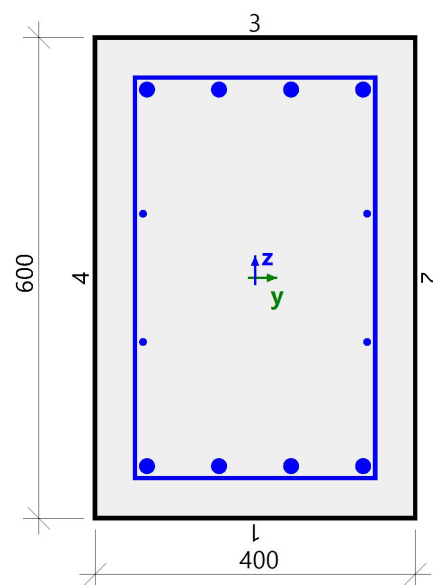
Summary of reinforcement

Upper :	$A_{sz,req+} = 75.4 \text{ mm}^2$	$A_{sz,prov+} = 1257 \text{ mm}^2$
Lower :	$A_{sz,req-} = 158.7 \text{ mm}^2$	$A_{sz,prov-} = 1257 \text{ mm}^2$
Right :	$A_{sy,req+} = 105.5 \text{ mm}^2$	$A_{sy,prov+} = 785.4 \text{ mm}^2$
Left :	$A_{sy,req-} = 105.5 \text{ mm}^2$	$A_{sy,prov-} = 785.4 \text{ mm}^2$
Total vertical :	$A_{sz,req} = 234.1 \text{ mm}^2$	$A_{sz,prov} = 2513 \text{ mm}^2$
Total horizontal :	$A_{sy,req} = 210.9 \text{ mm}^2$	$A_{sy,prov} = 1571 \text{ mm}^2$
Total :	$A_{s,req} = 445 \text{ mm}^2$	$A_{s,prov} = 4084 \text{ mm}^2$

Required bars



Provided bars



Beam S77	Rectangle (600; 400)
NEN EN 1992-1-1+C2:2011/NB:2016	Section 78 [dx = 9.69 m]

Member length	Ld = 14.9 m
Buckling length y	Ly = 13.5 m
Buckling length z	Lz = 7.53 m

Materials

Concrete	C35/45
Reinforcement	B 500B

Longitudinal reinforcement

upper: $\phi_{up} = 20 \text{ mm}$, $c_{up} = 45 \text{ mm}$	lower: $\phi_{lo} = 20 \text{ mm}$, $c_{lo} = 45 \text{ mm}$
side: $c_{side} = 45 \text{ mm}$	

Shear reinforcement

$$n_{s,req} = 2, \phi_{s,req} = 10 \text{ mm}, \alpha_{s,req} = 90^\circ$$

Design shear reinforcement

Content of combination: NC_ULS-SetB(automatisch).37

$V_{Ed} = 0.432 \text{ kN}$ $V_{Rdmax} = 352 \text{ kN}$ $V_{Rdc} = 190 \text{ kN}$ $T_{Ed} = -0.598 \text{ kNm}$ $T_{Rdc} = 48.4 \text{ kNm}$ $T_{Rdmax} = 137 \text{ kNm}$

Required shear reinforcement: $\phi 10/197 \text{ mm}$ ($n_{s.req} = 2$) => (A_{sw}/s_l) = $799 \text{ mm}^2/\text{m}$

Provided shear reinforcement: $\phi 10/150 \text{ mm}$ ($n_{s.prov} = 2$) => (A_{sw}/s_l) = $1047 \text{ mm}^2/\text{m}$

$A_{swm.req}$ [mm ² /m]	$A_{swm.prov}$ [mm ² /m]	$A_{swm.add.req}$ [mm ² /m]	Check $A_{swm.prov} > A_{swm.req}$
799	1047	0	YES (0,76)

$\Delta A\sigma$: NC_ULS-SetB(automatisch).17: $T_{Ed} = -1 \text{ kNm}$, $F_{ds.max} = 20 \text{ kN}$

Required

Edge	y [m]	z [m]	$A_{s.stat}$ [mm ²]	$A_{s.det.min}$ [mm ²]	$A_{s.det.max}$ [mm ²]	$\Delta A_{s.tor}$ [mm ²]	$A_{s.req}$ [mm ²]	$A_{s.req.bar}$ [mm ²]	Reinf
1	0	-0.235	420	526	1792	8.66	526	942	3 ϕ 20
2	0.14	0	114	142	3008	13	142	78.5	1 ϕ 10+2 ϕ 20
3	0	0.235	0	62.8	1792	8.66	62.8	628	2 ϕ 20
4	-0.14	0	159	199	3008	13	199	157	2 ϕ 10+2 ϕ 20

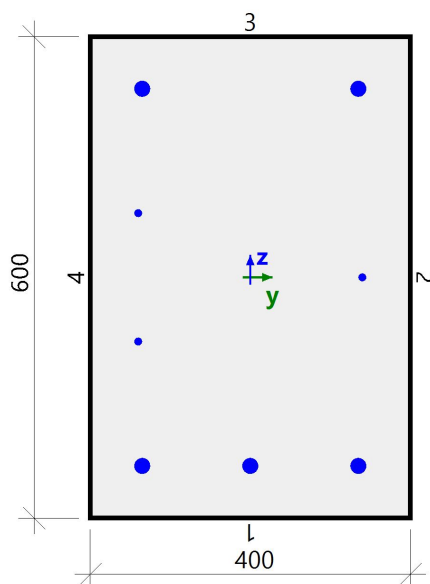
Provided

Edge	$A_{s.req}$ [mm ²]	$A_{s.bas.prov}$ [mm ²]	$A_{s.add.prov}$ [mm ²]	$A_{s.det.prov}$ [mm ²]	$A_{s.prov}$ [mm ²]	$A_{s.add.req}$ [mm ²]	Check $A_{s.prov} > A_{s.req}$	Reinf Prov.
1	526	1257	0	0	1257	0	YES (0,42)	4 ϕ 20
2	142	785	0	0	785	0	YES (0,18)	2 ϕ 10+2 ϕ 20
3	62.8	1257	0	0	1257	0	YES (0,05)	4 ϕ 20
4	199	785	0	0	785	0	YES (0,25)	2 ϕ 10+2 ϕ 20

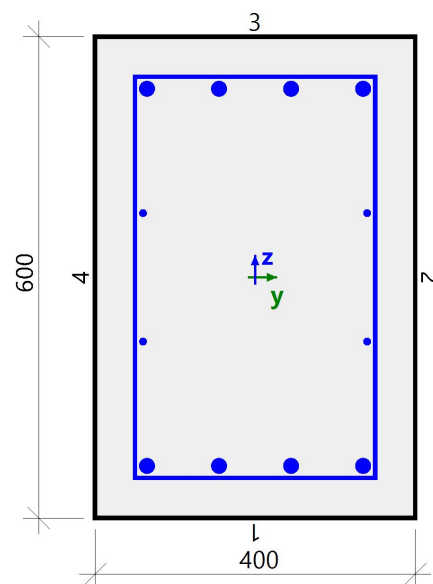
Summary of reinforcement

Upper :	$A_{sz.req+} = 62.83 \text{ mm}^2$	$A_{sz.prov+} = 1257 \text{ mm}^2$
Lower :	$A_{sz.req-} = 525.5 \text{ mm}^2$	$A_{sz.prov-} = 1257 \text{ mm}^2$
Right :	$A_{sy.req+} = 142 \text{ mm}^2$	$A_{sy.prov+} = 785.4 \text{ mm}^2$
Left :	$A_{sy.req-} = 199.3 \text{ mm}^2$	$A_{sy.prov-} = 785.4 \text{ mm}^2$
Total vertical :	$A_{sz.req} = 588.4 \text{ mm}^2$	$A_{sz.prov} = 2513 \text{ mm}^2$
Total horizontal :	$A_{sy.req} = 341.2 \text{ mm}^2$	$A_{sy.prov} = 1571 \text{ mm}^2$
Total :	$A_{s.req} = 929.6 \text{ mm}^2$	$A_{s.prov} = 4084 \text{ mm}^2$

Required bars



Provided bars



Beam S77		Rectangle (600; 400)	
NEN EN 1992-1-1+C2:2011/NB:2016		Section 92 [dx = 11.4 m]	
Member length	Ld = 14.9 m	Materials	
Buckling length y	Ly = 13.5 m	Concrete	C35/45
Buckling length z	Lz = 7.53 m	Reinforcement	B 500B

Longitudinal reinforcement

upper: $\phi_{up} = 20$ mm, $c_{up} = 45$ mm

lower: $\phi_{lo} = 20$ mm, $c_{lo} = 45$ mm

side: $c_{side} = 45$ mm

Shear reinforcement

 $n_{s,req} = 2$, $\phi_{s,req} = 10$ mm, $\alpha_{s,req} = 90^\circ$

Design shear reinforcement

Content of combination: NC_ULS-SetB(automatisch).12

 $V_{Ed} = 0.219$ kN $V_{Rdmax} = 382$ kN $V_{Rdc} = 171$ kN $T_{Ed} = 0.817$ kNm $T_{Rdc} = 48.4$ kNm $T_{Rdmax} = 137$ kNm

Required shear reinforcement: $\phi 10/209$ mm ($n_{s,req} = 2$) => (A_{sw}/s_l) = 750 mm²/m

Provided shear reinforcement: $\phi 10/150$ mm ($n_{s,prov} = 2$) => (A_{sw}/s_l) = 1047 mm²/m

$A_{swm,req}$ [mm ² /m]	$A_{swm,prov}$ [mm ² /m]	$A_{swm,add,req}$ [mm ² /m]	Check $A_{swm,prov} > A_{swm,req}$
750	1047	0	YES (0,72)

$\Delta\sigma$: NC_ULS-SetB(automatisch).15: $T_{Ed} = 2 \text{ kNm}$, $F_{ds,max} = 24 \text{ kN}$

Required

Edge	y [m]	z [m]	$A_{s,stat}$ [mm ²]	$A_{s,det,min}$ [mm ²]	$A_{s,det,max}$ [mm ²]	$\Delta A_{s,tor}$ [mm ²]	$A_{s,req}$ [mm ²]	$A_{s,req,bar}$ [mm ²]	Reinf
1	0	-0.235	420	525	1792	10.1	525	942	3 ϕ 20
2	0.14	0	141	176	3008	15.2	176	157	2 ϕ 10+2 ϕ 20
3	0	0.235	0	62.8	1792	10.1	62.8	628	2 ϕ 20
4	-0.14	0	116	145	3008	15.2	145	78.5	1 ϕ 10+2 ϕ 20

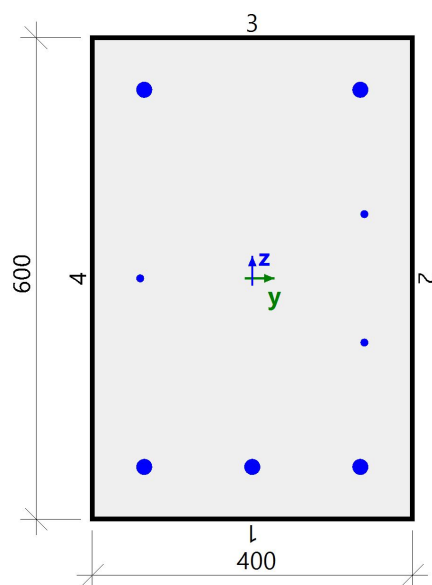
Provided

Edge	$A_{s,req}$ [mm ²]	$A_{s,bas,prov}$ [mm ²]	$A_{s,add,prov}$ [mm ²]	$A_{s,det,prov}$ [mm ²]	$A_{s,prov}$ [mm ²]	$A_{s,add,req}$ [mm ²]	Check $A_{s,prov} > A_{s,req}$	Reinf Prov.
1	525	1257	0	0	1257	0	YES (0,42)	4 ϕ 20
2	176	785	0	0	785	0	YES (0,22)	2 ϕ 10+2 ϕ 20
3	62.8	1257	0	0	1257	0	YES (0,05)	4 ϕ 20
4	145	785	0	0	785	0	YES (0,18)	2 ϕ 10+2 ϕ 20

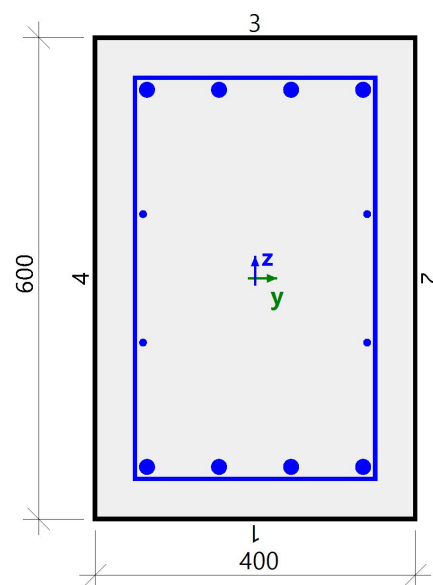
Summary of reinforcement

Upper :	$A_{sz,req+} = 62.83 \text{ mm}^2$	$A_{sz,prov+} = 1257 \text{ mm}^2$
Lower :	$A_{sz,req-} = 524.5 \text{ mm}^2$	$A_{sz,prov-} = 1257 \text{ mm}^2$
Right :	$A_{sy,req+} = 176.1 \text{ mm}^2$	$A_{sy,prov+} = 785.4 \text{ mm}^2$
Left :	$A_{sy,req-} = 145.3 \text{ mm}^2$	$A_{sy,prov-} = 785.4 \text{ mm}^2$
Total vertical :	$A_{sz,req} = 587.3 \text{ mm}^2$	$A_{sz,prov} = 2513 \text{ mm}^2$
Total horizontal :	$A_{sy,req} = 321.4 \text{ mm}^2$	$A_{sy,prov} = 1571 \text{ mm}^2$
Total :	$A_{s,req} = 908.7 \text{ mm}^2$	$A_{s,prov} = 4084 \text{ mm}^2$

Required bars



Provided bars



Beam S77	Rectangle (600; 400)
NEN EN 1992-1-1+C2:2011/NB:2016	Section 84 [dx = 10.4 m]

Member length Ld = 14.9 m

Buckling length y Ly = 13.5 m

Buckling length z Lz = 7.53 m

Materials

Concrete C35/45

Reinforcement B 500B

Longitudinal reinforcement

upper: $\phi_{up} = 20$ mm, $c_{up} = 45$ mm

lower: $\phi_{lo} = 20$ mm, $c_{lo} = 45$ mm

side: $c_{side} = 45$ mm

Shear reinforcement

$n_{s.req} = 2$, $\phi_{s.req} = 10$ mm, $\alpha_{s.req} = 90^\circ$

Design shear reinforcement

Content of combination: NC_ULS-SetB(automatisch).14

$V_{Ed} = 9.39$ kN $V_{Rdmax} = 420$ kN $V_{Rdc} = 195$ kN $T_{Ed} = -0.852$ kNm $T_{Rdc} = 48.4$ kNm $T_{Rdmax} = 137$ kNm

Required shear reinforcement: $\phi 10/213$ mm ($n_{s.req} = 2$) => (A_{sw}/s_l) = 737 mm²/m

Provided shear reinforcement: $\phi 10/150$ mm ($n_{s.prov} = 2$) => (A_{sw}/s_l) = 1047 mm²/m

$A_{swm.req}$ [mm ² /m]	$A_{swm.prov}$ [mm ² /m]	$A_{swm.add.req}$ [mm ² /m]	Check $A_{swm.prov} > A_{swm.req}$
737	1047	0	YES (0,70)

$\Delta A\sigma$: NC_ULS-SetB(automatisch).20: $T_{Ed} = -2$ kNm, $F_{ds.max} = 26$ kN

Required

Edge	y [m]	z [m]	$A_{s.stat}$ [mm ²]	$A_{s.det.min}$ [mm ²]	$A_{s.det.max}$ [mm ²]	$\Delta A_{s.tor}$ [mm ²]	$A_{s.req}$ [mm ²]	$A_{s.req.bar}$ [mm ²]	Reinf
1	0	-0.235	438	511	1792	11.4	511	942	3 ϕ 20
2	0.14	0	134	156	3008	17	156	78.5	1 ϕ 10+2 ϕ 20
3	0	0.235	0	62.8	1792	11.4	62.8	628	2 ϕ 20
4	-0.14	0	182	213	3008	17	213	157	2 ϕ 10+2 ϕ 20

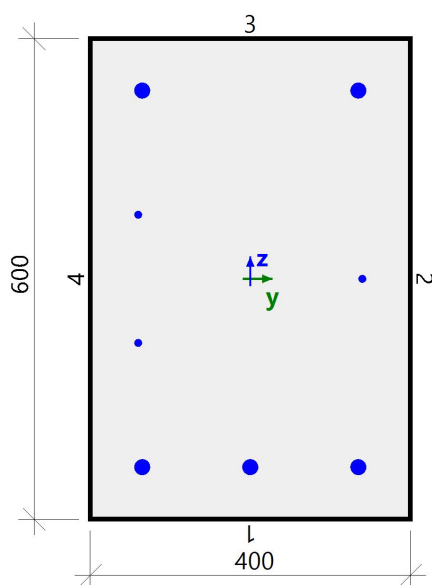
Provided

Edge	$A_{s.req}$ [mm ²]	$A_{s.bas.prov}$ [mm ²]	$A_{s.add.prov}$ [mm ²]	$A_{s.det.prov}$ [mm ²]	$A_{s.prov}$ [mm ²]	$A_{s.add.req}$ [mm ²]	Check $A_{s.prov} > A_{s.req}$	Reinf Prov.
1	511	1257	0	0	1257	0	YES (0,41)	4 ϕ 20
2	156	785	0	0	785	0	YES (0,20)	2 ϕ 10+2 ϕ 20
3	62.8	1257	0	0	1257	0	YES (0,05)	4 ϕ 20
4	213	785	0	0	785	0	YES (0,27)	2 ϕ 10+2 ϕ 20

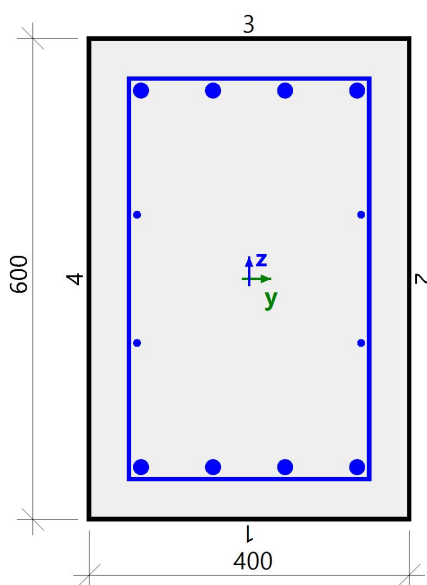
Summary of reinforcement

Upper :	$A_{sz.req+} = 62.83 \text{ mm}^2$	$A_{sz.prov+} = 1257 \text{ mm}^2$
Lower :	$A_{sz.req-} = 511 \text{ mm}^2$	$A_{sz.prov-} = 1257 \text{ mm}^2$
Right :	$A_{sy.req+} = 156.4 \text{ mm}^2$	$A_{sy.prov+} = 785.4 \text{ mm}^2$
Left :	$A_{sy.req-} = 212.5 \text{ mm}^2$	$A_{sy.prov-} = 785.4 \text{ mm}^2$
Total vertical :	$A_{sz.req} = 573.9 \text{ mm}^2$	$A_{sz.prov} = 2513 \text{ mm}^2$
Total horizontal :	$A_{sy.req} = 368.9 \text{ mm}^2$	$A_{sy.prov} = 1571 \text{ mm}^2$
Total :	$A_{s.req} = 942.8 \text{ mm}^2$	$A_{s.prov} = 4084 \text{ mm}^2$

Required bars



Provided bars



10.1.3. Section 600 x 800 mm Overall Design (ULS)

Nonlinear calculation

Class: RC_NC_ULS - Set B (automatisch)

Coordinate system: Member

Extreme 1D: Global

Selection: All

Filter: Cross-section = FB2 - Rectangle (800; 600)

Note: Longitudinal reinforcement is designed in the centre of the edges of the cross-section. Checks use the real position of the reinforcement.

Beam S74	Rectangle (800; 600)
NEN EN 1992-1-1+C2:2011/NB:2016	Section 40 [dx = 5.03 m]

Member length Ld = 5.78 m

Buckling length y Ly = 4.42 m

Buckling length z Lz = 3.29 m

Materials

Concrete C35/45

Reinforcement B 500B

Longitudinal reinforcement

upper: $\phi_{up} = 20$ mm, $c_{up} = 45$ mm

lower: $\phi_{lo} = 20$ mm, $c_{lo} = 45$ mm

side: $c_{side} = 45$ mm

Shear reinforcement

$n_{s.req} = 2$, $\phi_{s.req} = 10$ mm, $\alpha_{s.req} = 90^\circ$

Design shear reinforcement

Content of combination: NC_ULS-SetB(automatisch).62

$V_{Ed} = 50$ kN $V_{Rdmax} = 1006$ kN $V_{Rdc} = 168$ kN $T_{Ed} = -3.68$ kNm $T_{Rdc} = 135$ kNm $T_{Rdmax} = 383$ kNm

Required shear reinforcement: $\phi 10/300$ mm ($n_{s.req} = 2$) => (A_{sw}/s_l) = 524 mm²/m

Provided shear reinforcement: $\phi 10/150$ mm ($n_{s.prov} = 2$) => (A_{sw}/s_l) = 1047 mm²/m

$A_{swm.req}$ [mm ² /m]	$A_{swm.prov}$ [mm ² /m]	$A_{swm.add.req}$ [mm ² /m]	Check $A_{swm.prov} > A_{swm.req}$
524	1047	0	YES (0,50)

$\Delta A\sigma$: NC_ULS-SetB(automatisch).33: $T_{Ed} = -4$ kNm, $F_{ds.max} = 36$ kN

Required

Edge	y [m]	z [m]	$A_{s.stat}$ [mm ²]	$A_{s.det.min}$ [mm ²]	$A_{s.det.max}$ [mm ²]	$\Delta A_{s.tor}$ [mm ²]	$A_{s.req}$ [mm ²]	$A_{s.req.bar}$ [mm ²]	Reinf
1	0	-0.335	244	305	4007	16.8	305	707	1 ϕ 10+2 ϕ 20
2	0.24	0	167	208	5593	22.4	208	157	2 ϕ 10+2 ϕ 20
3	0	0.335	0	108	4007	16.8	108	707	1 ϕ 10+2 ϕ 20
4	-0.24	0	0	150	5593	22.4	150	78.5	1 ϕ 10+2 ϕ 20

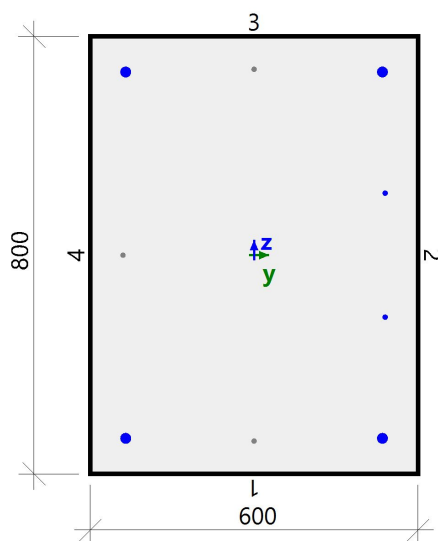
Provided

Edge	$A_{s.req}$ [mm ²]	$A_{s.bas.prov}$ [mm ²]	$A_{s.add.prov}$ [mm ²]	$A_{s.det.prov}$ [mm ²]	$A_{s.prov}$ [mm ²]	$A_{s.add.req}$ [mm ²]	Check $A_{s.prov} > A_{s.req}$	Reinf Prov.
1	305	1257	0	0	1257	0	YES (0,24)	4 ϕ 20
2	208	785	0	0	785	0	YES (0,27)	2 ϕ 10+2 ϕ 20
3	108	1257	0	0	1257	0	YES (0,09)	4 ϕ 20
4	150	785	0	0	785	0	YES (0,19)	2 ϕ 10+2 ϕ 20

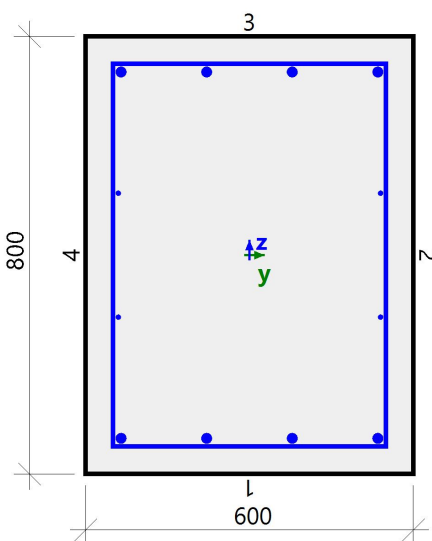
Summary of reinforcement

Upper :	$A_{sz.req+} = 107.7 \text{ mm}^2$	$A_{sz.prov+} = 1257 \text{ mm}^2$
Lower :	$A_{sz.req-} = 305.5 \text{ mm}^2$	$A_{sz.prov-} = 1257 \text{ mm}^2$
Right :	$A_{sy.req+} = 208.1 \text{ mm}^2$	$A_{sy.prov+} = 785.4 \text{ mm}^2$
Left :	$A_{sy.req-} = 150.3 \text{ mm}^2$	$A_{sy.prov-} = 785.4 \text{ mm}^2$
Total vertical :	$A_{sz.req} = 413.2 \text{ mm}^2$	$A_{sz.prov} = 2513 \text{ mm}^2$
Total horizontal :	$A_{sy.req} = 358.5 \text{ mm}^2$	$A_{sy.prov} = 1571 \text{ mm}^2$
Total :	$A_{s.req} = 771.7 \text{ mm}^2$	$A_{s.prov} = 4084 \text{ mm}^2$

Required bars



Provided bars



Beam S72		Rectangle (800; 600)	
NEN EN 1992-1-1+C2:2011/NB:2016		Section 22 [dx = 2.76 m]	
Member length	Ld = 5.78 m	Materials	
Buckling length y	Ly = 4.31 m	Concrete	C35/45
Buckling length z	Lz = 3.35 m	Reinforcement	B 500B

Longitudinal reinforcement

upper: $\phi_{up} = 20 \text{ mm}$, $c_{up} = 45 \text{ mm}$ lower: $\phi_{lo} = 20 \text{ mm}$, $c_{lo} = 45 \text{ mm}$
side: $c_{side} = 45 \text{ mm}$

Shear reinforcement

$n_{s.req} = 2$, $\phi_{s.req} = 10 \text{ mm}$, $\alpha_{s.req} = 90^\circ$

Design shear reinforcement

Content of combination: NC_ULS-SetB(automatisch).62

$V_{Ed} = 1.95 \text{ kN}$ $V_{Rdmax} = 1614 \text{ kN}$ $V_{Rdc} = 169 \text{ kN}$ $T_{Ed} = -0.144 \text{ kNm}$ $T_{Rdc} = 135 \text{ kNm}$ $T_{Rdmax} = 383 \text{ kNm}$

Required shear reinforcement: $\phi 10/277 \text{ mm}$ ($n_{s.req} = 2$) => (A_{sw}/s_l) = $568 \text{ mm}^2/\text{m}$

Provided shear reinforcement: $\phi 10/150 \text{ mm}$ ($n_{s.prov} = 2$) => (A_{sw}/s_l) = $1047 \text{ mm}^2/\text{m}$

$A_{swm.req}$ [mm ² /m]	$A_{swm.prov}$ [mm ² /m]	$A_{swm.add.req}$ [mm ² /m]	Check $A_{swm.prov} > A_{swm.req}$
568	1047	0	YES (0,54)

$\Delta\sigma$: NC_ULS-SetB(automatisch).28: $T_{Ed} = 0$ kNm, $F_{ds,max} = 2$ kN

Required

Edge	y [m]	z [m]	$A_{s,stat}$ [mm ²]	$A_{s,det,min}$ [mm ²]	$A_{s,det,max}$ [mm ²]	$\Delta A_{s,tor}$ [mm ²]	$A_{s,req}$ [mm ²]	$A_{s,req,bar}$ [mm ²]	Reinf
1	0	-0.335	459	573	4007	0.822	573	942	3 ϕ 20
2	0.24	0	0	150	5593	1.1	150	157	2 ϕ 10+1 ϕ 20
3	0	0.335	0	108	4007	0.822	108	78.5	3 ϕ 10
4	-0.24	0	0	150	5593	1.1	150	157	2 ϕ 10+1 ϕ 20

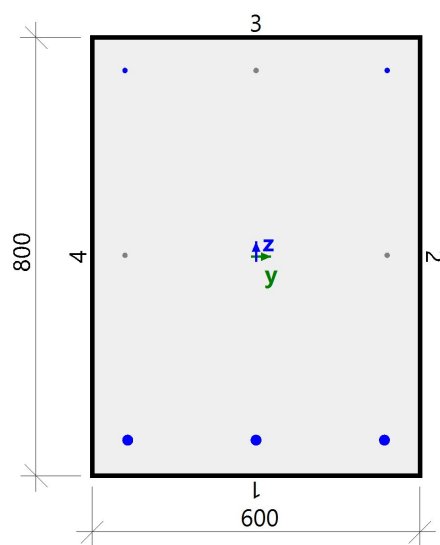
Provided

Edge	$A_{s,req}$ [mm ²]	$A_{s,bas,prov}$ [mm ²]	$A_{s,add,prov}$ [mm ²]	$A_{s,det,prov}$ [mm ²]	$A_{s,prov}$ [mm ²]	$A_{s,add,req}$ [mm ²]	Check $A_{s,prov} > A_{s,req}$	Reinf Prov.
1	573	1257	0	0	1257	0	YES (0,46)	4 ϕ 20
2	150	785	0	0	785	0	YES (0,19)	2 ϕ 10+2 ϕ 20
3	108	1257	0	0	1257	0	YES (0,09)	4 ϕ 20
4	150	785	0	0	785	0	YES (0,19)	2 ϕ 10+2 ϕ 20

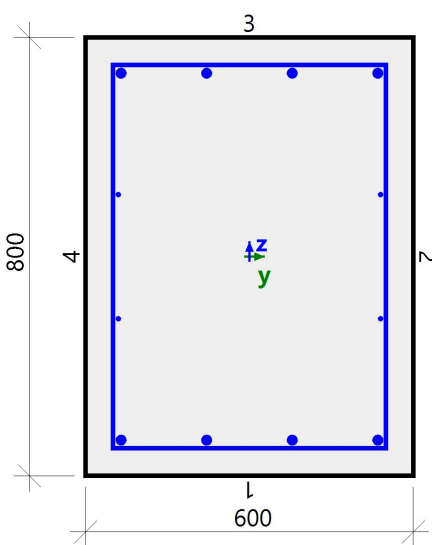
Summary of reinforcement

Upper :	$A_{sz,req+} = 107.7$ mm ²	$A_{sz,prov+} = 1257$ mm ²
Lower :	$A_{sz,req-} = 573.4$ mm ²	$A_{sz,prov-} = 1257$ mm ²
Right :	$A_{sy,req+} = 150.3$ mm ²	$A_{sy,prov+} = 785.4$ mm ²
Left :	$A_{sy,req-} = 150.3$ mm ²	$A_{sy,prov-} = 785.4$ mm ²
Total vertical :	$A_{sz,req} = 681.1$ mm ²	$A_{sz,prov} = 2513$ mm ²
Total horizontal :	$A_{sy,req} = 300.7$ mm ²	$A_{sy,prov} = 1571$ mm ²
Total :	$A_{s,req} = 981.8$ mm ²	$A_{s,prov} = 4084$ mm ²

Required bars



Provided bars



Beam S74	Rectangle (800; 600)
NEN EN 1992-1-1+C2:2011/NB:2016	Section 22 [dx = 2.76 m]

Member length Ld = 5.78 m

Buckling length y Ly = 4.42 m

Buckling length z Lz = 3.29 m

Materials

Concrete C35/45

Reinforcement B 500B

Longitudinal reinforcement

upper: $\phi_{up} = 20$ mm, $c_{up} = 45$ mm

lower: $\phi_{lo} = 20$ mm, $c_{lo} = 45$ mm

side: $c_{side} = 45$ mm

Shear reinforcement

$n_{s.req} = 2$, $\phi_{s.req} = 10$ mm, $\alpha_{s.req} = 90^\circ$

Design shear reinforcement

Content of combination: NC_ULS-SetB(automatisch).62

$V_{Ed} = 4.02$ kN $V_{Rdmax} = 695$ kN $V_{Rdc} = 125$ kN $T_{Ed} = 0.305$ kNm $T_{Rdc} = 135$ kNm $T_{Rdmax} = 383$ kNm

Required shear reinforcement: $\phi 10/300$ mm ($n_{s.req} = 2$) => (A_{sw}/s_l) = 524 mm²/m

Provided shear reinforcement: $\phi 10/150$ mm ($n_{s.prov} = 2$) => (A_{sw}/s_l) = 1047 mm²/m

$A_{swm.req}$ [mm ² /m]	$A_{swm.prov}$ [mm ² /m]	$A_{swm.add.req}$ [mm ² /m]	Check $A_{swm.prov} > A_{swm.req}$
524	1047	0	YES (0,50)

$\Delta A\sigma$: NC_ULS-SetB(automatisch).32: $T_{Ed} = 0$ kNm, $F_{ds.max} = 3$ kN

Required

Edge	y [m]	z [m]	$A_{s.stat}$ [mm ²]	$A_{s.det.min}$ [mm ²]	$A_{s.det.max}$ [mm ²]	$\Delta A_{s.tor}$ [mm ²]	$A_{s.req}$ [mm ²]	$A_{s.req.bar}$ [mm ²]	Reinf
1	0	-0.335	303	379	4007	1.38	379	942	3 ϕ 20
2	0.24	0	55.6	150	5593	1.84	150	78.5	1 ϕ 10+2 ϕ 20
3	0	0.335	0	108	4007	1.38	108	707	1 ϕ 10+2 ϕ 20
4	-0.24	0	196	245	5593	1.84	245	236	3 ϕ 10+2 ϕ 20

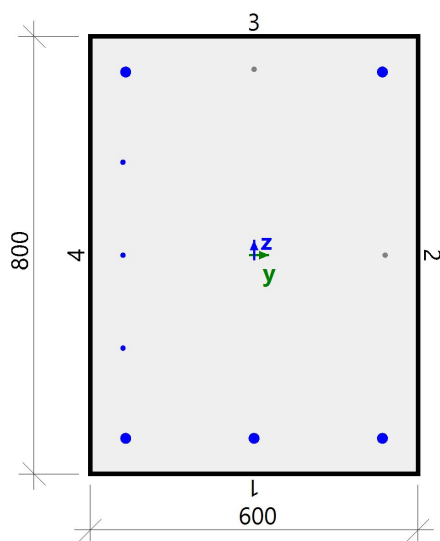
Provided

Edge	$A_{s.req}$ [mm ²]	$A_{s.bas.prov}$ [mm ²]	$A_{s.add.prov}$ [mm ²]	$A_{s.det.prov}$ [mm ²]	$A_{s.prov}$ [mm ²]	$A_{s.add.req}$ [mm ²]	Check $A_{s.prov} > A_{s.req}$	Reinf Prov.
1	379	1257	0	0	1257	0	YES (0,30)	4 ϕ 20
2	150	785	0	0	785	0	YES (0,19)	2 ϕ 10+2 ϕ 20
3	108	1257	0	0	1257	0	YES (0,09)	4 ϕ 20
4	245	785	0	0	785	0	YES (0,31)	2 ϕ 10+2 ϕ 20

