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ISO 9001:2008 certified

STRUCTURAL CALCULATIONS
Foundation – soil reactions

Project Asheklon
Client Alfa Afikim
Country ISRAEL

Rev	DATE	BY	CH	APP'D	DESCRIPTION
0	10.2015	M.P	P.P		• Design calculations – Foundation Design
1	11.11.2015	M.P	P.P		• Concrete grade update C25/30 to C30/37 • Rebar steel grade update B500 to B400

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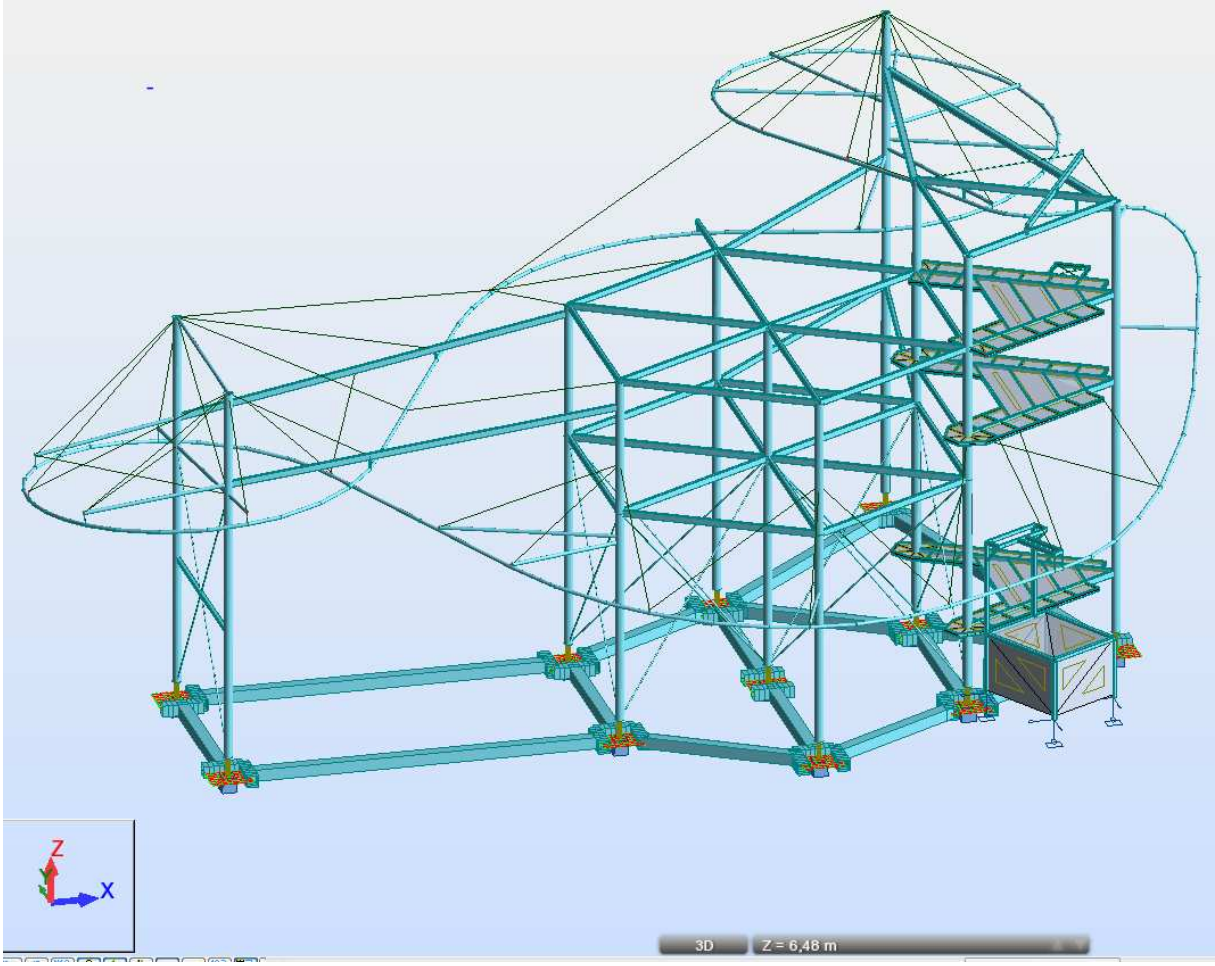
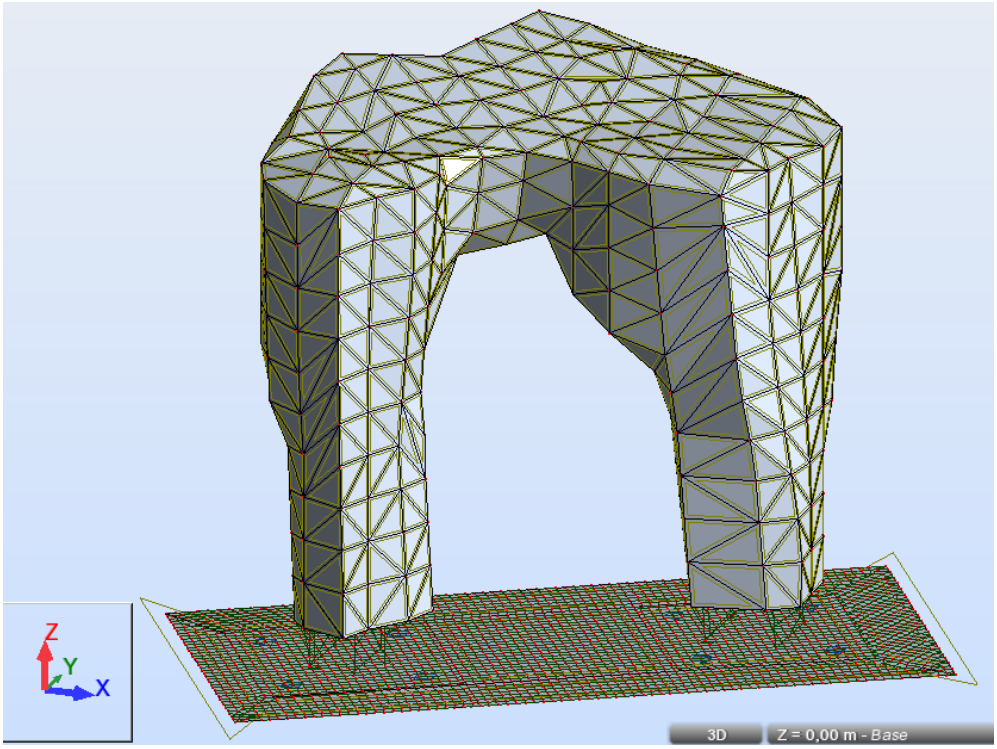
1. Common

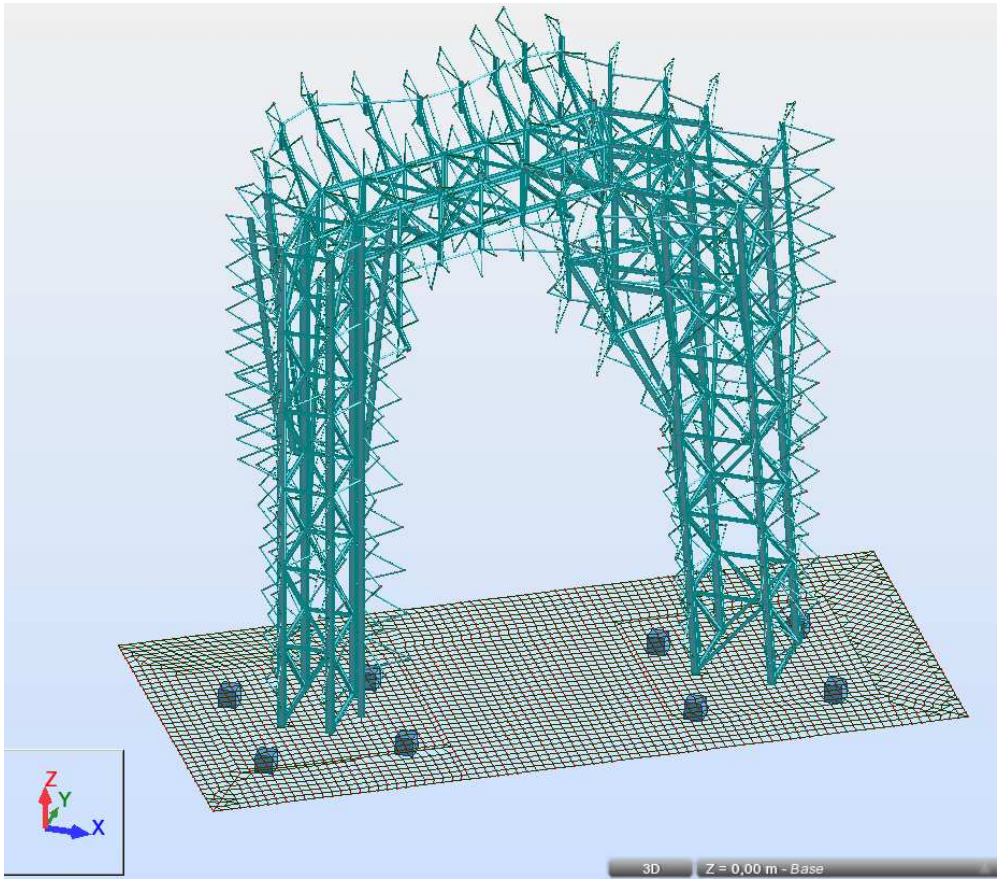
There are four separate structures in the project – Rope course with roll glider, Climbing tower, Large boulder and small boulder.

Rope course with roll Glider FEM model :

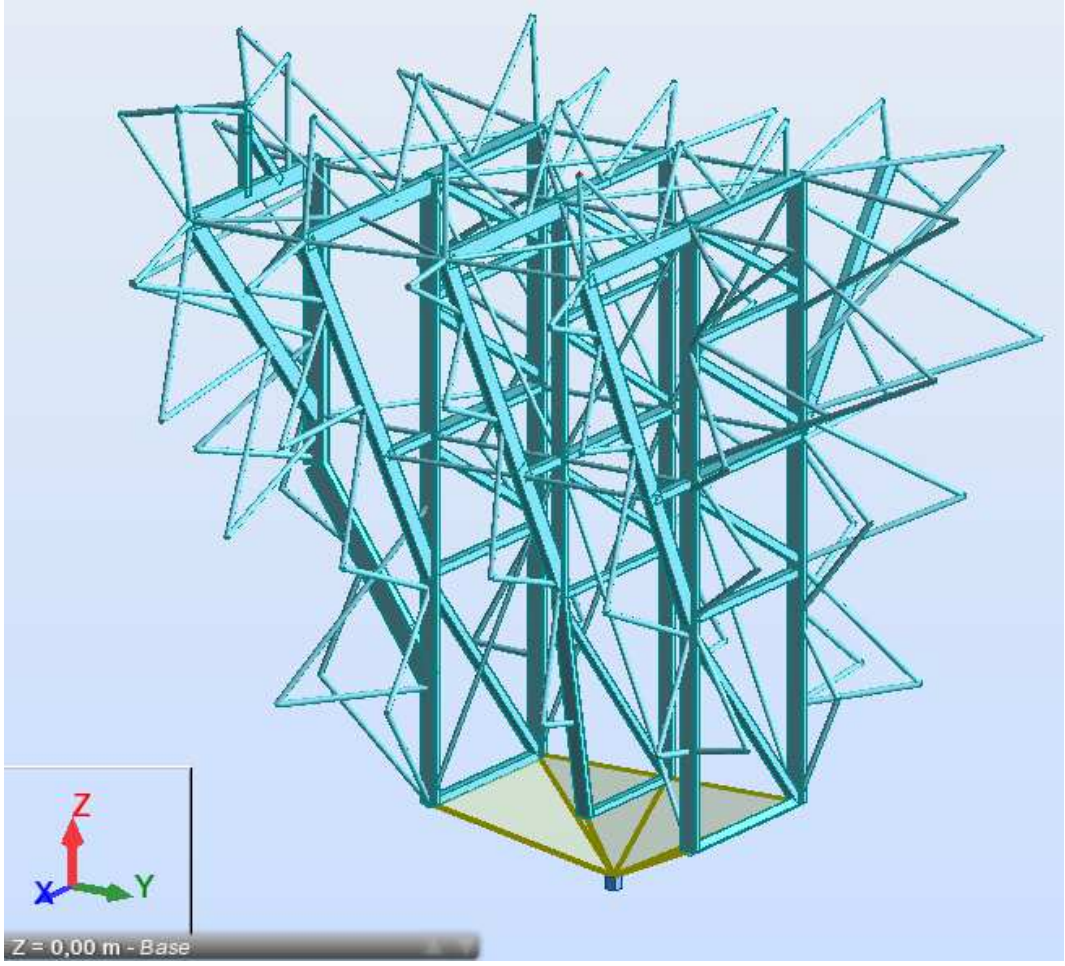


Climbing tower FEM model :





Large boulder FEM priliminaly model :



2. Used codes:

** Basic

- BS EN1990 – Basis of structural design

** Loading

- BS EN1991-1-1: Actions on structures - Part 1-1: General actions - Densities, self-weight, imposed loads for buildings

- BS EN1991-1-3 - Actions on structures - General actions - Part 1-3: Snow loads

- BS EN 1991-1-3 Snow loads - national annexes for EN1991-1-4

- BS EN1991-1-4 - Actions on structures - General actions - Part 1-4: Wind actions

- BS EN 1991-1-4 Wind actions - national annexes for EN1991-1-4

- BS EN15567-1:2007 - Sports and recreationalfacilities — Ropes courses — Part 1: Construction and safety requirements

- BS EN 13814 - Fairground and anusement park machinery and structures - Safety

- BS8100

** Tension elements – steel wire rope

- BS EN 12385-8: Steel wire ropes - Safety: Part 8: Stranded hauling and carrying-hauling ropes for cableway installations designed to carry persons

- BS EN 12385-1: Steel wire ropes - Safety: Part 1: General Requirements

** Design steel

- BS EN1993-1-1: Design of steel structures – Part 1-1: General rules and rules for buildings (includes Corrigendum AC:2009)

- BS EN 1991-1-3 – national annexes for EN1993-1-1

- BS EN1993-1-3 : Design of steel structures – Part 1.3: General rules - Supplementary rules for cold formed thin gauge members and sheeting

- BS EN1993-1-5 : Design of steel structures: Part 1.5 : Plated structural elements

- BS EN1993-1-8 : Design of steel structures – Part 1-8: Design of joints

- BS EN1993-1-10: Design of steel structures – Part 1-10:

Material thickness and through-thickness properties

- BS EN1993-3-1 - Design of steel structures - Part 3-1: Towers, masts and chimneys - Towers and masts

- BS EN1993-1-9: Design of steel structures - Part 1-9: Fatigue

** Design concrete

- BS EN1992-1-1 : Design of concrete structures -

Part 1: General rules and rules for buildings

** Anchorage design

- BS EN1992-4-1 : Design of of fastenings for use in concrete-

Part 1: General

- BS EN1992-4-2 : Design of of fastenings for use in concrete-

Part 2: Headed fasteners

** Seizmic design

- BS EN1998-1-1 : Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings

**Geotechical design

BS EN1997-1-1: Geotechnical design —Part 1: General rules

** Execution

- BS EN 1090: Execution of steel structures and aluminium structures - Part 2:Technical requirements for steel structures

A. **Materials: Reference standards, Group 1, Weldable structural steels.**

3. Steel S235JR according to EN 10025

fy, kN/cm2	fu, kN/cm2	E, kN/cm2	kN/m3
Resistance	Limit for tension	Young modulus	Force dencity
23.5	36.0	21000	77.1

Steel used: non-alloy structural steel S235JR according to*"EN10025: Hot rolled products of non-alloy structural steels"*.

EN 10025 : part 2 : 2004 Non-alloy structural steels

Comparison between grades in EN 10025 : part 2 : 2004 and nearest equivalent versions in EN 10025 : 1993 and BS					
EN 10025 : part 2 : 2004					EN 10025 : 1993
Grade	Yield (Reh) min	Tensile (Rm)	Charpy V-notch longitudinal		Grade
	Strength at t = 16mm (MPa)		Temp (°C)	Energy (J) t = 16mm	
S185	185	290/510	-	-	S185
- [1]	235	360/510	-	-	S235
S235JR [2]			20	27	S235JRG1/G2
S235J0			0	27	S235J0
S235J2			-20	27	S235J2G3/G4
- [1]	275	410/560	-	-	S275
S275JR [2]			20	27	S275JR
S275J0			0	27	S275J0
S275J2			-20	27	S275J2G3/G4
- [1]	355	470/630	-	-	S355
S355JR [2]			20	27	S355JR
S355J0			0	27	S355J0
S355J2			-20	27	S355J2G3/G4
S355K2			-20	40	S355K2G3/G4
E295	295	470/610	-	-	E295
S335	335	570/710	-	-	S335
E360	360	650/830	-	-	E360

1 MPa = 1 N/mm²

Material through thickness properties - EN1993-1-10

$f_{y235} := 235MPa$

(5) The reference temperature T_{Ed} at the potential fracture location should be determined using the following expression:

$$T_{Ed} = T_{md} + \Delta T_r + \Delta T_\sigma + \Delta T_R + \Delta T_{\dot{\varepsilon}} + \Delta T_{\varepsilon_{cf}} \quad (2.2)$$

where T_{md} is the lowest air temperature with a specified return period, see EN 1991-1-5

ΔT_r is an adjustment for radiation loss, see EN 1991-1-5

ΔT_σ is the adjustment for stress and yield strength of material, crack imperfection and member shape and dimensions, see 2.4(3)

ΔT_R is a safety allowance, if required, to reflect different reliability levels for different applications

$\Delta T_{\dot{\varepsilon}}$ is the adjustment for a strain rate other than the reference strain rate $\dot{\varepsilon}_0$ (see equation 2.3)

$\Delta T_{\varepsilon_{cf}}$ is the adjustment for the degree of cold forming ε_{cf} (see equation 2.4)

NOTE 1 The safety element ΔT_R to adjust T_{Ed} to other reliability requirements may be given in the National Annex. $\Delta T_R = 0$ °C is recommended, when using the tabulated values according to 2.3.

NOTE 2 In preparing the tabulated values in 2.3 a standard curve has been used for the temperature shift ΔT_σ that envelopes the design values of the stress intensity function [K] from applied stresses σ_{Ed} and residual stresses and includes the Wallin-Sanz-correlation between the stress intensity function [K] and the temperature T. A value of $\Delta T_\sigma = 0$ °C may be assumed when using the tabulated values according to 2.3.

NOTE 3 The National Annex may give maximum values of the range between T_{Ed} and the test temperature and also the range of σ_{Ed}, to which the validity of values for permissible thicknesses in Table 2.1 may be restricted.

NOTE 4 The application of Table 2.1 may be limited in the National Annex to use of up to S 460 steels.

- a reference strain rate $\dot{\varepsilon}_0 = 4\times10^{-4}$/sec has been used. This covers the dynamic action effects for most transient and persistent design situations. For other strain rates $\dot{\varepsilon}$ (e.g. for impact loads) the tabulated values may be used by reducing T_{Ed} by deducting $\Delta T_{\dot{\varepsilon}}$ given by

$$\Delta T_{\dot{\varepsilon}} = \frac{1440 - f_y(t)}{550} \times \left(\ln\frac{\dot{\varepsilon}}{\dot{\varepsilon}_0}\right)^{1.5} \quad [°C] \quad (2.3)$$

$$\Delta T_\varepsilon := \frac{1440 - \frac{f_{y235}}{MPa}}{550} \cdot (\ln(1))^{1.5} = 0$$

$T_{mod} := 30$ $\Delta T_r := 0$ $\Delta T_\sigma := 0$ $\Delta T_R := 0$ $\Delta T_\varepsilon = 0$ $\Delta T_{\varepsilon f} := 0$

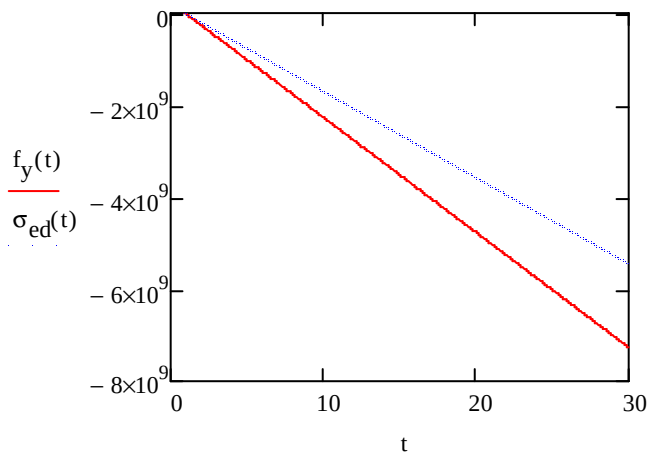
$$T_{ed} := T_{mod} + \Delta T_r + \Delta T_\sigma + \Delta T_R + \Delta T_\varepsilon + \Delta T_{\varepsilon f} = 30$$

$$f_y(t) := \left(\frac{f_{y235}}{MPa} - 0.25\cdot\frac{t}{mm}\right)\cdot MPa$$

For plate thickness to 30mm, S235JR is applied
For plate thickness 30 to 40mm, S235J0 is applied
For plate thickness >40mm , S235J2 is applied

$f_y(0) = 235MPa$

$\sigma_{ed}(t) := 0.75\cdot f_y(t)$ $\quad \sigma_{ed}(10mm) = 174.38MPa$ $\quad \sigma_{ed}(20mm) = 172.5MPa$ $\quad \sigma_{ed}(30mm) = 170.63MPa$



1.1.1. Reference standards, Group 1: bolt, nut, washers

1.1.2.

- Nut with plastic, grade 8, DIN 982 - EN ISO 7040:1997 - Prevailing torque hexagon nuts (with non-metallic insert), style 1 - Property classes 5, 8 and 10

- Nut grade 8, DIN 934 - EN ISO 4032:2001 Hexagon nuts, style 1 -

Table 2.1: Maximum permissible values of element thickness t in mm

Steel grade	Sub-grade	Charpy energy CVN at T [°C]	Charpy energy CVN J_{min}	Reference temperature T_{Ed} [°C] 10	0	-10	-20	-30	-40	-50	10	0	-10	-20	-30	-40	-50	10	0	-10	-20	-30	-40	-50
				$\sigma_{Ed} = 0,75\ f_y(t)$							$\sigma_{Ed} = 0,50\ f_y(t)$							$\sigma_{Ed} = 0,25\ f_y(t)$						
S235	JR	20	27	60	50	40	35	30	25	20	90	75	65	55	45	40	35	135	115	100	85	75	65	60
	J0	0	27	90	75	60	50	40	35	30	125	105	90	75	65	55	45	175	155	135	115	100	85	75
	J2	-20	27	125	105	90	75	60	50	40	170	145	125	105	90	75	65	200	200	175	155	135	115	100
S275	JR	20	27	55	45	35	30	25	20	15	80	70	55	50	40	35	30	125	110	95	80	70	60	55
	J0	0	27	75	65	55	45	35	30	25	115	95	80	70	55	50	40	165	145	125	110	95	80	70
	J2	-20	27	110	95	75	65	55	45	35	155	130	115	95	80	70	55	200	190	165	145	125	110	95
	M,N	-20	40	135	110	95	75	65	55	45	180	155	130	115	95	80	70	200	200	190	165	145	125	110
	ML,NL	-50	27	185	160	135	110	95	75	65	200	200	180	155	130	115	95	230	200	200	200	190	165	145
S355	JR	20	27	40	35	25	20	15	15	10	65	55	45	40	30	25	25	110	95	80	70	60	55	45
	J0	0	27	60	50	40	35	25	20	15	95	80	65	55	45	40	30	150	130	110	95	80	70	60
	J2	-20	27	90	75	60	50	40	35	25	135	110	95	80	65	55	45	200	175	150	130	110	95	80
	K2,M,N	-20	40	110	90	75	60	50	40	35	155	135	110	95	80	65	55	200	200	175	150	130	110	95
	ML,NL	-50	27	155	130	110	90	75	60	50	200	180	155	135	110	95	80	210	200	200	200	175	150	130
S420	M,N	-20	40	95	80	65	55	45	35	30	140	120	100	85	70	60	50	200	185	160	140	120	100	85
	ML,NL	-50	27	135	115	95	80	65	55	45	190	165	140	120	100	85	70	200	200	200	185	160	140	120
S460	Q	-20	30	70	60	50	40	30	25	20	110	95	75	65	55	45	35	175	155	130	115	95	80	70
	M,N	-20	40	90	70	60	50	40	30	25	130	110	95	75	65	55	45	200	175	155	130	115	95	80
	QL	-40	30	105	90	70	60	50	40	30	155	130	110	95	75	65	55	200	200	175	155	130	115	95
	ML,NL	-50	27	125	105	90	70	60	50	40	180	155	130	110	95	75	65	200	200	200	175	155	130	115
	QL1	-60	30	150	125	105	90	70	60	50	200	180	155	130	110	95	75	215	200	200	200	175	155	130
S690	Q	0	40	40	30	25	20	15	10	10	65	55	45	35	30	20	20	120	100	85	75	60	50	45
	Q	-20	30	50	40	30	25	20	15	10	80	65	55	45	35	30	20	140	120	100	85	75	60	50
	QL	-20	40	60	50	40	30	25	20	15	95	80	65	55	45	35	30	165	140	120	100	85	75	60
	QL	-40	30	75	60	50	40	30	25	20	115	95	80	65	55	45	35	190	165	140	120	100	85	75
	QL1	-40	40	90	75	60	50	40	30	25	135	115	95	80	65	55	45	200	190	165	140	120	100	85
	QL1	-60	30	110	90	75	60	50	40	30	160	135	115	95	80	65	55	200	200	190	165	140	120	100

NOTE 1 Linear interpolation can be used in applying Table 2.1. Most applications require σ_{Ed} values between $\sigma_{Ed} = 0,75\ f_y(t)$ and $\sigma_{Ed} = 0,50\ f_y(t)$. $\sigma_{Ed} = 0,25\ f_y(t)$ is given for interpolation purposes. Extrapolations beyond the extreme values are not valid.

Product grades A and B (ISO 4032:1999)

- Washers DIN125 Form A Stahl 300HV - EN ISO 7089:2000 Plain washers- Nominal series- Product grade A

- Belay bolt grade 10.9, ISO 7380
- Bolt grade 8.8 DIN 931 - EN ISO 4017:2001 Hexagon head screws - Product grades A and B (ISO 4017:1999)

2. Reference standards, Group 2: Tolerances, dimensions and technical delivery conditions

- EN 10029:1991 Hot rolled steel plates 3 mm thick or above - Tolerances on dimensions, shape and mass
- EN 10219-1:1997 Cold formed welded structural hollow sections of non-alloy and fine grain steels – Part 1: Technical delivery requirements
- EN 10219-2:1997 Cold formed welded structural hollow sections of non-alloy and fine grain steels – Part 2: Tolerances, dimensions and sectional properties
- EN 10056-1:1995 Structural steel equal and unequal leg angles - Part 1: Dimensions
- EN 10056-2:1993 Structural steel equal and unequal leg angles - Part 2: Tolerances on shape and dimensions
- EN 10055:1995 Hot rolled steel equal flange tees with radiused root and toes - Dimensions and tolerances on shape and dimensions

3. Welding

- EN 12345:1998 Welding-Multilingual terms for welded joints with illustrations. September 1998.
- EN 1011-1:2002 Welding - Recommendations for welding of metallic materials - Part 1: General guidance for arc welding
- EN ISO 2560:2007 - Welding consumables - Covered electrodes for manual metal arc welding of non-alloy and fine grain steels - Classification (ISO 2560:2002) -

  Covered electrode ISO 2560-A - E 35 0 is applied.
- EN ISO 14341: 2008 Welding consumables - Wire electrodes and weld deposits for gas shielded metal arc welding of non alloy and fine grain steels - Classification (ISO 14341:2010) -

  - Wire electrodes ISO 14341 – A – G35
- EN ISO 9692-1:2003 Welding and allied processes — Recommendations for joint preparation — Part 1: Manual metal-arc welding, gasshielded metal-arc welding, gas welding, TIG welding and beam welding of steels .

- ISO 5817:2007 Welding - Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) - Quality levels for imperfection.
- EN ISO 17637 Non-destructive testing of welds - Visual testing of fusion-welded joints.

- EN ISO 17640:2011 Non-destructive testing of welds - Ultrasonic testing - Techniques, testing levels, and assessment

- EN ISO 17638:2010 Non-destructive testing of welds - Magnetic particle testing

4. *Chemistry for anchorage: Hilti hit HY – 200*

3. Site location

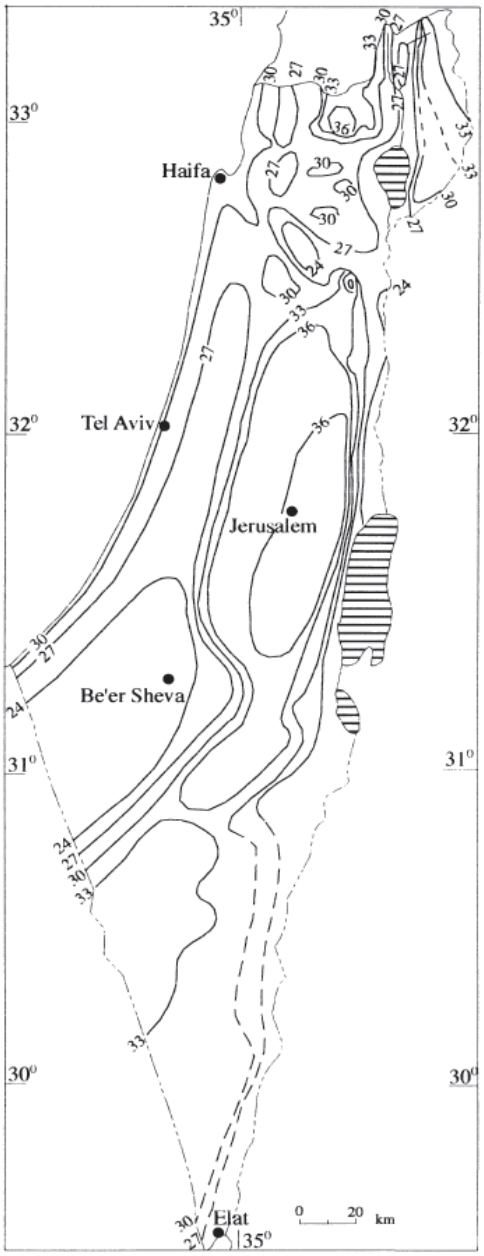
Ashkelon / Ashqelon / - city - Israel

4. Loads

4.1 Permanent load

- Steel weight 7850kg/m^3
- Concrete weight - 2500kg/m^3

4.2 Wind load –



V_{bmap}=30m/s.

$V_{b.map} := 30 \frac{m}{s}$ $C_{at} := 1.05$ $C_{dir} := 1$ $C_{season} := 1$ $C_{prob} := 1$

$V_b := C_{dir} \cdot C_{season} \cdot C_{prob} \cdot C_{at} \cdot V_{b.map} = 31.5 \frac{m}{s}$ $\rho_{air} := 1.226 \frac{kg}{m^3}$

$q_b := 0.5 \cdot \rho_{air} \cdot V_b^2 = 0.608 \cdot \frac{kN}{m^2}$

NA.2.18 Value to be used for air density p
[BS EN 1991-1-4:2005, 4.5 (1) Note 2]
The air density p should be taken as 1,226 kg/m3.

$C_s := 1$

$C_{e.z} := 3$ **Figure 7** distance to shorel ine 1км **distance to shoreline 15м**

$q_{p1} := C_{e.z} \cdot q_b = 1.8 \cdot \frac{kN}{m^2}$

$q_{p1} := C_{e.z} \cdot q_b = 1.8 \cdot \frac{kN}{m^2}$

$q_p := 1.8 \frac{kN}{m^2}$

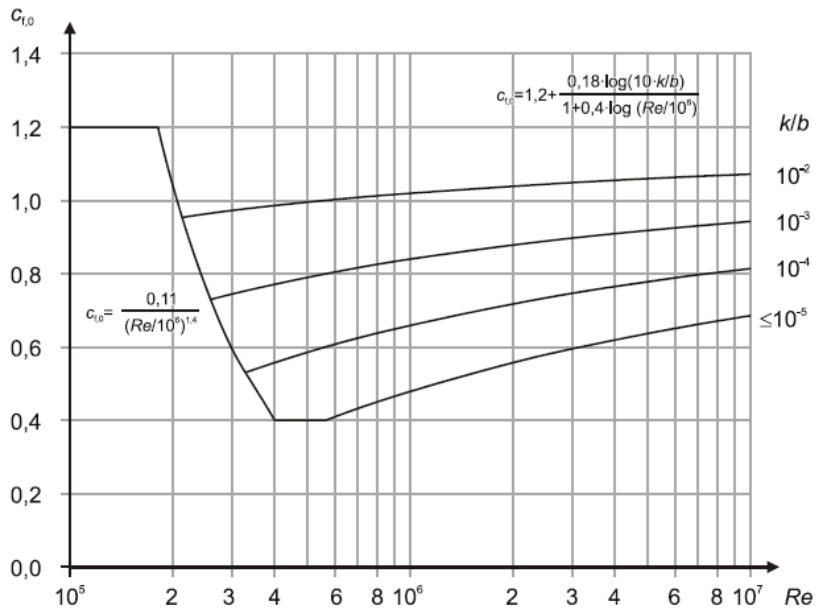


Figure 7.28 — Force coefficient $c_{f,0}$ for circular cylinders without free-end flow and for different equivalent roughness k/b

NOTE 1 Figure 7.28 may also be used for building with $h/d > 5.0$

NOTE 2 Figure 7.28 is based on the Reynolds number with $v = \sqrt{\frac{2 \cdot q_p}{\rho}}$ and q_p given in 4.5

(2) Values of equivalent surface roughness k are given in Table 7.13.