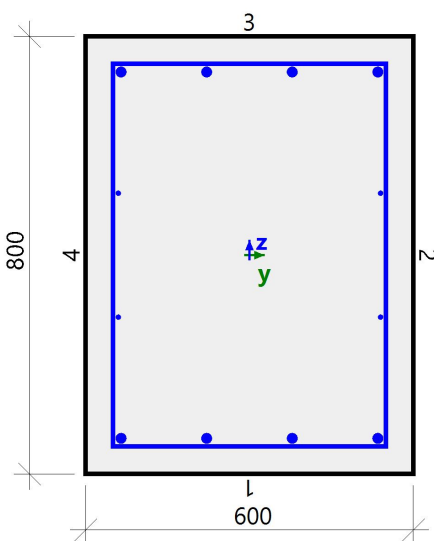
Summary of reinforcement

Upper :	$A_{sz.req+} = 107.7 \text{ mm}^2$	$A_{sz.prov+} = 1257 \text{ mm}^2$
Lower :	$A_{sz.req-} = 378.8 \text{ mm}^2$	$A_{sz.prov-} = 1257 \text{ mm}^2$
Right :	$A_{sy.req+} = 150.3 \text{ mm}^2$	$A_{sy.prov+} = 785.4 \text{ mm}^2$
Left :	$A_{sy.req-} = 245 \text{ mm}^2$	$A_{sy.prov-} = 785.4 \text{ mm}^2$
Total vertical :	$A_{sz.req} = 486.5 \text{ mm}^2$	$A_{sz.prov} = 2513 \text{ mm}^2$
Total horizontal :	$A_{sy.req} = 395.4 \text{ mm}^2$	$A_{sy.prov} = 1571 \text{ mm}^2$
Total :	$A_{s.req} = 881.9 \text{ mm}^2$	$A_{s.prov} = 4084 \text{ mm}^2$

Required bars



Provided bars



10.1.4. Check crack width (SLS) - Global

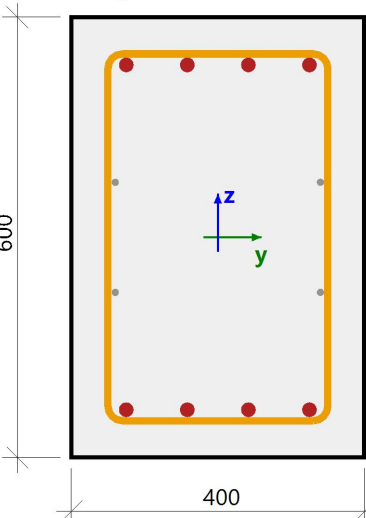
Nonlinear calculation

Class: RC_NC_SLS - Frequent (automatisch)

Coordinate system: Member

Extreme 1D: Global

Selection: S71..S81

Beam S75		Rectangle (600; 400)
NEN EN 1992-1-1+C2:2011/NB:2016		Section 28 [dx = 3.55 m]
Member length:	L = 8.62 m	Concrete: C35/45
Buckling y-y	L _y = 8.26 m (non-sway)	Bi-linear stress-strain diagram
Buckling z-z	L _z = 4.47 m (non-sway)	Exposure class: XC4, XD3, XS1, XF4, XA2, XM1
	4φ20 (1257 mm ²)	Longitudinal reinforcement: B 500B
	2φ10 (157 mm ²)	Bi-linear with an inclined top branch
	2φ10 (157 mm ²)	4φ10 mm + 8φ20 mm (A _s = 2827 mm ²)
	4φ20 (1257 mm ²)	ρ _l = 1,178 % (22.2 kg/m)
	φ10/144 mm, ns=2	Shear reinforcement: B 500B
		Bi-linear with an inclined top branch
		φ10/144 mm (n _s = 2) (A _{sw} = 157 mm ²)
		ρ _w = 0,456 % (8.58 kg/m) (A _{swm} = 1093 mm ² /m)
		Cover (stirrup)
		Top: 45 mm
		Bottom: 45 mm
		Left: 45 mm
		Right: 45 mm

Material characteristics

Effective strength of concrete:

$$f_{ct,eff} = f_{ctm} = 3.2 \text{ MPa}$$

Modulus of elasticity of concrete:

$$E_c = \frac{E_{cm}}{1 + \varphi_{ef}} = \frac{34.1}{1 + 2.02} = 11.3 \text{ GPa} \quad (3.23, 5.27)$$

Strength in concrete, when crack is appeared:

$$\sigma_{cr} = 3.2 \text{ MPa}$$

Forces

Characteristic values

NC_SLS-Frequent(automatisch).1

N_{char} = -11.3 kN M_{y, char} = -1.09 kNm M_{z, char} = -0.209 kNm

Frequent values

NC_SLS-Frequent(automatisch).1

N_{freq} = -11.3 kN M_{y, freq} = -1.09 kNm M_{z, freq} = -0.209 kNm

Angle of bending moment resultant

$$\alpha_M = -101^\circ$$

Cross-section characteristics

Type	Css-uncracked	Css cracked
t _{iy} [m]	0	-1.59·10 ⁻³
t _{iz} [m]	0	-2.7·10 ⁻³
A _i [m ²]	0.284	0.282
I _{iy} [m ⁴]	9.66·10 ⁻³	9.44·10 ⁻³
I _{iz} [m ⁴]	3.59·10 ⁻³	3.51·10 ⁻³

Calculation of cracking forces (uncracked section)

Maximal stress in concrete

$$\sigma_{ct} = 5.96 \cdot 10^{-3} \text{ MPa}$$

Cracking forces

$$N_{cr} = -6060 \text{ kN} \quad M_{cry} = -588 \text{ kNm} \quad M_{crz} = -112 \text{ kNm}$$

$$\sigma_{ct} = 5.96 \cdot 10^{-3} \text{ MPa} < \sigma_{cr} = 3.2 \text{ MPa} \Rightarrow \text{No cracks appear}$$

Note: The crack is not appeared, because maximal tensile stress is lesser than cracking strength.

Calculation crack width

$$w = 0 \text{ mm}$$

Unity check

Calculation unity check

$$UC = \frac{w}{w_{\max}} = \frac{0 \text{ mm}}{0.15 \text{ mm}} = 0$$

Check crack width

$$w = 0 \text{ mm} = < w_{\max} = 0.15 \text{ mm}$$

Note: Check crack width satisfies, because the crack width is lesser than limit value.

10.2. 2D Members

10.2.1. Reinforcement design (ULS+SLS) Concrete slab – Truck loading area

Nonlinear calculation

Class: RC_NC_ULS - Set B (automatisch)

Extreme: Global

Selection: E1

Location: In nodes avg. on macro. System: LCS mesh element

Plate E1	h=250 mm
NEN EN 1992-1-1+C2:2011/NB:2016	Node 462/1636 [X= 4,400, Y=3,394, Z=0,000 m]

Design assumptions

Reinforcement

Longitudinal: **B 500B**

Upper surface

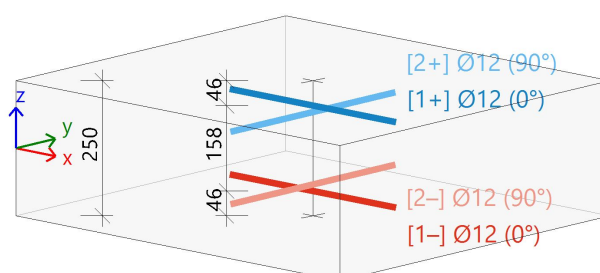
[1+] First layer (0°) Ø12,0 mm / Principal
[2+] Second layer (90°) Ø12,0 mm / Principal
Cover: $c_{nom} = 40$ mm

Lower surface

[1-] First layer (0°) Ø12,0 mm / Principal
[2-] Second layer (90°) Ø12,0 mm / Principal
Cover: $c_{nom} = 40$ mm

Shear: **B 500B**

Ø8 mm



Concrete:

Material: **C35/45**

Structural class: S3 (design working life of 50 years, no special quality control)

(Table 4.3N)

Environmental conditions: XC4, XF4, XD3, XS1, XA2, XM1 (in situ)

(Table 4.1N)

Minimum cover

(§4.4.1.2)

$$c_{min} = \max(c_{min,br}, c_{min,dur} + \Delta c_{dur,y} - \Delta c_{dur,st} - \Delta c_{dur,add}; 10)$$

$$= \max(12; 35 + 0 - 0 - 0; 10) = 35 \text{ mm}$$

(4.2)

Nominal cover

(§4.4.1.1)

$$c_{nom} = c_{min} + \Delta c_{dev} = 35 + 5 = 40 \text{ mm}$$

(4.1)

Internal forces from structural analysis

Ultimate limit state										(93.132)
Including the self-weight of concrete (NEN 6750:2010)										93.132
a = 1.0; Concrete C20/25; $\gamma_c = 25.0$ kN/m ³										93.132
Case	N _{Ed} [kN]	M _{Ed} [kNm]	V _{Ed} [kN]	N _{Ed} [kN]	M _{Ed} [kNm]	V _{Ed} [kN]	N _{Ed} [kN]	M _{Ed} [kNm]	V _{Ed} [kN]	
HC_UJS - Set B	-1.31	-1.54	-1.37	5.14	0.44	1.05	2.06	-0.87		
(automatized)1										
HC_UJS - Set B	-8.88	-1.37	-7.20	40.44	1.71	7.39	14.31	-3.53		
(automatized)2										
HC_UJS - Set B	12.66	6.13	-8.25	-33.07	1.47	-30.35	53.06	9.55		
(automatized)3										
HC_UJS - Set B	8.20	0.89	-6.56	30.04	1.50	6.90	12.97	-2.12		
(automatized)4										
HC_UJS - Set B	12.88	2.80	-14.19	-51.70	-0.93	-15.38	58.37	6.65		
(automatized)5										
HC_UJS - Set B	13.45	3.16	-13.84	-54.10	-1.13	-15.87	57.03	7.06		
(automatized)6										
HC_UJS - Set B	3.38	2.96	-13.93	6.52	3.05	-14.30	54.49	-3.31		
(automatized)7										
HC_UJS - Set B	17.62	4.33	-7.62	-105.06	-3.13	-2.30	32.21	16.95		
(automatized)8										
HC_UJS - Set B	8.51	8.51	-1.58	4.40	5.21	-15.80	33.53	-2.58		
(automatized)9										
HC_UJS - Set B	-24.34	4.77	17.18	117.84	5.30	19.95	-76.54	-0.69		
(automatized)10										
HC_UJS - Set B	2.82	2.58	-14.58	6.52	3.26	-13.81	53.83	-3.72		
(automatized)11										
HC_UJS - Set B	-4.37	2.11	-11.25	30.39	2.82	-6.08	35.30	5.22		
(automatized)12										
HC_UJS - Set B	18.32	4.02	-7.13	-108.36	-3.33	-2.79	18.87	17.36		
(automatized)13										
HC_UJS - Set B	-54.08	4.50	16.87	119.04	5.50	20.44	-49.21	-1.10		
(automatized)14										
HC_UJS - Set B	11.23	5.62	-3.62	-23.49	1.50	1.94	6.20	0.71		
(automatized)15										
HC_UJS - Set B	11.78	5.82	-2.96	-25.89	1.50	1.45	4.97	1.12		
(automatized)16										
HC_UJS - Set B	9.10	6.71	-4.91	2.08	5.60	-16.29	31.19	-2.17		
(automatized)17										
HC_UJS - Set B	-4.95	1.81	-11.89	32.99	3.12	-5.59	35.64	5.62		
(automatized)18										
HC_UJS - Set B	-2.18	-2.54	-2.27	6.51	0.72	1.73	4.74	-1.44		
(automatized)19										
HC_UJS - Set B	12.22	6.50	-7.87	-25.47	1.28	-30.83	51.74	9.96		
(automatized)20										
HC_UJS - Set B	6.50	5.86	16.58	-2.12	-0.68	37.69	-82.39	8.21		
(automatized)21										
HC_UJS - Set B	32.28	7.70	13.31	-169.39	-8.80	27.94	-44.09	29.92		
(automatized)22										
HC_UJS - Set B	-7.58	-1.23	-8.23	40.85	2.51	2.05	34.95	-4.08		
(automatized)23										
HC_UJS - Set B	-7.02	1.44	-8.57	38.25	2.31	1.54	23.62	-4.48		
(automatized)24										
HC_UJS - Set B	32.87	8.37	13.95	-171.79	-8.91	27.45	-45.43	30.33		
(automatized)25										
HC_UJS - Set B	5.91	5.32	16.10	0.28	-0.48	38.18	-91.65	7.80		
(automatized)26										
HC_UJS - Set B	39.21	6.89	-7.94	-222.82	-8.92	-8.08	22.04	34.02		
(automatized)27										
HC_UJS - Set B	-2.18	-2.54	-2.27	6.51	0.72	1.73	4.74	-1.44		
(automatized)28										
HC_UJS - Set B	-1.31	-1.54	-1.37	5.14	0.44	1.05	2.06	-0.87		
(automatized)29										
HC_UJS - Set B	39.86	7.60	-7.38	-225.22	-10.13	-8.97	20.71	34.42		
(automatized)30										
HC_UJS - Set B	-1.31	-1.54	-1.37	5.14	0.44	1.05	2.06	-0.87		
(automatized)31										
HC_UJS - Set B	-2.18	-2.54	-2.27	6.51	0.72	1.73	4.74	-1.44		
(automatized)32										
HC_UJS - Set B	-2.18	-2.54	-2.27	6.51	0.72	1.73	4.74	-1.44		
(automatized)33										
HC_UJS - Set B	-4.96	-1.90	-5.89	31.44	1.47	5.81	11.79	-3.01		
(automatized)34										
HC_UJS - Set B	-18.98	-1.75	6.73	89.12	3.86	4.88	-24.31	-2.45		
(automatized)35										
HC_UJS - Set B	-18.44	1.73	7.22	86.72	3.78	4.39	-25.63	-2.04		
(automatized)36										
HC_UJS - Set B	-18.08	2.78	10.94	86.78	4.11	14.91	-46.42	-1.32		
(automatized)37										
HC_UJS - Set B	-1.31	-1.54	-1.37	5.14	0.44	1.05	2.06	-0.87		
(automatized)38										
HC_UJS - Set B	3.54	3.30	11.97	3.45	-0.06	27.27	-62.06	4.85		
(automatized)39										
HC_UJS - Set B	-2.18	-2.54	-2.27	6.51	0.72	1.73	4.74	-1.44		
(automatized)40										
HC_UJS - Set B	-2.18	-2.54	-2.27	6.51	0.72	1.73	4.74	-1.44		
(automatized)41										
HC_UJS - Set B	-15.97	-2.19	4.02	69.37	5.05	4.08	-15.13	-2.26		
(automatized)42										
HC_UJS - Set B	21.88	4.40	8.40	-114.90	-5.86	20.14	-42.86	20.30		
(automatized)43										
HC_UJS - Set B	-1.31	-1.54	-1.37	5.14	0.44	1.05	2.06	-0.87		
(automatized)44										
HC_UJS - Set B	-1.31	-1.54	-1.37	5.14	0.44	1.05	2.06	-0.87		
(automatized)45										
HC_UJS - Set B	-6.07	-1.82	-7.39	31.89	2.03	2.08	19.21	3.96		
(automatized)46										
HC_UJS - Set B	4.25	-1.52	-8.16	28.25	2.45	-3.23	28.44	-4.47		
(automatized)47										
HC_UJS - Set B	8.05	3.78	-4.54	-19.79	1.30	-20.48	38.81	6.10		
(automatized)48										
HC_UJS - Set B	-1.49	1.27	-11.03	9.47	2.55	-8.97	48.72	-3.14		
(automatized)49										
HC_UJS - Set B	28.43	-4.73	-6.10	-152.04	-6.84	-5.87	17.18	22.18		
(automatized)50										
HC_UJS - Set B	8.21	-1.56	-10.67	-32.78	-0.37	-10.06	42.49	4.08		
(automatized)51										
HC_UJS - Set B	11.34	-4.82	-5.87	-70.38	-1.86	-4.94	15.90	11.28		
(automatized)52										
HC_UJS - Set B	9.19	3.91	-6.17	6.38	3.90	-10.35	25.18	-2.35		
(automatized)53										
HC_UJS - Set B	7.68	3.32	-3.41	-13.12	1.32	2.02	6.14	-0.06		
(automatized)54										
HC_UJS - Set B	-2.18	-2.54	-2.27	6.51	0.72	1.73	4.74	-1.44		
(automatized)55										
HC_UJS - Set B	-2.18	-2.54	-2.27	6.51	0.72	1.73	4.74	-1.44		
(automatized)56										
HC_UJS - Set B	-2.18	-2.54	-2.27	6.51	0.72	1.73	4.74	-1.44		
(automatized)57										
HC_UJS - Set B	-1.31	-1.54	-1.37	5.14	0.44	1.05	2.06	-0.87		
(automatized)58										
HC_UJS - Set B	-1.31	-1.54	-1.37	5.14	0.44	1.05	2.06	-0.87		
(automatized)59										
HC_UJS - Set B	-1.31	-1.54	-1.37	5.14	0.44	1.05	2.06	-0.87		
(automatized)60										
HC_UJS - Set B	-2.18	-2.54	-2.27	6.51	0.72	1.73	4.74	-1.44		
(automatized)61										
HC_UJS - Set B	-2.18	-2.54	-2.27	6.51	0.72	1.73	4.74	-1.44		
(automatized)62										

Case	Combination key
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)1
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)2
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)3
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)4
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)5
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)6
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)7
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)8
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)9
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)10
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)11
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)12
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)13
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)14
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)15
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)16
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)17
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)18
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)19
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)20
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)21
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)22
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)23
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)24
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)25
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)26
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)27
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)28
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)29
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)30
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)31
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)32
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)33
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)34
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)35
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)36
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)37
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)38
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)39
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)40
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)41
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)42
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)43
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)44
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)45
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)46
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)47
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)48
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)49
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)50
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)51
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)52
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)53
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)54
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)55
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)56
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)57
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)58
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)59
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)60
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)61
HC_UJS - Set B (juu)	HC_UJS-SetB(automatized)62

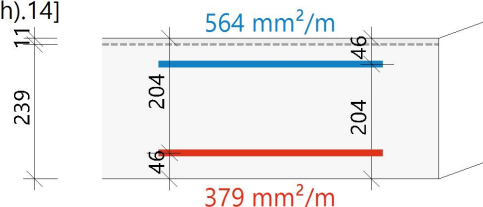
Limit state design of longitudinal reinforcement

Ultimate limit state

Direction of reinforcement layer [$\alpha=0^\circ$]

[1+]: upper surface

$m_{Ed} = -15.8 \text{ kNm/m}$ | $n_{Ed} = 291 \text{ kN/m}$ [NC_ULS - Set B (automatisch).14]
 $f_{cd} = 23.3 \text{ [MPa]}$ ($\gamma_c = 1.5$, $\alpha_{cc} = 1$)
 $f_{yd} = 435 \text{ [MPa]}$ ($\gamma_s = 1.15$)
 $\varnothing 12 \text{ mm} : d_1=46 \text{ mm} \rightarrow d=204 \text{ mm}$
 $x=-2 \text{ mm} \rightarrow z=184 \text{ mm}$
 $A_{s,ult}=564 \text{ mm}^2/\text{m}$ (tensile)
 $\rho=0,276\%$



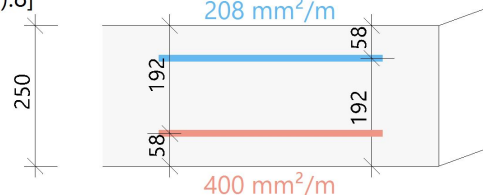
[1-]: lower surface

$m_{Ed} = 36.1 \text{ kNm/m}$ | $n_{Ed} = -26.7 \text{ kN/m}$ [NC_ULS - Set B (automatisch).25]
 $f_{cd} = 23.3 \text{ [MPa]}$ ($\gamma_c = 1.5$, $\alpha_{cc} = 1$)
 $f_{yd} = 435 \text{ [MPa]}$ ($\gamma_s = 1.15$)
 $\varnothing 12 \text{ mm} : d_1=46 \text{ mm} \rightarrow d=204 \text{ mm}$
 $x=11 \text{ mm} \rightarrow z=200 \text{ mm}$
 $A_{s,ult}=379 \text{ mm}^2/\text{m}$ (tensile)
 $\rho=0,186\%$

Direction of reinforcement layer [$\alpha=90^\circ$]

[2+]: upper surface

$m_{Ed} = -7.94 \text{ kNm/m}$ | $n_{Ed} = 75 \text{ kN/m}$ [NC_ULS - Set B (automatisch).8]
 $f_{cd} = 23.3 \text{ [MPa]}$ ($\gamma_c = 1.5$, $\alpha_{cc} = 1$)
 $f_{yd} = 435 \text{ [MPa]}$ ($\gamma_s = 1.15$)
 $\varnothing 12 \text{ mm} : d_1=58 \text{ mm} \rightarrow d=192 \text{ mm}$
 $x=0.9 \text{ mm} \rightarrow z=192 \text{ mm}$
 $A_{s,ult}=208 \text{ mm}^2/\text{m}$ (tensile)
 $\rho=0,108\%$



[2-]: lower surface

$m_{Ed} = 11.2 \text{ kNm/m}$ | $n_{Ed} = 181 \text{ kN/m}$ [NC_ULS - Set B (automatisch).10]
 $f_{cd} = 23.3 \text{ [MPa]}$ ($\gamma_c = 1.5$, $\alpha_{cc} = 1$)
 $f_{yd} = 435 \text{ [MPa]}$ ($\gamma_s = 1.15$)
 $\varnothing 12 \text{ mm} : d_1=58 \text{ mm} \rightarrow d=192 \text{ mm}$
 $x=-0.3 \text{ mm} \rightarrow z=173 \text{ mm}$
 $A_{s,ult}=400 \text{ mm}^2/\text{m}$ (tensile)
 $\rho=0,208\%$

Check of concrete diagonal strut

Check direction (extreme) [$\alpha=135^\circ$]

Design normal force in direction of concrete strut

$n_{Ed,sc} = -228 \text{ kN}$ [NC_ULS - Set B (automatisch).21]

with full cross-section height:

$h=250 \text{ mm} \rightarrow A_{cc} = h \cdot b = 0.25 \cdot 1000 = 250000 \text{ mm}^2$

$f_{cd} = \frac{\alpha_{cc} \cdot f_{ck}}{\gamma_c} = \frac{1 \cdot 35}{1.5} = 23 \text{ MPa}$

Design resistance of concrete strut (in compression)

$n_{Rd,sc} = A_{cc} \cdot \text{Red}_{fcd} \cdot f_{cd} = 250000 \cdot 0.85 \cdot 23 = 4958 \text{ kN}$

Unity check

$UC_{sc} = \frac{\text{abs}(n_{Ed,sc})}{n_{Rd,sc}} = \frac{\text{abs}(-228)}{4958} = 0.046$

Detailing of the longitudinal reinforcement

Minimum principal reinforcement

Principal [1-] (tension)

Minimum area from reinforcement ratio

(\$9.2.1.1(1))

First order eccentricity

$$e_y = 0 \text{ mm}$$

$$e_z = 1353 \text{ mm}$$

$$e = \sqrt{e_y^2 + e_z^2} = \sqrt{0^2 + 1353^2} = 1353 \text{ mm}$$

Elastic section modulus

$$\alpha_e = 0^\circ$$

$$W_{ely} = 10.4 \cdot 10^6 \text{ mm}^3$$

$$W_{elz} = 41.7 \cdot 10^6 \text{ mm}^3$$

$$W_{el} = 10.4 \cdot 10^6 \text{ mm}^3$$

$$\eta_y = \frac{e_z \cdot A_c}{W_{ely}} = \frac{1353 \cdot 250000}{10.4 \cdot 10^6} = 32.5$$

$$\eta_z = \frac{e_y \cdot A_c}{W_{elz}} = \frac{0 \cdot 250000}{41.7 \cdot 10^6} = 0$$

$$\eta = \frac{e \cdot A_c}{W_{el}} = \frac{1353 \cdot 250000}{10.4 \cdot 10^6} = 32.5$$

Combination for compression

$$M_{E,min,y} = \frac{f_{ctm} \cdot W_{ely} \cdot \eta_y}{\eta_y - 1} = \frac{3.2 \cdot 10.4 \cdot 10^6 \cdot 32.5}{32.5 - 1} = 34.4 \text{ kNm}$$

$$M_{E,min,z} = \frac{f_{ctm} \cdot W_{elz} \cdot \eta_z}{\eta_z - 1} = \frac{3.2 \cdot 41.7 \cdot 10^6 \cdot 0}{0 - 1} = 0 \text{ kNm}$$

$$N_{E,min} = \frac{f_{ctm} \cdot A_c \cdot 1}{\eta - 1} = \frac{3.2 \cdot 250000 \cdot 1}{32.5 - 1} = 25.4 \text{ kN}$$

$$A_{s,req,comp} = 338 \text{ mm}^2$$

Combination for tension

$$M_{E,min,y} = \frac{f_{ctm} \cdot W_{ely} \cdot \eta_y}{\eta_y + 1} = \frac{3.2 \cdot 10.4 \cdot 10^6 \cdot 32.5}{32.5 + 1} = 32.3 \text{ kNm}$$

$$M_{E,min,z} = \frac{f_{ctm} \cdot W_{elz} \cdot \eta_z}{\eta_z + 1} = \frac{3.2 \cdot 41.7 \cdot 10^6 \cdot 0}{0 + 1} = 0 \text{ kNm}$$

$$N_{E,min} = \frac{f_{ctm} \cdot A_c \cdot 1}{\eta + 1} = \frac{3.2 \cdot 250000 \cdot 1}{32.5 + 1} = 23.9 \text{ kN}$$

$$A_{s,req,tens} = 379 \text{ mm}^2$$

Combination for bending

$$M_{E,min,y} = f_{ctm} \cdot W_{ely} = 3.2 \cdot 10.4 \cdot 10^6 = 33.3 \text{ kNm}$$

$$M_{E,min,z} = f_{ctm} \cdot W_{elz} = 3.2 \cdot 41.7 \cdot 10^6 = 133 \text{ kNm}$$

$$A_{s,req,bend} = 359 \text{ mm}^2$$

$$A_{s,min,1} = \max(A_{s,req,comp}; A_{s,req,tens}; A_{s,req,bend}) = \max(338; 379; 359) = 379 \text{ mm}^2/\text{m}$$

Required area from ULS

$$A_s = 379 \text{ mm}^2$$

$$\text{Coeff}_{A_{smin}} = 1.25$$

$$A_{s,min,2} = \text{Coeff}_{A_{smin}} \cdot A_s = 1.25 \cdot 379 = 474 \text{ mm}^2/\text{m}$$

Final minimal allowed area of longitudinal reinforcement

$$A_{s,min} = \min(A_{s,min,1}; A_{s,min,2}) = \min(379; 474) = 379 \text{ mm}^2/\text{m}$$

Minimum area from maximum spacing of reinforcement bars

$$s_{max,slab} = \min(\text{Coeff}_{s_{max,slab,A}} \cdot h; \text{Coeff}_{s_{max,slab,B}}) = \min(3 \cdot 250; 400) = 400 \text{ mm} \quad (\$9.3.1.1(3))$$

$$A_{s,min} = \frac{b}{s_{max,slab}} \cdot 0.25 \cdot \pi \cdot \phi^2 = \frac{1000}{400} \cdot 0.25 \cdot 3.14 \cdot 12^2 = 283 \text{ mm}^2/\text{m}$$

Principal [2-] (tension)

Minimum area from reinforcement ratio (\\$9.2.1.1(1))

First order eccentricity

$$e_y = 0 \text{ mm}$$

$$e_z = 61.6 \text{ mm}$$

$$e = \sqrt{e_y^2 + e_z^2} = \sqrt{0^2 + 61.6^2} = 61.6 \text{ mm}$$

Elastic section modulus

$$\alpha_e = 0^\circ$$

$$W_{ely} = 10.4 \cdot 10^6 \text{ mm}^3$$

$$W_{elz} = 41.7 \cdot 10^6 \text{ mm}^3$$

$$W_{el} = 10.4 \cdot 10^6 \text{ mm}^3$$

$$\eta_y = \frac{e_z \cdot A_c}{W_{ely}} = \frac{61.6 \cdot 250000}{10.4 \cdot 10^6} = 1.48$$

$$\eta_z = \frac{e_y \cdot A_c}{W_{elz}} = \frac{0 \cdot 250000}{41.7 \cdot 10^6} = 0$$

$$\eta = \frac{e \cdot A_c}{W_{el}} = \frac{61.6 \cdot 250000}{10.4 \cdot 10^6} = 1.48$$

Combination for compression

$$M_{E,min,y} = \frac{f_{ctm} \cdot W_{ely} \cdot \eta_y}{\eta_y - 1} = \frac{3.2 \cdot 10.4 \cdot 10^6 \cdot 1.48}{1.48 - 1} = 103 \text{ kNm}$$

$$M_{E,min,z} = \frac{f_{ctm} \cdot W_{elz} \cdot \eta_z}{\eta_z - 1} = \frac{3.2 \cdot 41.7 \cdot 10^6 \cdot 0}{0 - 1} = 0 \text{ kNm}$$

$$N_{E,min} = \frac{f_{ctm} \cdot A_c \cdot 1}{\eta - 1} = \frac{3.2 \cdot 250000 \cdot 1}{1.48 - 1} = 1676 \text{ kN}$$

$$A_{s,req,comp} = 0 \text{ mm}^2$$

Combination for tension

$$M_{E,min,y} = \frac{f_{ctm} \cdot W_{ely} \cdot \eta_y}{\eta_y + 1} = \frac{3.2 \cdot 10.4 \cdot 10^6 \cdot 1.48}{1.48 + 1} = 19.9 \text{ kNm}$$

$$M_{E,min,z} = \frac{f_{ctm} \cdot W_{elz} \cdot \eta_z}{\eta_z + 1} = \frac{3.2 \cdot 41.7 \cdot 10^6 \cdot 0}{0 + 1} = 0 \text{ kNm}$$

$$N_{E,min} = \frac{f_{ctm} \cdot A_c \cdot 1}{\eta + 1} = \frac{3.2 \cdot 250000 \cdot 1}{1.48 + 1} = 323 \text{ kN}$$

$$A_{s,req,tens} = 693 \text{ mm}^2$$

Combination for bending

$$M_{E,min,y} = f_{ctm} \cdot W_{ely} = 3.2 \cdot 10.4 \cdot 10^6 = 33.3 \text{ kNm}$$

$$M_{E,min,z} = f_{ctm} \cdot W_{elz} = 3.2 \cdot 41.7 \cdot 10^6 = 133 \text{ kNm}$$

$$A_{s,req,bend} = 382 \text{ mm}^2$$

$$A_{s,min,1} = \max(A_{s,req,comp}; A_{s,req,tens}; A_{s,req,bend}) = \max(0; 693; 382) = 693 \text{ mm}^2/\text{m}$$

Required area from ULS

$$A_s = 400 \text{ mm}^2$$

$$\text{Coeff}_{A_{smin}} = 1.25$$

$$A_{s,min,2} = \text{Coeff}_{A_{smin}} \cdot A_s = 1.25 \cdot 400 = 500 \text{ mm}^2/\text{m}$$

Final minimal allowed area of longitudinal reinforcement

$$A_{s,min} = \min(A_{s,min,1}; A_{s,min,2}) = \min(693; 500) = 500 \text{ mm}^2/\text{m}$$

Minimum area from maximum spacing of reinforcement bars

$$s_{max,slab} = \min(\text{Coeff}_{s_{max,slab,A}} \cdot h; \text{Coeff}_{s_{max,slab,B}}) = \min(3 \cdot 250; 400) = 400 \text{ mm} \quad (\$9.3.1.1(3))$$

$$A_{s,min} = \frac{b}{s_{max,slab}} \cdot 0.25 \cdot \pi \cdot \phi^2 = \frac{1000}{400} \cdot 0.25 \cdot 3.14 \cdot 12^2 = 283 \text{ mm}^2/\text{m}$$

Principal [1+] (tension)

Minimum area from reinforcement ratio

(\\$9.2.1.1(1))

First order eccentricity

$$e_y = 0 \text{ mm}$$

$$e_z = 54.2 \text{ mm}$$

$$e = \sqrt{e_y^2 + e_z^2} = \sqrt{0^2 + 54.2^2} = 54.2 \text{ mm}$$

Elastic section modulus

$$\alpha_e = 0^\circ$$

$$W_{ely} = 10.4 \cdot 10^6 \text{ mm}^3$$

$$W_{elz} = 41.7 \cdot 10^6 \text{ mm}^3$$

$$W_{el} = 10.4 \cdot 10^6 \text{ mm}^3$$

$$\eta_y = \frac{e_z \cdot A_c}{W_{ely}} = \frac{54.2 \cdot 250000}{10.4 \cdot 10^6} = 1.3$$

$$\eta_z = \frac{e_y \cdot A_c}{W_{elz}} = \frac{0 \cdot 250000}{41.7 \cdot 10^6} = 0$$

$$\eta = \frac{e \cdot A_c}{W_{el}} = \frac{54.2 \cdot 250000}{10.4 \cdot 10^6} = 1.3$$

Combination for compression

$$M_{E,min,y} = \frac{f_{ctm} \cdot W_{ely} \cdot \eta_y}{\eta_y - 1} = \frac{3.2 \cdot 10.4 \cdot 10^6 \cdot 1.3}{1.3 - 1} = 144 \text{ kNm}$$

$$M_{E,min,z} = \frac{f_{ctm} \cdot W_{elz} \cdot \eta_z}{\eta_z - 1} = \frac{3.2 \cdot 41.7 \cdot 10^6 \cdot 0}{0 - 1} = 0 \text{ kNm}$$

$$N_{E,min} = \frac{f_{ctm} \cdot A_c \cdot 1}{\eta - 1} = \frac{3.2 \cdot 250000 \cdot 1}{1.3 - 1} = 2663 \text{ kN}$$

$$A_{s,req,comp} = 0 \text{ mm}^2$$

Combination for tension

$$M_{E,min,y} = \frac{f_{ctm} \cdot W_{ely} \cdot \eta_y}{\eta_y + 1} = \frac{3.2 \cdot 10.4 \cdot 10^6 \cdot 1.3}{1.3 + 1} = 18.8 \text{ kNm}$$

$$M_{E,min,z} = \frac{f_{ctm} \cdot W_{elz} \cdot \eta_z}{\eta_z + 1} = \frac{3.2 \cdot 41.7 \cdot 10^6 \cdot 0}{0 + 1} = 0 \text{ kNm}$$

$$N_{E,min} = \frac{f_{ctm} \cdot A_c \cdot 1}{\eta + 1} = \frac{3.2 \cdot 250000 \cdot 1}{1.3 + 1} = 348 \text{ kN}$$

$$A_{s,req,tens} = 746 \text{ mm}^2$$

Combination for bending

$$M_{E,min,y} = f_{ctm} \cdot W_{ely} = 3.2 \cdot 10.4 \cdot 10^6 = 33.3 \text{ kNm}$$

$$M_{E,min,z} = f_{ctm} \cdot W_{elz} = 3.2 \cdot 41.7 \cdot 10^6 = 133 \text{ kNm}$$

$$A_{s,req,bend} = 359 \text{ mm}^2$$

$$A_{s,min,1} = \max(A_{s,req,comp}; A_{s,req,tens}; A_{s,req,bend}) = \max(0; 746; 359) = 746 \text{ mm}^2/\text{m}$$

Required area from ULS

$$A_s = 564 \text{ mm}^2$$

$$\text{Coeff}_{A_{smin}} = 1.25$$

$$A_{s,min,2} = \text{Coeff}_{A_{smin}} \cdot A_s = 1.25 \cdot 564 = 705 \text{ mm}^2/\text{m}$$