(3) For stranded cables $c_{f,0}$ is equal to 1,2 for all values of the Reynolds number Re.

Force coeficient for column CHS273

$b := 273\,mm$ - *Diameter of column*

$\nu := 15 \cdot 10^{-6} \frac{m^2}{s}$ - *Kinematic viscosity of the air*

$q_p = 1.8 \cdot \frac{kN}{m^2}$ $\rho_{air} = 1.226 \frac{kg}{m^3}$

NA.2.18 Value to be used for air density *p*
[BS EN 1991-1-4:2005, 4.5 (1) Note 2]
The air density *p* should be taken as 1,226 kg/m3.

$v_{ze} := \sqrt{\frac{2 \cdot q_p}{\rho_{air}}}$

$v_{ze} = 54.188 \frac{m}{s}$

$R_e := \frac{b \cdot v_{ze}}{\nu} = 9.862 \times 10^5$

$k := 0.2\,mm$ equivalent roughness

$\frac{k}{b} = 7.326 \times 10^{-4}$

from graphic $R_e = 9.862 \times 10^5$ и $\frac{k}{b} = 7.326 \times 10^{-4}$ $C_{f.0} := 0.83$

$\psi_\lambda := 1$

$C_f := C_{f.0} \cdot \psi_\lambda = 0.83$

$A_{f.cplumn} := 1m \cdot b = 0.273\ m^2$

$F_{w.column} := C_f \cdot q_p \cdot A_{f.cplumn} = 0.408 \cdot kN$

Force coeficient for beam RHS200x100x8м м

$d := 100mm$

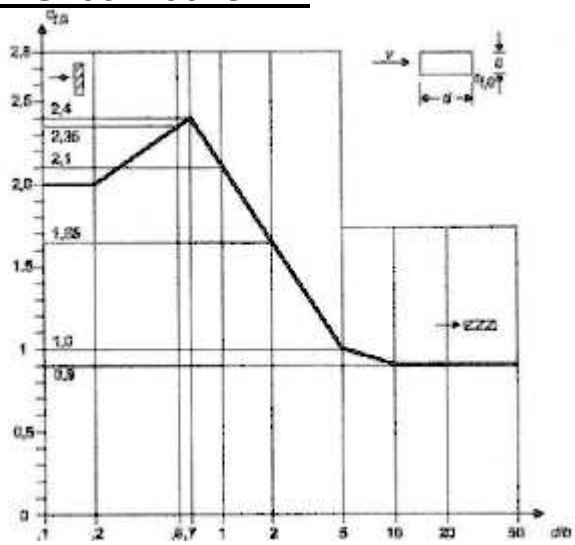
$b := 200mm$

$\frac{d}{b} = 0.5$ $\quad \psi_r := 0.80$ $\quad \psi_\lambda := 0.85$

$c_{f.0} := 2.35 \cdot \psi_r \cdot \psi_\lambda = 1.598$

$A_{ref.beam} := 1m \cdot b = 0.2\,m^2$

$F_{w.beam} := \psi_\lambda \cdot c_{f.0} \cdot q_p \cdot A_{ref.beam} = 0.489 \cdot kN$



Roll Glider Pipe CHS104x4

$b := 100mm$ - *Diameter of column*

$\nu := 15 \cdot 10^{-6} \frac{m^2}{s}$ - *Kinematic viscosity of the air*

$q_p = 1.8 \cdot \frac{kN}{m^2}$ $\quad \rho_{air} = 1.226 \frac{kg}{m^3}$

NA.2.18 Value to be used for air density ρ
[BS EN 1991-1-4:2005, 4.5 (1) Note 2]
The air density ρ should be taken as 1,226 kg/m3.

$v_{ze} := \sqrt{\frac{2 \cdot q_p}{\rho_{air}}}$

$v_{ze} = 54.188 \frac{m}{s}$

$R_e := \frac{b \cdot v_{ze}}{\nu} = 3.613 \times 10^5$

$k := 0.2mm$ equivalent roughness

$\frac{k}{b} = 2 \times 10^{-3}$

$R_e = 3.613 \times 10^5$ и $\frac{k}{b} = 2 \times 10^{-3}$ $\quad C_{f.0} := 0.8$

$\psi_\lambda := 1$

$C_f := C_{f.0} \cdot \psi_\lambda = 0.8$

$A_{f.cplumn} := 1m \cdot b = 0.1\,m^2$

$F_{w.column} := C_f \cdot q_p \cdot A_{f.cplumn} = 0.144 \cdot kN$

Platform load

zone A $\grave{A}_{up} := -1.5$

$q_p = 1.8 \cdot \frac{kN}{m^2}$

$Wp_{upward} := q_p \cdot \grave{A}_{up} = -2.7 \cdot \frac{kN}{m^2}$

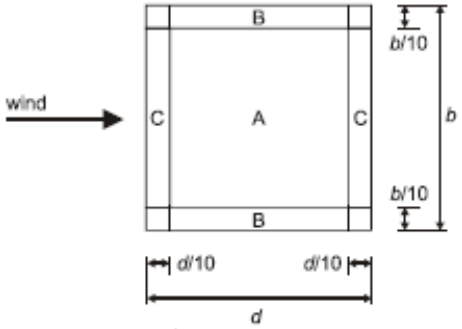
$\grave{A}_{down} := 0.5$

$Wp_{down} := q_p \cdot \grave{A}_{down} = 0.9 \cdot \frac{kN}{m^2}$

Table 7.6 — $c_{p,net}$ and c_f values for monopitch canopies

Net Pressure coefficients $c_{p,net}$

Key plan



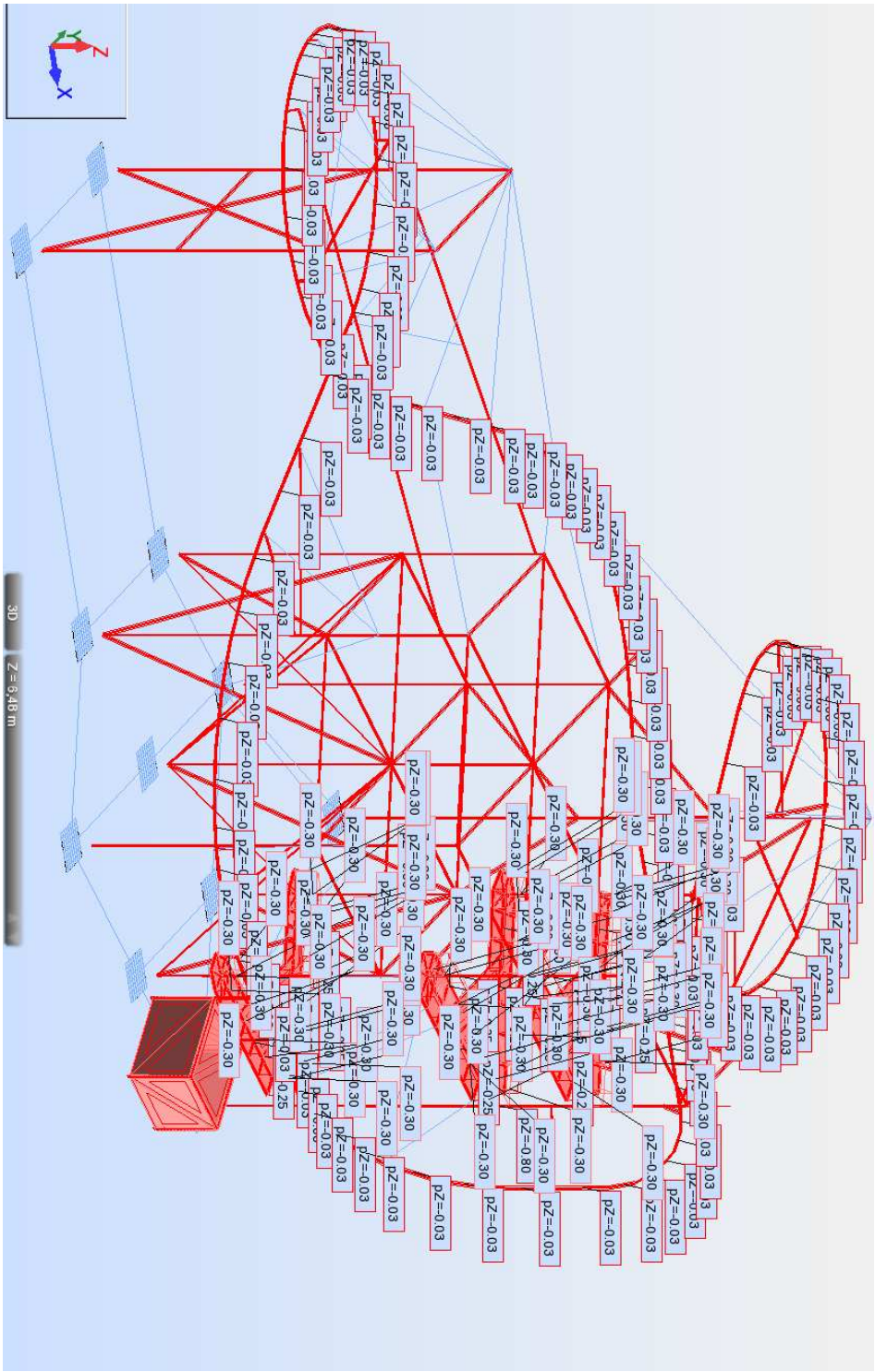
Roof angle α	Blockage φ	Overall Force Coefficients c_f	Zone A	Zone B	Zone C
0°	Maximum all φ	+ 0,2	+ 0,5	+ 1,8	+ 1,1
	Minimum $\varphi = 0$	- 0,5	- 0,6	- 1,3	- 1,4
	Minimum $\varphi = 1$	- 1,3	- 1,5	- 1,8	- 2,2
5°	Maximum all φ	+ 0,4	+ 0,8	+ 2,1	+ 1,3
	Minimum $\varphi = 0$	- 0,7	- 1,1	- 1,7	- 1,8
	Minimum $\varphi = 1$	- 1,4	- 1,6	- 2,2	- 2,5
10°	Maximum all φ	+ 0,5	+ 1,2	+ 2,4	+ 1,6
	Minimum $\varphi = 0$	- 0,9	- 1,5	- 2,0	- 2,1
	Minimum $\varphi = 1$	- 1,4	- 2,1	- 2,6	- 2,7
15°	Maximum all φ	+ 0,7	+ 1,4	+ 2,7	+ 1,8
	Minimum $\varphi = 0$	- 1,1	- 1,8	- 2,4	- 2,5
	Minimum $\varphi = 1$	- 1,4	- 1,6	- 2,9	- 3,0
20°	Maximum all φ	+ 0,8	+ 1,7	+ 2,9	+ 2,1
	Minimum $\varphi = 0$	- 1,3	- 2,2	- 2,8	- 2,9
	Minimum $\varphi = 1$	- 1,4	- 1,6	- 2,9	- 3,0
25°	Maximum all φ	+ 1,0	+ 2,0	+ 3,1	+ 2,3
	Minimum $\varphi = 0$	- 1,6	- 2,6	- 3,2	- 3,2
	Minimum $\varphi = 1$	- 1,4	- 1,5	- 2,5	- 2,8
30°	Maximum all φ	+ 1,2	+ 2,2	+ 3,2	+ 2,4
	Minimum $\varphi = 0$	- 1,8	- 3,0	- 3,8	- 3,6
	Minimum $\varphi = 1$	- 1,4	- 1,5	- 2,2	- 2,7

NOTE + values indicate a net downward acting wind action

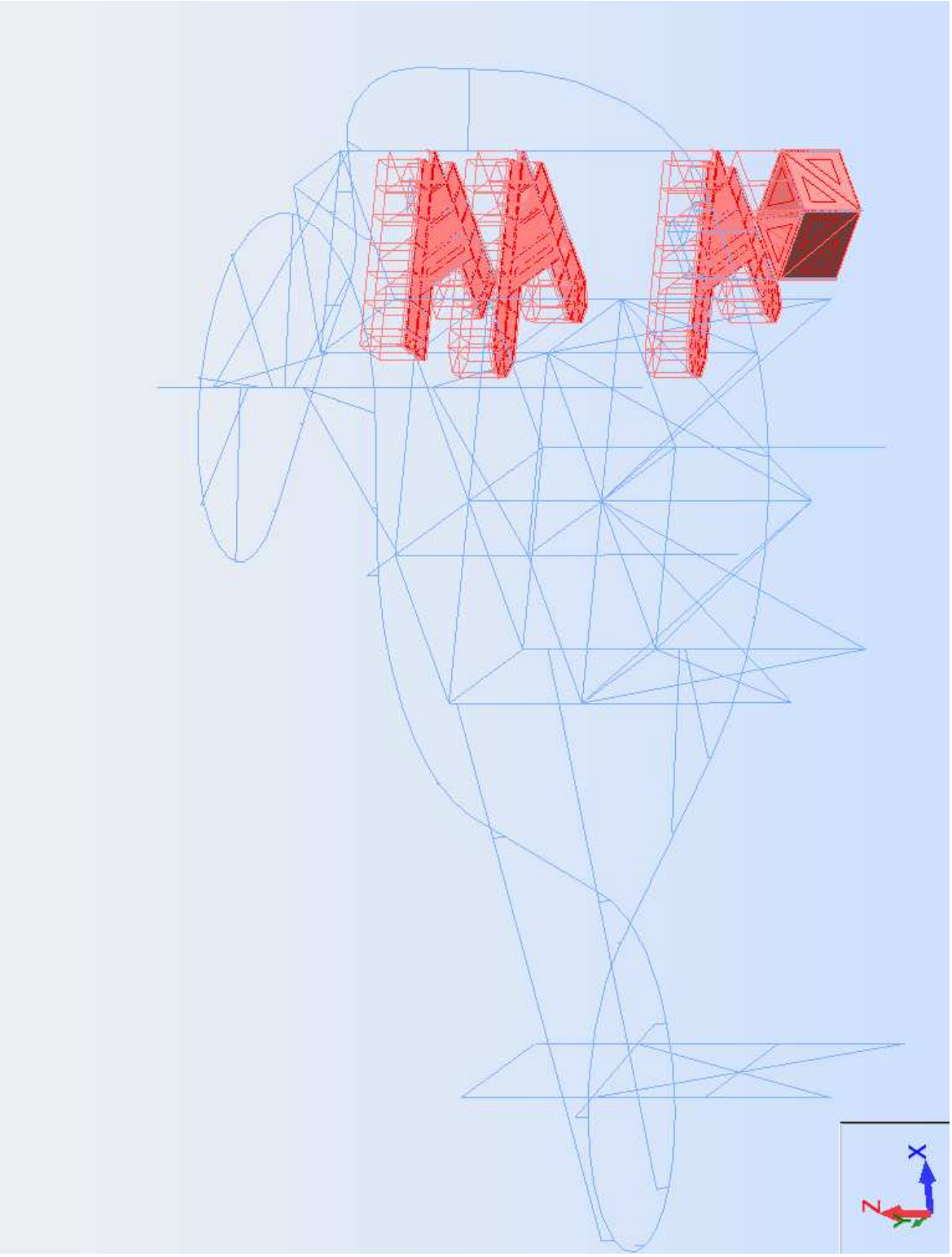
- values represent a net upward acting wind action

I. Rope course and rollglider foundation

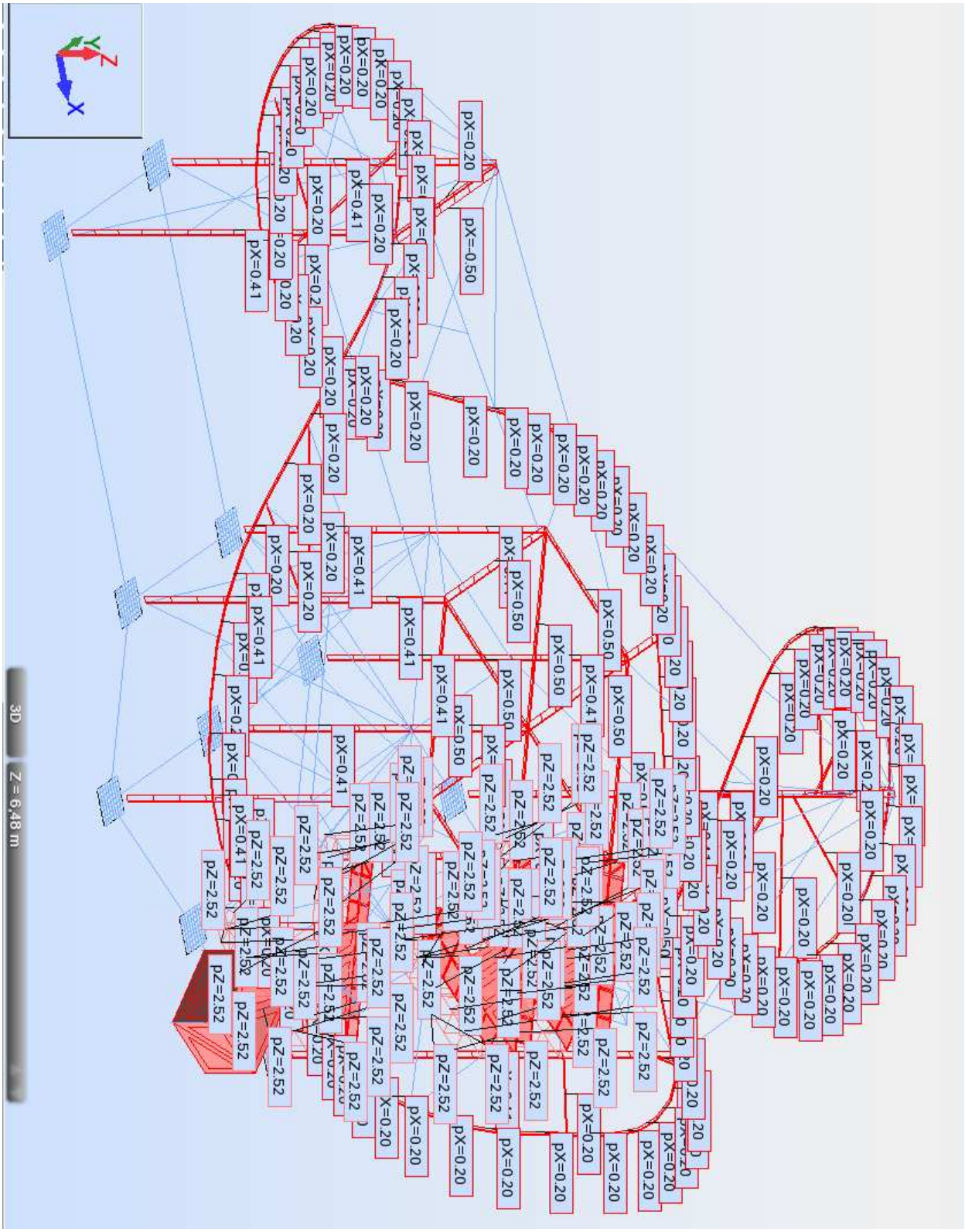
Dead Load on structure :



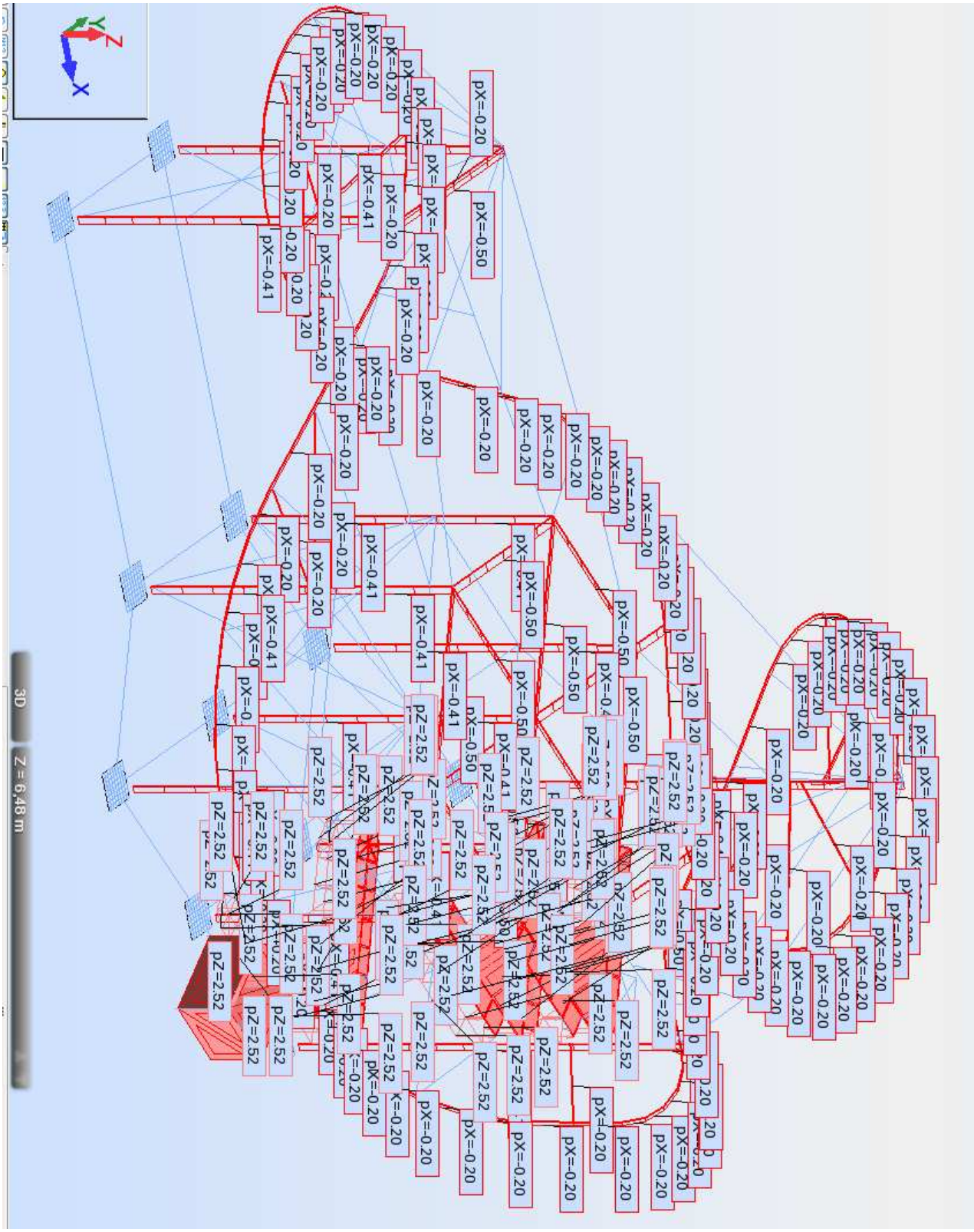
Live load on platforms : - 3 kN/m2



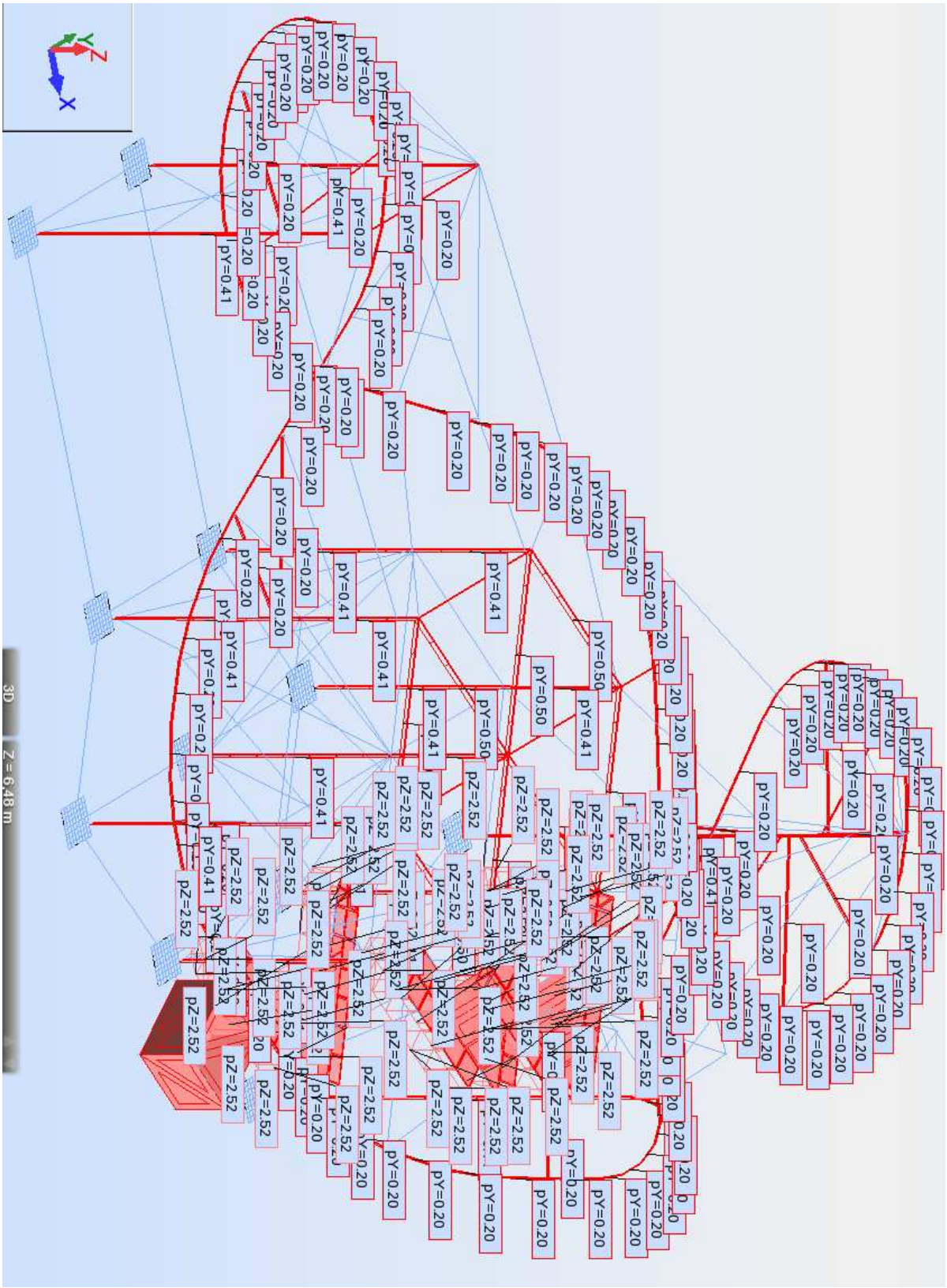
Wind load + X



Wind load -X

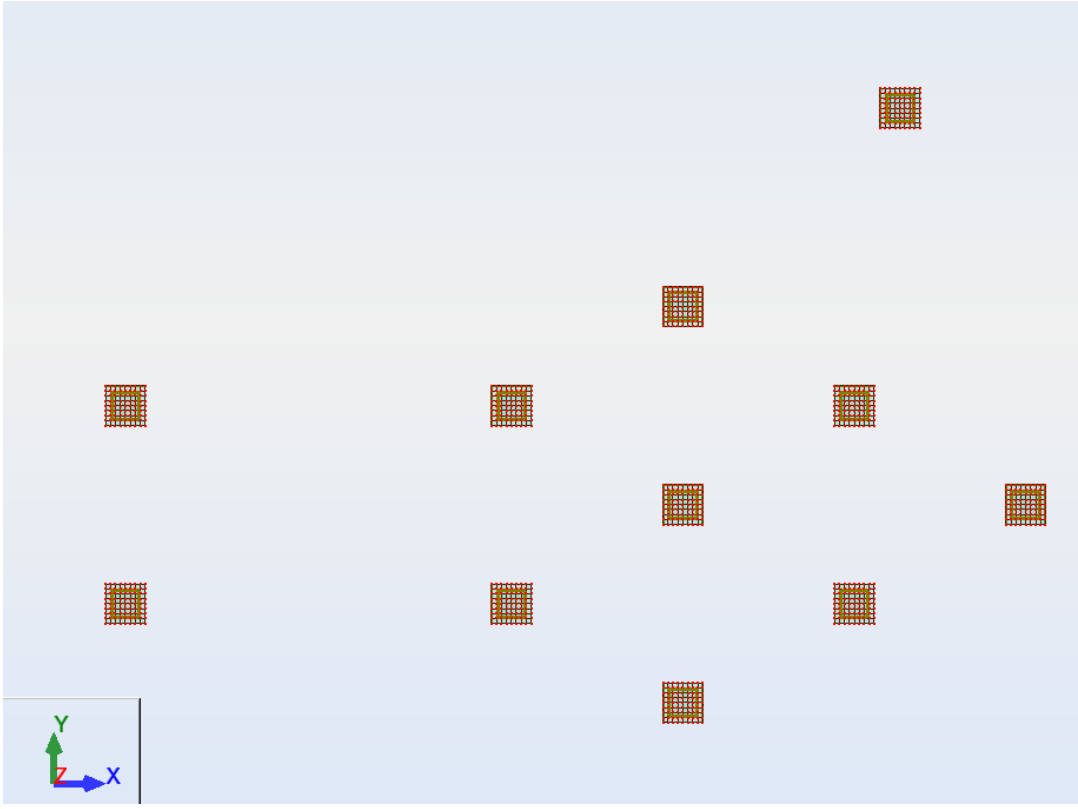


Wind load Y+



Wind load Y-

Concrete Pile caps : Dimesions 1.2x1.2x0.6m

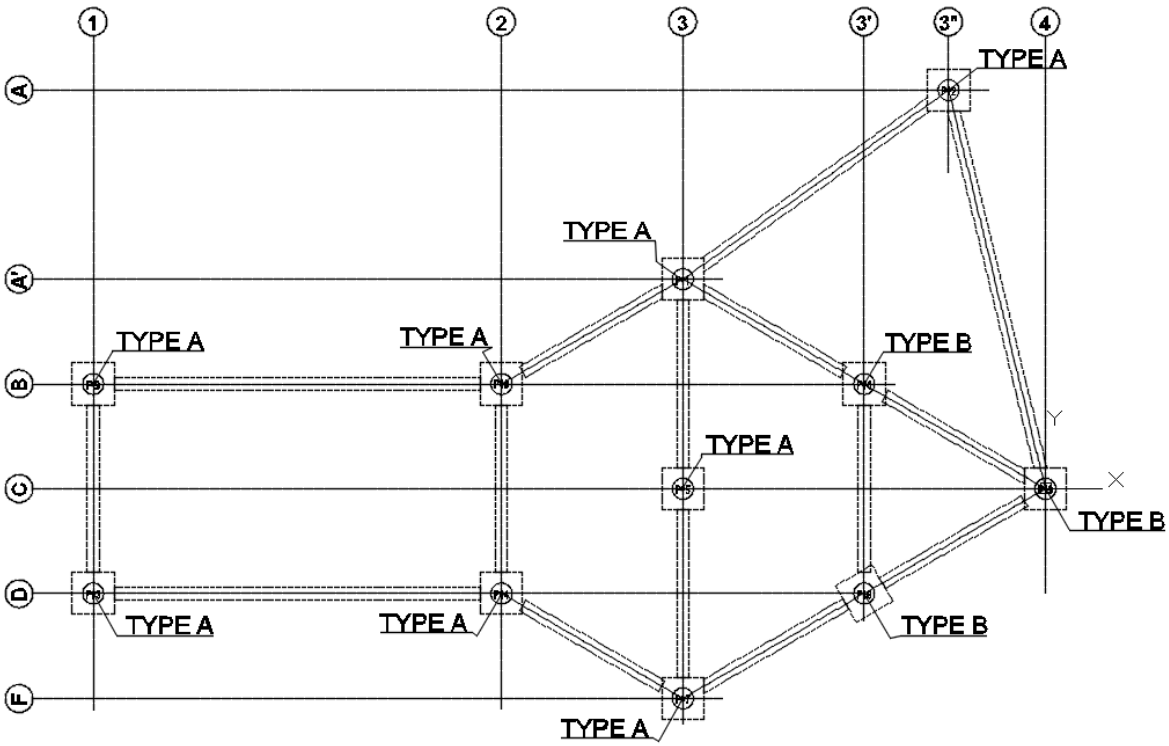


Nodes for loads on piles :

Maximum Reactions on piles from SLS combinations : (Dead Load)*1 + (Wind or Live load)*1

Pile dimension and rebar is given in the drawings.