Final minimal allowed area of longitudinal reinforcement

$$A_{s,min} = \min(A_{s,min,1}; A_{s,min,2}) = \min(746; 705) = 705 \text{ mm}^2/\text{m}$$

Minimum area from maximum spacing of reinforcement bars

$$s_{max,slab} = \min(\text{Coeff}_{s_{max,slab,A}} \cdot h; \text{Coeff}_{s_{max,slab,B}}) = \min(3 \cdot 250; 400) = 400 \text{ mm} \quad (\S 9.3.1.1(3))$$

$$A_{s,min} = \frac{b}{s_{max,slab}} \cdot 0.25 \cdot \pi \cdot \phi^2 = \frac{1000}{400} \cdot 0.25 \cdot 3.14 \cdot 12^2 = 283 \text{ mm}^2/\text{m}$$

Principal [2+] (tension)

Minimum area from reinforcement ratio (\S 9.2.1.1(1))

First order eccentricity

$$e_y = 0 \text{ mm}$$

$$e_z = 106 \text{ mm}$$

$$e = \sqrt{e_y^2 + e_z^2} = \sqrt{0^2 + 106^2} = 106 \text{ mm}$$

Elastic section modulus

$$\alpha_e = 0^\circ$$

$$W_{ely} = 10.4 \cdot 10^6 \text{ mm}^3$$

$$W_{elz} = 41.7 \cdot 10^6 \text{ mm}^3$$

$$W_{el} = 10.4 \cdot 10^6 \text{ mm}^3$$

$$\eta_y = \frac{e_z \cdot A_c}{W_{ely}} = \frac{106 \cdot 250000}{10.4 \cdot 10^6} = 2.54$$

$$\eta_z = \frac{e_y \cdot A_c}{W_{elz}} = \frac{0 \cdot 250000}{41.7 \cdot 10^6} = 0$$

$$\eta = \frac{e \cdot A_c}{W_{el}} = \frac{106 \cdot 250000}{10.4 \cdot 10^6} = 2.54$$

Combination for compression

$$M_{E,min,y} = \frac{f_{ctm} \cdot W_{ely} \cdot \eta_y}{\eta_y - 1} = \frac{3.2 \cdot 10.4 \cdot 10^6 \cdot 2.54}{2.54 - 1} = 55 \text{ kNm}$$

$$M_{E,min,z} = \frac{f_{ctm} \cdot W_{elz} \cdot \eta_z}{\eta_z - 1} = \frac{3.2 \cdot 41.7 \cdot 10^6 \cdot 0}{0 - 1} = 0 \text{ kNm}$$

$$N_{E,min} = \frac{f_{ctm} \cdot A_c \cdot 1}{\eta - 1} = \frac{3.2 \cdot 250000 \cdot 1}{2.54 - 1} = 520 \text{ kN}$$

$$A_{s,req,comp} = 0 \text{ mm}^2$$

Combination for tension

$$M_{E,min,y} = \frac{f_{ctm} \cdot W_{ely} \cdot \eta_y}{\eta_y + 1} = \frac{3.2 \cdot 10.4 \cdot 10^6 \cdot 2.54}{2.54 + 1} = 23.9 \text{ kNm}$$

$$M_{E,min,z} = \frac{f_{ctm} \cdot W_{elz} \cdot \eta_z}{\eta_z + 1} = \frac{3.2 \cdot 41.7 \cdot 10^6 \cdot 0}{0 + 1} = 0 \text{ kNm}$$

$$N_{E,min} = \frac{f_{ctm} \cdot A_c \cdot 1}{\eta + 1} = \frac{3.2 \cdot 250000 \cdot 1}{2.54 + 1} = 226 \text{ kN}$$

$$A_{s,req,tens} = 584 \text{ mm}^2$$

Combination for bending

$$M_{E,min,y} = f_{ctm} \cdot W_{ely} = 3.2 \cdot 10.4 \cdot 10^6 = 33.3 \text{ kNm}$$

$$M_{E,min,z} = f_{ctm} \cdot W_{elz} = 3.2 \cdot 41.7 \cdot 10^6 = 133 \text{ kNm}$$

$$A_{s,req,bend} = 382 \text{ mm}^2$$

$$A_{s,min,1} = \max(A_{s,req,comp}; A_{s,req,tens}; A_{s,req,bend}) = \max(0; 584; 382) = 584 \text{ mm}^2/\text{m}$$

Required area from ULS

$$A_s = 208 \text{ mm}^2$$

$$\text{Coeff}_{A_{smin}} = 1.25$$

$$A_{s,min,2} = \text{Coeff}_{A_{smin}} \cdot A_s = 1.25 \cdot 208 = 259 \text{ mm}^2/\text{m}$$

Final minimal allowed area of longitudinal reinforcement

$$A_{s,min} = \min(A_{s,min,1}; A_{s,min,2}) = \min(584; 259) = 259 \text{ mm}^2/\text{m}$$

Minimum area from maximum spacing of reinforcement bars

$$s_{max,slab} = \min(\text{Coeff}_{smax,slab,A} \cdot h; \text{Coeff}_{smax,slab,B}) = \min(3 \cdot 250; 400) = 400 \text{ mm} \quad (\$9.3.1.1(3))$$

$$A_{s,min} = \frac{b}{s_{max,slab}} \cdot 0.25 \cdot \pi \cdot \phi^2 = \frac{1000}{400} \cdot 0.25 \cdot 3.14 \cdot 12^2 = 283 \text{ mm}^2/\text{m}$$

Maximum reinforcement

Principal [1-] (tension)

Maximum area from reinforcement ratio

$$A_{s,max} = \text{Coeff}_{A_{smax}} \cdot A_c = 0.04 \cdot 250000 = 10000 \text{ mm}^2/\text{m} \quad (\$9.2.1.1(3))$$

Maximum area from minimum clear spacing of reinforcement bars

$$s_{min,lim} = \max(k_1 \cdot \phi; d_g + k_2 \cdot s_{lb,min}) = \max(1 \cdot 12; 32 + 5 \cdot 20) = 37 \text{ mm} \quad (\$8.2(2))$$

$$A_{s,max} = \frac{b}{\phi + s_{min,lim}} \cdot 0.25 \cdot \pi \cdot \phi^2 = \frac{1000}{12 + 37} \cdot 0.25 \cdot 3.14 \cdot 12^2 = 2308 \text{ mm}^2/\text{m}$$

Principal [2-] (tension)

Maximum area from reinforcement ratio

$$A_{s,max} = \text{Coeff}_{A_{s,max}} \cdot A_c = 0.04 \cdot 250000 = 10000 \text{ mm}^2/\text{m} \quad (\$9.2.1.1(3))$$

Maximum area from minimum clear spacing of reinforcement bars

$$s_{min,lim} = \max(k_1 \cdot \phi; d_g + k_2; s_{lb,min}) = \max(1 \cdot 12; 32 + 5; 20) = 37 \text{ mm} \quad (\$8.2(2))$$

$$A_{s,max} = \frac{b}{\phi + s_{min,lim}} \cdot 0.25 \cdot \pi \cdot \phi^2 = \frac{1000}{12 + 37} \cdot 0.25 \cdot 3.14 \cdot 12^2 = 2308 \text{ mm}^2/\text{m}$$

Principal [1+] (tension)

Maximum area from reinforcement ratio

$$A_{s,max} = \text{Coeff}_{A_{s,max}} \cdot A_c = 0.04 \cdot 250000 = 10000 \text{ mm}^2/\text{m} \quad (\$9.2.1.1(3))$$

Maximum area from minimum clear spacing of reinforcement bars

$$s_{min,lim} = \max(k_1 \cdot \phi; d_g + k_2; s_{lb,min}) = \max(1 \cdot 12; 32 + 5; 20) = 37 \text{ mm} \quad (\$8.2(2))$$

$$A_{s,max} = \frac{b}{\phi + s_{min,lim}} \cdot 0.25 \cdot \pi \cdot \phi^2 = \frac{1000}{12 + 37} \cdot 0.25 \cdot 3.14 \cdot 12^2 = 2308 \text{ mm}^2/\text{m}$$

Principal [2+] (tension)

Maximum area from reinforcement ratio

$$A_{s,max} = \text{Coeff}_{A_{s,max}} \cdot A_c = 0.04 \cdot 250000 = 10000 \text{ mm}^2/\text{m} \quad (\$9.2.1.1(3))$$

Maximum area from minimum clear spacing of reinforcement bars

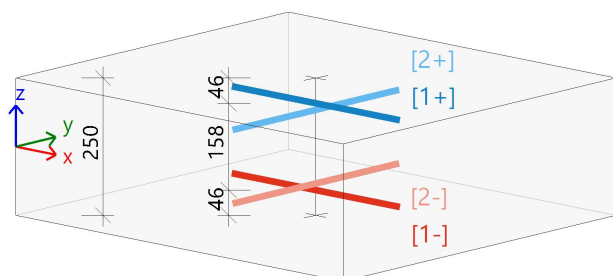
$$s_{min,lim} = \max(k_1 \cdot \phi; d_g + k_2; s_{lb,min}) = \max(1 \cdot 12; 32 + 5; 20) = 37 \text{ mm} \quad (\$8.2(2))$$

$$A_{s,max} = \frac{b}{\phi + s_{min,lim}} \cdot 0.25 \cdot \pi \cdot \phi^2 = \frac{1000}{12 + 37} \cdot 0.25 \cdot 3.14 \cdot 12^2 = 2308 \text{ mm}^2/\text{m}$$

Longitudinal reinforcement - Summary

	Basic	Additional		$A_{s,ult}$ [mm ²]	$\Delta A_{s, serv}$ [mm ²]	$A_{s,min}$ [mm ²]	$A_{s, req}$ [mm ²]	$A_{s, prov}$ [mm ²]	$A_{s, max}$ [mm ²]	Status
		User	Provided							
[1+]	φ12,0/100	no reinf.	no reinf.	564	---	705	705	1131	2308	OK
[2+]	φ12,0/100	no reinf.	no reinf.	208	---	283	283	1131	2308	OK
[1-]	φ12,0/100	no reinf.	no reinf.	379	---	379	379	1131	2308	OK
[2-]	φ12,0/100	no reinf.	no reinf.	400	---	500	500	1131	2308	OK

$A_{s,ult}$ - required reinforcement area from ULS design; $\Delta A_{s, serv}$ - increase of required reinforcement area from SLS design; $A_{s, req}$ - required reinforcement area including detailings; $A_{s, prov}$ - provided reinforcement area (sum from considered basic and additional rebars)



[1+] **φ12,0/100**
[2+] **φ12,0/100**
[1-] **φ12,0/100**
[2-] **φ12,0/100**

Design of shear reinforcement

Design shear force

$$V_{Ed} = \sqrt{V_x^2 + V_y^2} = \sqrt{-93.0^2 + 8.2^2} = 93.3 \text{ kN/m [NC_ULS - Set B (automatisch).21]}$$

Principal forces and plane of deformation

$$m_z = 25 \text{ kNm} \mid n_z = 36 \text{ kN}$$

$$d = 198 \text{ mm} \mid z = 195 \text{ mm}$$

Longitudinal reinforcement ratio (considering lower surface is in tension)

(\$6.4.4(1))

$$\rho_{lx} = \frac{A_{sl,x}}{b \cdot d} = \frac{1131}{1000 \cdot 198} = 0.571 \% \quad \rho_{ly} = \frac{A_{sl,y}}{b \cdot d} = \frac{1131}{1000 \cdot 198} = 0.571 \%$$

$$\rho_l = \min\left(\sqrt{\rho_{lx} \cdot \rho_{ly}}; 0.02\right) = \min\left(\sqrt{5.71 \cdot 10^{-3} \cdot 5.71 \cdot 10^{-3}}; 0.02\right) = 0.571 \%$$

Shear resistance without shear reinforcement

Normal concrete stresses (positive if compression)

Normal forces (from FEM): $n_x = -2.1 \text{ kN/m}$ $n_y = -0.7 \text{ kN/m}$ [NC_ULS - Set B (automatisch).21]

$$\sigma_{cp,1} = \min\left(\frac{-n_x}{A_c}; 0.2 \cdot f_{cd}\right) = \min\left(\frac{-2.1}{0.25}; 0.2 \cdot 23.3 \cdot 10^6\right) = 0.01 \text{ MPa} \quad (\$6.2.2(1))$$

$$\sigma_{cp,2} = \min\left(\frac{-n_y}{A_c}; 0.2 \cdot f_{cd}\right) = \min\left(\frac{-0.7}{0.25}; 0.2 \cdot 23.3 \cdot 10^6\right) = 0.00 \text{ MPa} \quad (\$6.2.2(1))$$

$$\sigma_{cp} = \frac{\sigma_{cp,1} + \sigma_{cp,2}}{2} = \frac{0.01 + 0.00}{2} = 0.01 \text{ MPa}$$

Design shear resistance without shear reinforcement

(\$6.4.4(1))

$$k = \min\left(1 + \left(\frac{200}{d}\right)^{\frac{1}{2}}; 2\right) = \min\left(1 + \left(\frac{200}{198}\right)^{\frac{1}{2}}; 2\right) = 2$$

$$C_{Rdc} = 0.12 \quad v_{min} = 0.586 \text{ MPa} \quad k_1 = 0.15$$

$$V_{Rdc} = \max\left(10^6 \cdot \left(C_{Rdc} \cdot k \cdot \left(100 \cdot \rho_l \cdot f_{ck}\right)^{\frac{1}{3}} + k_1 \cdot \sigma_{cp}\right) \cdot d; 0\right) \quad (6.47)$$

$$= \max\left(10^6 \cdot \left(0.12 \cdot 2 \cdot \left(100 \cdot 5.71 \cdot 10^{-3} \cdot 35\right)^{\frac{1}{3}} + 0.15 \cdot 5.61 \cdot 10^{-3}\right) \cdot 0.198; 0\right) = 129 \text{ kN/m}$$

$$V_{Rdcmin} = \max\left(10^6 \cdot \left(v_{min} + k_1 \cdot \sigma_{cp}\right) \cdot d; 0\right) = \max\left(10^6 \cdot \left(0.586 + 0.15 \cdot 5.61 \cdot 10^{-3}\right) \cdot 0.198; 0\right) = 116 \text{ kN/m}$$

$$V_{Rdc} = \max(V_{Rdc}; V_{Rdcmin}) = \max(129 \text{ kN/m}; 116 \text{ kN/m}) = 129 \text{ kN/m}$$

Maximal concrete shear resistance

Strength reduction factor for concrete cracked in shear

$$v = 0.6 \cdot \left(1 - \frac{f_{ck}}{250}\right) = 0.6 \cdot \left(1 - \frac{35}{250}\right) = 0.516 \quad (6.6N)$$

Angle of compression concrete strut

$$\theta = 21.8^\circ, \cot(\theta) = 2.5$$

Design value of the max shear force which can be sustained by the member

$$V_{Rd,max} = \frac{\alpha_{cw} \cdot b_w \cdot z \cdot v_1 \cdot f_{cd}}{(\cot(\theta) + \tan(\theta))} = \frac{1 \cdot 1 \cdot 0.195 \cdot 0.516 \cdot 23.3}{(\cot(21.8) + \tan(21.8))} = 812 \text{ kN/m} \quad (6.9)$$

Check shear capacity (without shear reinforcement)

Check $v_{Rd,max}$

$$v_{Ed} = 93.3 \text{ kN/m} \leq v_{Rd,max} = 812 \text{ kN/m} \quad (\text{OK})$$

Check v_{Rdc}

$$v_{Ed} = 93.3 \text{ kN/m} \leq v_{Rdc} = 129 \text{ kN/m} \quad (\text{OK, no shear reinforcement is required})$$

Shear reinforcement - Summary

		θ	v_{Ed}	$A_{sl,x}$	$A_{sl,y}$	ρ_l	$v_{Rd,c}$	$v_{Rd,max}$	$A_{sw,req}$	Status
	Case	[°]	[kN/m]	[mm ²]	[mm ²]	[%]	[kN/m]	[kN/m]	[mm ² /m ²]	
[-]	NC_ULS - Set B (autor	21,8	93,3	1131	1131	0,571	129,1	811,6	---	OK

v_{Ed} - design shear force, $A_{sl,x/y}$ - tensile longitudinal reinforcement, ρ_l - corresponding reinforcement ratio, v_{Rdc} - shear resistance without shear reinforcement, $v_{Rd,max}$ - maximal concrete shear resistance, $A_{sw,req}$ - required shear reinforcement

10.2.2. Reinforcement design (ULS+SLS) Concrete slab – Loading arm area

Nonlinear calculation

Class: RC_NC_ULS - Set B (automatisch)

Extreme: Global

Selection: E4

Location: In nodes avg. on macro. System: LCS mesh element

Plate E4	h=300 mm
NEN EN 1992-1-1+C2:2011/NB:2016	Node 142/1039 [X= 0,200, Y=0,600, Z=0,000 m]

Design assumptions

Reinforcement

Longitudinal: **B 500B**

Upper surface

[1+] First layer (0°)

Ø12,0 mm / Principal

[2+] Second layer (90°)

Ø12,0 mm / Principal

Cover:

$c_{nom} = 40$ mm

Lower surface

[1-] First layer (0°)

Ø12,0 mm / Principal

[2-] Second layer (90°)

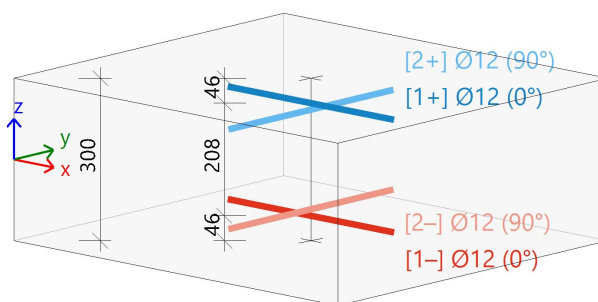
Ø12,0 mm / Principal

Cover:

$c_{nom} = 40$ mm

Shear: **B 500B**

Ø8 mm



Concrete:

Material: **C35/45**

Structural class: S3 (design working life of 50 years, no special quality control)

(Table 4.3N)

Environmental conditions: XC4, XF4, XD3, XS1, XA2, XM1 (in situ)

(Table 4.1N)

Minimum cover

(§4.4.1.2)

$$c_{min} = \max(c_{min,b}, c_{min,dur} + \Delta c_{dur,y} - \Delta c_{dur,st} - \Delta c_{dur,add}; 10)$$

$$= \max(12; 35 + 0 - 0 - 0; 10) = 35 \text{ mm}$$

(4.2)

Nominal cover

(§4.4.1.1)

$$c_{nom} = c_{min} + \Delta c_{dev} = 35 + 5 = 40 \text{ mm}$$

(4.1)

Internal forces from structural analysis

Ultimate limit state										(93.1302)
Including the self-weight of concrete (15)										93.1302
n = 1; Concrete: 150.00 x 275.00 mm										93.1302
Case	N _{Ed} [kN]	M _{Ed} [kNm]	V _{Ed} [kN]	N _{Ed} [kN]	M _{Ed} [kNm]	V _{Ed} [kN]	N _{Ed} [kN]	M _{Ed} [kNm]	V _{Ed} [kN]	
HC_UJS - Set B (automatisc1)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc2)	-13.04	-12.06	-5.34	20.06	-14.64	19.71	-24.98	-28.24		
HC_UJS - Set B (automatisc3)	-13.04	-12.06	-5.34	20.06	-14.64	19.71	-24.98	-28.24		
HC_UJS - Set B (automatisc4)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc5)	-13.04	-12.06	-5.34	20.06	-14.64	19.71	-24.98	-28.24		
HC_UJS - Set B (automatisc6)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc7)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc8)	-13.04	-12.06	-5.34	20.06	-14.64	19.71	-24.98	-28.24		
HC_UJS - Set B (automatisc9)	-13.04	-12.06	-5.34	20.06	-14.64	19.71	-24.98	-28.24		
HC_UJS - Set B (automatisc10)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc11)	-13.04	-12.06	-5.34	20.06	-14.64	19.71	-24.98	-28.24		
HC_UJS - Set B (automatisc12)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc13)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc14)	-13.04	-12.06	-5.34	20.06	-14.64	19.71	-24.98	-28.24		
HC_UJS - Set B (automatisc15)	-13.04	-12.06	-5.34	20.06	-14.64	19.71	-24.98	-28.24		
HC_UJS - Set B (automatisc16)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc17)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc18)	-13.04	-12.06	-5.34	20.06	-14.64	19.71	-24.98	-28.24		
HC_UJS - Set B (automatisc19)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc20)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc21)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc22)	-13.04	-12.06	-5.34	20.06	-14.64	19.71	-24.98	-28.24		
HC_UJS - Set B (automatisc23)	-13.04	-12.06	-5.34	20.06	-14.64	19.71	-24.98	-28.24		
HC_UJS - Set B (automatisc24)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc25)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc26)	-13.04	-12.06	-5.34	20.06	-14.64	19.71	-24.98	-28.24		
HC_UJS - Set B (automatisc27)	-19.36	-17.62	-7.86	26.47	-19.54	32.36	-37.33	-40.91		
HC_UJS - Set B (automatisc28)	-8.70	-8.51	-3.62	14.18	-12.14	13.07	-15.84	-20.70		
HC_UJS - Set B (automatisc29)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc30)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc31)	-8.31	-8.33	-3.89	12.87	-8.87	16.70	-18.70	-18.94		
HC_UJS - Set B (automatisc32)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc33)	-16.84	-17.52	-7.62	30.17	-19.84	26.12	-36.16	-41.22		
HC_UJS - Set B (automatisc34)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc35)	-13.04	-12.06	-5.34	20.06	-14.64	19.71	-24.98	-28.24		
HC_UJS - Set B (automatisc36)	-8.89	-8.22	-3.64	13.68	-8.98	13.64	-17.05	-19.25		
HC_UJS - Set B (automatisc37)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc38)	-13.04	-12.06	-5.34	20.06	-14.64	19.71	-24.98	-28.24		
HC_UJS - Set B (automatisc39)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc40)	-15.14	-13.72	-6.28	21.94	-16.42	25.49	-28.86	-31.56		
HC_UJS - Set B (automatisc41)	-14.53	-13.86	-6.01	23.15	-16.68	21.88	-27.00	-33.33		
HC_UJS - Set B (automatisc42)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc43)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc44)	-13.11	-12.16	-5.23	21.21	-13.10	20.31	-25.00	-28.60		
HC_UJS - Set B (automatisc45)	-12.82	-12.53	-5.21	21.71	-15.26	19.94	-23.80	-30.05		
HC_UJS - Set B (automatisc46)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc47)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc48)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc49)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc50)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc51)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc52)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc53)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc54)	-14.72	-13.62	-6.03	22.84	-16.53	22.25	-28.20	-31.88		
HC_UJS - Set B (automatisc55)	-18.94	-17.32	-7.82	30.17	-19.84	26.12	-36.16	-41.22		
HC_UJS - Set B (automatisc56)	-19.36	-17.62	-7.86	26.47	-19.54	32.36	-37.33	-40.91		
HC_UJS - Set B (automatisc57)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc58)	-13.11	-12.16	-5.23	21.21	-13.10	20.31	-25.00	-28.60		
HC_UJS - Set B (automatisc59)	-13.54	-12.24	-5.48	20.51	-12.89	23.55	-26.66	-28.28		
HC_UJS - Set B (automatisc60)	-12.82	-12.53	-5.21	21.71	-15.26	19.94	-23.80	-30.05		
HC_UJS - Set B (automatisc61)	-19.36	-17.62	-7.86	26.47	-19.54	32.36	-37.33	-40.91		
HC_UJS - Set B (automatisc62)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc63)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc64)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc65)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc66)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc67)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc68)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc69)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc70)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc71)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc72)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc73)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc74)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc75)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc76)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc77)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc78)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc79)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc80)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc81)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc82)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc83)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc84)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc85)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc86)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc87)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc88)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc89)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc90)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc91)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc92)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc93)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc94)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc95)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc96)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc97)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc98)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc99)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		
HC_UJS - Set B (automatisc100)	-18.75	-17.87	-7.80	30.88	-21.80	26.75	-34.97	-42.67		

Limit state design of longitudinal reinforcement

Ultimate limit state

Direction of reinforcement layer [$\alpha=0^\circ$]

[1+]: upper surface

$$m_{Ed} = -21 \text{ kNm/m} \mid n_{Ed} = 93.4 \text{ kN/m} \quad [\text{NC_ULS} - \text{Set B (automatisch).28}]$$

$$f_{cd} = 23.3 \text{ [MPa]} \quad (\gamma_c = 1.5, \alpha_{cc} = 1)$$

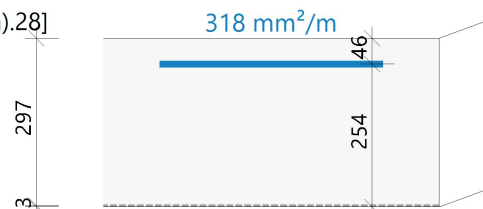
$$f_{yd} = 435 \text{ [MPa]} \quad (\gamma_s = 1.15)$$

$$\varnothing 12 \text{ mm} : d_1 = 46 \text{ mm} \rightarrow d = 254 \text{ mm}$$

$$x = 3 \text{ mm} \rightarrow z = 253 \text{ mm}$$

$$A_{s,ult} = 318 \text{ mm}^2/\text{m} \text{ (tensile)}$$

$$\rho = 0.125\%$$



Direction of reinforcement layer [$\alpha=90^\circ$]

[2+]: upper surface

$$m_{Ed} = -20.5 \text{ kNm/m} \mid n_{Ed} = 44.4 \text{ kN/m} \quad [\text{NC_ULS} - \text{Set B (automatisch).28}]$$

$$f_{cd} = 23.3 \text{ [MPa]} \quad (\gamma_c = 1.5, \alpha_{cc} = 1)$$

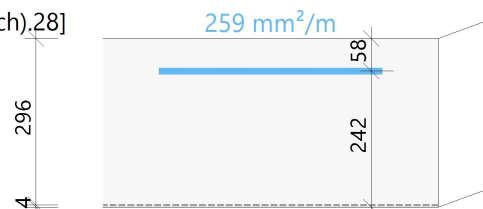
$$f_{yd} = 435 \text{ [MPa]} \quad (\gamma_s = 1.15)$$

$$\varnothing 12 \text{ mm} : d_1 = 58 \text{ mm} \rightarrow d = 242 \text{ mm}$$

$$x = 4 \text{ mm} \rightarrow z = 240 \text{ mm}$$

$$A_{s,ult} = 259 \text{ mm}^2/\text{m} \text{ (tensile)}$$

$$\rho = 0.107\%$$



Check of concrete diagonal strut

Check direction (extreme) [$\alpha=135^\circ$]

Design normal force in direction of concrete strut

$$n_{Ed,sc} = -96.3 \text{ kN} \quad [\text{NC_ULS} - \text{Set B (automatisch).28}]$$

with full cross-section height:

$$h = 300 \text{ mm} \rightarrow A_{cc} = h \cdot b = 0.3 \cdot 1000 = 300000 \text{ mm}^2$$

$$f_{cd} = \frac{\alpha_{cc} \cdot f_{ck}}{\gamma_c} = \frac{1 \cdot 35}{1.5} = 23 \text{ MPa}$$

Design resistance of concrete strut (in compression)

$$n_{Rd,sc} = A_{cc} \cdot \text{Red}_{fcd} \cdot f_{cd} = 300000 \cdot 0.85 \cdot 23 = 5950 \text{ kN}$$

Unity check

$$UC_{sc} = \frac{\text{abs}(n_{Ed,sc})}{n_{Rd,sc}} = \frac{\text{abs}(-96.3)}{5950} = 0.016$$

Detailing of the longitudinal reinforcement

Minimum principal reinforcement

Principal [1+] (tension)

Minimum area from reinforcement ratio

(\$9.2.1.1(1))

First order eccentricity

$$e_y = 0 \text{ mm}$$

$$e_z = 225 \text{ mm}$$

$$e = \sqrt{e_y^2 + e_z^2} = \sqrt{0^2 + 225^2} = 225 \text{ mm}$$

Elastic section modulus

$$\alpha_e = 0^\circ$$

$$W_{ely} = 15 \cdot 10^6 \text{ mm}^3$$

$$W_{elz} = 50 \cdot 10^6 \text{ mm}^3$$

$$W_{el} = 15 \cdot 10^6 \text{ mm}^3$$

$$\eta_y = \frac{e_z \cdot A_c}{W_{ely}} = \frac{225 \cdot 300000}{15 \cdot 10^6} = 4.5$$

$$\eta_z = \frac{e_y \cdot A_c}{W_{elz}} = \frac{0 \cdot 300000}{50 \cdot 10^6} = 0$$

$$\eta = \frac{e \cdot A_c}{W_{el}} = \frac{225 \cdot 300000}{15 \cdot 10^6} = 4.5$$

Combination for compression

$$M_{E,min,y} = \frac{f_{ctm} \cdot W_{ely} \cdot \eta_y}{\eta_y - 1} = \frac{3.2 \cdot 15 \cdot 10^6 \cdot 4.5}{4.5 - 1} = 61.7 \text{ kNm}$$

$$M_{E,min,z} = \frac{f_{ctm} \cdot W_{elz} \cdot \eta_z}{\eta_z - 1} = \frac{3.2 \cdot 50 \cdot 10^6 \cdot 0}{0 - 1} = 0 \text{ kNm}$$

$$N_{E,min} = \frac{f_{ctm} \cdot A_c \cdot 1}{\eta - 1} = \frac{3.2 \cdot 300000 \cdot 1}{4.5 - 1} = 274 \text{ kN}$$

$$A_{s,req,comp} = 211 \text{ mm}^2$$

Combination for tension

$$M_{E,min,y} = \frac{f_{ctm} \cdot W_{ely} \cdot \eta_y}{\eta_y + 1} = \frac{3.2 \cdot 15 \cdot 10^6 \cdot 4.5}{4.5 + 1} = 39.3 \text{ kNm}$$

$$M_{E,min,z} = \frac{f_{ctm} \cdot W_{elz} \cdot \eta_z}{\eta_z + 1} = \frac{3.2 \cdot 50 \cdot 10^6 \cdot 0}{0 + 1} = 0 \text{ kNm}$$

$$N_{E,min} = \frac{f_{ctm} \cdot A_c \cdot 1}{\eta + 1} = \frac{3.2 \cdot 300000 \cdot 1}{4.5 + 1} = 175 \text{ kN}$$

$$A_{s,req,tens} = 555 \text{ mm}^2$$

Combination for bending

$$M_{E,min,y} = f_{ctm} \cdot W_{ely} = 3.2 \cdot 15 \cdot 10^6 = 48 \text{ kNm}$$

$$M_{E,min,z} = f_{ctm} \cdot W_{elz} = 3.2 \cdot 50 \cdot 10^6 = 160 \text{ kNm}$$

$$A_{s,req,bend} = 414 \text{ mm}^2$$

$$A_{s,min,1} = \max(A_{s,req,comp}; A_{s,req,tens}; A_{s,req,bend}) = \max(211; 555; 414) = 555 \text{ mm}^2/\text{m}$$

Required area from ULS

$$A_s = 318 \text{ mm}^2$$

$$\text{Coeff}_{A_{smin}} = 1.25$$

$$A_{s,min,2} = \text{Coeff}_{A_{smin}} \cdot A_s = 1.25 \cdot 318 = 397 \text{ mm}^2/\text{m}$$

Final minimal allowed area of longitudinal reinforcement

$$A_{s,min} = \min(A_{s,min,1}; A_{s,min,2}) = \min(555; 397) = 397 \text{ mm}^2/\text{m}$$

Minimum area from maximum spacing of reinforcement bars

$$s_{max,slab} = \min(\text{Coeff}_{s_{max,slab,A}} \cdot h; \text{Coeff}_{s_{max,slab,B}}) = \min(3 \cdot 300; 400) = 400 \text{ mm} \quad (\S 9.3.1.1(3))$$

$$A_{s,min} = \frac{b}{s_{max,slab}} \cdot 0.25 \cdot \pi \cdot \phi^2 = \frac{1000}{400} \cdot 0.25 \cdot 3.14 \cdot 12^2 = 283 \text{ mm}^2/\text{m}$$

Principal [2+] (tension)

Minimum area from reinforcement ratio

(§9.2.1.1(1))

First order eccentricity

$$e_y = 0 \text{ mm}$$

$$e_z = 462 \text{ mm}$$

$$e = \sqrt{e_y^2 + e_z^2} = \sqrt{0^2 + 462^2} = 462 \text{ mm}$$

Elastic section modulus

$$\alpha_e = 0^\circ$$

$$W_{ely} = 15 \cdot 10^6 \text{ mm}^3$$

$$W_{elz} = 50 \cdot 10^6 \text{ mm}^3$$

$$W_{el} = 15 \cdot 10^6 \text{ mm}^3$$

$$\eta_y = \frac{e_z \cdot A_c}{W_{ely}} = \frac{462 \cdot 300000}{15 \cdot 10^6} = 9.23$$

$$\eta_z = \frac{e_y \cdot A_c}{W_{elz}} = \frac{0 \cdot 300000}{50 \cdot 10^6} = 0$$

$$\eta = \frac{e \cdot A_c}{W_{el}} = \frac{462 \cdot 300000}{15 \cdot 10^6} = 9.23$$

Combination for compression

$$M_{E,min,y} = \frac{f_{ctm} \cdot W_{ely} \cdot \eta_y}{\eta_y - 1} = \frac{3.2 \cdot 15 \cdot 10^6 \cdot 9.23}{9.23 - 1} = 53.8 \text{ kNm}$$

$$M_{E,min,z} = \frac{f_{ctm} \cdot W_{elz} \cdot \eta_z}{\eta_z - 1} = \frac{3.2 \cdot 50 \cdot 10^6 \cdot 0}{0 - 1} = 0 \text{ kNm}$$

$$N_{E,min} = \frac{f_{ctm} \cdot A_c \cdot 1}{\eta - 1} = \frac{3.2 \cdot 300000 \cdot 1}{9.23 - 1} = 117 \text{ kN}$$

$$A_{s,req,comp} = 344 \text{ mm}^2$$

Combination for tension

$$M_{E,min,y} = \frac{f_{ctm} \cdot W_{ely} \cdot \eta_y}{\eta_y + 1} = \frac{3.2 \cdot 15 \cdot 10^6 \cdot 9.23}{9.23 + 1} = 43.3 \text{ kNm}$$

$$M_{E,min,z} = \frac{f_{ctm} \cdot W_{elz} \cdot \eta_z}{\eta_z + 1} = \frac{3.2 \cdot 50 \cdot 10^6 \cdot 0}{0 + 1} = 0 \text{ kNm}$$

$$N_{E,min} = \frac{f_{ctm} \cdot A_c \cdot 1}{\eta + 1} = \frac{3.2 \cdot 300000 \cdot 1}{9.23 + 1} = 93.8 \text{ kN}$$

$$A_{s,req,tens} = 514 \text{ mm}^2$$

Combination for bending

$$M_{E,min,y} = f_{ctm} \cdot W_{ely} = 3.2 \cdot 15 \cdot 10^6 = 48 \text{ kNm}$$

$$M_{E,min,z} = f_{ctm} \cdot W_{elz} = 3.2 \cdot 50 \cdot 10^6 = 160 \text{ kNm}$$

$$A_{s,req,bend} = 436 \text{ mm}^2$$

$$A_{s,min,1} = \max(A_{s,req,comp}; A_{s,req,tens}; A_{s,req,bend}) = \max(344; 514; 436) = 514 \text{ mm}^2/\text{m}$$