Node	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
16889 / MAX	1,18	4,10	83,05	25,89	2,43	2,27
16889 / MIN	-1,14	-2,98	34,49	8,13	-3,80	-2,37
17281 / MAX	119,24	20,51	105,78	10,81	70,17	0,68
17281 / MIN	-104,96	-17,53	50,38	-14,71	-62,21	-0,46
17370 / MAX	1,22	1,43	96,46	-3,66	-13,97	1,77
17370 / MIN	-0,80	-1,22	50,94	-9,85	-18,69	-1,31
27318 / MAX	-0,07	51,27	139,70	-5,70	26,96	0,92
27318 / MIN	-49,05	-0,14	4,70	-38,50	-3,47	-0,90
27319 / MAX	0,70	1,49	177,92	41,61	28,17	1,66
27319 / MIN	-42,49	-59,28	-22,00	2,25	-1,97	-0,75
27322 / MAX	5,86	36,73	89,40	-8,03	-11,93	2,22
27322 / MIN	-4,98	-1,55	12,28	-36,69	-60,86	-1,68
27323 / MAX	3,96	2,35	106,48	27,96	-20,42	2,99
27323 / MIN	-4,21	-23,00	29,66	6,36	-55,40	-1,17
27408 / MAX	52,95	92,66	146,88	-8,89	29,80	0,89
27408 / MIN	-4,92	-1,29	-75,23	-70,48	-8,17	-0,70
27489 / MAX	45,94	4,07	184,02	68,14	26,57	1,00
27489 / MIN	-4,31	-92,24	-97,05	6,44	-4,74	-0,87
27570 / MAX	1,54	1,90	73,52	-52,79	3,05	1,05
27570 / MIN	-1,81	-1,42	64,91	-61,15	0,17	-1,65
27651 / MAX	9,98	1,39	213,03	43,39	42,16	0,39
27651 / MIN	-14,75	-1,62	6,79	33,36	10,94	-0,70



Bentonite piles:				
	Diameter (cm)	Net length (m)	Allowable compressionservice loads (ton)	Allowable tension service loads (ton)
Type A	60	10	16-25	7.8.2005
Type B	60	14	25-40	8.5.2014

Pile section design
Design Forces

Node	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
27408 / MIN	-8,44	-2,39	-223,32	-107,57	-12,61	-1,07
27489 / MIN	-7,55	-141,56	-219,65	8,10	-8,63	-1,53
27319 / MIN	-63,66	-88,91	-71,04	2,25	-15,16	-1,32
27651 / MIN	-21,61	-2,40	-61,90	33,36	12,61	-0,90
27318 / MIN	-73,39	-0,38	-44,47	-47,07	-18,04	-1,35
16889 / MIN	-2,54	-4,41	7,41	8,13	-7,01	-2,37
27322 / MIN	-7,64	-2,27	11,55	-40,97	-85,77	-2,62
27323 / MIN	-6,31	-34,74	14,01	6,36	-77,39	-1,87
17370 / MIN	-1,34	-1,79	26,28	-12,18	-26,15	-2,64
17281 / MIN	-157,54	-30,27	38,13	-20,03	-93,16	-0,72
27570 / MIN	-2,76	-2,10	62,52	-80,86	-2,01	-1,65
27570 / MAX	2,42	2,26	100,46	-51,28	7,87	1,59
27322 / MAX	8,70	36,81	125,22	-6,78	0,50	3,34
27323 / MAX	5,88	2,45	127,74	40,14	-12,07	3,64
16889 / MAX	2,75	4,10	130,45	35,92	7,18	3,48
17370 / MAX	2,04	1,43	144,07	-2,57	-9,13	2,67
17281 / MAX	178,80	30,43	171,47	18,07	105,03	1,02
27318 / MAX	1,35	66,45	198,42	-5,32	40,21	1,01
27408 / MAX	79,29	145,67	221,37	-9,38	44,69	1,36
27319 / MAX	1,39	1,49	255,61	61,42	38,86	2,63
27489 / MAX	68,88	6,02	262,93	101,21	39,56	1,47
27651 / MAX	15,34	1,39	303,69	59,19	57,61	0,72

Concete grade C30/37 is used for the calculations – the concrete in the final drawing will be with cubic compression strenght 40 Mpa
Rebar steel used B400 , fy = 400Mpa

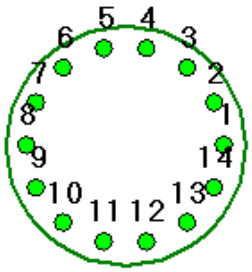
General

Design code: Eurocode 2
Analysis: Check section

Loads: N, Mx, My

N>0 is compression !

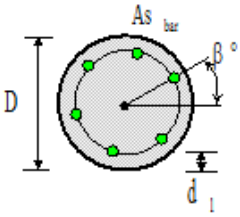
Section



Data [cm]

D =60

d1 =5



Materials

Concrete: C30/37
SSR: Rectangular

fck = 30.00 MPa
Ec = 31938.77 MPa
ecu = -3.500 o/oo

Reinforcing steel: S400
SSR: Standard

fyk = 400.00 MPa
Es = 200000.00 MPa
esu = 10.000 o/oo

Factors

Concrete: gama_c = 1.50
Steel: gama_s = 1.15

Reinforcement

Bars =14
beta = 0.00 deg
As,bar =3.14cm2

Loads

Load	N [kN]	Mx [kNm]	My [kNm]
L1	-223.32	-107.57	-12.61

Solve data

II order moments: No

Results: Legend

Np, Mp - Maximal permissible loads

Ratio = Applied load / Maximal permissible load

Load	Np [kN]	Mxp[kNm]	Myp[kNm]	Ratio	Permissible
L1	-494.71	-238.29	-27.93	0.451	Yes

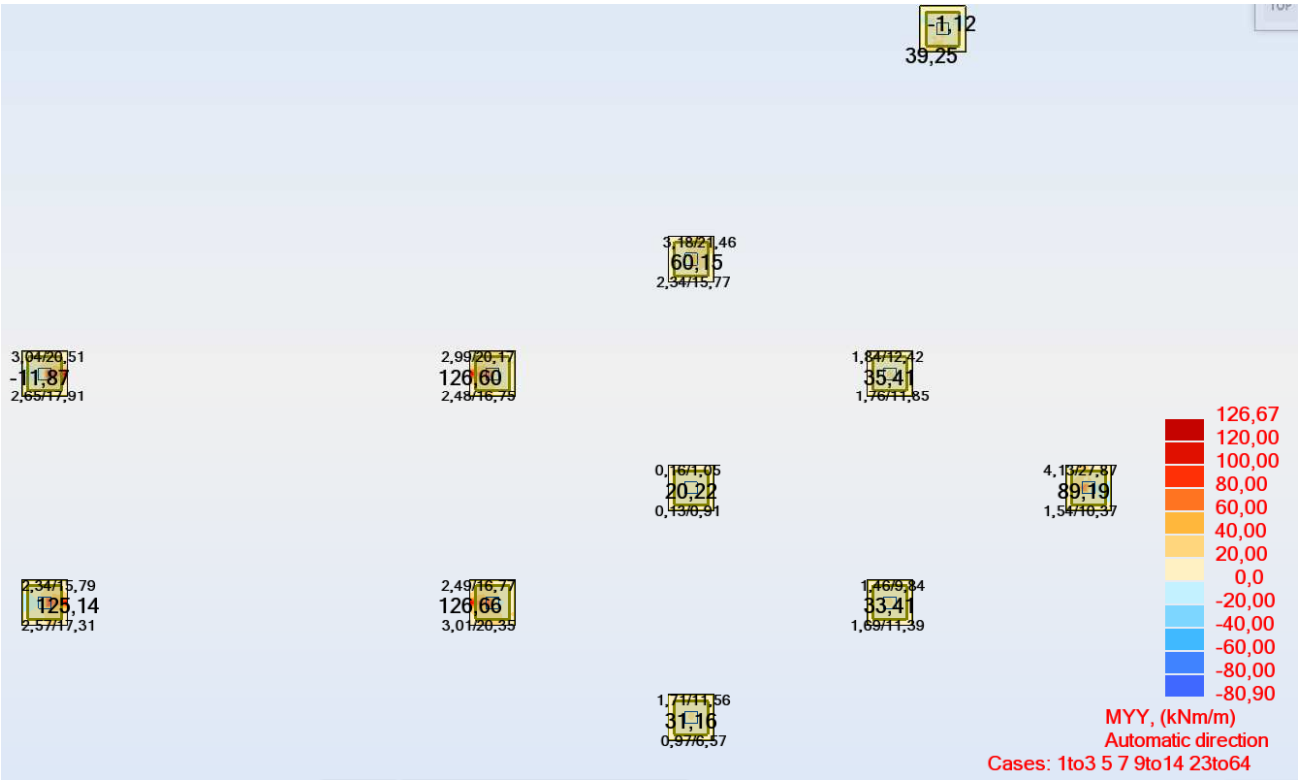
Section properties

Reinforcement :

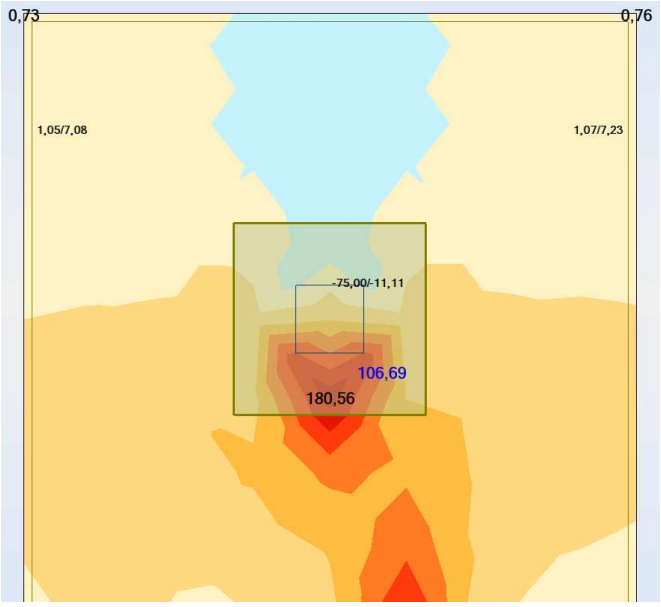
```
As,tot = 43.96 cm2

Concrete section:

Ac     = 2822.27 cm2
Ic,x   = 633850.86 cm4
Ic,y   = 633850.86 cm4

R/C section:

Ared   = 3053.59 cm2
Ired,x = 706137.35 cm4
Ired,y = 706137.35 cm4
rx     = 15.21 cm
ry     = 15.21 cm
```

Pile Cap Desing : (From ULS combinations - Envelope)

Bending moments


126,67
120,00
100,00
80,00
60,00
40,00
20,00
0,0
-20,00
-40,00
-60,00
-80,00
-80,90
MYY, (kNm/m)
Automatic direction
Cases: 1to3 5 7 9to14 23to64

86,03
72,50
58,00
43,50
29,00
14,50
0,0
-14,50
-29,00
-43,50
-58,00
-72,50
-75,44
MXY, (kNm/m)
Automatic direction
Cases: 1to3 5 7 9to14 23to64



Moment on edge of pile 106.69

Concrete punching cannot appear because the punching perimeter is outside the pile cap dimensions

Concete grade C30/37 is used for the calculations – the concrete in the final drawing will be with cubic compression strenght 40 Mpa
Rebar steel used B400 , fy = 400Mpa

Design of section

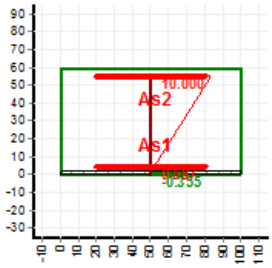
General

Design code: Eurocode 2
Analysis: Design section

Loads: N, Mx

N>0 is compression !

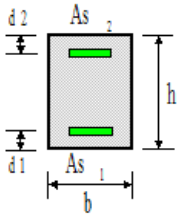
Section



Data [cm]

b =100
h =60

d1 =5
d2 =5



Materials

Concrete: C30/37
SSR: Rectangular

fck = 30.00 MPa
Ec = 31938.77 MPa
ecu = -3.500 o/oo

Reinforcing steel: S400
SSR: Standard

fyk = 400.00 MPa
Es = 200000.00 MPa
esu = 10.000 o/oo

Factors

Concrete: gama_c = 1.50
Steel: gama_s = 1.15

Reinforcement

Symmetric: As1=As2

Loads

Load	N [kN]	Mx [kNm]
L1	0	106.69

Solve data

II order moments: No

Results

	Area [cm2]	esi [o/oo]	Stress [MPa]
As2	5.51	10.000	347.83
As1	5.51	0.587	117.31

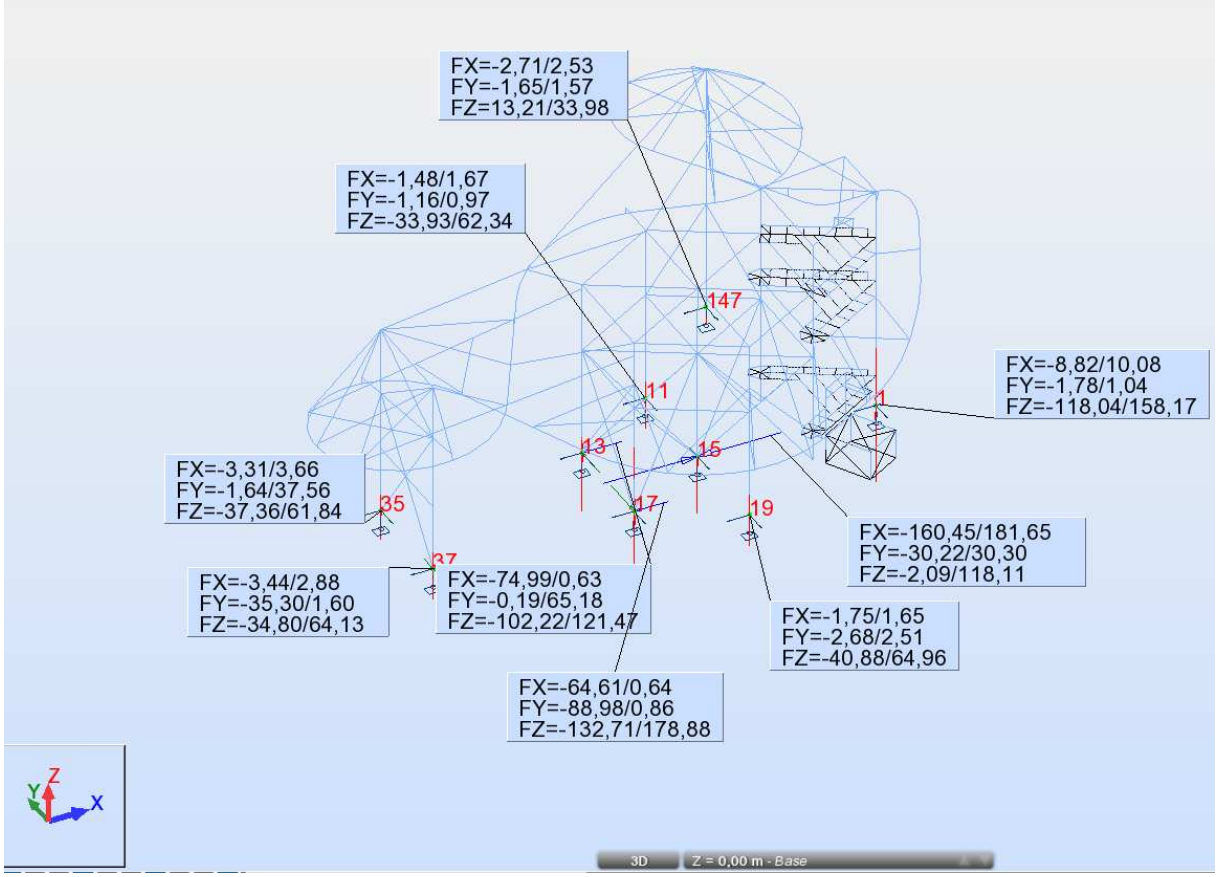
Concrete strain: ec,min = -0.355 o/oo
Compressive zone depth: x = 1.88 cm

Total reinf. area: As_tot = 11.02 cm2
Reinf. ratio: 0.18 %

As,prov = 7.69cm2

Base detail calculation :

1. Chemical anchor bases : Envelope forces

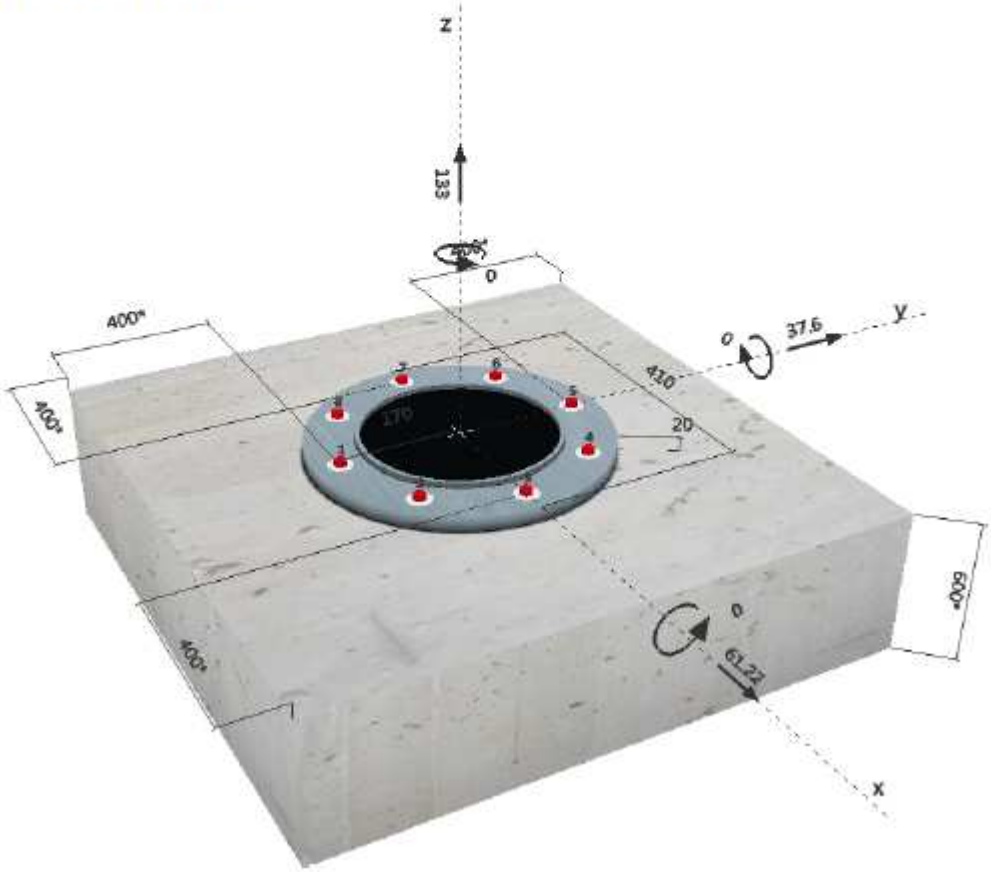


Node	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
17 / MIN	-64,61	-88,98	-132,71	-0,00	-0,00	-1,29
1 / MIN	-8,82	-1,78	-118,04	-0,00	-0,00	-1,01
13 / MIN	-74,99	-0,19	-102,22	-0,00	-0,00	-1,37
19 / MIN	-1,75	-2,68	-40,88	-0,00	-0,00	-2,38
35 / MIN	-3,31	-1,64	-37,36	-0,00	-0,00	-2,80
37 / MIN	-3,44	-35,30	-34,80	-0,00	-0,00	-1,97
11 / MIN	-1,48	-1,16	-33,93	-0,00	-0,00	-2,65
15 / MIN	-160,45	-30,22	-2,09	-0,00	-0,00	-0,78
147 / MIN	-2,71	-1,65	13,21	-0,00	-0,00	-1,64
147 / MAX	2,53	1,57	33,98	0,00	0,00	1,58
35 / MAX	3,66	37,56	61,84	0,00	0,00	3,49
11 / MAX	1,67	0,97	62,34	0,00	0,00	2,68
37 / MAX	2,88	1,60	64,13	0,00	0,00	3,75
19 / MAX	1,65	2,51	64,96	0,00	0,00	3,46
15 / MAX	181,65	30,30	118,11	0,00	0,00	1,06
13 / MAX	0,63	65,18	121,47	0,00	0,00	1,00
1 / MAX	10,08	1,04	158,17	0,00	0,00	0,82
17 / MAX	0,64	0,86	178,88	0,00	0,00	2,61

1 Input data

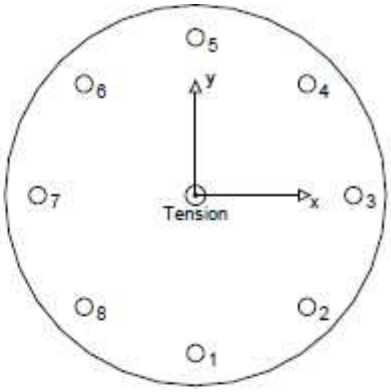
Anchor type and diameter:	**HIT-HY 200-A + HIT-V (8.8) M16**
Dynamic set or any suitable annular gap filling solution	
Effective embedment depth:	$h_{ef,opt}$ = 248 mm ($h_{ef,limit}$ = 320 mm)
Material:	8.8
Evaluation Service Report:	ETA 11/0493
Issued I Valid:	8.8.2012 r. | 23.12.2016 r.
Proof:	design method Engineering judgement SOFA BOND - based on ETAG BOND testing
Stand-off installation:	e_b = 0 mm (no stand-off); t = 20 mm
Anchor plate:	l_x x l_y x t = 410 mm x 410 mm x 20 mm; (Recommended plate thickness: not calculated)
Profile:	Pipe; (L x W x T) = 273 mm x 273 mm x 6 mm
Base material:	uncracked concrete, C20/25, f_c = 25.00 N/mm²; h = 600 mm, Temp. short/long: 40/24 °C
Installation:	hammer drilled hole, installation condition: dry
Reinforcement:	no reinforcement or reinforcement spacing >= 150 mm (any Ø) or >= 100 mm (Ø <= 10 mm)
	no longitudinal edge reinforcement
	Reinforcement to control splitting according to EOTA TR 029, 5.2.2.6 present.

Geometry [mm] & Loading [kN, kNm]



2 Load case/Resulting anchor forces

Load case: Design loads



Anchor reactions [kN]
Tension force: (+Tension, -Compression)

Anchor	Tension force	Shear force	Shear force x	Shear force y
1	16.625	8.981	7.653	4.700
2	16.625	8.981	7.653	4.700
3	16.625	8.981	7.653	4.700
4	16.625	8.981	7.653	4.700
5	16.625	8.981	7.653	4.700
6	16.625	8.981	7.653	4.700
7	16.625	8.981	7.653	4.700
8	16.625	8.981	7.653	4.700

max. concrete compressive strain: - [‰]
max. concrete compressive stress: - [N/mm²]
resulting tension force in (x/y)=(0/0): 133.000 [kN]
resulting compression force in (x/y)=(0/0): 0.000 [kN]

3 Tension load (EOTA TR 029, Section 5.2.2)

	Load [kN]	Capacity [kN]	Utilization β_N [%]	Status
Steel Strength*	16.625	84.000	20	OK
Combined pullout-concrete cone failure**	133.000	347.967	39	OK
Concrete Breakout Strength**	133.000	221.119	61	OK
Splitting failure**	N/A	N/A	N/A	N/A

* anchor having the highest loading **anchor group (anchors in tension)

3.1 Steel Strength

$N_{Rk,s}$ [kN]	$\gamma_{M,s}$	$N_{Rd,s}$ [kN]	N_{Sd} [kN]
126.000	1.500	84.000	16.625

3.2 Combined pullout-concrete cone failure

$A_{p,N}$ [mm²]	$A^0_{p,N}$ [mm²]	$\tau_{Rk,ucr,25}$ [N/mm²]	$s_{cr,Np}$ [mm]	$c_{cr,Np}$ [mm]	c_{min} [mm]
686006	273067	20.00	523	261	400

ψ_c	$\tau_{Rk,ucr}$ [N/mm²]	k	$\psi^0_{g,Np}$	$\psi_{g,Np}$
1.000	20.00	3.200	1.000	1.000

$e_{c1,N}$ [mm]	$\psi_{ec1,Np}$	$e_{c2,N}$ [mm]	$\psi_{ec2,Np}$	$\psi_{s,Np}$	$\psi_{re,Np}$
0	1.000	0	1.000	1.000	1.000

$N^0_{Rk,p}$ [kN]	$N_{Rk,p}$ [kN]	$\gamma_{M,p}$	$N_{Rd,p}$ [kN]	N_{Sd} [kN]
249.317	626.341	1.800	347.967	133.000

3.3 Concrete Breakout Strength

$A_{c,N}$ [mm²]	$A^0_{c,N}$ [mm²]	$c_{cr,N}$ [mm]	$s_{cr,N}$ [mm]
1117056	553536	372	744

$e_{c1,N}$ [mm]	$\psi_{ec1,N}$	$e_{c2,N}$ [mm]	$\psi_{ec2,N}$	$\psi_{s,N}$	$\psi_{re,N}$	k_1
0	1.000	0	1.000	1.000	1.000	10.100

$N^0_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Sd} [kN]
197.228	1.800	221.119	133.000

4 Shear load (EOTA TR 029, Section 5.2.3)

	Load [kN]	Capacity [kN]	Utilization β_V [%]	Status
Steel Strength (without lever arm)*	8.981	50.400	18	OK
Steel failure (with lever arm)*	N/A	N/A	N/A	N/A
Pryout Strength**	71.845	530.685	14	OK
Concrete edge failure in direction x+**	62.823	95.505	66	OK

* anchor having the highest loading **anchor group (relevant anchors)

4.1 Steel Strength (without lever arm)

$V_{Rk,s}$ [kN]	$\gamma_{M,s}$	$V_{Rd,s}$ [kN]	V_{Sd} [kN]
63.000	1.250	50.400	8.981

4.2 Pryout Strength (Concrete Breakout Strength controls)

$A_{c,N}$ [mm²]	$A^0_{c,N}$ [mm²]	$c_{cr,N}$ [mm]	$s_{cr,N}$ [mm]	k-factor
1117056	553536	372	744	2.000

$e_{c1,V}$ [mm]	$\psi_{ec1,N}$	$e_{c2,V}$ [mm]	$\psi_{ec2,N}$	$\psi_{s,N}$	$\psi_{re,N}$
0	1.000	0	1.000	1.000	1.000

$N^0_{Rk,c}$ [kN]	$\gamma_{M,c,p}$	$V_{Rd,cf}$ [kN]	V_{Sd} [kN]
197.228	1.500	530.685	71.845

4.3 Concrete edge failure in direction x+

l_f [mm]	d_{nom} [mm]	k_1	α	β
248	16.0	2.400	0.079	0.053

c_1 [mm]	$A_{c,V}$ [mm²]	$A^0_{c,V}$ [mm²]
400	684000	720000

$\psi_{s,V}$	$\psi_{h,V}$	$\psi_{ec,V}$	$e_{c,V}$ [mm]	$\psi_{ec,V}$	$\psi_{re,V}$
0.925	1.000	1.022	0	1.000	1.000

$V^0_{Rk,c}$ [kN]	$\gamma_{M,c}$	$V_{Rd,c}$ [kN]	V_{Sd} [kN]
159.539	1.500	95.505	62.823

5 Combined tension and shear loads (EOTA TR 029, Section 5.2.4)

β_N	β_V	α	Utilization $\beta_{N,V}$ [%]	Status
0.601	0.658	1.500	100	OK

$\beta_N^\alpha + \beta_V^\alpha <= 1$

6 Displacements (highest loaded anchor)

Short term loading:

N_{Sk} = 12.315 [kN] δ_N = 0.040 [mm]

V_{Sk} = 15.512 [kN] δ_V = 0.620 [mm]

δ_{NV} = 0.622 [mm]

Long term loading:

N_{Sk} = 12.315 [kN] δ_N = 0.079 [mm]

V_{Sk} = 15.512 [kN] δ_V = 0.931 [mm]

δ_{NV} = 0.934 [mm]

Comments: Tension displacements are valid with half of the required installation torque moment for uncracked concrete! Shear displacements are valid without friction between the concrete and the anchor plate! The gap due to the drilled hole and clearance hole tolerances are not included in this calculation!

The acceptable anchor displacements depend on the fastened construction and must be defined by the designer!

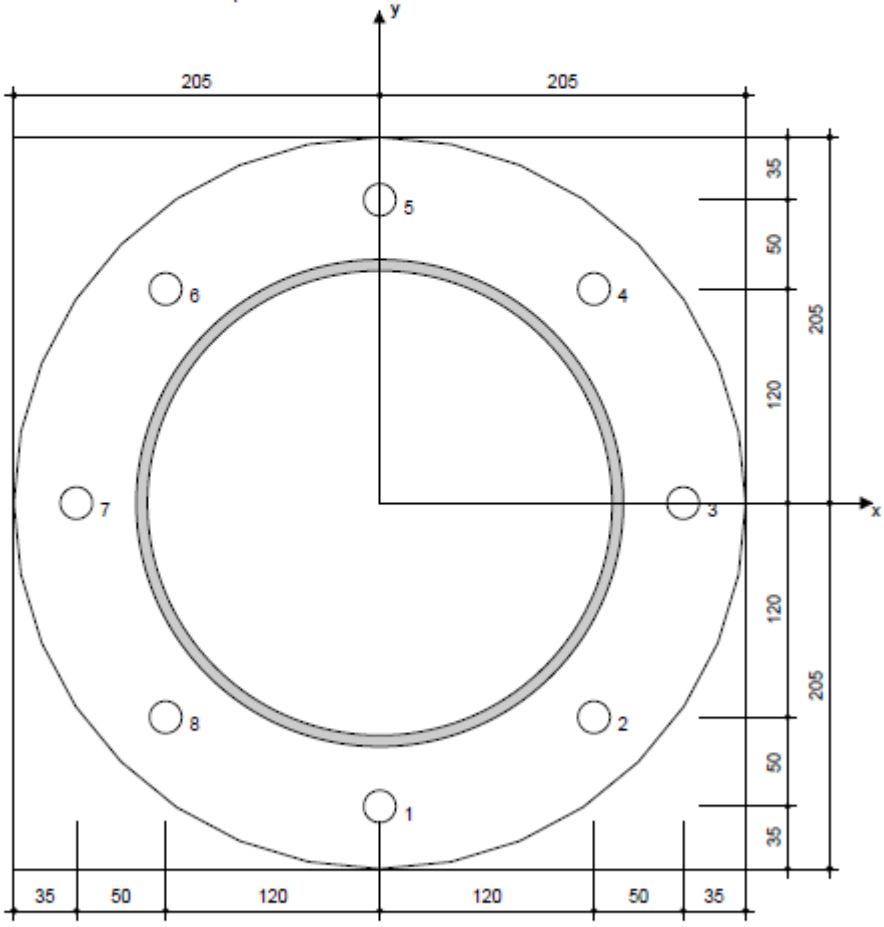
8 Installation data

Anchor plate, steel: -
Profile: Pipe; 273 x 273 x 6 mm
Hole diameter in the fixture: d_f = 18 mm
Plate thickness (input): 20 mm
Recommended plate thickness: not calculated
Cleaning: Premium cleaning of the drilled hole is required

Anchor type and diameter: HIT-HY 200-A + HIT-V (8.8) M16
Installation torque: 0.080 kNm
Hole diameter in the base material: 18 mm
Hole depth in the base material: 248 mm
Minimum thickness of the base material: 284 mm

8.1 Required accessories

Drilling	Cleaning	Setting
• Suitable Rotary Hammer • Properly sized drill bit	• Compressed air with required accessories to blow from the bottom of the hole • Proper diameter wire brush	• Dispenser including cassette and mixer • Dynamic set • Torque wrench

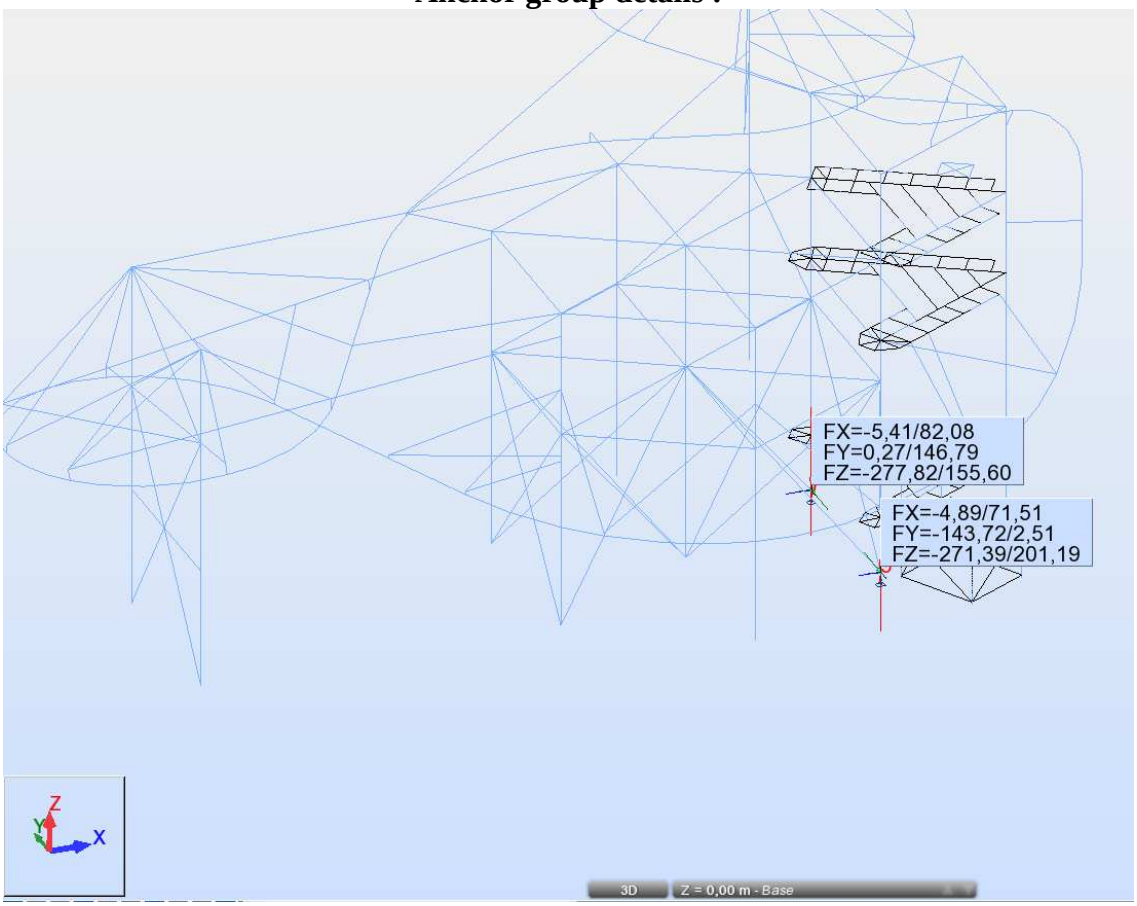


Coordinates Anchor [mm]