Required area from ULS

$$A_s = 259 \text{ mm}^2$$

$$\text{Coeff}_{A_{s,\min}} = 1.25$$

$$A_{s,\min,2} = \text{Coeff}_{A_{s,\min}} \cdot A_s = 1.25 \cdot 259 = 324 \text{ mm}^2/\text{m}$$

Final minimal allowed area of longitudinal reinforcement

$$A_{s,\min} = \min(A_{s,\min,1}; A_{s,\min,2}) = \min(514; 324) = 324 \text{ mm}^2/\text{m}$$

Minimum area from maximum spacing of reinforcement bars

$$s_{\max,\text{slab}} = \min(\text{Coeff}_{s_{\max,\text{slab},A}} \cdot h; \text{Coeff}_{s_{\max,\text{slab},B}}) = \min(3 \cdot 300; 400) = 400 \text{ mm} \quad (\$9.3.1.1(3))$$

$$A_{s,\min} = \frac{b}{s_{\max,\text{slab}}} \cdot 0.25 \cdot \pi \cdot \phi^2 = \frac{1000}{400} \cdot 0.25 \cdot 3.14 \cdot 12^2 = 283 \text{ mm}^2/\text{m}$$

Maximum reinforcement

Principal [1+] (tension)

Maximum area from reinforcement ratio

$$A_{s,\max} = \text{Coeff}_{A_{s,\max}} \cdot A_c = 0.04 \cdot 300000 = 12000 \text{ mm}^2/\text{m} \quad (\$9.2.1.1(3))$$

Maximum area from minimum clear spacing of reinforcement bars

$$s_{\min,\text{lim}} = \max(k_1 \cdot \phi; d_g + k_2; s_{\text{lb},\min}) = \max(1 \cdot 12; 32 + 5; 20) = 37 \text{ mm} \quad (\$8.2(2))$$

$$A_{s,\max} = \frac{b}{\phi + s_{\min,\text{lim}}} \cdot 0.25 \cdot \pi \cdot \phi^2 = \frac{1000}{12 + 37} \cdot 0.25 \cdot 3.14 \cdot 12^2 = 2308 \text{ mm}^2/\text{m}$$

Principal [2+] (tension)

Maximum area from reinforcement ratio

$$A_{s,\max} = \text{Coeff}_{A_{s,\max}} \cdot A_c = 0.04 \cdot 300000 = 12000 \text{ mm}^2/\text{m} \quad (\$9.2.1.1(3))$$

Maximum area from minimum clear spacing of reinforcement bars

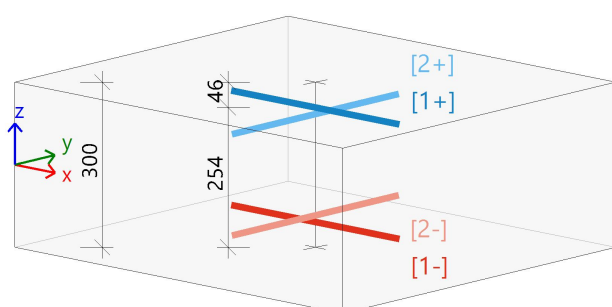
$$s_{\min,\text{lim}} = \max(k_1 \cdot \phi; d_g + k_2; s_{\text{lb},\min}) = \max(1 \cdot 12; 32 + 5; 20) = 37 \text{ mm} \quad (\$8.2(2))$$

$$A_{s,\max} = \frac{b}{\phi + s_{\min,\text{lim}}} \cdot 0.25 \cdot \pi \cdot \phi^2 = \frac{1000}{12 + 37} \cdot 0.25 \cdot 3.14 \cdot 12^2 = 2308 \text{ mm}^2/\text{m}$$

Longitudinal reinforcement - Summary

	Basic	Additional		$A_{s,\text{ult}}$ [mm ²]	$\Delta A_{s,\text{serv}}$ [mm ²]	$A_{s,\min}$ [mm ²]	$A_{s,\text{req}}$ [mm ²]	$A_{s,\text{prov}}$ [mm ²]	$A_{s,\max}$ [mm ²]	Status
		User	Provided							
[1+]	φ12,0/100	no reinf.	no reinf.	318	---	397	397	1131	2308	OK
[2+]	φ12,0/100	no reinf.	no reinf.	259	---	324	324	1131	2308	OK
[1-]	φ12,0/100	no reinf.	no reinf.	0	---	---	0	1131	---	OK
[2-]	φ12,0/100	no reinf.	no reinf.	0	---	---	0	1131	---	OK

$A_{s,\text{ult}}$ - required reinforcement area from ULS design; $\Delta A_{s,\text{serv}}$ - increase of required reinforcement area from SLS design; $A_{s,\text{req}}$ - required reinforcement area including detailings; $A_{s,\text{prov}}$ - provided reinforcement area (sum from considered basic and additional rebars)



[1+] φ12,0/100
[2+] φ12,0/100
[1-] φ12,0/100
[2-] φ12,0/100

Design of shear reinforcement

Design shear force

$$V_{Ed} = \sqrt{V_x^2 + V_y^2} = \sqrt{-37.8^2 + -40.9^2} = 55.7 \text{ kN/m [NC_ULS - Set B (automatisch).28]}$$

Principal forces and plane of deformation

$$m_z = -26 \text{ kNm} \quad | \quad n_z = 42 \text{ kN}$$

$$d = 248 \text{ mm} \quad | \quad z = 246 \text{ mm}$$

Longitudinal reinforcement ratio (considering upper surface is in tension)

(\$6.4.4(1))

$$\rho_{lx} = \frac{A_{sl,x}}{b \cdot d} = \frac{1131}{1000 \cdot 248} = 0.456 \% \quad \rho_{ly} = \frac{A_{sl,y}}{b \cdot d} = \frac{1131}{1000 \cdot 248} = 0.456 \%$$

$$\rho_l = \min\left(\sqrt{\rho_{lx} \cdot \rho_{ly}}; 0.02\right) = \min\left(\sqrt{4.56 \cdot 10^{-3} \cdot 4.56 \cdot 10^{-3}}; 0.02\right) = 0.456 \%$$

Shear resistance without shear reinforcement

Normal concrete stresses (positive if compression)

Normal forces (from FEM): $n_x = 29.5 \text{ kN/m}$ $n_y = -19.5 \text{ kN/m}$ [NC_ULS - Set B (automatisch).28]

$$\sigma_{cp,1} = \min\left(\frac{-n_x}{A_c}; 0.2 \cdot f_{cd}\right) = \min\left(\frac{-29.5}{0.3}; 0.2 \cdot 23.3 \cdot 10^6\right) = -0.10 \text{ MPa} \quad (\$6.2.2(1))$$

$$\sigma_{cp,2} = \min\left(\frac{-n_y}{A_c}; 0.2 \cdot f_{cd}\right) = \min\left(\frac{-19.5}{0.3}; 0.2 \cdot 23.3 \cdot 10^6\right) = 0.07 \text{ MPa} \quad (\$6.2.2(1))$$

$$\sigma_{cp} = \frac{\sigma_{cp,1} + \sigma_{cp,2}}{2} = \frac{-0.10 + 0.07}{2} = -0.02 \text{ MPa}$$

Design shear resistance without shear reinforcement

(\$6.4.4(1))

$$k = \min\left(1 + \left(\frac{200}{d}\right)^{\frac{1}{2}}; 2\right) = \min\left(1 + \left(\frac{200}{248}\right)^{\frac{1}{2}}; 2\right) = 1.9$$

$$C_{Rdc} = 0.12 \quad v_{min} = 0.541 \text{ MPa} \quad k_1 = 0.15$$

$$V_{Rdc} = \max\left(10^6 \cdot \left(C_{Rdc} \cdot k \cdot \left(100 \cdot \rho_l \cdot f_{ck}\right)^{\frac{1}{3}} + k_1 \cdot \sigma_{cp}\right) \cdot d; 0\right) \quad (6.47)$$

$$= \max\left(10^6 \cdot \left(0.12 \cdot 1.9 \cdot \left(100 \cdot 4.56 \cdot 10^{-3} \cdot 35\right)^{\frac{1}{3}} + 0.15 \cdot -0.0166\right) \cdot 0.248; 0\right) = 142 \text{ kN/m}$$

$$V_{Rdcmin} = \max\left(10^6 \cdot \left(v_{min} + k_1 \cdot \sigma_{cp}\right) \cdot d; 0\right) = \max\left(10^6 \cdot \left(0.541 + 0.15 \cdot -0.0166\right) \cdot 0.248; 0\right) = 134 \text{ kN/m}$$

$$V_{Rdc} = \max(V_{Rdc}; V_{Rdcmin}) = \max(142 \text{ kN/m}; 134 \text{ kN/m}) = 142 \text{ kN/m}$$

Maximal concrete shear resistance

Strength reduction factor for concrete cracked in shear

$$v = 0.6 \cdot \left(1 - \frac{f_{ck}}{250}\right) = 0.6 \cdot \left(1 - \frac{35}{250}\right) = 0.516 \quad (6.6N)$$

Angle of compression concrete strut

$$\theta = 21.8^\circ, \cot(\theta) = 2.5$$

Design value of the max shear force which can be sustained by the member

$$V_{Rd,max} = \frac{\alpha_{cw} \cdot b_w \cdot z \cdot v_1 \cdot f_{cd}}{(\cot(\theta) + \tan(\theta))} = \frac{1 \cdot 1 \cdot 0.246 \cdot 0.516 \cdot 23.3}{(\cot(21.8) + \tan(21.8))} = 1021 \text{ kN/m} \quad (6.9)$$

Check shear capacity (without shear reinforcement)

Check $v_{Rd,max}$

$$v_{Ed} = 55.7 \text{ kN/m} \leq v_{Rd,max} = 1021 \text{ kN/m} \text{ (OK)}$$

Check v_{Rdc}

$$v_{Ed} = 55.7 \text{ kN/m} \leq v_{Rdc} = 142 \text{ kN/m} \text{ (OK, no shear reinforcement is required)}$$

Shear reinforcement - Summary

		θ	v_{Ed}	$A_{sl,x}$	$A_{sl,y}$	ρ_l	$v_{Rd,c}$	$v_{Rd,max}$	$A_{sw,req}$	Status
	Case	[°]	[kN/m]	[mm ²]	[mm ²]	[%]	[kN/m]	[kN/m]	[mm ² /m ²]	
[+]	NC_ULS - Set B (autor	21,8	55,7	1131	1131	0,456	141,6	1021,2	---	OK

v_{Ed} - design shear force, $A_{sl,x/y}$ - tensile longitudinal reinforcement, ρ_l - corresponding reinforcement ratio, v_{Rdc} - shear resistance without shear reinforcement, $v_{Rd,max}$ - maximal concrete shear resistance, $A_{sw,req}$ - required shear reinforcement

10.2.3. Reinforcement design (ULS+SLS) Wall

Nonlinear calculation

Class: RC_NC_ULS - Set B (automatisch)

Extreme: Global

Selection: E2, E3, E5, E6

Location: In nodes avg. on macro. System: LCS mesh element

Wall E3	h=250 mm
NEN EN 1992-1-1+C2:2011/NB:2016	Node 134/17 [X= 15,300, Y=1,300, Z=0,000 m]

Design assumptions

Reinforcement

Longitudinal: **B 500B**

Upper surface

[1+] First layer (0°)

Ø12,0 mm / Horizontal

[2+] Second layer (90°)

Ø12,0 mm / Vertical

Cover:

$c_{nom} = 40$ mm

Lower surface

[1-] First layer (0°)

Ø12,0 mm / Horizontal

[2-] Second layer (90°)

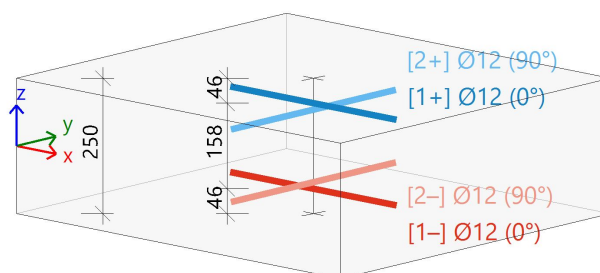
Ø12,0 mm / Vertical

Cover:

$c_{nom} = 40$ mm

Shear: **B 500B**

Ø8 mm



Concrete:

Material: **C35/45**

Structural class: S3 (design working life of 50 years, no special quality control)

(Table 4.3N)

Environmental conditions: XC4, XF4, XD3, XS1, XA2, XM1 (in situ)

(Table 4.1N)

Minimum cover

(§4.4.1.2)

$$c_{min} = \max(c_{min,b}; c_{min,dur} + \Delta c_{dur,y} - \Delta c_{dur,st} - \Delta c_{dur,add}; 10)$$

$$= \max(12; 35 + 0 - 0 - 0; 10) = 35 \text{ mm}$$

(4.2)

Nominal cover

(§4.4.1.1)

$$c_{nom} = c_{min} + \Delta c_{dev} = 35 + 5 = 40 \text{ mm}$$

(4.1)

Internal forces from structural analysis

Ultimate limit state

Plotting the following element case: 165
a-b: Centre: 120.00 x 255.00
(93.13x20)
96.030

Case	N _{Ed} [kN]	N _{Ed} [kN/m]	M _{Ed} [kNm]	M _{Ed} [kNm/m]	V _{Ed} [kN]	V _{Ed} [kN/m]	N _{Ed} [kN]	N _{Ed} [kN/m]	M _{Ed} [kNm]	M _{Ed} [kNm/m]	V _{Ed} [kN]	V _{Ed} [kN/m]
HC_UJS - Set B (automatistat01)	-0.65	-4.81	1.00	-2.71	-15.50	2.37	-5.34	19.14				
HC_UJS - Set B (automatistat02)	-5.05	-16.81	6.11	56.35	80.90	-45.40	-48.15	51.75				
HC_UJS - Set B (automatistat03)	0.28	-3.80	-0.07	-21.04	-54.69	17.60	-4.93	20.28				
HC_UJS - Set B (automatistat04)	4.74	-14.27	5.63	57.61	80.13	-46.59	-46.66	42.81				
HC_UJS - Set B (automatistat05)	1.62	1.37	-2.03	-35.15	-86.55	30.80	21.11	7.93				
HC_UJS - Set B (automatistat06)	2.03	3.50	-2.50	-33.89	-79.32	29.78	23.60	-1.00				
HC_UJS - Set B (automatistat07)	1.66	2.95	-2.20	-26.74	-68.63	24.39	20.23	0.15				
HC_UJS - Set B (automatistat08)	1.50	0.72	-1.80	-35.91	-85.80	30.98	19.70	9.66				
HC_UJS - Set B (automatistat09)	0.73	-0.09	-0.79	-47.59	-47.67	23.54	10.88	16.40				
HC_UJS - Set B (automatistat10)	-0.70	-0.06	1.11	-2.71	-15.07	2.23	-5.93	19.77				
HC_UJS - Set B (automatistat11)	1.24	0.82	-1.74	-28.00	-75.86	25.50	17.74	9.09				
HC_UJS - Set B (automatistat12)	0.48	0.32	-0.99	-10.14	-40.12	10.98	9.02	6.46				
HC_UJS - Set B (automatistat13)	1.92	2.85	-2.24	-34.84	-78.57	29.67	22.20	0.73				
HC_UJS - Set B (automatistat14)	-1.00	-7.31	1.57	-3.97	-22.30	3.34	-4.42	28.70				
HC_UJS - Set B (automatistat15)	1.13	-0.51	-1.35	-32.86	-78.53	28.03	15.82	12.73				
HC_UJS - Set B (automatistat16)	1.54	1.63	-1.73	-31.60	-71.35	26.92	18.32	3.80				
HC_UJS - Set B (automatistat17)	1.02	0.16	-1.13	-28.33	-68.44	22.23	11.17	7.48				
HC_UJS - Set B (automatistat18)	0.14	-1.89	-0.68	-11.40	-47.36	12.09	6.53	15.39				
HC_UJS - Set B (automatistat19)	-1.07	-7.56	1.86	-4.40	-25.66	3.93	-8.85	31.69				
HC_UJS - Set B (automatistat20)	0.53	-1.50	-0.53	-19.77	-47.43	16.57	7.43	11.33				
HC_UJS - Set B (automatistat21)	-0.44	-4.45	0.81	-6.27	-21.57	5.17	-3.38	18.28				
HC_UJS - Set B (automatistat22)	-0.44	-5.89	0.91	-11.68	-36.56	9.74	-2.73	25.27				
HC_UJS - Set B (automatistat23)	-1.79	-1.74	2.00	16.08	4.15	-11.40	-15.30	28.33				
HC_UJS - Set B (automatistat24)	-1.49	-0.50	1.53	17.94	11.41	-12.51	-12.81	20.20				
HC_UJS - Set B (automatistat25)	-0.14	-0.63	0.44	-10.42	-29.33	8.63	-0.24	16.34				
HC_UJS - Set B (automatistat26)	-0.75	-4.69	1.28	-7.54	-28.81	6.27	-5.88	27.21				
HC_UJS - Set B (automatistat27)	-0.06	-4.83	0.41	-16.55	-45.82	13.86	1.21	22.73				
HC_UJS - Set B (automatistat28)	-1.07	-7.56	1.86	-4.40	-25.66	3.93	-8.85	31.69				
HC_UJS - Set B (automatistat29)	-0.65	-4.81	1.00	-2.71	-15.50	2.37	-5.34	19.14				
HC_UJS - Set B (automatistat30)	0.23	-2.30	-0.06	-15.29	-38.68	12.76	3.70	13.80				
HC_UJS - Set B (automatistat31)	-0.65	-4.81	1.00	-2.71	-15.50	2.37	-5.34	19.14				
HC_UJS - Set B (automatistat32)	-1.07	-7.56	1.86	-4.40	-25.66	3.93	-8.85	31.69				
HC_UJS - Set B (automatistat33)	-1.07	-7.56	1.86	-4.40	-25.66	3.93	-8.85	31.69				
HC_UJS - Set B (automatistat34)	-1.93	-14.78	4.91	37.36	46.56	-30.19	-37.64	48.19				
HC_UJS - Set B (automatistat35)	-1.63	-7.32	1.59	-3.14	-21.01	2.73	-8.71	28.72				
HC_UJS - Set B (automatistat36)	-0.73	-0.07	1.12	-1.88	-13.78	1.62	-6.21	19.78				
HC_UJS - Set B (automatistat37)	-1.10	-0.14	1.73	-4.40	-25.66	3.93	-8.85	32.13				
HC_UJS - Set B (automatistat38)	-0.65	-4.81	1.00	-2.71	-15.50	2.37	-5.34	19.14				
HC_UJS - Set B (automatistat39)	-0.93	-0.71	1.53	-4.97	-29.89	5.88	-7.48	31.09				
HC_UJS - Set B (automatistat40)	-1.07	-7.56	1.86	-4.40	-25.66	3.93	-8.85	31.69				
HC_UJS - Set B (automatistat41)	-1.07	-7.56	1.86	-4.40	-25.66	3.93	-8.85	31.69				
HC_UJS - Set B (automatistat42)	-1.15	-4.15	1.74	-2.90	-24.46	3.41	-4.45	32.14				
HC_UJS - Set B (automatistat43)	-0.71	-7.15	1.27	-6.06	-19.30	8.28	-5.29	29.74				
HC_UJS - Set B (automatistat44)	-0.65	-4.81	1.00	-2.71	-15.50	2.37	-5.34	19.14				
HC_UJS - Set B (automatistat45)	-0.65	-4.81	1.00	-2.71	-15.50	2.37	-5.34	19.14				
HC_UJS - Set B (automatistat46)	-1.68	-0.44	2.03	9.91	-8.91	-4.44	-14.08	32.43				
HC_UJS - Set B (automatistat47)	-0.22	-4.43	0.13	-0.86	-42.82	9.93	1.17	22.85				
HC_UJS - Set B (automatistat48)	-0.20	-0.71	0.60	-16.38	-47.93	13.65	0.05	26.28				
HC_UJS - Set B (automatistat49)	0.43	-2.40	-0.78	-21.23	-42.69	19.28	8.98	16.46				
HC_UJS - Set B (automatistat50)	-0.45	-4.42	0.90	-13.25	-41.82	11.16	-2.54	27.97				
HC_UJS - Set B (automatistat51)	0.66	-0.03	-0.95	-26.22	-70.14	23.03	11.31	17.65				
HC_UJS - Set B (automatistat52)	0.80	-0.54	-0.78	-26.14	-69.62	22.10	10.35	18.88				
HC_UJS - Set B (automatistat53)	0.16	-4.57	0.07	-20.95	-56.86	17.77	4.06	23.55				
HC_UJS - Set B (automatistat54)	0.45	-0.47	-0.42	-26.62	-64.53	21.04	7.64	21.00				
HC_UJS - Set B (automatistat55)	-1.07	-7.56	1.86	-4.40	-25.66	3.93	-8.85	31.69				
HC_UJS - Set B (automatistat56)	-1.07	-7.56	1.86	-4.40	-25.66	3.93	-8.85	31.69				
HC_UJS - Set B (automatistat57)	-1.07	-7.56	1.86	-4.40	-25.66	3.93	-8.85	31.69				
HC_UJS - Set B (automatistat58)	-0.65	-4.81	1.00	-2.71	-15.50	2.37	-5.34	19.14				
HC_UJS - Set B (automatistat59)	-0.65	-4.81	1.00	-2.71	-15.50	2.37	-5.34	19.14				
HC_UJS - Set B (automatistat60)	-0.65	-4.81	1.00	-2.71	-15.50	2.37	-5.34	19.14				
HC_UJS - Set B (automatistat61)	-1.07	-7.56	1.86	-4.40	-25.66	3.93	-8.85	31.69				
HC_UJS - Set B (automatistat62)	-1.07	-7.56	1.86	-4.40	-25.66	3.93	-8.85	31.69				

Case	Combination key
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat01)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat02)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat03)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat04)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat05)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat06)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat07)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat08)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat09)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat10)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat11)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat12)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat13)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat14)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat15)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat16)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat17)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat18)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat19)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat20)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat21)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat22)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat23)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat24)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat25)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat26)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat27)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat28)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat29)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat30)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat31)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat32)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat33)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat34)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat35)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat36)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat37)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat38)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat39)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat40)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat41)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat42)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat43)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat44)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat45)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat46)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat47)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat48)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat49)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat50)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat51)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat52)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat53)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat54)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat55)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat56)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat57)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat58)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat59)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat60)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat61)
HC_UJS - Set B (au)	HC_UJS-SetB(automatistat62)

Limit state design of longitudinal reinforcement

Ultimate limit state

Direction of reinforcement layer [$\alpha=0^\circ$]

[1+]: upper surface

$$m_{Ed} = -6.52 \text{ kNm/m} \mid n_{Ed} = 118 \text{ kN/m} \quad [\text{NC_ULS} - \text{Set B (automatisch).2}]$$

$$f_{cd} = 23.3 \text{ [MPa]} \quad (\gamma_c = 1.5, \alpha_{cc} = 1)$$

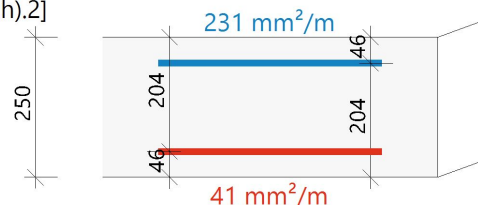
$$f_{yd} = 435 \text{ [MPa]} \quad (\gamma_s = 1.15)$$

$$\varnothing 12 \text{ mm} : d_1 = 46 \text{ mm} \rightarrow d = 204 \text{ mm}$$

$$x = -0.8 \text{ mm} \rightarrow z = 184 \text{ mm}$$

$$A_{s,ult} = \mathbf{231 \text{ mm}^2/\text{m}} \text{ (tensile)}$$

$$\rho = 0.113\%$$



[1-]: lower surface

$$m_{Ed} = -6.52 \text{ kNm/m} \mid n_{Ed} = 118 \text{ kN/m} \quad [\text{NC_ULS} - \text{Set B (automatisch).2}]$$

$$f_{cd} = 23.3 \text{ [MPa]} \quad (\gamma_c = 1.5, \alpha_{cc} = 1)$$

$$f_{yd} = 435 \text{ [MPa]} \quad (\gamma_s = 1.15)$$

$$\varnothing 12 \text{ mm} : d_1 = 46 \text{ mm} \rightarrow d = 204 \text{ mm}$$

$$x = -0.8 \text{ mm} \rightarrow z = 184 \text{ mm}$$

$$A_{s,ult} = \mathbf{41 \text{ mm}^2/\text{m}} \text{ (tensile)}$$

$$\rho = 0.020\%$$

Direction of reinforcement layer [$\alpha=90^\circ$]

[2+]: upper surface

$$m_{Ed} = -17.7 \text{ kNm/m} \mid n_{Ed} = 143 \text{ kN/m} \quad [\text{NC_ULS} - \text{Set B (automatisch).2}]$$

$$f_{cd} = 23.3 \text{ [MPa]} \quad (\gamma_c = 1.5, \alpha_{cc} = 1)$$

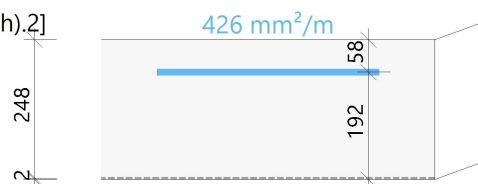
$$f_{yd} = 435 \text{ [MPa]} \quad (\gamma_s = 1.15)$$

$$\varnothing 12 \text{ mm} : d_1 = 58 \text{ mm} \rightarrow d = 192 \text{ mm}$$

$$x = 2 \text{ mm} \rightarrow z = 191 \text{ mm}$$

$$A_{s,ult} = \mathbf{426 \text{ mm}^2/\text{m}} \text{ (tensile)}$$

$$\rho = 0.222\%$$



Check of concrete diagonal strut

Check direction (extreme) [$\alpha=45^\circ$]

Design normal force in direction of concrete strut

$$n_{Ed,sc} = -108 \text{ kN} \quad [\text{NC_ULS} - \text{Set B (automatisch).2}]$$

with full cross-section height:

$$h = 250 \text{ mm} \rightarrow A_{cc} = h \cdot b = 0.25 \cdot 1000 = 250000 \text{ mm}^2$$

$$f_{cd} = \frac{\alpha_{cc} \cdot f_{ck}}{\gamma_c} = \frac{1 \cdot 35}{1.5} = 23 \text{ MPa}$$

Design resistance of concrete strut (in compression)

$$n_{Rd,sc} = A_{cc} \cdot \text{Red} f_{cd} \cdot f_{cd} = 250000 \cdot 0.85 \cdot 23 = 4958 \text{ kN}$$

Unity check

$$UC_{sc} = \frac{\text{abs}(n_{Ed,sc})}{n_{Rd,sc}} = \frac{\text{abs}(-108)}{4958} = 0.022$$

Detailing of the longitudinal reinforcement

Minimum reinforcement area

Vertical [2-]

Minimum ratio (area) of vertical reinforcement

$$A_{s,vmin} = \text{Coeff}_{Asvmin} \cdot A_c = 3 \cdot 10^{-3} \cdot 250000 = 750 \text{ mm}^2/\text{m} \quad (\text{NEN } \$9.6.2(1))$$

Half of the area should be located at each surface:

$$A_{s,vmin} = 0.5 \cdot A_{s,vmin} = 0.5 \cdot 750 = 375 \text{ mm}^2/\text{m} \quad (\$9.6.2(2))$$

Minimum area of vertical reinforcement from maximum spacing of bars

$$s_{vmax} = \min(\text{coef}_{s_{max,v}} \cdot h; s_{max,v}) = \min(3 \cdot 250; 400) = 400 \text{ mm} \quad (\$9.6.2(3))$$

$$A_{s,vmin} = \frac{1}{s_{vmax}} \cdot \pi \cdot \left(\frac{\phi_v}{2} \right)^2 = \frac{1}{400} \cdot 3.14 \cdot \left(\frac{12}{2} \right)^2 = 283 \text{ mm}^2/\text{m}$$

Horizontal [1-]

Minimum area of horizontal reinforcement from ratio

$$A_{s,hmin} = \max(\text{Coeff}_{AshminA} \cdot A_{s,v}; \text{Coeff}_{AshminB} \cdot A_c) = \max(0 \cdot 375; 0 \cdot 250000) = 0 \text{ mm}^2/\text{m} \quad (\text{NEN } \$9.6.3(1))$$

Minimum area of horizontal reinforcement from maximum spacing of bars

$$s_{hmax} = 400 \text{ mm} \quad (\$9.6.3(2))$$

$$A_{s,hmin} = \frac{1}{s_{hmax}} \cdot \pi \cdot \left(\frac{\phi_h}{2} \right)^2 = \frac{1}{400} \cdot 3.14 \cdot \left(\frac{12}{2} \right)^2 = 283 \text{ mm}^2/\text{m}$$

Vertical [2+]

Minimum ratio (area) of vertical reinforcement

$$A_{s,vmin} = \text{Coeff}_{Asvmin} \cdot A_c = 3 \cdot 10^{-3} \cdot 250000 = 750 \text{ mm}^2/\text{m} \quad (\text{NEN } \$9.6.2(1))$$

Half of the area should be located at each surface:

$$A_{s,vmin} = 0.5 \cdot A_{s,vmin} = 0.5 \cdot 750 = 375 \text{ mm}^2/\text{m} \quad (\$9.6.2(2))$$

Minimum area of vertical reinforcement from maximum spacing of bars

$$s_{vmax} = \min(\text{coef}_{s_{max,v}} \cdot h; s_{max,v}) = \min(3 \cdot 250; 400) = 400 \text{ mm} \quad (\$9.6.2(3))$$

$$A_{s,vmin} = \frac{1}{s_{vmax}} \cdot \pi \cdot \left(\frac{\phi_v}{2} \right)^2 = \frac{1}{400} \cdot 3.14 \cdot \left(\frac{12}{2} \right)^2 = 283 \text{ mm}^2/\text{m}$$

Horizontal [1+]

Minimum area of horizontal reinforcement from ratio

$$A_{s,hmin} = \max(\text{Coeff}_{AshminA} \cdot A_{s,v}; \text{Coeff}_{AshminB} \cdot A_c) = \max(0 \cdot 426; 0 \cdot 250000) = 0 \text{ mm}^2/\text{m} \quad (\text{NEN } \$9.6.3(1))$$

Minimum area of horizontal reinforcement from maximum spacing of bars

$$s_{hmax} = 400 \text{ mm} \quad (\$9.6.3(2))$$

$$A_{s,hmin} = \frac{1}{s_{hmax}} \cdot \pi \cdot \left(\frac{\phi_h}{2} \right)^2 = \frac{1}{400} \cdot 3.14 \cdot \left(\frac{12}{2} \right)^2 = 283 \text{ mm}^2/\text{m}$$

Maximum reinforcement area

Horizontal [1-]

Maximum area from minimum clear spacing of reinforcement bars

$$s_{min,lim} = \max(k_1 \cdot \phi; d_g + k_2; s_{lb,min}) = \max(1 \cdot 12; 32 + 5; 20) = 37 \text{ mm} \quad (\$8.2(2))$$

$$A_{s,max} = \frac{b}{\phi + s_{min,lim}} \cdot \pi \cdot \left(\frac{\phi}{2} \right)^2 = \frac{1000}{12 + 37} \cdot 3.14 \cdot \left(\frac{12}{2} \right)^2 = 2308 \text{ mm}^2/\text{m}$$

Vertical [2-]

Maximum area from minimum clear spacing of reinforcement bars

$$s_{\min, \lim} = \max(k_1 \cdot \phi; d_g + k_2; s_{lb, \min}) = \max(1 \cdot 12; 32 + 5; 20) = 37 \text{ mm} \quad (\S 8.2(2))$$

$$A_{s, \max} = \frac{b}{\phi + s_{\min, \lim}} \cdot \pi \cdot \left(\frac{\phi}{2}\right)^2 = \frac{1000}{12 + 37} \cdot 3.14 \cdot \left(\frac{12}{2}\right)^2 = 2308 \text{ mm}^2/\text{m}$$

Maximum area of vertical reinforcement from ratio

$$A_{s, v\max} = \text{Coeff}_{A_{sv\max}} \cdot A_c = 0.04 \cdot 0.25 = 10000 \text{ mm}^2/\text{m} \quad (\text{NEN } \S 9.6.2(1))$$

$$A_{s, \max} = \frac{A_{s, v\max}}{2} = \frac{10000}{2} = 5000 \text{ mm}^2/\text{m}$$

Horizontal [1+]

Maximum area from minimum clear spacing of reinforcement bars

$$s_{\min, \lim} = \max(k_1 \cdot \phi; d_g + k_2; s_{lb, \min}) = \max(1 \cdot 12; 32 + 5; 20) = 37 \text{ mm} \quad (\S 8.2(2))$$

$$A_{s, \max} = \frac{b}{\phi + s_{\min, \lim}} \cdot \pi \cdot \left(\frac{\phi}{2}\right)^2 = \frac{1000}{12 + 37} \cdot 3.14 \cdot \left(\frac{12}{2}\right)^2 = 2308 \text{ mm}^2/\text{m}$$

Vertical [2+]

Maximum area from minimum clear spacing of reinforcement bars

$$s_{\min, \lim} = \max(k_1 \cdot \phi; d_g + k_2; s_{lb, \min}) = \max(1 \cdot 12; 32 + 5; 20) = 37 \text{ mm} \quad (\S 8.2(2))$$

$$A_{s, \max} = \frac{b}{\phi + s_{\min, \lim}} \cdot \pi \cdot \left(\frac{\phi}{2}\right)^2 = \frac{1000}{12 + 37} \cdot 3.14 \cdot \left(\frac{12}{2}\right)^2 = 2308 \text{ mm}^2/\text{m}$$

Maximum area of vertical reinforcement from ratio

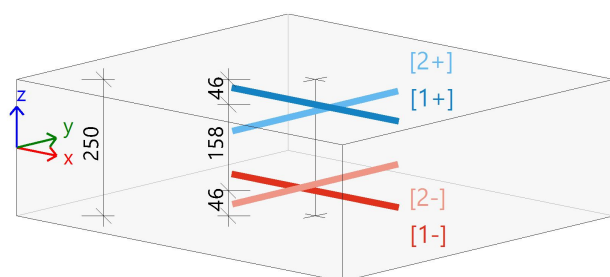
$$A_{s, v\max} = \text{Coeff}_{A_{sv\max}} \cdot A_c = 0.04 \cdot 0.25 = 10000 \text{ mm}^2/\text{m} \quad (\text{NEN } \S 9.6.2(1))$$

$$A_{s, \max} = \frac{A_{s, v\max}}{2} = \frac{10000}{2} = 5000 \text{ mm}^2/\text{m}$$

Longitudinal reinforcement - Summary

	Basic	Additional		$A_{s, \text{ult}}$ [mm ²]	$\Delta A_{s, \text{serv}}$ [mm ²]	$A_{s, \text{min}}$ [mm ²]	$A_{s, \text{req}}$ [mm ²]	$A_{s, \text{prov}}$ [mm ²]	$A_{s, \text{max}}$ [mm ²]	Status
		User	Provided							
[1+]	φ12,0/100	no reinf.	no reinf.	231	---	283	283	1131	2308	OK
[2+]	φ12,0/100	no reinf.	no reinf.	426	---	375	426	1131	2308	OK
[1-]	φ12,0/100	no reinf.	no reinf.	41	---	283	283	1131	2308	OK
[2-]	φ12,0/100	no reinf.	no reinf.	0	---	375	375	1131	2308	OK

$A_{s, \text{ult}}$ - required reinforcement area from ULS design; $\Delta A_{s, \text{serv}}$ - increase of required reinforcement area from SLS design; $A_{s, \text{req}}$ - required reinforcement area including detailings; $A_{s, \text{prov}}$ - provided reinforcement area (sum from considered basic and additional rebars)



[1+] φ12,0/100
[2+] φ12,0/100
[1-] φ12,0/100
[2-] φ12,0/100

Design of shear reinforcement

Design shear force

$$V_{Ed} = \sqrt{V_x^2 + V_y^2} = \sqrt{-49.2^2 + 51.7^2} = 71.4 \text{ kN/m [NC_ULS - Set B (automatisch).2]}$$

Principal forces and plane of deformation

$$m_z = -19 \text{ kNm} \quad | \quad n_z = 112 \text{ kN}$$

$$d = 198 \text{ mm} \quad | \quad z = 197 \text{ mm}$$

Longitudinal reinforcement ratio (considering upper surface is in tension)

(\$6.4.4(1))

$$\rho_{lx} = \frac{A_{sl,x}}{b \cdot d} = \frac{1131}{1000 \cdot 198} = 0.571 \% \quad \rho_{ly} = \frac{A_{sl,y}}{b \cdot d} = \frac{1131}{1000 \cdot 198} = 0.571 \%$$

$$\rho_l = \min\left(\sqrt{\rho_{lx} \cdot \rho_{ly}}; 0.02\right) = \min\left(\sqrt{5.71 \cdot 10^{-3} \cdot 5.71 \cdot 10^{-3}}; 0.02\right) = 0.571 \%$$

Shear resistance without shear reinforcement

Normal concrete stresses (positive if compression)

Normal forces (from FEM): $n_x = 56.3 \text{ kN/m}$ $n_y = 80.9 \text{ kN/m}$ [NC_ULS - Set B (automatisch).2]

$$\sigma_{cp,1} = \min\left(\frac{-n_x}{A_c}; 0.2 \cdot f_{cd}\right) = \min\left(\frac{-56.3}{0.25}; 0.2 \cdot 23.3 \cdot 10^6\right) = -0.23 \text{ MPa} \quad (\$6.2.2(1))$$

$$\sigma_{cp,2} = \min\left(\frac{-n_y}{A_c}; 0.2 \cdot f_{cd}\right) = \min\left(\frac{-80.9}{0.25}; 0.2 \cdot 23.3 \cdot 10^6\right) = -0.32 \text{ MPa} \quad (\$6.2.2(1))$$

$$\sigma_{cp} = \frac{\sigma_{cp,1} + \sigma_{cp,2}}{2} = \frac{-0.23 + -0.32}{2} = -0.27 \text{ MPa}$$

Design shear resistance without shear reinforcement

(\$6.4.4(1))

$$k = \min\left(1 + \left(\frac{200}{d}\right)^{\frac{1}{2}}; 2\right) = \min\left(1 + \left(\frac{200}{198}\right)^{\frac{1}{2}}; 2\right) = 2$$

$$C_{Rdc} = 0.12 \quad v_{min} = 0.586 \text{ MPa} \quad k_1 = 0.15$$

$$V_{Rdc} = \max\left(10^6 \cdot \left(C_{Rdc} \cdot k \cdot \left(100 \cdot \rho_l \cdot f_{ck}\right)^{\frac{1}{3}} + k_1 \cdot \sigma_{cp}\right) \cdot d; 0\right) \quad (6.47)$$

$$= \max\left(10^6 \cdot \left(0.12 \cdot 2 \cdot \left(100 \cdot 5.71 \cdot 10^{-3} \cdot 35\right)^{\frac{1}{3}} + 0.15 \cdot -0.274\right) \cdot 0.198; 0\right) = 121 \text{ kN/m}$$

$$V_{Rdcmin} = \max\left(10^6 \cdot \left(v_{min} + k_1 \cdot \sigma_{cp}\right) \cdot d; 0\right) = \max\left(10^6 \cdot \left(0.586 + 0.15 \cdot -0.274\right) \cdot 0.198; 0\right) = 108 \text{ kN/m}$$

$$V_{Rdc} = \max(V_{Rdc}; V_{Rdcmin}) = \max(121 \text{ kN/m}; 108 \text{ kN/m}) = 121 \text{ kN/m}$$

Maximal concrete shear resistance

Strength reduction factor for concrete cracked in shear

$$v = 0.6 \cdot \left(1 - \frac{f_{ck}}{250}\right) = 0.6 \cdot \left(1 - \frac{35}{250}\right) = 0.516 \quad (6.6N)$$

Angle of compression concrete strut

$$\theta = 21.8^\circ, \cot(\theta) = 2.5$$

Design value of the max shear force which can be sustained by the member

$$V_{Rd,max} = \frac{\alpha_{cw} \cdot b_w \cdot z \cdot v_1 \cdot f_{cd}}{(\cot(\theta) + \tan(\theta))} = \frac{1 \cdot 1 \cdot 0.197 \cdot 0.516 \cdot 23.3}{(\cot(21.8) + \tan(21.8))} = 817 \text{ kN/m} \quad (6.9)$$

Check shear capacity (without shear reinforcement)

Check $v_{Rd,max}$

$$v_{Ed} = 71.4 \text{ kN/m} \leq v_{Rd,max} = 817 \text{ kN/m} \quad (\text{OK})$$

Check v_{Rdc}

$$v_{Ed} = 71.4 \text{ kN/m} \leq v_{Rdc} = 121 \text{ kN/m} \quad (\text{OK, no shear reinforcement is required})$$

Detailing of shear reinforcement

Minimal area of transverse reinforcement from maximum spacing of links 9.6.4(1)

Total area of vertical reinforcement in the two faces

$$A_{sl} = 801 \text{ mm}^2$$

Area of concrete section

$$A_c = 250000 \text{ mm}^2$$

Condition for detailing

$$A_{sl} < 0.02 \cdot A_c$$

$$801 \text{ mm}^2 < 5000 \text{ mm}^2$$

Minimal area of transverse reinforcement from minimum number of links 9.6.4(2)

Diameter of main reinforcement

$$\phi_l = 12 \text{ mm}$$

Concrete cover

$$c = 52 \text{ mm}$$

Detailing check is not necessary for next conditions:

$$\phi_l \leq 16 \text{ mm}, c \geq 2 \cdot \phi_l$$

$$12 \text{ mm} \leq 16 \text{ mm}, 52 \text{ mm} \geq 24 \text{ mm}$$

Shear reinforcement - Summary

		θ	v_{Ed}	$A_{sl,x}$	$A_{sl,y}$	ρ_l	$v_{Rd,c}$	$v_{Rd,max}$	$A_{sw,req}$	Status
	Case	[°]	[kN/m]	[mm ²]	[mm ²]	[%]	[kN/m]	[kN/m]	[mm ² /m ²]	
[+]	NC_ULS - Set B (autor)	21,8	71,4	1131	1131	0,571	120,8	816,7	---	OK

v_{Ed} - design shear force, $A_{sl,x/y}$ - tensile longitudinal reinforcement, ρ_l - corresponding reinforcement ratio, $v_{Rd,c}$ - shear resistance without shear reinforcement, $v_{Rd,max}$ - maximal concrete shear resistance, $A_{sw,req}$ - required shear reinforcement

10.2.4. Crack width (SLS) Global

Nonlinear calculation

Class: RC_NC_SLS - Frequent (automatisch)

Extreme: Global

Selection: All

Location: In nodes avg. on macro. System: LCS mesh element

Plate E1	h=250 mm
NEN EN 1992-1-1+C2:2011/NB:2016	Node 123/0 [X= 6,480, Y=0,200, Z=0,000 m]

Calculation setting:

Code	NEN EN 1992-1-1+C2:2011/NB:2016
Coefficient for effective height	Coeff _d = 0.9
Coefficient perc. of longterm load	Coeff _{long} = 0.7
Effective creep ratio	φ _{ef} = 2.07
Strength for calculation f _{ct,eff}	f _{ctm}
Strength for calculation cracking force	f _{cteff}
Modulus of concrete	E _{ceff}
Limit value of crack width	w _{max-} = 0.15 mm
	w _{max+} = 0.15 mm

Material

Concrete:

Concrete: **C35/45**

Mean tensile strength:

$$f_{ctm} = 3.2 \text{ MPa}$$

Effective strength of concrete:

$$f_{ct,eff} = f_{ctm} = 3.2 \text{ MPa}$$

Modulus of elasticity of concrete:

$$E_c = \frac{E_{cm}}{1 + \varphi_{ef}} = \frac{34.1 \cdot 10^9}{1 + 2.07} = 11.1 \text{ GPa}$$

(3.23, 5.27)

Strength in concrete, when crack is appeared:

$$\sigma_{cr} = f_{ct,eff} = 3.2 \text{ MPa}$$

Reinforcement:

Reinforcement: **B 500B**

Characteristic yield strength:

$$f_{yk} = 500 \text{ MPa}$$

Modulus of elasticity of reinforcement:

$$E_s = 200 \text{ GPa}$$

Characteristic strain of reinforcement:

$$\varepsilon_{yk} = 2.5 \text{ ‰}$$

Internal forces

Basic forces (centroid), critical

Table of internal forces

Case	m_x [kNm/m]	m_y [kNm/m]	m_{xy} [kNm/m]	n_x [kN/m]	n_y [kN/m]	n_{xy} [kN/m]	v_x [kN/m]	v_y [kN/m]
NC_SLS - Frequent (automatisch).1/1	0,81	2,48	-0,75	2,19	-8,07	1,32	-4,31	-3,24
NC_SLS - Frequent (automatisch).2/2	1,21	2,33	-0,83	0,74	-7,75	2,27	-4,95	-4,16
NC_SLS - Frequent (automatisch).3/3	0,82	2,89	-0,63	3,14	-10,10	-1,37	-4,28	-3,91
NC_SLS - Frequent (automatisch).4/4	0,98	1,96	-1,29	0,75	-4,89	2,19	-5,00	-2,96
NC_SLS - Frequent (automatisch).5/5	1,15	2,49	-0,77	0,74	-8,46	2,18	-4,85	-4,50
NC_SLS - Frequent (automatisch).6/6	0,49	2,31	-1,19	4,97	-6,44	2,94	-4,51	-2,64
NC_SLS - Frequent (automatisch).7/7	1,31	2,17	-0,93	0,61	-6,89	2,54	-5,20	-3,78
NC_SLS - Frequent (automatisch).8/8	1,25	1,96	-1,10	-0,25	-5,23	2,00	-5,32	-3,28
NC_SLS - Frequent (automatisch).9/9	1,11	2,64	-0,75	1,32	-9,09	-2,09	-4,82	-4,57
NC_SLS - Frequent (automatisch).10/10	1,36	2,04	-1,03	0,04	-5,97	2,63	-5,42	-3,52
NC_SLS - Frequent (automatisch).11/11	0,61	2,21	-1,25	4,00	-6,01	2,90	-4,64	-2,49
NC_SLS - Frequent (automatisch).12/12	0,76	2,12	-1,27	2,64	-5,65	2,71	-4,73	-2,51
NC_SLS - Frequent (automatisch).13/13	0,99	2,78	-0,71	2,29	-9,66	-1,53	-4,60	-4,34
NC_SLS - Frequent (automatisch).14/14	0,94	2,05	-1,21	0,87	-5,46	2,26	-4,78	-2,76
NC_SLS - Frequent (automatisch).15/15	0,62	2,42	-0,90	3,79	-7,37	2,01	-4,37	-2,99
NC_SLS - Frequent (automatisch).16/16	0,81	2,48	-0,75	2,19	-8,07	1,32	-4,31	-3,24
NC_SLS - Frequent (automatisch).17/17	0,81	2,48	-0,75	2,19	-8,07	1,32	-4,31	-3,24
NC_SLS - Frequent (automatisch).18/18	0,81	2,48	-0,75	2,19	-8,07	1,32	-4,31	-3,24
NC_SLS - Frequent (automatisch).19/19	0,81	2,48	-0,75	2,19	-8,07	1,32	-4,31	-3,24
NC_SLS - Frequent (automatisch).20/20	0,81	2,48	-0,75	2,19	-8,07	1,32	-4,31	-3,24
NC_SLS - Frequent (automatisch).21/21	0,81	2,48	-0,75	2,19	-8,07	1,32	-4,31	-3,24
NC_SLS - Frequent (automatisch).22/22	0,81	2,48	-0,75	2,19	-8,07	1,32	-4,31	-3,24
NC_SLS - Frequent (automatisch).23/23	0,81	2,48	-0,75	2,19	-8,07	1,32	-4,31	-3,24
NC_SLS - Frequent (automatisch).24/24	0,81	2,48	-0,75	2,19	-8,07	1,32	-4,31	-3,24
NC_SLS - Frequent (automatisch).25/25	0,81	2,48	-0,75	2,19	-8,07	1,32	-4,31	-3,24
NC_SLS - Frequent (automatisch).26/26	0,81	2,48	-0,75	2,19	-8,07	1,32	-4,31	-3,24
NC_SLS - Frequent (automatisch).27/27	0,81	2,48	-0,75	2,19	-8,07	1,32	-4,31	-3,24
NC_SLS - Frequent (automatisch).28/28	0,81	2,48	-0,75	2,19	-8,07	1,32	-4,31	-3,24

Table of combinations

Case	Combination key
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).1
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).2
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).3
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).4
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).5
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).6
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).7
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).8
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).9
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).10
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).11
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).12
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).13
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).14
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).15
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).16
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).17
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).18
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).19
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).20
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).21
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).22
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).23
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).24
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).25
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).26
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).27
NC_SLS - Frequent ...	NC_SLS-Frequent(automatisch).28

Table of 2D reinforcement

Reinforcement type - User

ID	Diameter d[mm]	Bars distance s[mm]	Angle α [°]	Vert.position z[mm]	Material	f_{yk} [MPa]	E_s [GPa]
1	12,0	100,0	0,0	79,0	B 500B	500,0	200,0
2	12,0	100,0	90,0	67,0	B 500B	500,0	200,0
3	12,0	100,0	90,0	-67,0	B 500B	500,0	200,0
4	12,0	100,0	0,0	-79,0	B 500B	500,0	200,0

Check of crack width

Lower surface

Direction of principal stress (direction for recalculation forces): $\alpha_\sigma = -68.9^\circ$

Content of combination: NC_SLS-Frequent(automatisch).3

Characteristic values: $n_{char} = -7.46 \text{ kN/m}$ $m_{char} = 3.05 \text{ kNm/m}$

Quasi-permanent values: $n_{qp} = -7.46 \text{ kN/m}$ $m_y = 3.05 \text{ kNm/m}$

Type	Css-uncracked
t_i [m]	0
A_i [m ²]	0.291
S_i [m ³]	0
I_i [m ⁴]	$1.49 \cdot 10^{-3}$

Calculation of cracking forces (uncracked section)

Maximal stress in concrete

$$\sigma_{ct} = 0.2 \text{ MPa}$$

Cracking forces

$$N_{cr} = \frac{f_{ct,eff}}{\frac{1}{A_i} + \frac{M_{char} \cdot 0.5 \cdot h + t_i}{N_{char} \cdot I_i}} = \frac{3.2 \cdot 10^6}{\frac{1}{0.291} + \frac{3050 \cdot 0.5 \cdot 0.25 + 0}{-7465 \cdot 1.49 \cdot 10^{-3}}} = -104.1 \text{ kN}$$

$$M_{cr} = \frac{N_{cr} \cdot M_{char}}{N_{char}} = \frac{-104093.3 \cdot 3050}{-7465} = 42.5 \text{ kNm}$$

$$\sigma_{ct} = 0.2 \text{ MPa} < \sigma_{cr} = 3.2 \text{ MPa} \Rightarrow \text{No cracks appear}$$

Calculation crack width

$$w = 0.000 \text{ mm}$$

Limit value of crack width

$$k_x = \min\left(\frac{c_{used}}{c_{nom}}; 2\right) = \min\left(\frac{40 \text{ mm}}{40 \text{ mm}}; 2\right) = 1$$

$$w_{max} = k_x \cdot w_{max} = 1 \cdot 0.15 \text{ mm} = 0.15 \text{ mm}$$

(\$7.3.1(5))

Calculation unity check

$$UC = \frac{w}{w_{max}} = \frac{0}{0.15} = 0$$

Check crack width

$$w = 0 \text{ mm} = < w_{max} = 0.15 \text{ mm}$$

Note: Check crack width satisfies, because the crack width is lesser than limit value.

Upper surface

Direction of principal stress (direction for recalculation forces): $\alpha_\sigma = 24.5^\circ$

Content of combination: NC_SLS-Frequent(automatisch).6

Characteristic values: $n_{char} = 5.24 \text{ kN/m}$ $m_{char} = -0.0933 \text{ kNm/m}$

Quasi-permanent values: $n_{qp} = 5.24 \text{ kN/m}$ $m_y = -0.0933 \text{ kNm/m}$

Type	Css-uncracked
t_i [m]	0
A_i [m ²]	0.291
S_i [m ³]	0
I_i [m ⁴]	$1.54 \cdot 10^{-3}$

Calculation of cracking forces (uncracked section)

Maximal stress in concrete

$$\sigma_{ct} = 0.0 \text{ MPa}$$

Cracking forces

$$N_{cr} = \frac{f_{ct,eff}}{\frac{1}{A_i} - \frac{M_{char} \cdot 0.5 \cdot h - t_i}{N_{char} \cdot I_i}} = \frac{3.2 \cdot 10^6}{\frac{1}{0.291} - \frac{-93.3 \cdot 0.5 \cdot 0.25 - 0}{5237 \cdot 1.54 \cdot 10^{-3}}} = 655.6 \text{ kN}$$

$$M_{cr} = \frac{-N_{cr} \cdot M_{char}}{N_{char}} = \frac{-655.6 \cdot -93.3}{5237} = 11.7 \text{ kNm}$$

$$\sigma_{ct} = 0.0 \text{ MPa} < \sigma_{cr} = 3.2 \text{ MPa} \Rightarrow \text{No cracks appear}$$

Calculation crack width

$$w = 0.000 \text{ mm}$$

Limit value of crack width

$$k_x = \min\left(\frac{c_{used}}{c_{nom}}; 2\right) = \min\left(\frac{40 \text{ mm}}{40 \text{ mm}}; 2\right) = 1$$

$$w_{max} = k_x \cdot w_{max} = 1 \cdot 0.15 \text{ mm} = 0.15 \text{ mm}$$

(\$7.3.1(5))

Calculation unity check

$$UC = \frac{w}{w_{max}} = \frac{0}{0.15} = 0$$

Check crack width

$$w = 0 \text{ mm} = < w_{max} = 0.15 \text{ mm}$$

Note: Check crack width satisfies, because the crack width is lesser than limit value.

Appendix B. R1901326-03 Geotechnical advice

Opdracht : 1901326
Plaats : Botlek Rotterdam
Project : Verladingsplaats aan de Welplaatweg 12

Betreft : Verladingsplaats in de tankputdijk voor een project
aan de Welplaatweg 12
te
BOTLEK ROTTERDAM

Opdrachtgever : Shin-Etsu PVC B.V.
T.a.v. Dhr. A. Vogelezang
Postbus 641
3190 AN HOOGVLIET ROTTERDAM
NL

Behandeld door : ir. J.C.M. de Jong (088 - 51 30 211)

Kenmerk : R1901326-03

Datum : 24 september 2020

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Vestiging Amsterdam	Pleimuiden 8B	1046 AG	Amsterdam
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1. INLEIDING

In opdracht van Shin-Etsu PVC B.V is door Mos Grondmechanica B.V. een grondonderzoek uitgevoerd en is op basis daarvan een advies opgesteld voor insnede in de tankputdijk en de terreinverharding ten behoeve van een laadplatform naast een tankput.

Van de resultaten van het uitgevoerde grondonderzoek is verslag gedaan in Mos Grondmechanica rapport R1901326-01, d.d. 23 augustus 2019.

Rapport R1901326-02 d.d. 30 augustus 2019 bevat het op de resultaten van het voornoemde grondonderzoek gebaseerde damwand en verhardingsadvies voor de bovengenoemde nieuwbouw.

In dit rapport R1901326-03 is de fundering voor de betonnen verladingsplaat en de staalconstructie uitgewerkt. De staalconstructie wordt op palen gefundeerd.

Als constructeur is KH engineering betrokken bij dit project.

2. PROJECTBESCHRIJVING

Het project betreft de herpositionering van het TAR verladersplatform.

Ten behoeve van dit project zijn de volgende documenten beschikbaar gesteld:

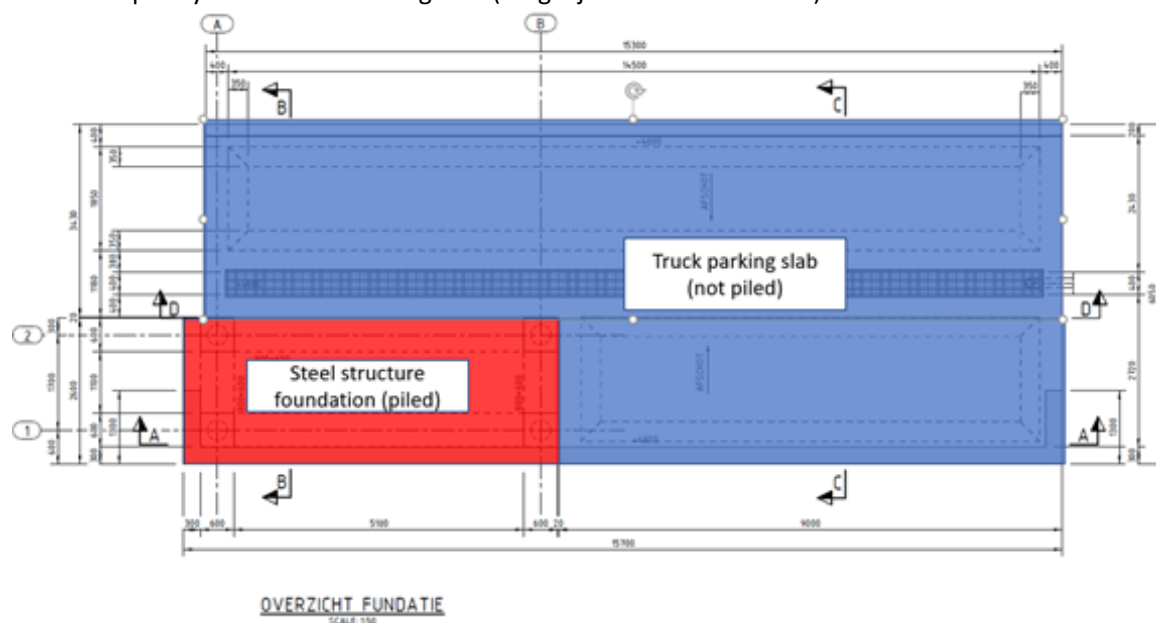
- KH-Engineering rapport 62596-102, 4.002.937, revisie 0 d.d. 9 april 2019 "Relocation TAR loading, Aanvraag grondmechanisch advies";
- KH-Engineering tekening 62596-102, 4.002.929, revisie 0A d.d. 5 april 2019 "Relocation TAR loading, Bestaande situatie";
- ShinEtsu tekening 4.007.215, "Relocation TAR loading, Nieuwe situatie" For Information Only;
- ShinEtsu tekening 4.007.223, "Relocation TAR loading, Palenplan Layout" For Information Only;
- ShinEtsu tekening 4.007.225, "Relocation TAR loading, Fundering verlaadstation" A0; Voor commentaar.

Uit deze documenten en aanvullende informatie van de constructeur zijn de volgende projectgegevens afgeleid:

- De verlading bestaat uit een op staal gefundeerde betonplaten een staalconstructie op palen zie figuur 2-1.
- Gewenste paalsysteem Tubex met groutinjectie (o.g.).
- Paalbelastingen (in kN):

	Druk		Trek		Horizontaal	
	UGT	BGT	UGT	BGT	UGT	BGT
Paal 1	780	500	-450	-250	35	25
Paal 2	600	400	-260	-135	20	15

- Paalkopniveau = NAP + 4,02 m.
- In verband met mogelijk vervuilde grond dient rekening te worden gehouden met de keuze van het paalsysteem en de ondergrond (mogelijk versnelde corrosie).

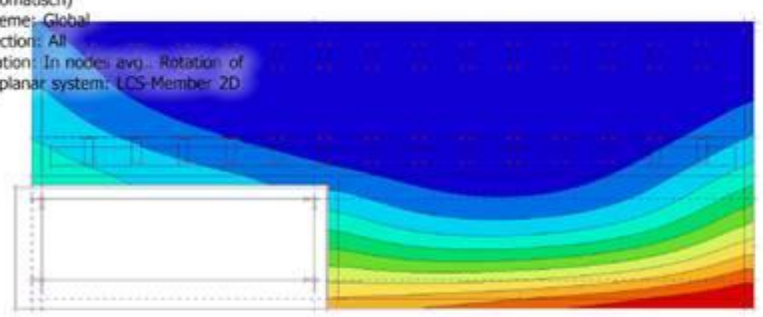


Figuur 2-1 Opstelling TAR verlading met staalconstructie

- BGT gronddruk onder de plaat: 24-37 kN/m²

5.7. 2D contact stresses; σ_z (RC_NC_BGT-quasi (automatisch))

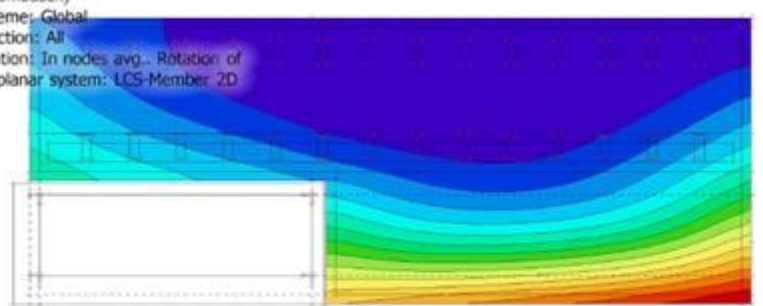
Values: σ_z
 Nonlinear calculation
 Class: RC_NC_BGT-quasi
 (automatisch)
 Extreme: Global
 Selection: All
 Location: In nodes avg.: Rotation of
 the planar system: LCS-Member 2D



- UGT gronddruk onder de plaat: 60-76 kN/m²

5.3. 2D contact stresses; σ_z (RC_NC_UGT-Set B (automatisch))

Values: σ_z
 Nonlinear calculation
 Class: RC_NC_UGT-Set B
 (automatisch)
 Extreme: Global
 Selection: All
 Location: In nodes avg.: Rotation of
 the planar system: LCS-Member 2D



Figuur 2-2 Overzicht gronddrukken in BGT en UGT

- Funderingsplaat in beton op staal gefundeerd.

De fundering is op basis van bovenstaande projectgegevens ingedeeld in geotechnische categorie 2.

3. GEOTECHNISCHE GEGEVENS

3.1 Uitgevoerd grondonderzoek

Op 18 juli 2019 zijn door Mos Grondmechanica de sonderingen 1 tot en met 4 uitgevoerd tot een diepte van maaiveld -30 m (maximaal NAP -25,7 m). Naast de conusweerstand (q_c) is de plaatselijke wrijving (f_s) en de helling (i) gemeten. Uit de plaatselijke wrijving en de conusweerstand is het wrijvingsgetal (R_f) berekend. Dit getal geeft nader inzicht in de aanwezige grondsoorten.

Tevens zijn een boring 1 tot en met 3 uitgevoerd tot maaiveld -3 m. De vrijgekomen grondslag is visueel geïdentificeerd, conform NEN 5104, en tot boorprofiel verwerkt.

Tijdens het boren is het grondwater aangetroffen op NAP +3,1 à NAP + 3,4 m. Deze waarneming is slechts een indicatie omdat spanningswater, het grondprofiel, lokale omstandigheden en seizoensafhankelijke factoren een invloed kunnen hebben.

De sondeer- en boorlocaties zijn door onze landmeetkundige afdeling in het terrein uitgezet en gewaterpast ten opzichte van NAP. Voor de resultaten van het veldwerk, de waterpassing en een situatietekening met de ligging van de onderzoekslocaties wordt verwezen naar veldwerkverslag R1901326-01, d.d. 23 augustus 2019.

3.2 Geotechnisch profiel

De maaiveldhoogte ter plaatse van de sondeerlocaties varieert van NAP +4,49 m tot NAP +4,48 m.

Aan de hand van het uitgevoerde grondonderzoek is het volgende geotechnische profiel opgesteld:

- Vanaf maaiveld tot NAP +1,5 m à NAP +1,0 m is matig fijn, zwak siltig zand aangetroffen waarin conusweerstand (q_c) zijn gemeten van 4 MPa tot 12 MPa.
- Vanaf NAP +1,5 m à NAP +1,0 m tot NAP +0,0 m à NAP -1,0 m is klei aangetroffen met een conusweerstand van ongeveer 1,0 MPa.
- Vanaf NAP +0,0 m à NAP -1,0 m tot NAP -2,5 m à NAP -5,3 m is zandige klei aangetroffen.
- Vanaf NAP -2,5 m à NAP -5,3 m tot NAP -17 m is een zandig pakket aangetroffen met conusweerstand van 4 tot 12 MPa en hoger, op verschillende diepten zijn lenzen en stoorlagen aanwezig bestaande uit siltig zand en lokale kleilenzen.
- Vanaf NAP -17 m tot circa NAP -19 m is een stijve kleilaag aanwezig waarin de conusweerstand 1,0 MPa à 1,5 MPa bedraagt.
- Hieronder tot aan de maximaal verkende diepte van NAP -25,6 m is een draagkrachtig zandpakket aangetroffen waarin conusweerstand zijn gemeten van 12 MPa tot 30 MPa en hoger. Terugvallen in de conusweerstand tot 8 MPa worden veroorzaakt door silthoudend of los gepakt zand.

4. FUNDERINGSADVIES STAALCONSTRUCTIE

4.1 Keuze funderingstype

Gelet op de projectgegevens en de opbouw en samenstelling van de ondergrond, kunnen wij vanuit geotechnisch oogpunt instemmen met de keuze voor een fundering op Tubexpalen met groutinjectie (o.g.).

De berekeningen van de rekenwaarden van de maximale verticale *paaldruk*- en *-trek*weerstand zijn uitgevoerd voor Tubexpalen met groutinjectie en zijn voor de *paaldruk*weerstand en de *paaltrek*weerstand gebaseerd op de geotechnische norm NEN 9997-1:2017 "Geotechnisch ontwerp van constructies".

4.2 Paalpuntniveaus en maximum puntweerstand en paalschachtwrijvingen

In Tabel 4-1a (ondiep paalpuntniveau) en Tabel 4-1b (diep paalpuntniveau) is per sondering voor Tubexpalen met groutinjectie (o.g.) het voor de benodigde *paaldruk*weerstand geadviseerde paalpuntniveau aangegeven met de bijbehorende waarden voor de representatieve negatieve kleef, de maximum paalschachtwrijvingen en de maximum puntweerstand.

In de toekomst kunnen zettingen optreden in de samendrukbare lagen van de ondergrond. Deze zettingen leiden tot negatieve kleef langs de funderingspalen. Voor de berekening van de negatieve kleef is de grondwaterstand aangenomen op een niveau van NAP + 1,5 m. De negatieve kleef is vanaf maaiveld tot NAP – 2,4 m à NAP – 5,4 m in rekening gebracht.

De maximum paalschachtwrijving is met de procentenmethode berekend. Voor druk over het traject vanaf de bovenkant van de draagkrachtige zandlagen op NAP – 2,4 m à NAP – 5,4 m tot het geadviseerde paalpuntniveau, en voor trek over het traject vanaf NAP – 2,4 m à NAP – 5,4 m tot het geadviseerde paalpuntniveau. Voor het diepe paalpuntniveau is daarbij voor de drukbelasting over het traject van NAP – 2,4 m à NAP – 5,4 m tot NAP – 19,0 m à NAP – 19,3 m de schachtwrijving voor 50 % gereduceerd. Hierbij is voor Tubexpalen met groutinjectie (o.g.) een factor gehanteerd van $\alpha_s = 0,009$ voor druk en $\alpha_t = 0,009$ voor trek.

De maximum puntweerstand zijn voor Tubexpalen met groutinjectie (o.g.) berekend met een paalklassefactor $\alpha_p = 0,63$; voor de overige paalfactoren geldt: $\beta = s = 1,0$. Hierbij is uitgegaan dat door groutinjectie de diameter gelijk is aan de boorpunt over het traject waarvoor de positieve kleef is berekend.

Tabel 4-1a Paalpuntniveaus en maximum paalschachtwrijvingen en puntweerstand

Sondering Nr.	"ondiep" paalpuntniveau		Tubexpalen met groutinjectie (o.g.)			
	Maaiveldhoogte [NAP + m]	Paalpuntniveau [NAP + m]	$F_{nk,rep,i}$ [kN/m]	$q_{s,cal,max,i}$ [kN/m]		$q_{b,max,i}^{1)}$ [MPa]
				druk	trek ²⁾	
1	4,48	-14,5	135	685	685	5,5
2	4,49	-14,5	125	700	700	4,5
3	4,49	-14,5	165	565	565	4,4

	"ondiep" paalpuntniveau		Tubexpalen met groutinjectie (o.g.)			
Sondering Nr.	Maaiveldhoogte [NAP + m]	Paalpuntniveau [NAP + m]	$F_{nk,rep,i}$ [kN/m]	$q_{s,cal,max,i}$ [kN/m]		$q_{b,max,i}^{1)}$ [MPa]
				druk	trek ²⁾	
4	4,49	-14,5	90	730	730	5,2

Tabel 4-1b Paalpuntniveaus en maximum paalschachtwrijvingen en puntweerstand

	"diep" paalpuntniveau		Tubexpalen met groutinjectie (o.g.)			
Sondering Nr.	Maaiveldhoogte [NAP + m]	Paalpuntniveau [NAP + m]	$F_{nk,rep,i}$ [kN/m]	$q_{s,cal,max,i}$ [kN/m]		$q_{b,max,i}^{1)}$ [MPa]
				Druk	trek ²⁾	
1	4,48	-22,0	135	870	1400	9,9
2	4,49	-22,0	125	840	1325	6,3
3	4,49	-22,0	165	760	1185	5,9
4	4,49	-22,0	90	815	1325	6,4

$F_{nk,rep,i}$ is de representatieve waarde van de negatieve kleef bij sondering i, per meter paalomtrek;

$q_{s,cal,max,i}$ is de representatieve waarde van de maximumpaalschachtwrijvingskracht bij sondering i, per meter paalomtrek;

$q_{b,max,i}$ is de maximale puntweerstand bij sondering i;

1) deze waarden gelden voor palen, $\varnothing_{buis/punt}$: $\varnothing$ 324/450 mm;

2) deze waarden hebben betrekking op de maximale paalschachtwrijving voor een alleenstaande trekpaal, dus exclusief eventuele reducties voor groepseffecten.

4.3 Rekenwaarden netto paaldrukweerstand en netto paaltrekweerstand

Met de hiervoor aangegeven waarden van de negatieve kleef en de maximum paalschachtwrijving en de maximum puntweerstand zijn voor Tubexpalen met groutinjectie (o.g.) de rekenwaarden van de netto paaldrukweerstand en de netto paaltrekweerstand berekend. Hierbij zijn, conform NEN 9997-1, de volgende factoren gehanteerd; $\xi = 1,3$ (2 sonderingen; niet-stijf bouwwerk), $\gamma_t (= \gamma_b = \gamma_{s;c}) = 1,20$, $\gamma_{f,nk} = 1,00$, $\gamma_{s;t} = 1,35$, $\gamma_{m,var;q_c} = 1,50$ en $\gamma_\gamma = 1,1$.