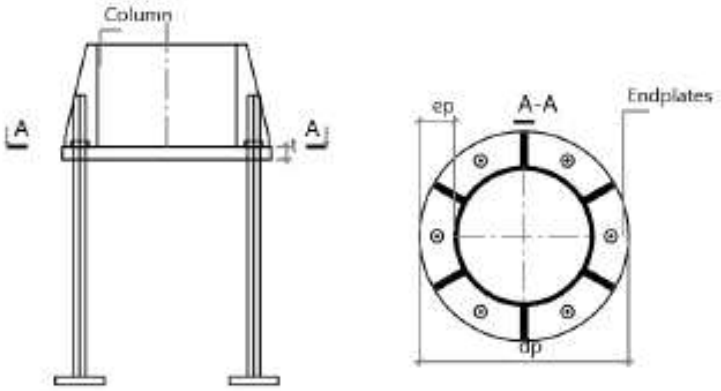
Anchor	x	y	c_{-x}	c_{+x}	c_{-y}	c_{+y}
1	0	-170	570	570	400	740
2	120	-120	690	450	450	690
3	170	0	740	400	570	570
4	120	120	690	450	690	450

Anchor	x	y	c_{-x}	c_{+x}	c_{-y}	c_{+y}
5	0	170	570	570	740	400
6	-120	120	450	690	690	450
7	-170	0	400	740	570	570
8	-120	-120	450	690	450	690

Anchor group details :



Node	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
7 / MIN	-5,41	0,27	-277,82	-0,00	-0,00	-0,95
9 / MIN	-4,89	-143,72	-271,39	-0,00	-0,00	-1,76
7 / MAX	82,08	146,79	155,60	0,00	0,00	1,22
9 / MAX	71,51	2,51	201,19	0,00	0,00	1,74



General Information

Column: TRON 273x6,3

Material:	S 235	
D_{b1} =	273 mm	Column diameter
t_{p1} =	6,3 mm	Section thickness
A_b =	52,79 cm²	Section area
I_{by} =	4695,82 cm⁴	Moment of inertia
W_{pl} =	448,18 cm³	Plastic section modulus
W =	344,02 cm³	Elastic section modulus
f_{yb} =	235 MPa	Resistance

Endplate:

Material:	S 235	
dp =	410 mm	Plate diameter
tp =	25 mm	Plate thickness
f_{yp} =	235 MPa	Resistance

Stiffeners:

Material:	S 235	
h =	200 mm	Height of stiffener
h1 =	20 mm	Lower height
l1 =	20 mm	Length of upper part of the stiffener
es =	5 mm	Shift
ts	12 mm	Thicknes of stiffeners

Anchorage:

Class:	8.8	
Type:	Plate	
d =	24 mm	Diameter
h =	550 mm	Length of anchor bolt
heff =	450 mm	Effective length of an anchor bolt
n =	6	Number of anchor bolts
e1 =	34,25 mm	Distance from profile to bolts
e2 =	34,25 mm	Distance from bolts to edge of endplate
p2 =	60 Deg	Angle between bolts

Welds:

a =	5 mm	Weld thickness
asv =	5 mm	Thickness of weld between column and stiffeners
ash =	5 mm	Thickness of weld between column base plate and stiffener

Foundation:

Hf =	600 mm	Foundation height
Wf =	1200 mm	Foundation width
Lf =	1200 mm	Foundation length
t_g =	50 mm	Thickness of leveling layer (grout)
$f_{ck,f}$ =	25 MPa	Characteristic resistance - concrete
$f_{ck,g}$ =	25 MPa	Characteristic resistance - grout
Y_C =	1,5	Partial safety factor
$C_{f,g}$ =	0,5	Friction coefficient - grout

Safety factors:

γ_{M0} =	1
γ_{M1} =	1
γ_{M2} =	1,25
γ_{M3} =	1,25

Case: Case 1:

Nodal forces:

N =	271 kN	Axial force
M =	0 kNm	Bending moment
V =	144 kN	Shear force

Capacity verification

Results of calculations

Resistances of components

$F_{t,Rd}$ =	203,33 kN	Tension resistance of single anchor bolt	[tab.3.4]
$F_{t,Rd,p}$ =	91,38 kN	Resistance for pulling out of concrete	EN 1992-1-1 [8.4.2]
$F_{vj,Rd}$=	71,8 kN	Total shear capacity of anchor bolt	EN 1993-1-8 [6.2.2(7)]
$M_{c,Rd}$ =	112,08 kNm	Design resistance of the section for bending	EN 1993-1-1 [6.2.5]
Class:	1	Section class	EN 1993-1-1 [5.5.2]

Tension resistance

Resistances of components

$F_{T1,Rd}$ =	1988,87 kN	Complete endplate yielding	NCCI: SN04a-EN-EU
$F_{T2,Rd}$ =	803,38 kN	Bolt failure with endplate yielding	NCCI: SN04a-EN-EU
$F_{T3,Rd}$ =	548,27 kN	Bolt failure	NCCI: SN04a-EN-EU

Tension capacity of connection

$$N_{j,Rd} = \min(F_{T1,Rd}, F_{T2,Rd}, F_{T3,Rd})$$

$$N_{j,Rd} = 548{,}27 \text{ kN}$$

Verification of tension capacity :

$N/N_{j,Rd} = 0{,}49 < 1.0$ The condition is satisfied (49%)

Shear verification

$F_{v,Rd}$ =	71,8 kN	Shear capacity of anchor bolt	[6.2.2(7)]
$F_{b,Rd}$ =	150,88 kN	Bearing capacity of anchor bolt	[tab.3.4]
$F_{vj,Rd}$ =	71,8 kN	Total shear capacity of anchor bolt	
$F_{f,Rd}$ =	0 kN	Slip capacity of node	[6.2.2(6)]

Shear capacity of connection:

$$V_{j,Rd} = n^{*}F_{vj,Rd} + F_{f,Rd} + F_{v,Rd,wg,y}$$

$$V_{j,Rd} = 430{,}82 \text{ kN}$$

Verification of shear capacity :

$V/V_{j,Rd} = 0{,}33 < 1.0$ The condition is satisfied (33%)

Welds control

A_w =	87,47 cm²	Total area of welds
A_{wy} =	66,25 cm²	Area of vertical welds
I_{wy} =	10438,47 cm⁴	Moment of inertia of welds about Y axis
$\sigma_{perp} = \tau_{perp}$ =	21,91 MPa	Perpendicular stress in welds
τ_{par} =	21,74 MPa	Parallel stress in welds

β_w = 0,8 Appropriate correlation factor [ta

Sqrt $[(\sigma_{perp}^2 + 3(\tau_{perp}^2 + \tau_{par}^2)]$ <= $f_u / (\beta_w * \gamma_{M2})$; 57,77 MPa < 360 MPa The condition is satisfied (16%)

σ_{perp} <= $0,9*f_u / \gamma_{M2}$; 21,91 MPa < 259,2 MPa The condition is satisfied (8%)

Additional condition

$N/N_{t,Rd}$ = 0,12 < 1.0 The condition is satisfied

$V/V_{c,Rd}$ = 0,22 < 1.0 The condition is satisfied

Final verification

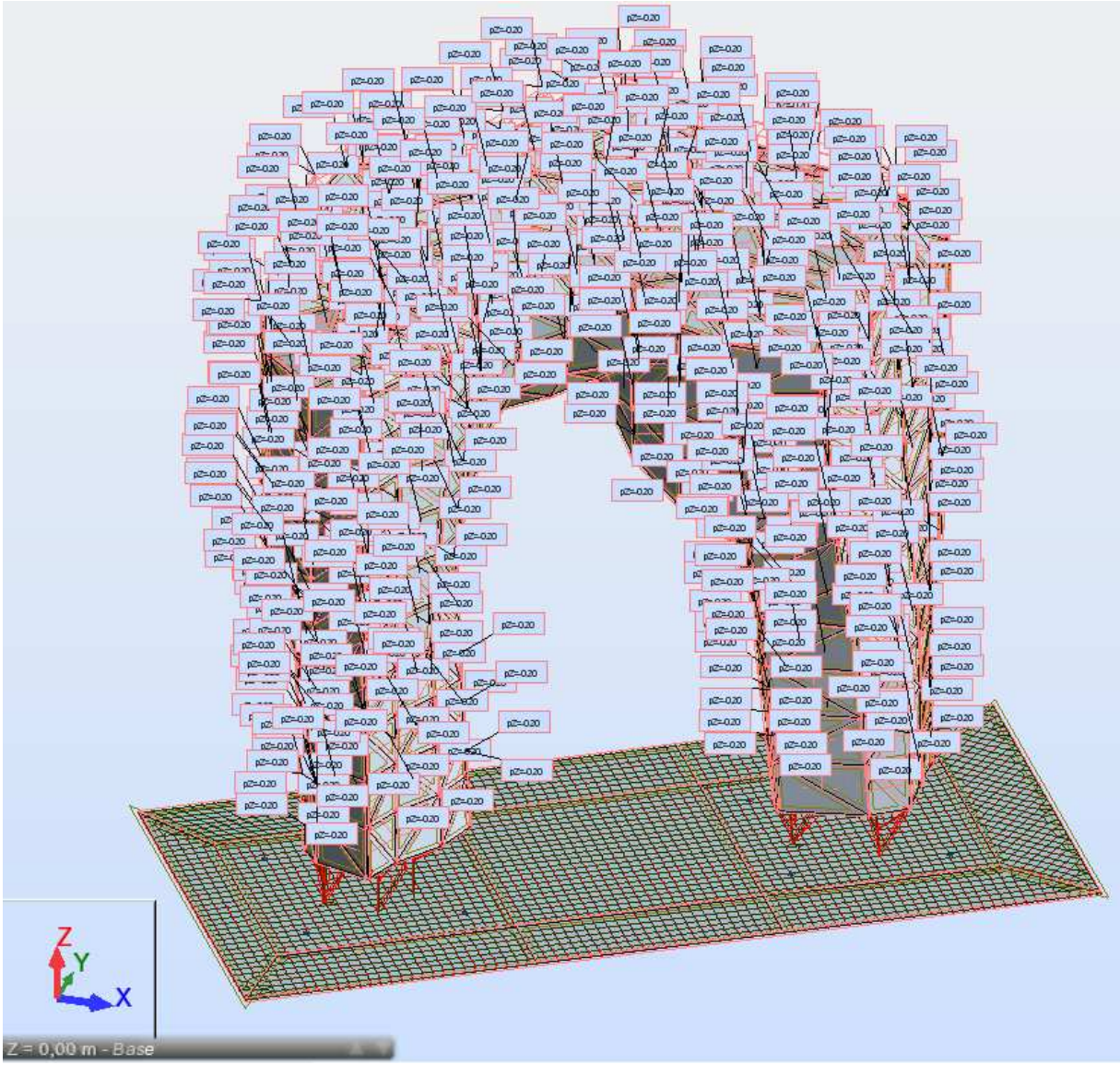
Connection verification:

Verification of connection	F_{Ed} – force	F_{Rd} - capacity	Ratio F_{Ed}/F_{Rd}
Tension capacity	N = 271 kN	$N_{j,Rd}$ = 548,27 kN	49%
Shear capacity	V = 144 kN	$V_{j,Rd}$ = 430,82 kN	33%
Welds	57,77 MPa	360 MPa	16%
Tension capacity of column	N = 271 kN	$N_{t,Rd}$ = 2314,88 kN	12%
Shear capacity of column	V = 144 kN	$V_{c,Rd}$ = 662,71 kN	22%

The connection conforms to the (EN 1993-1-8:2005/AC:2009)

II. Climbing tower foundation

Dead load : GRP Pannels – 0.2 kN/m2



Wind loads – the structure has been designed as a shed structure

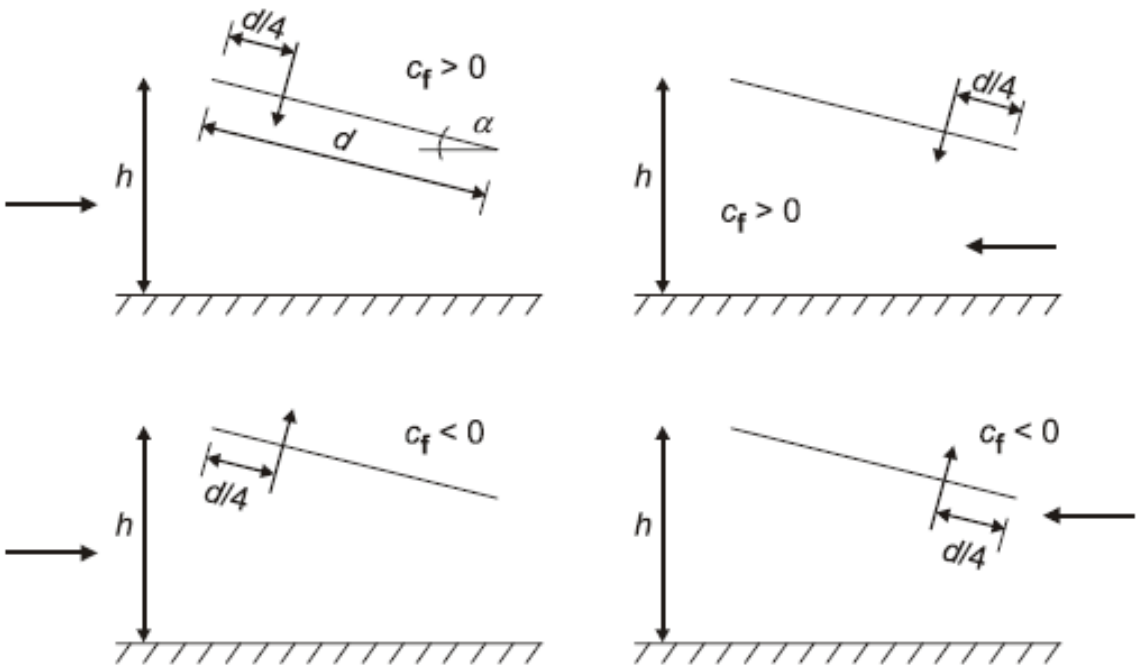
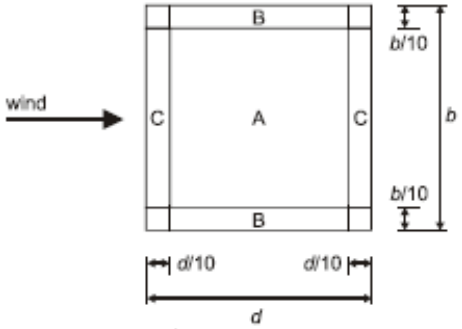