Dit geeft de volgende rekenwaarden voor de netto paaldruk- en -trekweerstand (Tabel 4-2):

Tabel 4-2 Rekenwaarden voor de netto paaldrukweerstand en de netto paaltrekweerstand

Tubexpalen met groutinjectie (o.g.)				
Paalafmetingen $\varnothing_{\text{buis}} / \varnothing_{\text{punt}}$ [mm × mm]	Paalpuntniveau [NAP + m]	$R_{c;\text{net};d}$ [kN]	$R_{t;\text{net};1;d}$ [kN]	$R_{t;\text{net};\text{groep};d}$ [kN]
"Ondiep" paalpuntniveau				
$\varnothing 273 / 350$	- 14,5	525	250	240
$\varnothing 324 / 450$	- 14,5	780	330	310
$\varnothing 356 / 560$	- 14,5	1115	415	380
"Diep" paalpuntniveau				
$\varnothing 273 / 350$	- 22,0	785	515	475
$\varnothing 324 / 450$	- 22,0	1105	670	600
$\varnothing 356 / 560$	- 22,0	1515	840	740

$R_{c;\text{net};d}$ is de rekenwaarde van de netto paaldrukweerstand, na aftrek van de negatieve kleeft.

$R_{t;\text{net};1;d}$ is de rekenwaarde van de netto paaltrekweerstand voor een "alleenstaande trekpaal", inclusief de rekenwaarde van het effectieve gewicht van de paal (zonder paalgroep-effect);

$R_{t;\text{net};\text{groep};d}$ is de rekenwaarde van de netto paaltrekweerstand voor een paal in een paalgroep, inclusief de rekenwaarde van het effectieve gewicht van de paal en een reductie vanwege het groepeffect voor trekpalen, uitgaande van plaatsing in een rechthoekig stramien van 1,70 m × 5,78 m. De vermelde waarden betreffen een "hoekpaal";

De vermelde rekenwaarden van de netto paaldruk- en -trekweerstand ($R_{c;\text{net};d}$ en $R_{t;\text{net};d}$) betreffen de rekenwaarden van de maximale paaldrukweerstand, c.q. de maximale paaltrekweerstand die door de paal op paalkopniveau aan de funderingsgrondslag kan worden ontleend. De constructieve sterkte moet separaat worden beoordeeld door de constructeur.

Berekeningsvoorbeelden zijn opgenomen onder bijlage A.

4.4 Paalkopzakkingen en -rijzingen en axiale paalveerstijfheden

De maximale paalkopzakkingen in de bruikbaarheidsgrenstoestand bedragen (bij de maximale karakteristieke paalbelastingen) circa 5 à 15 mm. Afhankelijk van de opbouw van de ondergrond en de gekozen paalafmetingen en paalpuntniveau bedragen de maximale zettingsverschillen, uitgaande van praktisch gelijke paalbelastingen, 5 mm.

De maximale paalkoprijzingen in de bruikbaarheidsgrenstoestand bedragen (bij de maximale karakteristieke paaltrekbelastingen) circa 5 mm. Afhankelijk van de opbouw van de ondergrond en de belastingsverschillen bedragen de maximale rijzingsverschillen, uitgaande van praktisch gelijke paalbelastingen, circa enkele millimeters.

De werkelijk optredende zettingen en zettingsverschillen (van drukpalen), dan wel rijzingen en rijzingsverschillen (van trekpalen) zijn onder meer afhankelijk van de beschouwde locatie, de toegepaste paalaftmetingen en de werkelijk optredende paalbelastingen.

Voor langdurig aanwezige (permanente) belastingen kan een karakteristieke verticale veerstijfheid worden aangehouden ter grootte van:

Voor de ondiepe palen op paalpuntniveau NAP – 14,5 m bij een belasting tot 75 % van $R_{C;net;d}$ geldt:

- $k_{v;langd;k} = 71$ [MN/m] voor Tubex palen met groutinjectie $\varnothing 273 \times 6,3 / 350$ mm;
- $k_{v;langd;k} = 90$ [MN/m] voor Tubex palen met groutinjectie $\varnothing 324 \times 7,1 / 450$ mm;
- $k_{v;langd;k} = 108$ [MN/m] voor Tubex palen met groutinjectie $\varnothing 356 \times 8,0 / 560$ mm.

Voor de ondiepe palen op paalpuntniveau NAP – 22,0 m bij een belasting tot 75 % van $R_{C;net;d}$ geldt:

- $k_{v;langd;k} = 73$ [MN/m] voor Tubex palen met groutinjectie $\varnothing 273 \times 6,3 / 350$ mm;
- $k_{v;langd;k} = 96$ [MN/m] voor Tubex palen met groutinjectie $\varnothing 324 \times 7,1 / 450$ mm;
- $k_{v;langd;k} = 117$ [MN/m] voor Tubex palen met groutinjectie $\varnothing 356 \times 8,0 / 560$ mm.

Deze waarden zijn bepaald voor een relatief minder draagkrachtige funderingsgrondslag.

Noot: de wanddikte is een aanname, de daadwerkelijke wanddikte dient i.o.m. de aannemer van de palen te worden bepaald.

In verband met onzekerheden, waaronder variaties in de funderingsgrondslag adviseren wij rekening te houden met hoge respectievelijk lage waarden van de veerstijfheden welke uit voornoemde veerstijfheid kunnen worden bepaald door vermenigvuldiging met een onzekerheidsfactor 1,5, respectievelijk deling van voornoemde veerstijfheid door een onzekerheidsfactor ter grootte van 1,35.

De veerstijfheden in de uiterste grenstoestand worden verkregen door voornoemde veerstijfheden te delen door een factor ter grootte van 1,3.

4.5 Het gedrag van de palen onder een horizontale paalkopbelasting

De funderingspalen zullen op paalkopniveau niet alleen verticaal maar ook horizontaal worden belast. Door deze horizontale belasting zal de funderingspaal op buiging worden belast en zal de paal(kop) verplaatsen.

Voor de berekening van horizontaal belaste palen is nog geen (door geotechnische normen voorgestane) berekeningsmethode beschikbaar. Daarom zijn deze berekeningen van het gedrag van de horizontaal belaste palen op traditionele wijze uitgevoerd (met karakteristieke waarden); een en ander betekent dat de resultaten van deze berekeningen ook karakteristieke waarden betreffen.

Voor het gedrag van de horizontaal belaste palen zijn karakteristieke ($\approx$ representatieve) horizontale belastingen op de paalkop opgegeven ter grootte van 25 of 15 kN.

Het gedrag van de palen onder een horizontale belasting is berekend met behulp van de 'single pile' module van het programma D-SheetPiling (versie 19.3).

Daarbij is uitgegaan van de volgende factoren en aannamen:

- De buigstijfheid $EI = \frac{2}{3} \times E_{\text{beton}} I_{\text{beton; ongescheurd}} + E_{\text{staal}} I_{\text{staal}}$
- $E_{\text{paal}} = 25 \text{ GPa}$ voor Tubexpalen met groutinjectie (o.g.).
- Voor de werkende breedte van de palen is gerekend met $d_{\text{eq (schacht)}}$.
- De paalkop bevindt zich op paalkopniveau $\approx \text{NAP} + 4,1 \text{ m}$.
- De verbinding van de palen met de bovenliggende "buigstijve" constructie wordt vrij met betrekking tot de translatie en de rotatie van de paalkop wordt verhinderd ("ingeklemd"), dan wel ongehinderd ("scharnierend"); beide situaties worden berekend.
- In de berekeningen leveren de grondlagen *boven* paalkopniveau geen horizontale steundruk, maar hebben via het volumegewicht wel invloed op de effectieve verticale korrelspanningen van dieper aanwezige grondlagen.
- De berekeningen zijn uitgevoerd voor alleenstaande palen met een karakteristieke ($\approx$ representatieve) horizontale belastingen op paalkopniveau ter grootte van 25 en 15 kN/paal.

De berekeningsresultaten van het gedrag van alleenstaande horizontaal belaste Tubex groutinjectie palen zijn tabellarisch samengevat in:

- Tabel 4-3 voor palen met een paalkop die vrij kan transleren en waarvan de rotatie is verhinderd is ("ingeklemd").
- Tabel 4-4 voor palen met een paalkop die vrij kan transleren en roteren ("scharnierend").

*Tabel 4-3 Berekeningsresultaten voor alleenstaande horizontaal belaste Tubexpalen met groutinjectie (o.g.) met paalkop die vrij kan transleren en waarvan de rotatie is verhinderd ("ingeklemd") **

Tubexpalen met groutinjectie (o.g.), Ø _{buis} x t / Ø _{boorpunt} [mm x mm/ mm]	Karakteristieke horizontale paalkopbelasting [kN]	"ingeklemde" paalkop; translatie is vrij			
		M _{paalkop;max} * [kNm]	M _{veld;max} * [kNm]	Niveau M _{veld;max} [NAP + m]	U _{max;paalkop} [mm]
"ondiep" p.p.n.					
273 x 6,3 / 350	15	12,8	2,6	1,7	1
324 x 7,1 / 450	15	14,3	2,8	1,3	1
356 x 8,0 / 560	15	15,3	2,9	1,0	1
"diep" p.p.n.					
273 x 6,3 / 350	25	22,3	4,5	1,7	2
324 x 7,1 / 450	25	24,7	4,9	1,2	2
356 x 8,0 / 560	25	26,2	5,0	1,2	1

* LET OP: de vermelde waarden betreffen karakteristieke waarden.

De toelaatbaarheid van de deformaties en de constructieve sterkte (tevens rekening houdend met de normaalkracht) moet separaat worden beoordeeld door de constructeur.

Tabel 4-4 Berekeningsresultaten voor alleenstaande horizontaal belaste Tubexpalen met groutinjectie (o.g.) met een paalkop die vrij kan transleren en roteren ("scharnierend") *

Tubexpalen met groutinjectie (o.g.), Ø _{buis} x t / Ø _{boorpunt} [mm x mm/ mm]	Karakteristieke horizontale paalkopbelasting [kN]	"scharnierende" paalkop; translatie is vrij			
		M _{veld;max} * [kNm]	Niveau M _{veld;max} [NAP + m]	θ _{paalkop} [10 ⁻³ rad]	U _{max;paalkop} [mm]
"ondiep" p.p.n.					
273 x 6,3 / 350	15	9,8	2,7	1,8	3
324 x 7,1 / 450	15	10,5	2,6	1,2	2
356 x 8,0 / 560	15	10,9	2,6	0,8	2
"diep" p.p.n.					
273 x 6,3 / 350	25	19,0	2,7	3,7	6
324 x 7,1 / 450	25	19,3	2,7	2,3	4
356 x 8,0 / 560	25	20,0	2,9	1,7	3

* LET OP: de vermelde waarden betreffen karakteristieke waarden.

De toelaatbaarheid van de deformaties en de constructieve sterkte (tevens rekening houdend met de normaalkracht) moet separaat worden beoordeeld door de constructeur.

Berekeningsvoorbeelden zijn opgenomen onder bijlage B.

De karakteristieke veerstijfheden voor het gedrag van palen onder een horizontale paalkopbelasting kunnen worden bepaald uit $k_{u;F_h;k} = F_h / u_{\text{max};\text{paalkop}}$ en uit $k_{\theta;F_h;k} = F_h / \theta_{\text{paalkop}}$. De hoge respectievelijk lage waarden van de veerstijfheden kunnen worden bepaald door vermenigvuldiging, respectievelijk deling van deze karakteristieke veerstijfheden door een onzekerheidsfactor ter grootte van 1,5.

4.6 Uitvoering

Voor het inbrengen van trillingsvrij en grondverdringend ingeschroefde palen, Tubex groutinjectiepaal, moet een boormotor worden gebruikt met een voldoende capaciteit. De keuze van de capaciteit van de boormotor dient voor uitvoering van het boorwerk met de leverancier afgestemd te worden. Wij adviseren om dit vooraf met de (beoogde) paalleverancier te bespreken, evenals de mogelijkheden voor een probleemloze installatie, waarbij rekening dient te worden gehouden met de lokale omstandigheden (o.a. toegang en werkruimte). Verder dient bij dit paalttype altijd extra aandacht te worden besteed aan een goede kwaliteit van het grout (-mengsel) en van de verbindingen van de buizen alsmede de wanddikte.

Voor algemene richtlijnen voor de uitvoering van heiwerven wordt verwezen naar bijlage D (Verdringingsschroefpalen).

5. FUNDERINGSADVIES BETONPLAAT TRUCKVERLADING

5.1 Keuze funderingstype

Gelet op de projectgegevens en de opbouw en samenstelling van de ondergrond is een fundering op staal goed mogelijk, zeker in onderhavig geval waar de permanente belasting niet leidt tot een al te grote belasting toename in de ondergrond.

5.2 Minimaal vereiste ontgravingsniveaus

Voor een vorstvrij aanlegniveau van de funderingselementen wordt een diepte van ten minste toekomstig maaiveld – 0,80 m geadviseerd.

In tabel 4-1 is per sondeerlocatie het minimaal vereiste ontgravingsniveau aangegeven. Indien dit ontgravingsniveau beneden het aanlegniveau ligt, dient een grondverbetering te worden uitgevoerd.

Tabel 4-1 Minimaal vereiste ontgravingsniveaus

Sondering nummer	Maaiveldhoogte [NAP + m]	Minimaal vereist ontgravingsniveau	
		[NAP + m]	[maaiveld - m]
1	4,48	-	-
2	4,49	-	-
3	4,49	-	-
4	4,49	-	-

- Ondergrond bestaat tot circa NAP + 1,0 m uit zand. Volstaan kan worden met verwijderen eventuele leeflaag en vlakken ondergrond.

5.3 Berekening maximale weerstand

De berekening van de maximale weerstand (weerstandskracht) van de fundering is gebaseerd op de geotechnische norm NEN 9997-1. De berekening van de rekenwaarden van de maximale verticale weerstand van staalfunderingen met een horizontaal funderingsoppervlak is gebaseerd op artikel 6.5.2.2 van NEN 9997-1.

Bij de berekening van de maximale verticale weerstandskracht is een hoogste grondwaterstand aangenomen op een niveau gelijk aan NAP + 3,8 m (uitgaande van enige drooglegging op het terrein).

De maximale verticale weerstandskrachten ($R_{v,d}$) zijn berekend voor verschillende strookbreedten en of poerafmetingen en voor een dekking van 0,00 m (in verband aanleg leidingen juist naast de betonnen funderingsplaat), 0,20 m en 0,40 m. Onder gronddekking wordt verstaan het minimale hoogteverschil tussen het aanlegniveau van funderingselementen en het (toekomstige) naastliggende maaiveld of de bodem van een kruipruimte. De berekeningsresultaten zijn opgenomen in bijlage C.

5.4 Zakkingen in de gebruikssituatie

Gezien de grondopbouw en uitgaande van een goed uitgevoerde grondverbetering kunnen, door zettingen van de onderliggende samendrukbare lagen, in de bruikbaarheidsgrenstoestand eindzakkingen van de funderingselementen optreden van circa 10 mm. Verder moeten zettingsverschillen van maximaal 5 mm worden verwacht. Een en ander is mede afhankelijk van de werkelijk optredende belastingen en belastingsverschillen en de verschillen in opbouw van de ondergrond. Hierbij is ervan uitgegaan dat het terrein niet of nauwelijks wordt opgehoogd. Ook is geen rekening gehouden met restzettingen van in het verleden uitgevoerde terreinophogingen.

5.5 Beddingsconstante

Voor de berekening van (een) op een zandbed aangelegde betonnen vloer(en) of funderingsplaten kan, bij een zorgvuldige uitvoering, een statische beddingsconstante van 10.000 kN/m³ worden aangehouden.

5.6 Uitvoering

Gezien de tijdens het grondonderzoek aangetroffen grondwaterstand is ter plaatse van de diepere ontgravingsniveaus mogelijk een bemaling vereist.

Voor algemene richtlijnen voor de uitvoering van ontgravingen en grondverbeteringen voor staalfunderingen wordt verwezen naar bijlage D.

Opgesteld door:

ir. J.C.M. de Jong (088 - 51 30 211)

Rotterdam, 24 september 2020

Mos Grondmechanica B.V.

Contr. : g.s.



Bijlage A

Berekeningsvoorbeeld paaldrukweerstand



Berekening weerstand trekpalen

Tubex-groutinjectionpaal

NEN 9997-1

Opdrachtnummer: 1901326

Printdatum: 22-9-2020

Project: Project aan de Welplaatweg 12 te Botlek Rotterdam

Versie 6.0.1.0

Sondering: 3

Maaiveld hoogte: NAP + 4,49 m

Omschrijving:

Grondwaterstand: NAP + 1,50 m

Putbodem:

Afmetingen ontgraving:

Terreinbelasting: 0 kN/m²

Geotechnisch profiel						Terreinspanningen			incl. G' _{stb;paal;d}	
laag nr.	ok. laag [NAP +m]	γ [kN/m ³]	q _{c,gem} [MPa]	grondsoort	trek J / N	σ _{v;z,i,gem} [kN/m ²]	σ _{v;z,i,ontgr} [kN/m ²]	q _{c,i,corr} [MPa]	ΣR _{c,αt1;d} [kN]	ΣR _{c,Gmax1;d} [kN]
1	4,28	17,5	2,0	Voorboren /Klinker etc	n	2	2	2,0	20	43
2	4,27	13,0	0,0	Slap	n	4	4	0,0	20	43
3	3,73	20,0	12,5	Zand	n	9	9	12,5	19	48
4	3,59	18,6	4,6	Klei	n	16	16	4,6	19	52
5	2,15	20,0	8,9	Zand	n	32	32	8,9	17	148
6	2,01	18,9	3,3	Leem	n	47	47	3,3	17	165
7	1,50	19,4	5,0	Zand	n	54	54	5,0	16	237
8	1,15	19,4	4,3	Zand	n	60	60	4,3	16	299
9	1,01	17,1	1,9	Leem	n	62	62	1,9	16	326
10	0,87	17,7	1,5	Leem	n	63	63	1,5	16	354
11	0,51	15,3	0,6	Klei	n	65	65	0,6	15	432
12	0,47	16,5	0,7	Leem	n	66	66	0,7	15	441
13	0,15	17,8	1,0	Leem	n	67	67	1,0	15	519
14	-0,09	16,8	0,9	Klei	n	69	69	0,9	15	582
15	-0,21	13,7	0,3	Klei/Veen	n	70	70	0,3	15	615
16	-0,37	15,0	0,3	Klei	n	71	71	0,3	14	660
17	-0,49	17,0	0,6	Leem	n	72	72	0,6	14	695
18	-1,43	15,3	0,4	Klei	n	75	75	0,4	13	993
19	-1,85	17,1	0,7	Leem	n	79	79	0,7	13	1137
20	-2,11	15,0	0,4	Klei	n	81	81	0,4	12	1230
21	-2,31	17,0	0,7	Leem	n	82	82	0,7	12	1304
22	-2,47	15,3	0,4	Klei	n	83	83	0,4	12	1363
23	-2,75	18,9	2,1	Zand	n	85	85	2,1	12	1470
24	-3,19	15,8	0,6	Klei	n	87	87	0,6	11	1643
25	-3,45	18,9	2,7	Zand	n	90	90	2,7	11	1750
26	-3,97	17,2	1,3	Leem	n	93	93	1,3	10	1972
27	-5,23	16,1	0,7	Klei	n	99	99	0,7	9	2571
28	-5,35	17,2	1,0	Leem	n	103	103	1,0	9	2633
29	-5,43	17,8	2,4	Klei	n	104	104	2,4	9	2675
30	-6,65	19,8	8,0	Zand	j	110	110	8,0	46	3373
31	-7,47	16,7	1,9	Klei	j	119	119	1,9	52	3904
32	-7,59	17,8	2,8	Leem	j	122	122	2,8	54	3986
33	-7,95	19,6	6,9	Zand	j	124	124	6,9	63	4236
34	-8,21	14,2	1,0	Klei/Veen	j	126	126	1,0	64	4423
35	-8,33	16,7	1,4	Klei	j	127	127	1,4	65	4511





Berekening weerstand trekpalen

Tubex-groutinjectiepaal

NEN 9997-1

Opdrachtnummer: 1901326

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Versie 6.0.1.0

Sondering: 3

Maaiveld hoogte: NAP + 4,49 m

Omschrijving:

Grondwaterstand: NAP + 1,50 m

Putbodem:

Afmetingen ontgraving:

Terreinbelasting: 0 kN/m²

Geotechnisch profiel						Terreinspanningen			incl. G' _{stb;paal;d}	
laag nr.	ok. laag [NAP +m]	γ [kN/m ³]	$q_{c,gem}$ [MPa]	grondsoort	trek J / N	$\sigma_{v,z,i,gem}$ [kN/m ²]	$\sigma_{v,z,i,ontgr}$ [kN/m ²]	$q_{c,i,corr}$ [MPa]	$\Sigma R_{c,\alpha 1;d}$ [kN]	$\Sigma R_{c,Gmax1;d}$ [kN]
36	-8,53	18,9	3,7	Leem	j	129	129	3,7	68	4659
37	-8,73	20,0	9,0	Zand	j	130	130	9,0	75	4811
38	-9,45	18,5	4,0	Leem	j	135	135	4,0	86	5381
39	-9,87	18,1	3,0	Leem	j	139	139	3,0	91	5732
40	-9,99	19,0	3,7	Leem	j	142	142	3,7	93	5835
41	-10,43	19,1	4,4	Leem	j	144	144	4,4	100	6224
42	-10,95	19,0	5,4	Leem	j	148	148	5,4	111	6706
43	-11,63	19,8	11,1	Zand	j	154	154	11,1	137	7373
44	-12,11	19,3	7,9	Leem	j	160	160	7,9	151	7871
45	-12,35	19,9	9,3	Zand	j	163	163	9,3	159	8128
46	-12,49	19,0	8,0	Leem	j	165	165	8,0	163	8280
47	-12,89	20,0	13,6	Zand	j	168	168	13,6	180	8724
48	-13,09	19,1	9,7	Leem	j	170	170	9,7	186	8951
49	-13,21	18,0	5,2	Klei	j	172	172	5,2	189	9089
50	-13,49	20,0	11,7	Zand	j	174	174	11,7	200	9416
51	-13,63	19,4	8,1	Leem	j	176	176	8,1	204	9582
52	-13,97	20,0	15,9	Zand	j	178	178	15,9	218	9992
53	-14,05	19,0	12,3	Leem	j	180	180	12,3	222	10090
54	-14,50	20,0	15,5	Zand	j	183	183	15,5	240	10425

Parameters	
α_t (in zand)	0,009
ξ_3	1,32
$\gamma_{s,t}$	1,35
$\gamma_{m,var,qc}$	1,50
γ_v	24,00 [kN/m ³]
$\gamma_{f,g}$	1,10

Paalgroep
Rechthoekig stramien, hoekpaal.
$X_1 = 1,70$ m.
$Y_1 = 5,78$ m.
$X_2 = 1000,00$ m.
$Y_2 = 1000,00$ m.

Heiverdichting
Geen heiverdichting.





Berekening weerstand trekpalen Tubex-groutinjectiepaal

NEN 9997-1

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Sondering: 3

Maaiveld hoogte: NAP + 4,49 m

Omschrijving:

Grondwaterstand: NAP + 1,50 m

Putbodem:

Afmetingen ontgraving:

Terreinbelasting: 0 kN/m²

Rekenwaarde trekweerstand op een diepte van NAP - 14,50 m								
Buisdiam. [mm]	Puntdiam. [mm]	O _s [mm]	β	q _{s;cal;max} [kN/m]	R _{t;wrijving;d} [kN]	R _{t;kluit;d} [kN]	G' _{stb;paal;d} [kN]	R _{c;d;trek} [kN]
273	350	1100	1,00	0	221	10406	19	240
324	450	1414	1,00	0	280	10505	29	309
356	560	1759	1,00	0	341	10612	41	382

Rekenvoorbeeld:

$$R_{c;d;trek} = \min(R_{t;wrijving;d}, R_{t;kluit;d}) + G'_{stb;paal;d} = \min(221; 10405,8) + 18,9 = 240 \text{ kN}$$



Berekening paaldrukweerstand Sond. 3

Conform NEN 9997-1 (α_p -factoren per 1-1-2017)

Tubex-groutinjectiepaal

Opdracht: 1901326

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Versie 6.0.1.0

Maaiveld hoogte: NAP + 4,49 m

Grondwaterstand: NAP + 1,50 m

Putbodem:

Omschrijving:

Afmetingen ontgraving:

Terreinbelasting: 0 kN/m²

Percentages schachtwrijving: 100,0 % vanaf NAP -5,43 m; 100,0 % vanaf NAP -19,12 m;

Geotechnisch profiel						Terreinspanningen		F _{pos}	F _{neg}
laag nr.	ok. laag [NAP +m]	γ [kN/m ³]	Q _{c,gem} [MPa]	K _{otan} δ	grondsoort	$\sigma_{v,z;i,gem}$ [kN/m ²]	$\sigma_{v,z;i,ontgr}$ [kN/m ²]	Q _{s,cal,max;i} [kN/m]	F _{nk,rep} [kN/m]
1	4,28	17,5	2,0	0,25	Voorboren/ Klinker etc	1,84	1,84	0	0
2	4,27	13,0	0,0	0,25	Slap	3,74	3,74	0	0
3	3,73	20,0	12,5	0,25	Zand	9,21	9,21	0	1
4	3,59	18,6	4,6	0,25	Klei	15,90	15,90	0	2
5	2,15	20,0	8,9	0,25	Zand	31,58	31,58	0	13
6	2,01	18,9	3,3	0,25	Leem	47,27	47,27	0	15
7	1,50	19,4	5,0	0,25	Zand	53,52	53,52	0	22
8	1,15	19,4	4,3	0,25	Zand	60,09	60,09	0	27
9	1,01	17,1	1,9	0,25	Leem	62,23	62,23	0	29
10	0,87	17,7	1,5	0,25	Leem	63,27	63,27	0	31
11	0,51	15,3	0,6	0,25	Klei	64,76	64,76	0	37
12	0,47	16,5	0,7	0,25	Leem	65,84	65,84	0	38
13	0,15	17,8	1,0	0,25	Leem	67,22	67,22	0	43
14	-0,09	16,8	0,9	0,25	Klei	69,28	69,28	0	47
15	-0,21	13,7	0,3	0,25	Klei/Veen	70,31	70,31	0	50
16	-0,37	15,0	0,3	0,25	Klei	70,93	70,93	0	52
17	-0,49	17,0	0,6	0,25	Leem	71,75	71,75	0	55
18	-1,43	15,3	0,4	0,25	Klei	74,66	74,66	0	72
19	-1,85	17,1	0,7	0,25	Leem	78,63	78,63	0	80
20	-2,11	15,0	0,4	0,25	Klei	80,76	80,76	0	86
21	-2,31	17,0	0,7	0,25	Leem	82,11	82,11	0	90
22	-2,47	15,3	0,4	0,25	Klei	83,23	83,23	0	93
23	-2,75	18,9	2,1	0,25	Zand	84,89	84,89	0	99
24	-3,19	15,8	0,6	0,25	Klei	87,40	87,40	0	109
25	-3,45	18,9	2,7	0,25	Zand	89,83	89,83	0	114
26	-3,97	17,2	1,3	0,25	Leem	92,86	92,86	0	126
27	-5,23	16,1	0,7	0,25	Klei	98,59	98,59	0	158
28	-5,35	17,2	1,0	0,25	Leem	102,88	102,88	0	161
29	-5,43	17,8	2,4	0,25	Klei	103,62	103,62	0	163
30	-6,65	19,8	8,0		Zand	109,91	109,91	88	
31	-7,47	16,7	1,9		Klei	118,64	118,64	101	
32	-7,59	17,8	2,8		Leem	121,86	121,86	105	
33	-7,95	19,6	6,9		Zand	124,05	124,05	127	
34	-8,21	14,2	1,0		Klei/Veen	126,31	126,31	129	
35	-8,33	16,7	1,4		Klei	127,25	127,25	131	
36	-8,53	18,9	3,7		Leem	128,54	128,54	138	
37	-8,73	20,0	9,0		Zand	130,43	130,43	154	
38	-9,45	18,5	4,0		Leem	134,50	134,50	180	
39	-9,87	18,1	3,0		Leem	139,27	139,27	191	
40	-9,99	19,0	3,7		Leem	141,52	141,52	195	
41	-10,43	19,1	4,4		Leem	144,05	144,05	212	
42	-10,95	19,0	5,4		Leem	148,39	148,39	238	

Berekening paaldrukweerstand Sond. 3

Conform NEN 9997-1 (α_p -factoren per 1-1-2017)

Tubex-groutinjectiepaal

Opdracht:	1901326	Printdatum: 22-9-2020
Project:	Project aan de Welplaatweg 12 te Botlek Rotterdam	Versie 6.0.1.0
Maaiveld hoogte:	NAP + 4,49 m	Omschrijving:
Grondwaterstand:	NAP + 1,50 m	
Putbodem:		
Afmetingen ontgraving:		
Terreinbelasting:	0 kN/m ²	
Percentages schachtwrijving:	100,0 % vanaf NAP -5,43 m; 100,0 % vanaf NAP -19,12 m;	

Geotechnisch profiel						Terreinspanningen		F _{pos}	F _{neg}
laag nr.	ok. laag [NAP +m]	γ [kN/m ³]	q _{c,gem} [MPa]	K _o tan δ	grondsoort	$\sigma_{v,z,i,gem}$ [kN/m ²]	$\sigma_{v,z,i,ontgr}$ [kN/m ²]	q _{s,cal,max,i} [kN/m]	F _{nk,rep} [kN/m]
43	-11,63	19,8	11,1		Zand	154,07	154,07	304	
44	-12,11	19,3	7,9		Leem	159,63	159,63	339	
45	-12,35	19,9	9,3		Zand	163,06	163,06	359	
46	-12,49	19,0	8,0		Leem	164,88	164,88	369	
47	-12,89	20,0	13,6		Zand	167,51	167,51	411	
48	-13,09	19,1	9,7		Leem	170,42	170,42	428	
49	-13,21	18,0	5,2		Klei	171,81	171,81	434	
50	-13,49	20,0	11,7		Zand	173,69	173,69	463	
51	-13,63	19,4	8,1		Leem	175,75	175,75	473	
52	-13,97	20,0	15,9		Zand	178,11	178,11	510	
53	-14,05	19,0	12,3		Leem	180,17	180,17	519	
54	-14,50	20,0	15,5		Zand	182,78	182,78	567	

Parameters	
α_s (in zand)	0,009
α_p	0,63
ξ_3	1,32
γ_t	1,20
$\gamma_{f,nk}$	1,00
OCR	1,0

F _{nk,rep}	163 kN/m
q _{s,cal,max}	567 kN/m

Rekenwaarde drukweerstand op een diepte van NAP - 14,50 m									
Buisdiam. [mm]	Punt diam. [mm]	A _{punt} [mm ²]	O _s [mm]	β	q _{b,max} [MPa]	R _{b,cal,max} [kN]	R _{s,cal,max} [kN]	F _{nk,rep} [kN]	R _{c,net;d} [kN]
273	350	96211	1100	1,00	4,42	426	624	140	523
324	450	159043	1414	1,00	4,39	699	802	166	782
356	560	246301	1759	1,00	4,29	1056	998	182	1114

Rekenvoorbeeld (onderste paalafmeting):

$$\begin{aligned}
 q_{c,I,gem} &= 13,06 \text{ MPa} & q_{c,II,gem} &= 5,39 \text{ MPa} & q_{c,III,gem} &= 4,38 \text{ MPa} & q_{b,max} &= 4,29 \text{ MPa} \\
 R_{c,cal,max} &= A_{punt} q_{b,max} + O_s q_{s,cal,max} & & & & & & = 1056 + 998 = 2053 \text{ kN} \\
 R_{c,d,net} &= R_{c,cal,max} / (\xi_3 \cdot \gamma_t) - F_{nk,rep} \gamma_{f,nk} & & & & & & = 1296 - 182 = 1114 \text{ kN}
 \end{aligned}$$

Berekening paaldrukweerstand Sond. 3

Conform NEN 9997-1 (α_p -factoren per 1-1-2017)

Tubex-groutinjectiepaal

Opdracht: 1901326

Printdatum: 22-9-2020

Project: Project aan de Welplaatweg 12 te Botlek Rotterdam

Versie 6.0.1.0

Maaiveld hoogte: NAP + 4,49 m

Grondwaterstand: NAP + 1,50 m

Putbodem:

Omschrijving:

Afmetingen ontgraving:

Terreinbelasting: 0 kN/m²

Percentages schachtwrijving: 50,0 % vanaf NAP -5,43 m; 100,0 % vanaf NAP -19,12 m;

Geotechnisch profiel						Terreinspanningen		F _{pos}	F _{neg}
laag nr.	ok. laag [NAP +m]	γ [kN/m ³]	Q _{c,gem} [MPa]	K _{otan} δ	grondsoort	$\sigma_{v,z;i,gem}$ [kN/m ²]	$\sigma_{v,z;i,ontgr}$ [kN/m ²]	Q _{s,cal,max;i} [kN/m]	F _{nk,rep} [kN/m]
1	4,28	17,5	2,0	0,25	Voorboren/ Klinker etc	1,84	1,84	0	0
2	4,27	13,0	0,0	0,25	Slap	3,74	3,74	0	0
3	3,73	20,0	12,5	0,25	Zand	9,21	9,21	0	1
4	3,59	18,6	4,6	0,25	Klei	15,90	15,90	0	2
5	2,15	20,0	8,9	0,25	Zand	31,58	31,58	0	13
6	2,01	18,9	3,3	0,25	Leem	47,27	47,27	0	15
7	1,50	19,4	5,0	0,25	Zand	53,52	53,52	0	22
8	1,15	19,4	4,3	0,25	Zand	60,09	60,09	0	27
9	1,01	17,1	1,9	0,25	Leem	62,23	62,23	0	29
10	0,87	17,7	1,5	0,25	Leem	63,27	63,27	0	31
11	0,51	15,3	0,6	0,25	Klei	64,76	64,76	0	37
12	0,47	16,5	0,7	0,25	Leem	65,84	65,84	0	38
13	0,15	17,8	1,0	0,25	Leem	67,22	67,22	0	43
14	-0,09	16,8	0,9	0,25	Klei	69,28	69,28	0	47
15	-0,21	13,7	0,3	0,25	Klei/Veen	70,31	70,31	0	50
16	-0,37	15,0	0,3	0,25	Klei	70,93	70,93	0	52
17	-0,49	17,0	0,6	0,25	Leem	71,75	71,75	0	55
18	-1,43	15,3	0,4	0,25	Klei	74,66	74,66	0	72
19	-1,85	17,1	0,7	0,25	Leem	78,63	78,63	0	80
20	-2,11	15,0	0,4	0,25	Klei	80,76	80,76	0	86
21	-2,31	17,0	0,7	0,25	Leem	82,11	82,11	0	90
22	-2,47	15,3	0,4	0,25	Klei	83,23	83,23	0	93
23	-2,75	18,9	2,1	0,25	Zand	84,89	84,89	0	99
24	-3,19	15,8	0,6	0,25	Klei	87,40	87,40	0	109
25	-3,45	18,9	2,7	0,25	Zand	89,83	89,83	0	114
26	-3,97	17,2	1,3	0,25	Leem	92,86	92,86	0	126
27	-5,23	16,1	0,7	0,25	Klei	98,59	98,59	0	158
28	-5,35	17,2	1,0	0,25	Leem	102,88	102,88	0	161
29	-5,43	17,8	2,4	0,25	Klei	103,62	103,62	0	163
30	-6,65	19,8	8,0		Zand	109,91	109,91	44	
31	-7,47	16,7	1,9		Klei	118,64	118,64	51	
32	-7,59	17,8	2,8		Leem	121,86	121,86	52	
33	-7,95	19,6	6,9		Zand	124,05	124,05	63	
34	-8,21	14,2	1,0		Klei/Veen	126,31	126,31	64	
35	-8,33	16,7	1,4		Klei	127,25	127,25	65	
36	-8,53	18,9	3,7		Leem	128,54	128,54	69	
37	-8,73	20,0	9,0		Zand	130,43	130,43	77	
38	-9,45	18,5	4,0		Leem	134,50	134,50	90	
39	-9,87	18,1	3,0		Leem	139,27	139,27	96	
40	-9,99	19,0	3,7		Leem	141,52	141,52	98	
41	-10,43	19,1	4,4		Leem	144,05	144,05	106	
42	-10,95	19,0	5,4		Leem	148,39	148,39	119	

Berekening paaldrukweerstand Sond. 3

Conform NEN 9997-1 (α_p -factoren per 1-1-2017)

Tubex-groutinjectiepaal

Opdracht:	1901326	Printdatum:	22-9-2020
Project:	Project aan de Welplaatweg 12 te Botlek Rotterdam	Versie	6.0.1.0
Maaiveld hoogte:	NAP + 4,49 m	Omschrijving:	
Grondwaterstand:	NAP + 1,50 m		
Putbodem:			
Afmetingen ontgraving:			
Terreinbelasting:	0 kN/m ²		
Percentages schachtwrijving:	50,0 % vanaf NAP -5,43 m; 100,0 % vanaf NAP -19,12 m;		

Geotechnisch profiel						Terreinspanningen		F _{pos}	F _{neg}
laag nr.	ok. laag [NAP +m]	γ [kN/m ³]	Q _{c,gem} [MPa]	K _o tan δ	grondsoort	$\sigma_{v,z,i,gem}$ [kN/m ²]	$\sigma_{v,z,i,ontgr}$ [kN/m ²]	Q _{s,cal,max;i} [kN/m]	F _{nk,rep} [kN/m]
43	-11,63	19,8	11,1		Zand	154,07	154,07	152	
44	-12,11	19,3	7,9		Leem	159,63	159,63	169	
45	-12,35	19,9	9,3		Zand	163,06	163,06	179	
46	-12,49	19,0	8,0		Leem	164,88	164,88	184	
47	-12,89	20,0	13,6		Zand	167,51	167,51	206	
48	-13,09	19,1	9,7		Leem	170,42	170,42	214	
49	-13,21	18,0	5,2		Klei	171,81	171,81	217	
50	-13,49	20,0	11,7		Zand	173,69	173,69	232	
51	-13,63	19,4	8,1		Leem	175,75	175,75	237	
52	-13,97	20,0	15,9		Zand	178,11	178,11	255	
53	-14,05	19,0	12,3		Leem	180,17	180,17	259	
54	-14,95	20,0	15,3		Zand	185,03	185,03	308	
55	-15,09	19,0	11,5		Leem	190,16	190,16	315	
56	-15,21	18,5	6,8		Klei	191,30	191,30	319	
57	-15,85	19,9	15,2		Zand	195,00	195,00	353	
58	-15,95	19,0	9,1		Leem	198,63	198,63	357	
59	-16,07	19,8	11,8		Zand	199,67	199,67	363	
60	-16,49	19,3	10,0		Leem	202,22	202,22	382	
61	-16,73	20,0	13,9		Zand	205,37	205,37	395	
62	-17,09	19,3	9,9		Leem	208,24	208,24	411	
63	-17,37	16,9	2,5		Klei	210,89	210,89	414	
64	-17,85	17,8	1,1		Leem	213,73	213,73	416	
65	-18,03	16,0	1,3		Klei	216,15	216,15	417	
66	-18,17	18,0	1,6		Leem	217,25	217,25	418	
67	-18,83	16,7	1,9		Klei	220,02	220,02	424	
68	-19,23	18,0	1,5		Leem	223,81	223,81	428	
69	-22,00	20,4	17,1		Zand	239,84	239,84	758	

Parameters	
α_s (in zand)	0,009
α_p	0,63
ξ_3	1,32
γ_t	1,20
$\gamma_{f,nk}$	1,00
OCR	1,0

F _{nk,rep}	163 kN/m
Q _{s,cal,max}	758 kN/m

Rekenwaarde drukweerstand op een diepte van NAP - 22,00 m									
Buisdiam. [mm]	Puntdiam. [mm]	A _{punt} [mm ²]	O _s [mm]	β	Q _{b,max} [MPa]	R _{b,cal,max} [kN]	R _{s,cal,max} [kN]	F _{nk,rep} [kN]	R _{c,net;d} [kN]
273	350	96211	1100	1,00	6,53	629	834	140	784
324	450	159043	1414	1,00	5,92	942	1072	166	1106
356	560	246301	1759	1,00	5,49	1353	1334	182	1515

Berekening paaldrukweerstand Sond. 3

Conform NEN 9997-1 (α_p -factoren per 1-1-2017)

Tubex-groutinjectiepaal

Opdracht:	1901326	Printdatum: 22-9-2020
Project:	Project aan de Welplaatweg 12 te Botlek Rotterdam	Versie 6.0.1.0
Maaiveld hoogte:	NAP + 4,49 m	Omschrijving:
Grondwaterstand:	NAP + 1,50 m	
Putbodem:		
Afmetingen ontgraving:		
Terreinbelasting:	0 kN/m ²	
Percentages schachtwrijving:	50,0 % vanaf NAP -5,43 m; 100,0 % vanaf NAP -19,12 m;	

Rekenvoorbeeld (onderste paalafmeting):

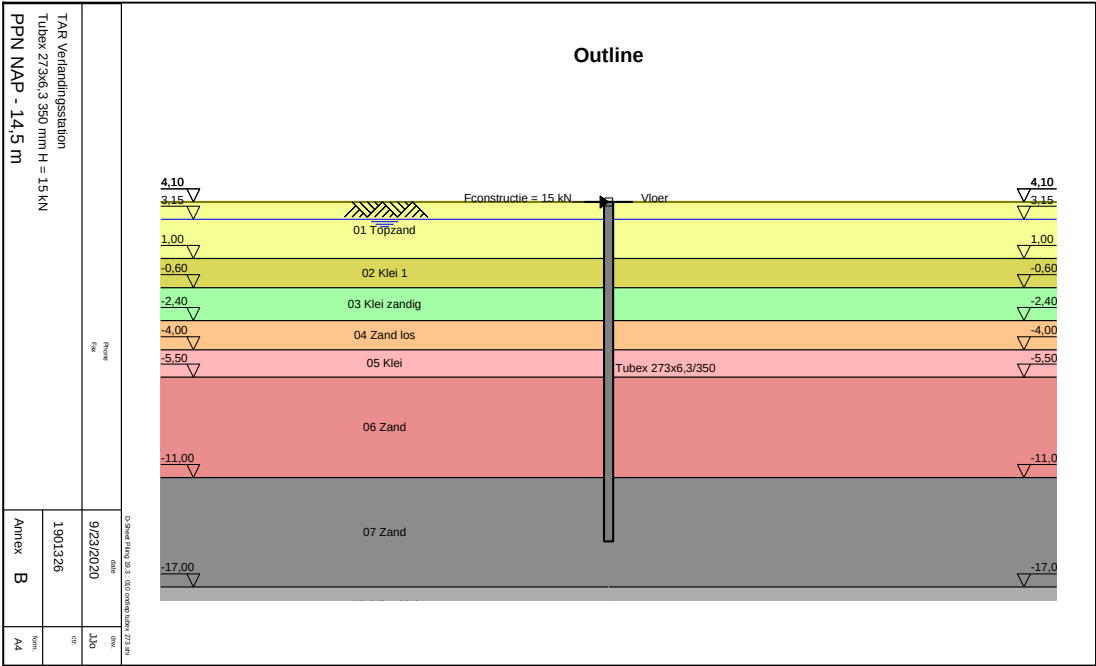
$$q_{c,I;gem} = 11,11 \text{ MPa} \quad q_{c,II;gem} = 10,42 \text{ MPa} \quad q_{c,III;gem} = 6,68 \text{ MPa} \quad q_{b;max} = 5,49 \text{ MPa}$$

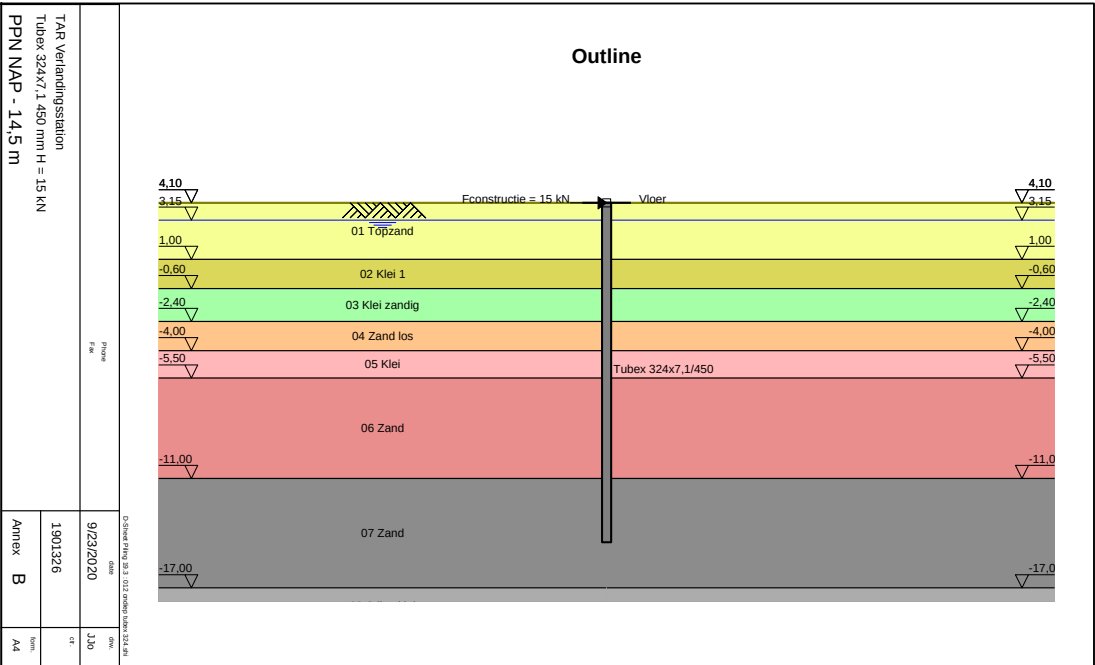
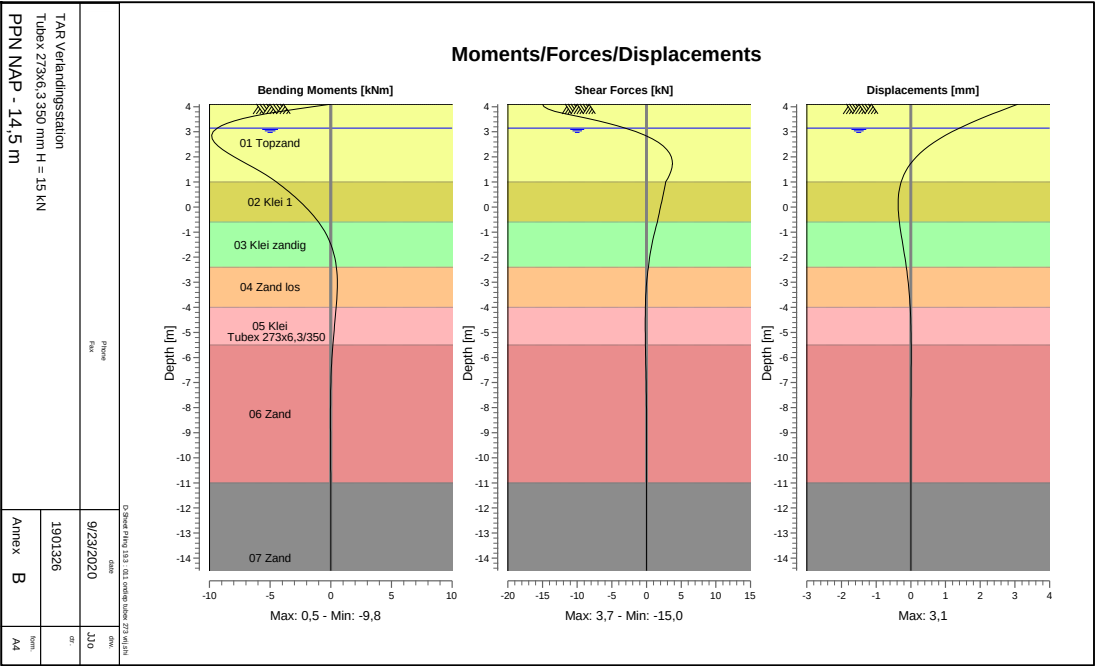
$$R_{c;cal;max} = A_{punt} q_{b;max} + O_s q_{s;cal;max} = 1353 + 1334 = 2687 \text{ kN}$$

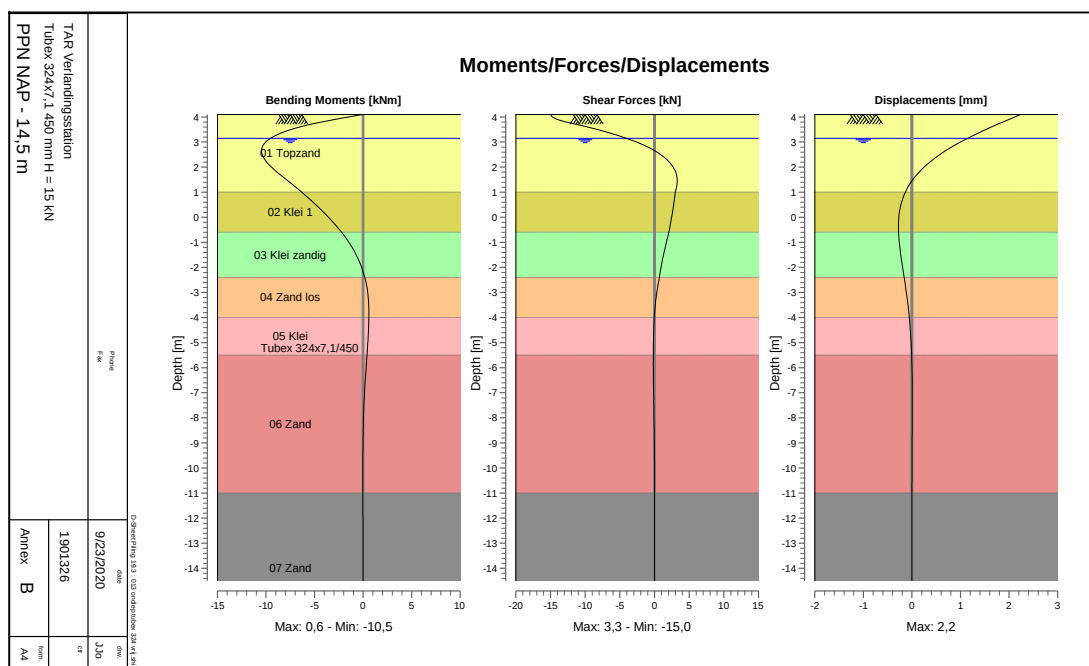
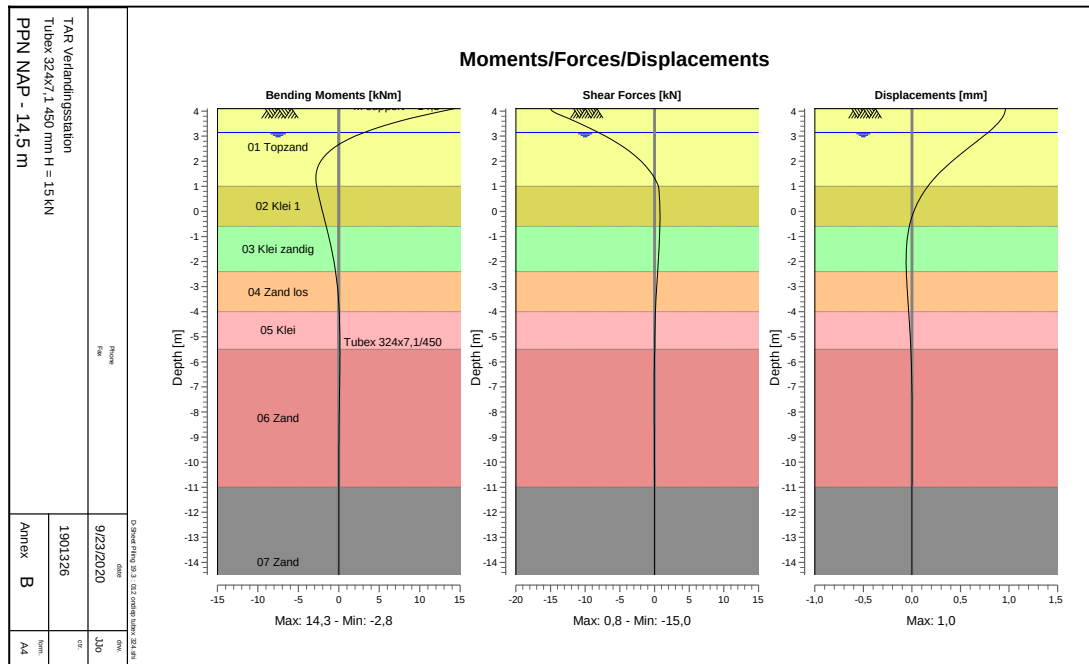
$$R_{c;d;net} = R_{c;cal;max} / (\xi_3 \cdot \gamma_t) - F_{nk;rep} \gamma_{f;nk} = 1697 - 182 = 1515 \text{ kN}$$

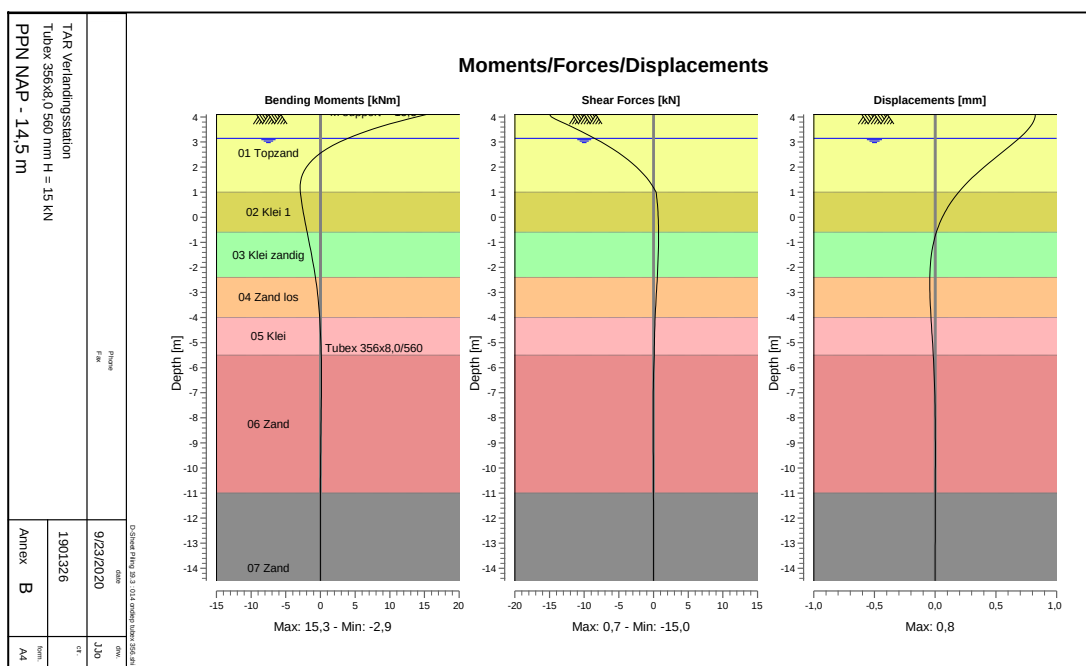
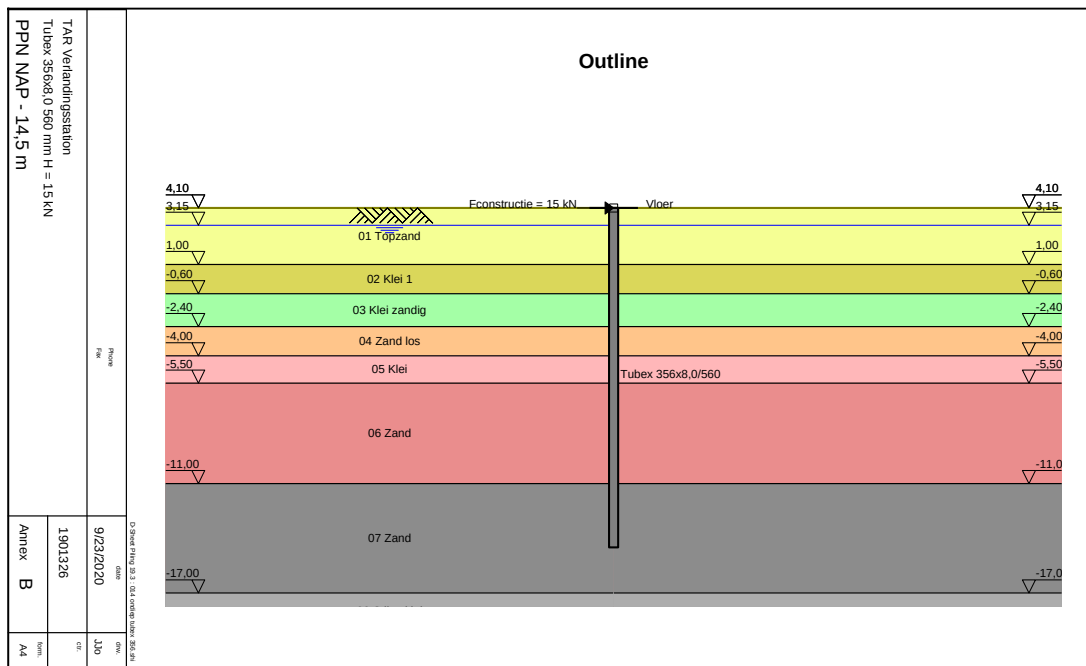
Bijlage B

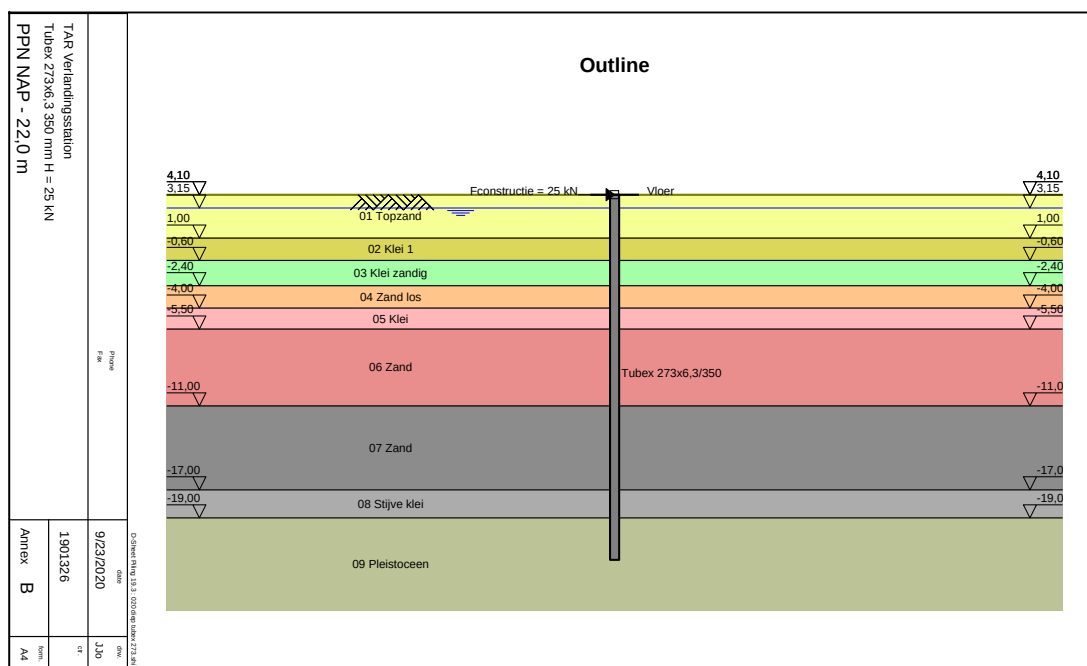
Berekeningsvoorbeeld horizontale paalbelasting

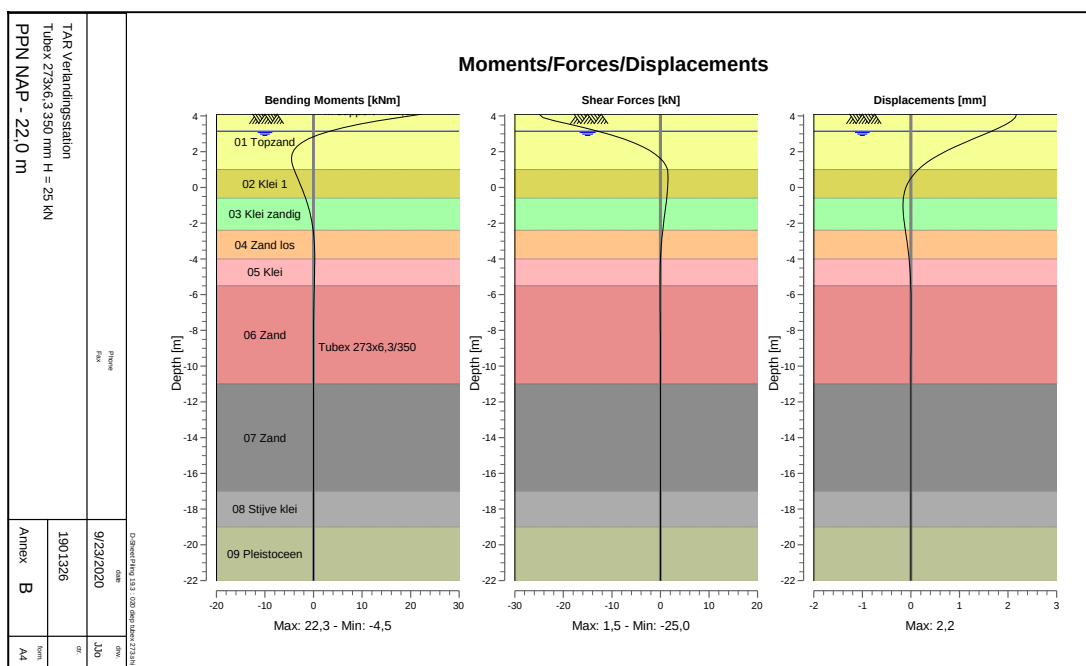
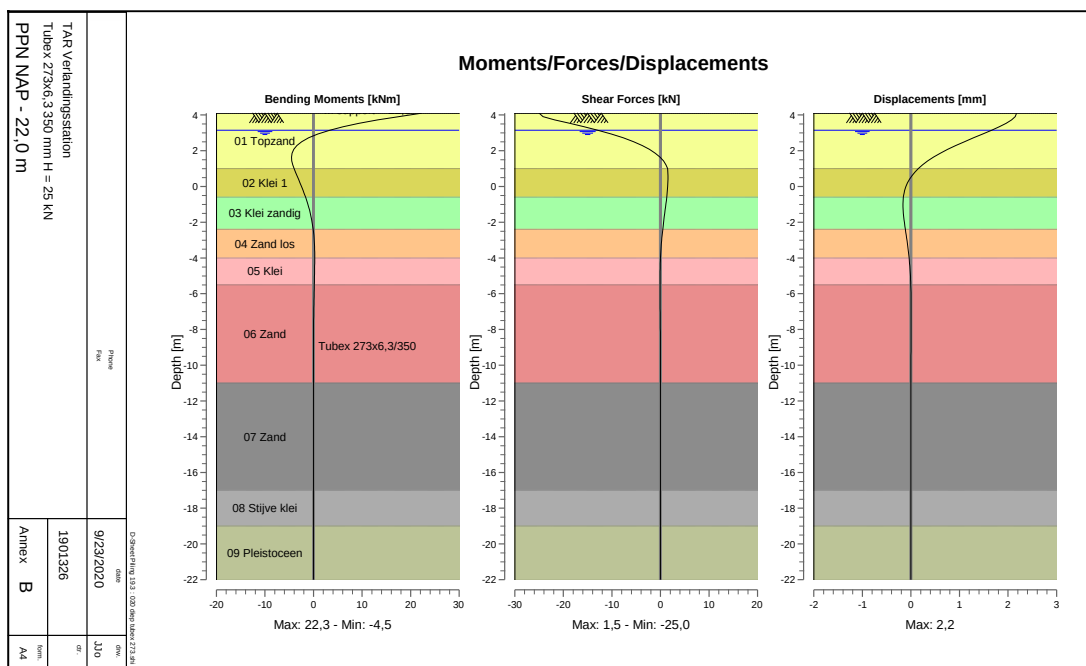


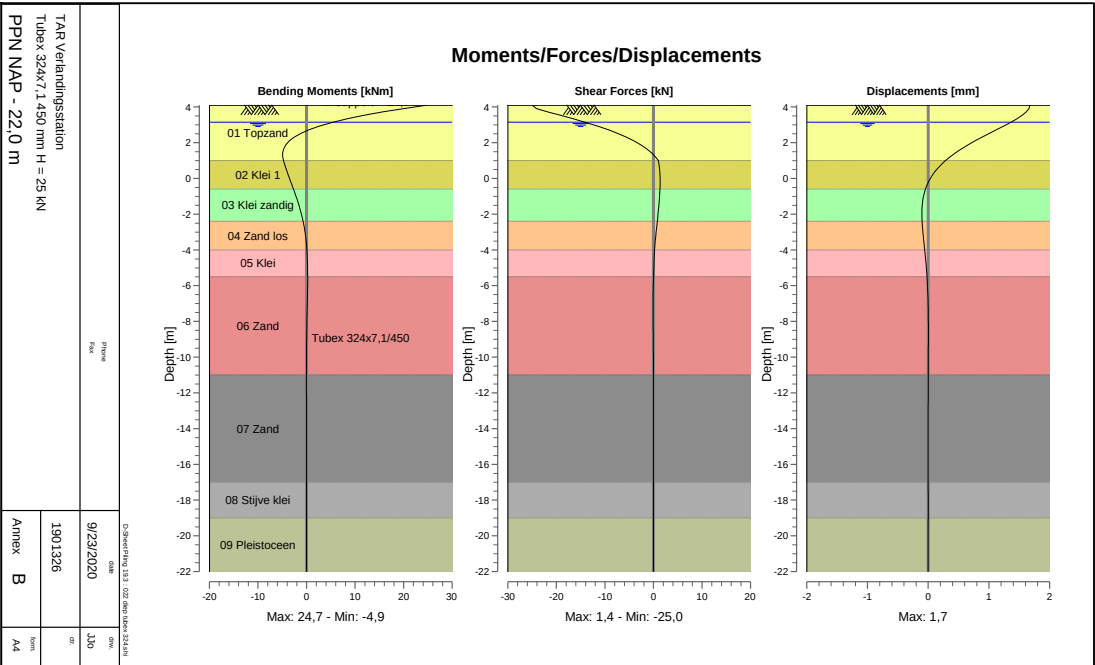
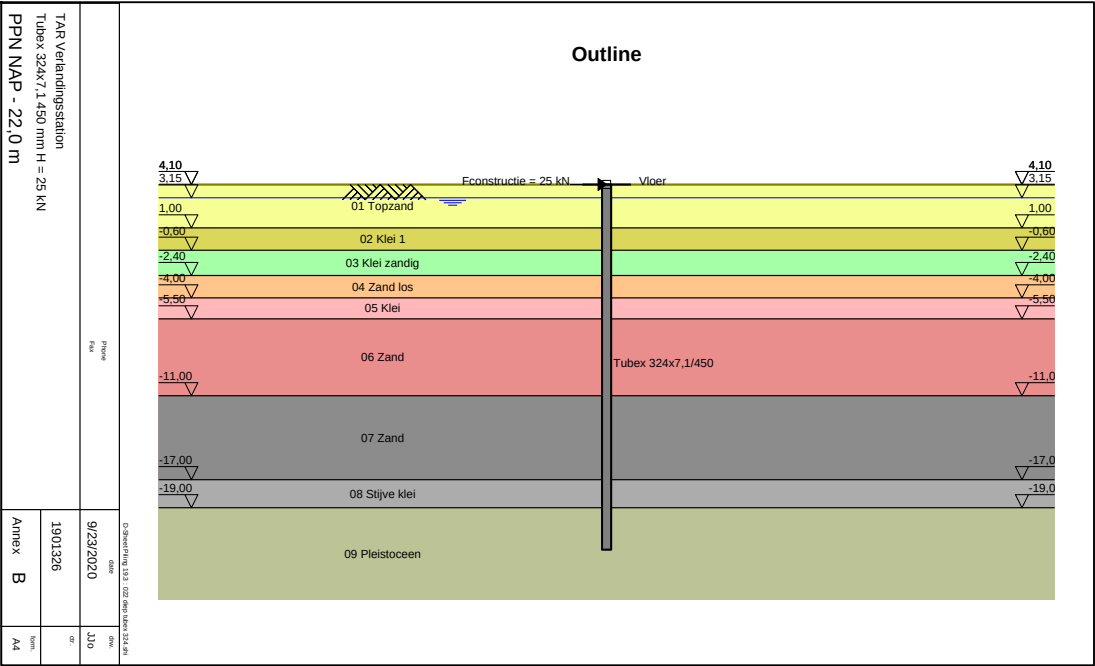


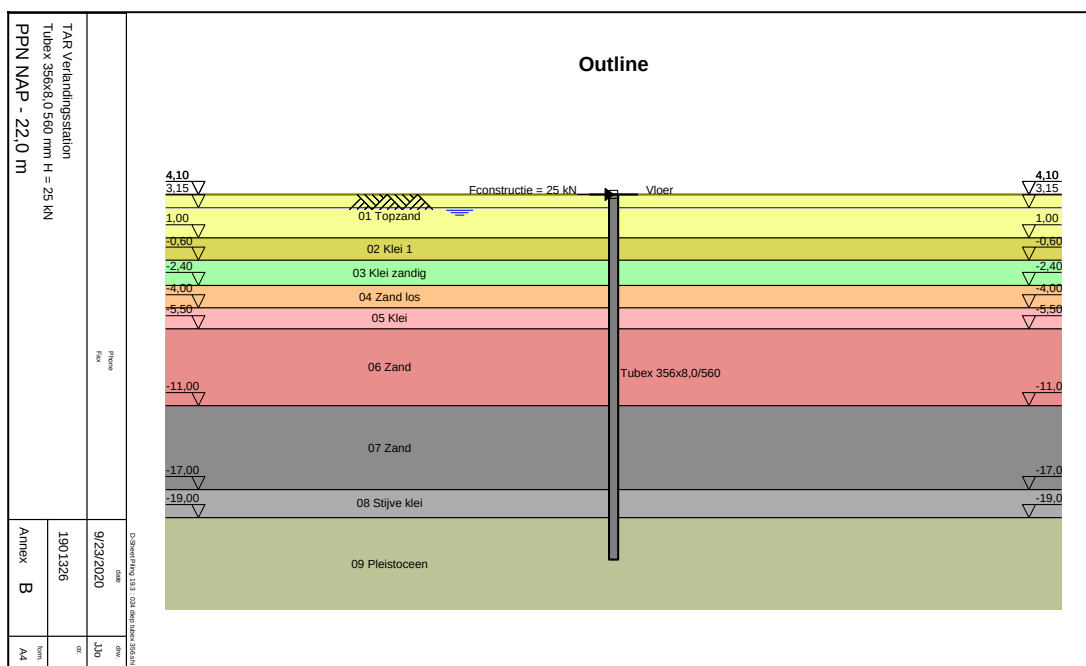
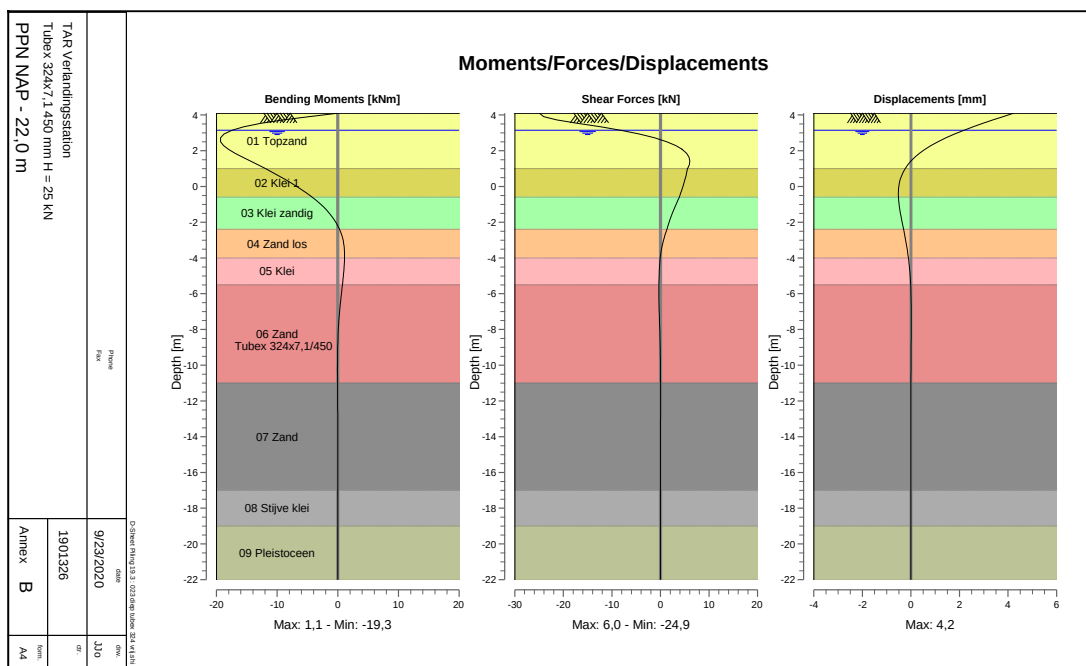


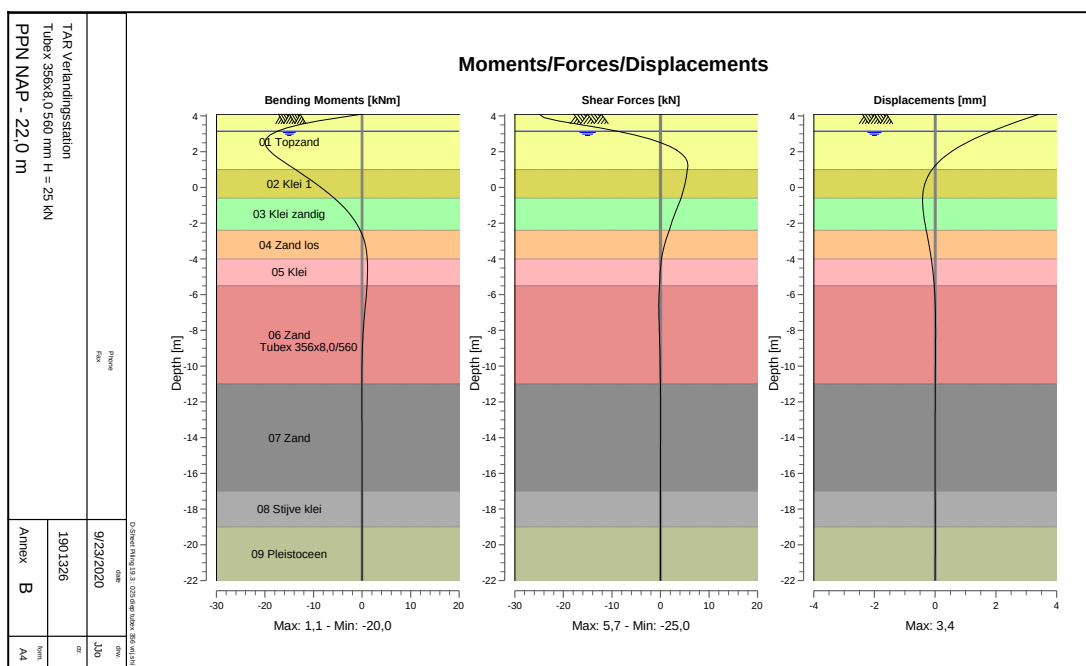
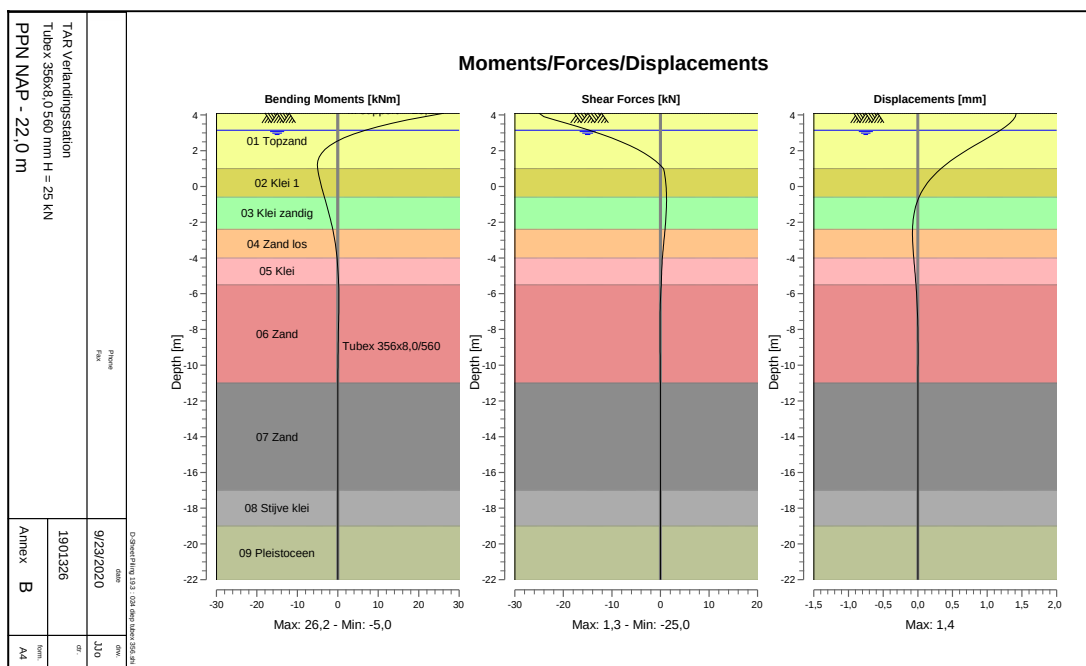












Bijlage C

Berekeningsvoorbeeld staalfundering

Mos Grondmechanica

Albert Plesmanweg 47

3088 GB Rotterdam

Tel. +31 (0)88 5130200

Opdrachtnummer

1901326

Datum 23-9-2020

ver 20180307

MAXIMALE WEERSTAND VAN FUNDERINGEN OP STAAL

Referentievlaak	NAP		Partiële materiaalfactoren	Project:
Maaiv. hoogte	[NAP + m]	4,67	$\gamma_{m,\gamma} = 1,10$	
Aanlegniveau	[NAP + m]	4,18	$\gamma_{m,\phi'} = 1,15$	
Gw. stand	[NAP + m]	3,80	$\gamma_{m,c'} = 1,60$	

KARAKTERISTIEKE WAARDEN VAN DE GRONDEIGENSCHAPPEN

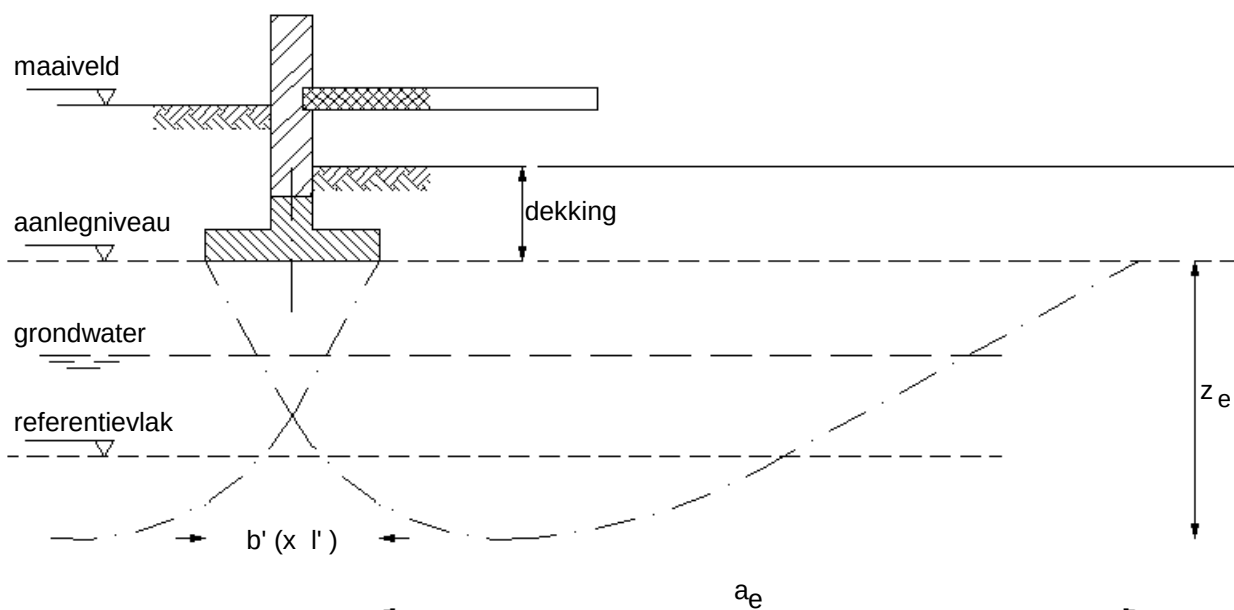
Laagnr.	bovenk. laag [NAP + m]	onderk. laag [NAP + m]	γ_k [kN/m ³]	$\gamma_{sat,k}$ [kN/m ³]	ϕ'_k [°]	c'_k [kN/m ²]
MV / dek.	4,67	4,18	17,0	19,0		
1	4,18	3,80	18,0	20,0	32,5	0,0
2	3,80	1,00	18,0	20,0	30,0	0,0
3	1,00		16,0	16,0	20,0	2,5
4						
5						
6						
7						
8						

REKENWAARDEN GRONDEIGENSCH.

γ_d [kN/m ³]	$\gamma_{sat,d}$ [kN/m ³]	ϕ'_d [°]	c'_d [kN/m ²]
15,45			
16,36		28,99	0,00
	18,18	26,66	0,00
	14,55	17,56	1,56

REKENWAARDEN VAN DE VERTICALE WEERSTAND OP EEN HORIZONTAAL FUNDERINGSOPPERVLAK ($R_{v,d}$)

Effectief funderingsopp.		dekking : 0,00 m		dekking : 0,20 m		dekking : 0,40 m		Invloedsgebied	
b' [m]	l' [m]	$\sigma'_{max,d}$ [kN/m ²]	$R_{v,d}$	$\sigma'_{max,d}$ [kN/m ²]	$R_{v,d}$	$\sigma'_{max,d}$ [kN/m ²]	$R_{v,d}$	z_e [m]	a_e [m]
0,40	strook	48	19 [kN/m']	99	40 [kN/m']	151	60 [kN/m']	0,61	1,60
0,50	strook	54	27 [kN/m']	104	52 [kN/m']	154	77 [kN/m']	0,75	1,97
0,60	strook	60	36 [kN/m']	109	65 [kN/m']	158	95 [kN/m']	0,90	2,34
0,70	strook	65	46 [kN/m']	113	79 [kN/m']	161	113 [kN/m']	1,04	2,70
0,80	strook	70	56 [kN/m']	118	94 [kN/m']	165	132 [kN/m']	1,18	3,06
0,90	strook	75	68 [kN/m']	122	110 [kN/m']	168	152 [kN/m']	1,33	3,42
1,00	strook	80	80 [kN/m']	126	126 [kN/m']	172	172 [kN/m']	1,47	3,79
1,10	strook	85	93 [kN/m']	131	144 [kN/m']	176	194 [kN/m']	1,61	4,15
1,20	strook	90	108 [kN/m']	135	162 [kN/m']	180	217 [kN/m']	1,75	4,51
1,25	strook	92	115 [kN/m']	137	172 [kN/m']	183	228 [kN/m']	1,82	4,69
1,50	strook	104	156 [kN/m']	149	223 [kN/m']	193	290 [kN/m']	2,18	5,58
3,40	14,50	157	7717 [kN]	197	9717 [kN]	238	11718 [kN]	4,73	11,77



Bijlage D

Uitvoeringsrichtlijnen

- Verdringingsschroefpalen
- Staalfundering

ALGEMENE RICHTLIJNEN VOOR DE UITVOERING VAN TRILLINGVRIJ EN GRONDVERDRINGEND IN DE GROND GESCHROEFDE PALEN

Trillingvrij en grondverdringend ingeschroefde palen zijn te verdelen in:

- In de grond gevormde geschroefde palen (zoals de Fundexpaal of de schroefinjectiepaal).
- Geprefabriceerde ingeschroefde palen (zoals de Tubexpaal).

Voor de aanvang van het inschroeven van de palen moeten de volgende zaken bekend zijn:

- Het palenplan met de paalafmetingen en de paalpuntniveaus. Hierop dienen de sondeerlocaties en de gedachte installatievolgorde tevens te zijn aangegeven.
- De maaiveldhoogten ter plaatse van de in te schroeven palen.
- De maaiveldhoogten ter plaatse van de sondeerlocaties.
- Het grondonderzoek en het bijbehorende funderingsadvies.

Bij de uitvoering van trillingvrij en grondverdringend ingeschroefde palen moeten de volgende punten in acht worden genomen:

- De "verloren" of terug te winnen casingbuis moet recht zijn.
- De diameter van de casingbuis moet over de volle lengte gelijk zijn.
- Bij het nabij belendingen inschroeven van palen verdient het (veelal) de voorkeur het inschroeven te starten op de kleinste afstand van de belendingen en vervolgens een inschroefvolgorde te hanteren met een ten opzichte van de belendingen toenemende afstand.
- Indien een verschil in paalpuntniveau is voorgeschreven, dan verdient het (veelal) aanbeveling het inschroeven van de palen te starten ter plaatse van het diepste paalpuntniveau en vervolgens van het diepste naar het hoogste niveau te werken.
- Omdat de funderingsgrondslag tussen sondeerlocaties kan variëren is een controle hierop gewenst. Dit kan door de oliedruk tijdens het inschroeven van de palen te registreren en de waarden van de maximale oliedruk per 0,25 m indringing vervolgens uit te zetten tegen de inschroefdiepte; het zo verkregen diagram wordt een oliedrukdiagram ¹⁾ genoemd. Bij een goede keuze van de boormotor (met een voldoende groot boormoment) zal onder gelijke omstandigheden meestal een duidelijke correlatie te zien zijn tussen het oliedrukdiagram en het sondeerdiagram.
- Om de verkregen oliedrukdiagrammen goed te kunnen vergelijken verdient het aanbeveling de eerste paal op of nabij een sondeerlocatie in te schroeven ("ijken"). Bij de eerste paal en alle overige dichtst nabij een sondeerlocatie gesitueerde palen, dient een volledig oliedrukdiagram te worden gemaakt.
- Bij de overige palen kan worden volstaan met een diagram waaruit de overgang naar de draagkrachtige zandformatie blijkt en dat wordt doorgezet tot paalpuntniveau. De oliedrukdiagrammen dienen te worden vergeleken met de diagrammen van de bijbehorende sondering(en), waarbij een maximale afwijking in ongunstige zin van $\frac{1}{3}$ is toegestaan.
- Na het bereiken van het geadviseerde paalpuntniveau dient controle op aanwezigheid van water of grond in de buis plaats te vinden. Bij afkeuring dient de buis voor het trekken te worden gevuld met beton, grout of - wanneer daar geen geohydrologische bezwaren tegen bestaan - een mengsel van zand en grind. Het paalpuntniveau van een nieuwe (vervangende) paal dient ten minste zo diep te zijn als het bereikte inschroefniveau van de afgekeurde paal.

- De wapening moet gecentreerd worden geplaatst.
- In geval van een terug te winnen casingbuis mag pas met het trekken worden begonnen als de specie het paalpuntniveau heeft bereikt en onder druk staat; de casingbuis moet geleidelijk worden getrokken.
- De hoeveelheid verbruikte specie moet ten minste overeenkomen met de theoretische inhoud van de paal.
- De palen kunnen onmiddellijk na elkaar worden vervaardigd, indien de onderlinge hart op hart afstand ten minste 4 maal de paalpuntdiameter bedraagt. Een kleinere afstand is toegestaan, als de tijd tussen het maken van de eerste en de tweede paal zodanig lang is dat de specie in de eerst gemaakte paal voldoende is opgestijfd. Voor genoemde tijd moet minimaal 20 uur worden aangehouden. Indien een vertragende hulpstof wordt toegepast, moet de tijdsduur zonodig worden verlengd.

Verder wordt verwezen naar:

- NEN-EN 12699 "Uitvoering van bijzonder geotechnische werken - Verdringingspalen".
- BRL 2356 (1992-06-01) "In de grond gevormde palen", bijlage E (1992-08-01) "Werkwijze bij het vervaardigen van trillingvrij, grondverdringend ingebrachte palen".
- CUR-Aanbeveling 114 (2009) "Toezicht op de realisatie van paalfunderingen".

In twijfelgevallen is het raadzaam de geotechnische adviseur te raadplegen. Deze kan aangeven of het zinvol is om controlesonderingen te laten maken.

Tot slot maken wij u erop attent dat Mos Grondmechanica beschikt over:

- Deskundige opzichters voor de begeleiding van alle grond- en funderingswerken.
- Goede apparatuur en medewerkers voor:
- Het uitzetten en of het inmeten van palenvelden.
- Het sonisch doormeten van palen (controle op eventueel aanwezige ernstige gebreken).

Noot:

- ¹⁾ Een oliedrukdiagram wordt verkregen door de per 0,25 m diepte gemeten maximale oliedruk grafisch uit te zetten tegen de corresponderende inschroefdiepte. De maximale oliedruk dient daartoe tijdens het (steeds weer) over een vaste afstand van 0,25 m inschroeven van de paal te worden gemeten en geregistreerd. Het zo verkregen oliedrukdiagram wordt bij voorkeur getekend in het sondeerdiagram van de sondering die zo dicht mogelijk bij de paal werd uitgevoerd.

(1 augustus 2017)

ALGEMENE RICHTLIJNEN VOOR DE UITVOERING VAN ONTGRAVINGEN EN GRONDVERBETERINGEN VOOR STAALFUNDERINGEN

Voor de aanvang van de uitvoering van ontgravingen / grondverbeteringen voor staalfunderingen moeten de volgende zaken bekend zijn:

- Het funderingsplan met de afmetingen en aanlegniveaus van de funderingselementen, hierop dienen de locaties waar de sonderingen (en boringen) zijn gemaakt te zijn aangegeven.
- De maaiveldhoogten ter plaatse van de te maken funderingen.
- De maaiveldhoogten ter plaatse van de sondeer(- en boor)locaties.
- Het grondonderzoek en het bijbehorende funderingsadvies.

Indien het geadviseerde ontgravingsniveau lager ligt dan het aanlegniveau moet een grondverbetering worden toegepast. Voor elk bouwdeel moet het graafwerk worden begonnen bij de sondering, waarvoor het diepste ontgravingsniveau is geadviseerd. Op deze wijze kunnen in het werk de overgangen naar minder diepe ontgravingsniveaus worden vastgesteld. Deze overgangen moeten geleidelijk of (bij abrupte overgangen in ontgravingsniveaus) terrasgewijs worden uitgevoerd in samenhang met de laagdikten van de grondverbetering.

De ontgravingen kunnen in het algemeen worden uitgevoerd onder een talud van circa 1:1. Bij een grondprofiel waarbij water uit het talud kan treden zijn extra maatregelen nodig. Verder is verondersteld dat langs de insteek van het talud geen zwaar materieel wordt geplaatst of zware materialen worden opgeslagen en dat de grondwaterstand permanent ten minste 0,5 m beneden het actuele ontgravingsniveau blijft of wordt gehouden.

Nadat de geadviseerde ontgravingsniveaus zijn bereikt, moet bij een staalfundering op zand met een handsondeerapparaat worden gecontroleerd of zich direct onder dit niveau nog samendrukbare laagjes bevinden. Deze controle moet vooral tussen de sonderingen (en boringen) intensief worden uitgevoerd. Worden dergelijke laagjes aangetroffen, dan moeten ze worden verwijderd en vervangen door zand of een ander hiervoor goedgekeurd materiaal. Vervolgens moet de bodem van de put of sleuf worden verdicht met een trilapparaat. Het te verdichten materiaal dient een vochtgehalte te hebben dat rond het optimum ligt van de Proctorproef. De mate van verdichting moet worden gecontroleerd, bijvoorbeeld met een handsondeerapparaat. Daarbij geldt als criterium dat de conusweerstand met de diepte moet toenemen tot minimaal 2,5 MPa op 0,10 m en 5 MPa op 0,30 m diepte. De mate van verdichting kan ook worden gerelateerd aan de uit (vooraf gemaakt!) Proctorproeven verkregen maximale Proctor-dichtheid. Hierbij moet de dichtheid, die in situ wordt gecontroleerd, ten minste 98% bedragen met een gemiddelde dichtheid van ten minste 100%. Hierna kan de werkvloer voor de fundering worden gestort of - bij een ontgravingsniveau beneden het aanlegniveau - de eerste laag van de grondverbetering worden aangebracht.

Soms blijkt (ook na verdichten) dat de hiervoor gestelde verdichtingseis niet (of niet meteen) wordt bereikt. Dit kan door diverse redenen of door een combinatie van dergelijke redenen worden veroorzaakt. Hierbij valt onder meer te denken aan een onvoldoende drooglegging, een te hoog vochtgehalte, een minder gunstige gradatie en of het gebruik van te zware verdichtingsapparatuur die minder goed in staat is om de zeer oppervlakkige lagen goed te verdichten.

In geval van twijfel dient in overleg met de geotechnisch adviseur te worden bepaald hoe hier verder mee omgegaan moet worden. De geotechnisch adviseur zal dan veelal op basis van eenvoudige metingen eerst willen weten of het aanwezige materiaal in principe geschikt is (controle via

handboringen, in geval van twijfel korrelverdelingen laten bepalen en of een in situ geschiktheidsproef uitvoeren) en dat de drooglegging voldoende is (peilbuismetingen).

Het zand voor de grondverbetering moet mineraal, matig grof materiaal zijn en mag ten hoogste 5 gewichtsprocenten (van de korrels) aan korrels kleiner dan $16\text{ }\mu\text{m}$ en ten hoogste 10 gewichtsprocenten aan korrels kleiner dan $63\text{ }\mu\text{m}$ bevatten. Het gehalte aan organische stof (gloeiverlies) moet kleiner zijn dan of gelijk zijn aan 3 gewichtsprocenten. De grondverbetering moet in lagen met een dikte van maximaal 0,3 m worden aangebracht. Iedere laag moet in minimaal 4 gangen, die elkaar kruisen en overlappen, mechanisch worden verdicht, waarbij voor iedere laag de reeds geformuleerde verdichtingseis geldt. Indien de bovenlaag door het gebruik van relatief zware trilapparatuur is losgeschud, moet het funderingsniveau met een lichte trilplaat worden afgetrild, voordat de werkvloer van de fundering wordt gestort. Voor de controle van de mate van verdichting gelden de bovenvermelde criteria.

De breedte van de grondverbetering moet op de bodem van de put of sleuf ten minste $B + 2d$ respectievelijk $L + 2d$ bedragen. Hierbij zijn B en L respectievelijk de breedte en de lengte van de fundering en d de dikte van de grondverbetering.

Soms wordt een staalfundering op klei (bijvoorbeeld op potklei), leem of löss aangelegd. In dit geval moet de laatste 0,1 m zo voorzichtig worden afgeschaafd, dat de klei, leem of löss beneden het ontgravingsniveau niet wordt geroerd. Om vervolgens verweking van de grondslag door neerslag te voorkomen moet zo snel mogelijk na ontgraving op de bodem van de ontgraving een beschermlaag (van bijvoorbeeld folie of 0,1 m stampbeton) worden aangebracht.

Extra aandacht moet worden besteed aan ontgravingen naast, dan wel nabij een bestaande, op staal gefundeerde belending. Dit geldt in het bijzonder voor ontgravingen dieper dan het aanlegniveau van de bestaande fundering. Dergelijke ontgravingen verminderen de draagkracht van de bestaande fundering en dienen daarom zo veel mogelijk te worden vermeden. Indien dergelijke ontgravingen noodzakelijk zijn dan moet worden nagegaan of speciale maatregelen moeten worden genomen.

Tijdens het verdichten van grondlagen moet de grondwaterstand zich minimaal 0,5 m beneden het ontgravingsniveau bevinden. Is dit niet het geval dan moet een bemaling worden geïnstalleerd, die in staat moet zijn de grondwaterstand tot ten minste dit niveau te verlagen. Deze verlaging moet zijn gerealiseerd voordat met ontgraven het vereiste niveau is bereikt.

Ter controle van de stijghoogte van het grondwater kan worden overwogen vooraf een of meer peilbuizen te plaatsen.

In twijfelgevallen ten aanzien van de uitvoering of andere omstandigheden is het raadzaam de geotechnische adviseur te raadplegen.

Tot slot maken wij u erop attent dat Mos Grondmechanica beschikt over:

- Deskundig opzichters voor de begeleiding van alle grond- en funderingswerken.
- Goede apparatuur en medewerkers voor het controleren van de gerealiseerde verdichting(en).
- Laboratoriumfaciliteiten voor het keuren van de geschiktheid van het materiaal voor de grondverbetering.

(7 april 2015)

MOS GRONDMECHANICA B.V.

Hieronder treft u de dienstverlening van Mos Grondmechanica b.v. aan. Voor specifieke diensten die niet direct in het overzicht terug zijn te vinden kunt u uiteraard vrijblijvend contact met ons opnemen.



VELDWERK

Sonderen op land, water en in beperkte ruimte, elektrisch, waterspanning, dissipatie, seismisch, magnetisch, geleidbaarheid, Bolconus, T-bar en slagsonderen

Geotechnisch boren en (on)geroerde monsternamen
Peilbuizen en waterspanningsmeters plaatsen
X, Y en Z metingen en Lintvoegmetingen
Plaatdruk-, CBR- en CPM proeven
In situ doorlatenheidspoeven

LABORATORIUM

Classificatie proeven (o.a. vol. gewicht, KVD, PI)
Samendrukkingsproeven (Oedometer en CRS)
Triaxiaalproeven
DS en DSS-proeven
Doorlatenheidspoeven
Dichtheidsbepaling (Proctor en CBR)
Cementbentoniet onderzoek

GEOMONITORING

Deformatiemeting (inclino- en extensometing)
(Grond)waterspanningsmeting
Zettingsmonitoring
Trillingsmonitoring (SBR)
Akoestisch doormeten van palen (CUR 109)
Online meetgegevens via portal

MILIEU (MOS MILIEU B.V.)

Verkennd-, nader- en saneringsonderzoek
Partijkeuringen besluit bodemkwaliteit (Bbk)
Saneringsbegeleiding. Waterbodemonderzoek.
Vergunning aanvragen.
2nd Opinion / Contra-Expertise Bodemonderzoeken.

Meer weten? Bezoek onze website www.mosgeo.com
Vragen? Mail ons op info@mosgeo.com
Offerte aanvragen? Mail ons op offerte@mosgeo.com

GEOTECHNISCH ADVIES

Paalfundering
Fundering op staal
Grondkerende constructies
Bouwputontwerp
Omgevingsbeïnvloeding (Plaxis)
Zettingsanalyse (bouwrijp maken, opslagtanks)
Taludstabiliteit
Tankbouwadvies
Trillingsprognose
Schade expertise
Review en 2nd Opinion

GEOHYDROLOGISCH ADVIES

Bemalingen (incl. retourbemalingen)
Vergunningsaanvragen
Pompproeven
Omgekeerde Osmose
Barrièrewerking
Drainage
Infiltratie hemelwater

BEMALINGEN (MOS GRONDWATERTECHNIEK)

Bronbemaling
Ondergrondse energie-opslag
Pomp- en leidingsystemen
Brandputten

OVERIG

Uitvoeringsbegeleiding

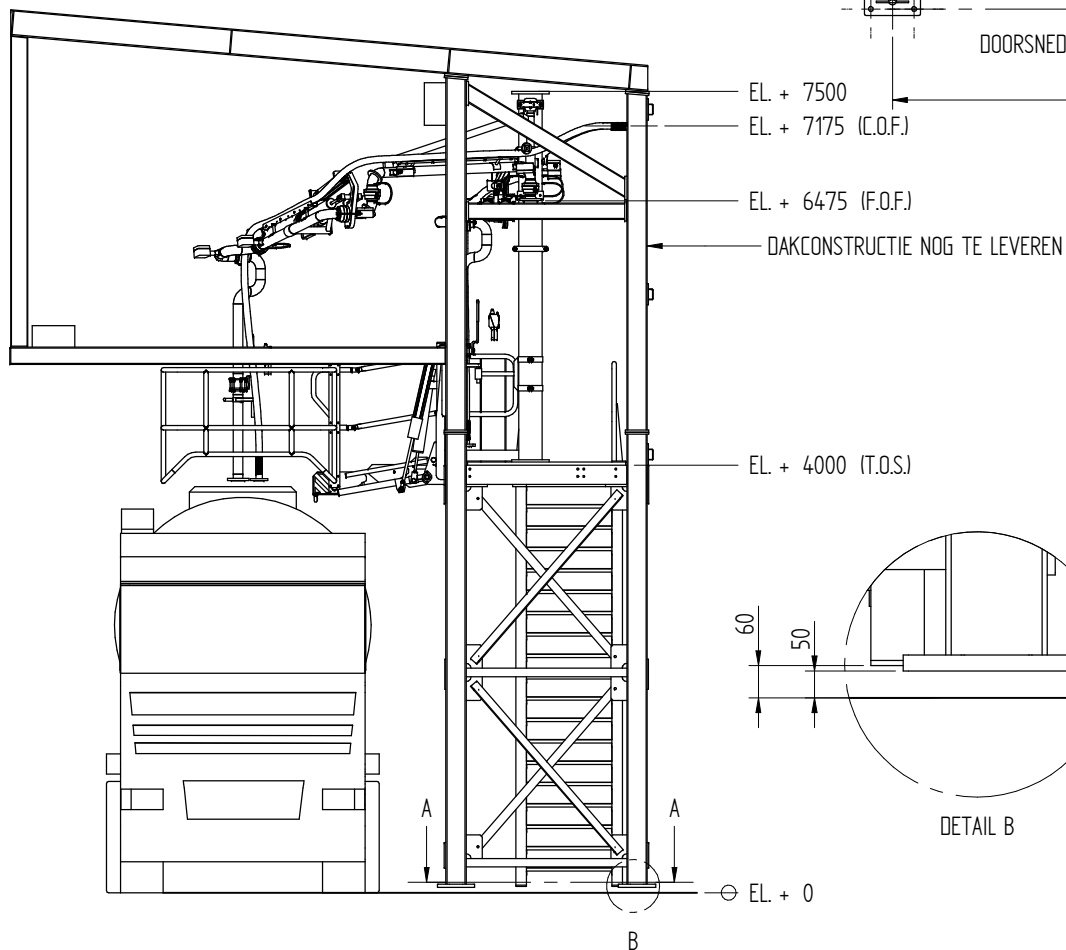
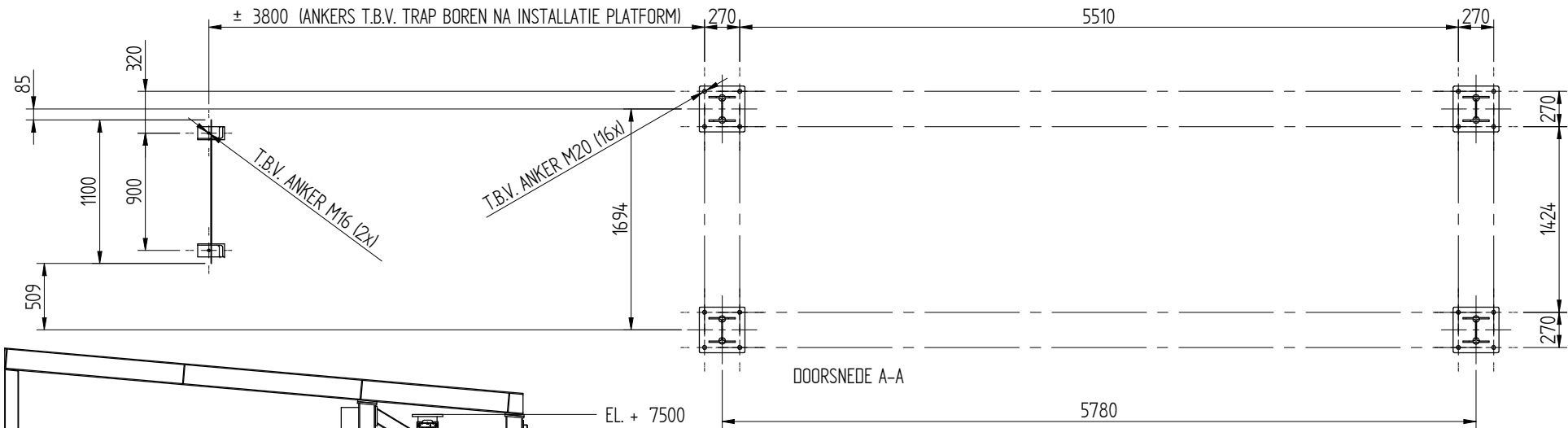
Mos Grondmechanica opereert structureel vanuit 5 vestigingen in Nederland en in Suriname. Via het zusterbedrijf Mosgeo b.v. worden wereldwijd projecten uitgevoerd, daar waar onze specifieke kennis en ervaring wordt gevraagd.

MOS GRONDMECHANICA B.V.

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Vestiging Enter	De Bleek 40	7468 DL	Enter
Vestiging Amsterdam	Pleimuiden 8B	1046 AG	Amsterdam
Mosgeo B.V.	Albert Plesmanweg 47	3088 GB	Rotterdam



Appendix C. WLT Steel structure



BELASTINGEN PER KOLOM:
 MAXIMALE TREKKRACHT: 300 kN
 MAXIMALE DRUKKRACHT: 300 kN
 MAXIMALE HORIZONTAALKRACHT: 20 kN

AS BUILT

		ITEMNR.	AANT.	NAAM	MATERIAAL	OPMERKINGEN
B	AS BUILT	1306/17	JW	TITEL:		GETEK.: 21-4-2017 GA
	A	VERBODING TBV DAK	05/05/17	HOOFDMATEN TBV FUNDATIE		CONTR.: 13-6-2017 SVG
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				SCHAAL:		173877.1.100
				Copyright © WLT BV All rights reserved		SHEET: 1/1
						Measures without tolerance ISO/TC3-1961