Figure 7.16 — Location of the centre of force for monopitch canopies

Table 7.6 — $c_{p,net}$ and c_f values for monopitch canopies

Net Pressure coefficients $c_{p,net}$

Key plan

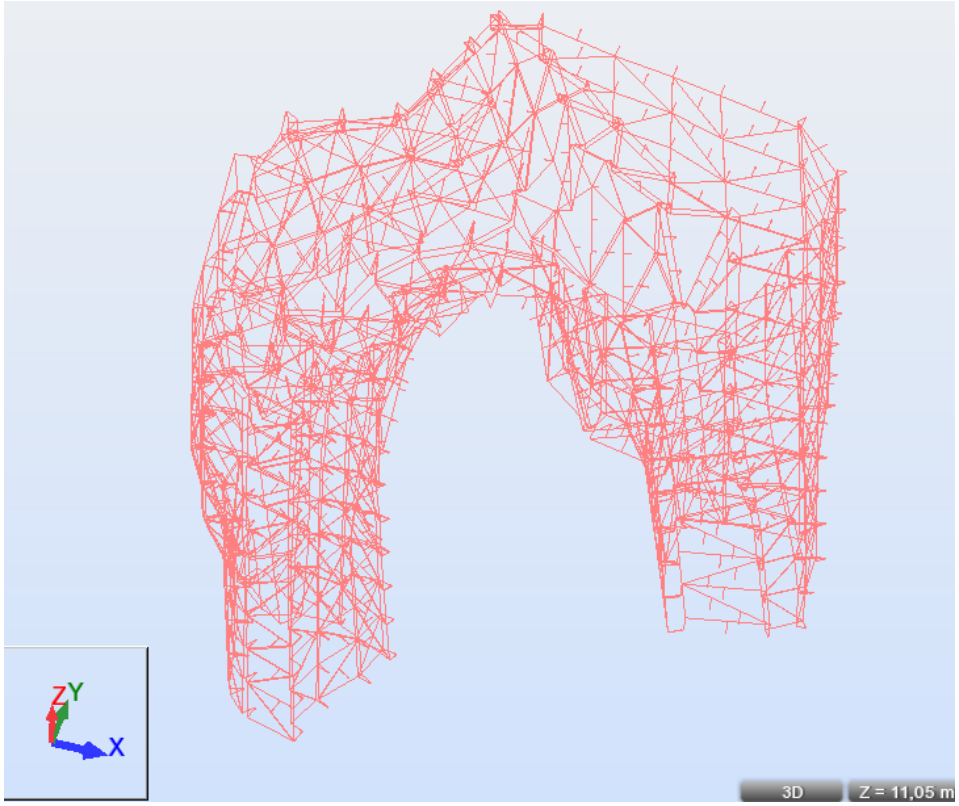


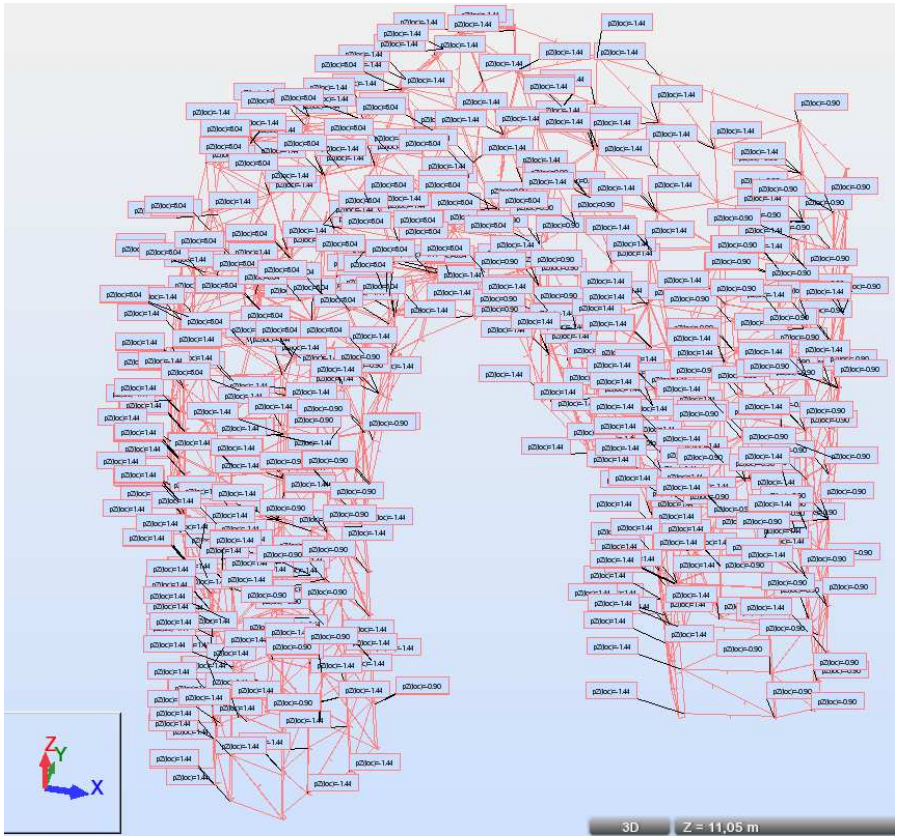
Roof angle α	Blockage φ	Overall Force Coefficients c_f	Zone A	Zone B	Zone C
0°	Maximum all φ	+ 0,2	+ 0,5	+ 1,8	+ 1,1
	Minimum $\varphi = 0$	- 0,5	- 0,6	- 1,3	- 1,4
	Minimum $\varphi = 1$	- 1,3	- 1,5	- 1,8	- 2,2
5°	Maximum all φ	+ 0,4	+ 0,8	+ 2,1	+ 1,3
	Minimum $\varphi = 0$	- 0,7	- 1,1	- 1,7	- 1,8
	Minimum $\varphi = 1$	- 1,4	- 1,6	- 2,2	- 2,5
10°	Maximum all φ	+ 0,5	+ 1,2	+ 2,4	+ 1,6
	Minimum $\varphi = 0$	- 0,9	- 1,5	- 2,0	- 2,1
	Minimum $\varphi = 1$	- 1,4	- 2,1	- 2,6	- 2,7
15°	Maximum all φ	+ 0,7	+ 1,4	+ 2,7	+ 1,8
	Minimum $\varphi = 0$	- 1,1	- 1,8	- 2,4	- 2,5
	Minimum $\varphi = 1$	- 1,4	- 1,6	- 2,9	- 3,0
20°	Maximum all φ	+ 0,8	+ 1,7	+ 2,9	+ 2,1
	Minimum $\varphi = 0$	- 1,3	- 2,2	- 2,8	- 2,9
	Minimum $\varphi = 1$	- 1,4	- 1,6	- 2,9	- 3,0
25°	Maximum all φ	+ 1,0	+ 2,0	+ 3,1	+ 2,3
	Minimum $\varphi = 0$	- 1,6	- 2,6	- 3,2	- 3,2
	Minimum $\varphi = 1$	- 1,4	- 1,5	- 2,5	- 2,8
30°	Maximum all φ	+ 1,2	+ 2,2	+ 3,2	+ 2,4
	Minimum $\varphi = 0$	- 1,8	- 3,0	- 3,8	- 3,6
	Minimum $\varphi = 1$	- 1,4	- 1,5	- 2,2	- 2,7

NOTE + values indicate a net downward acting wind action

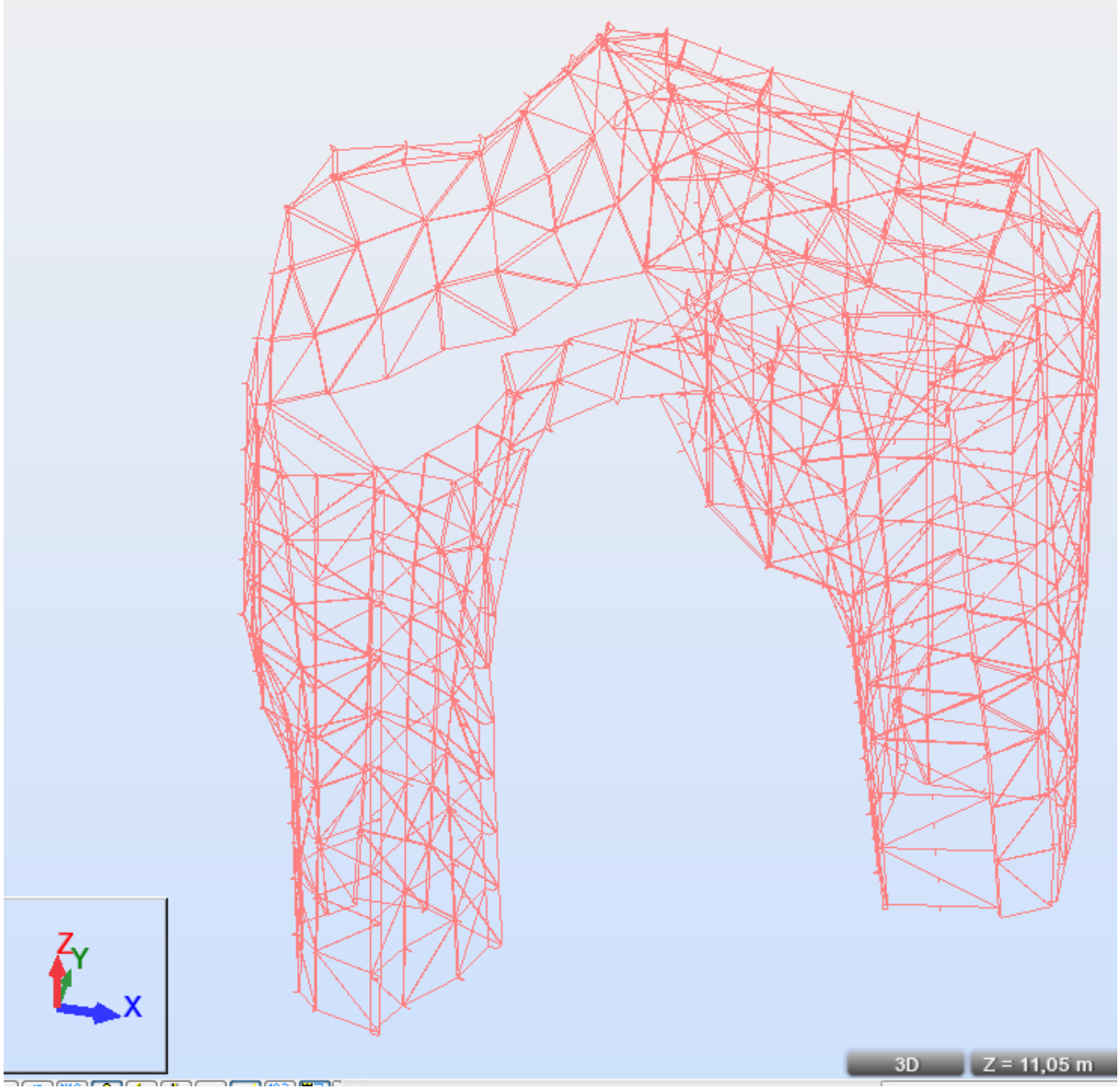
- values represent a net upward acting wind action

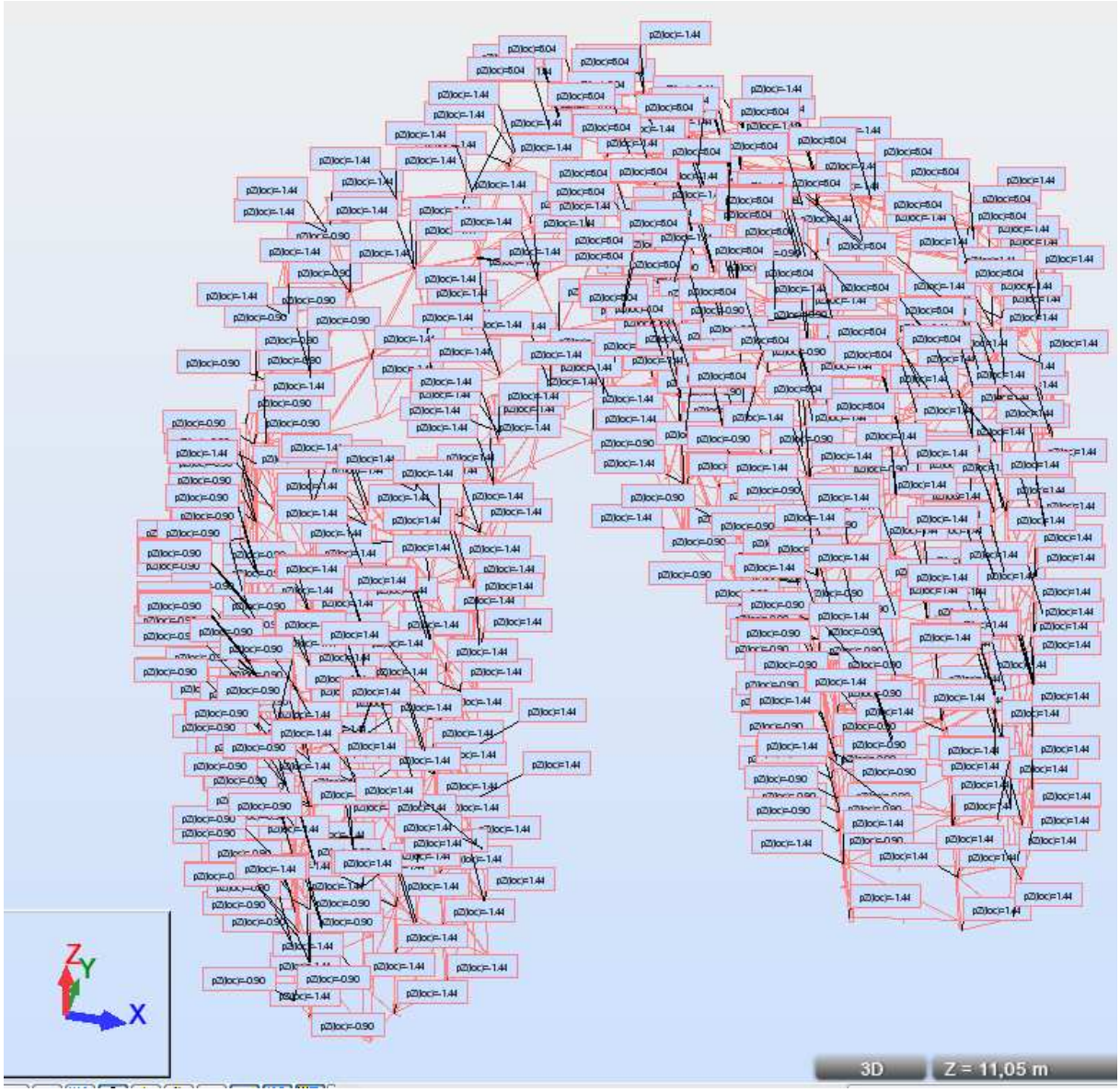
Wind + X



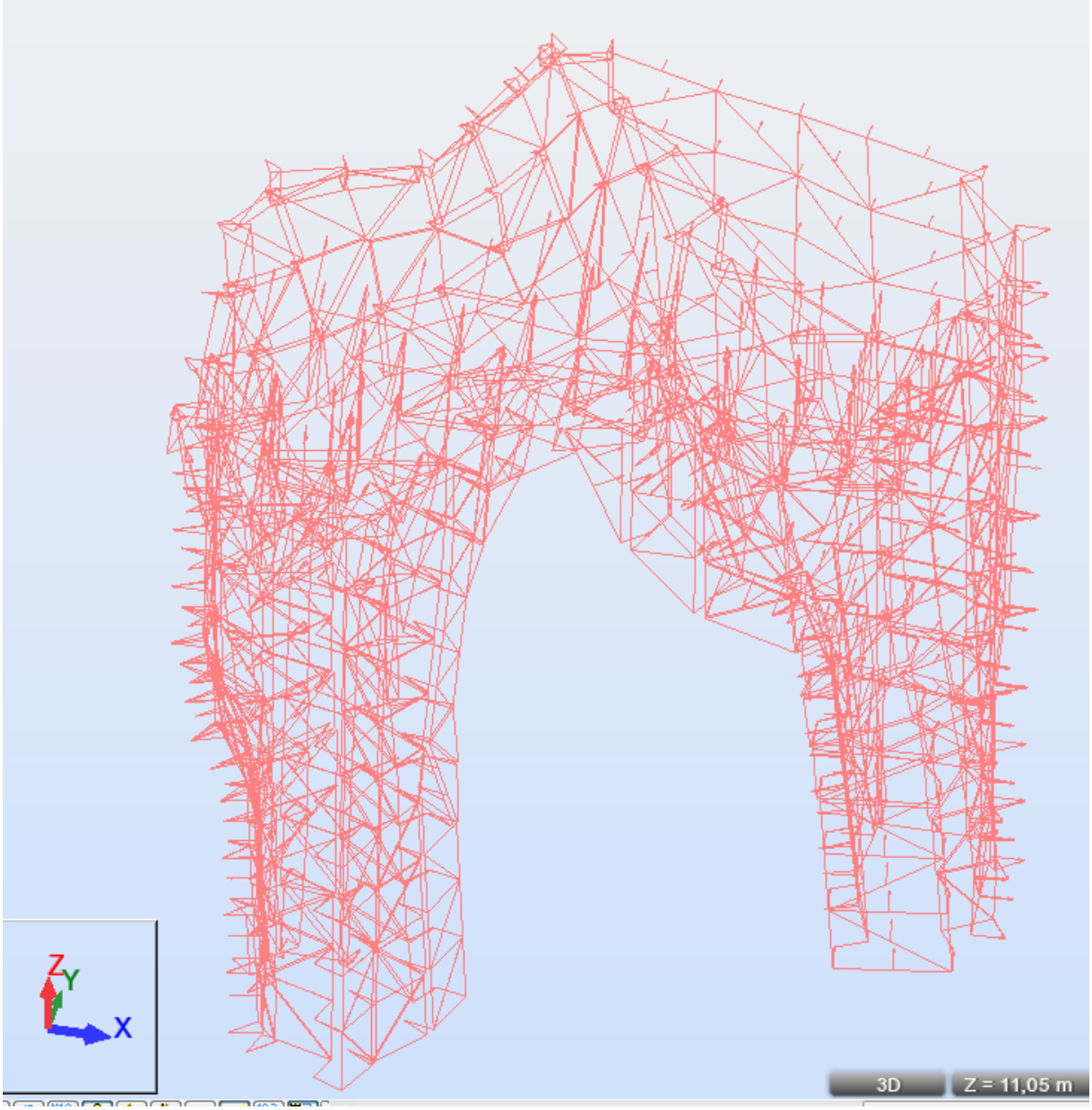


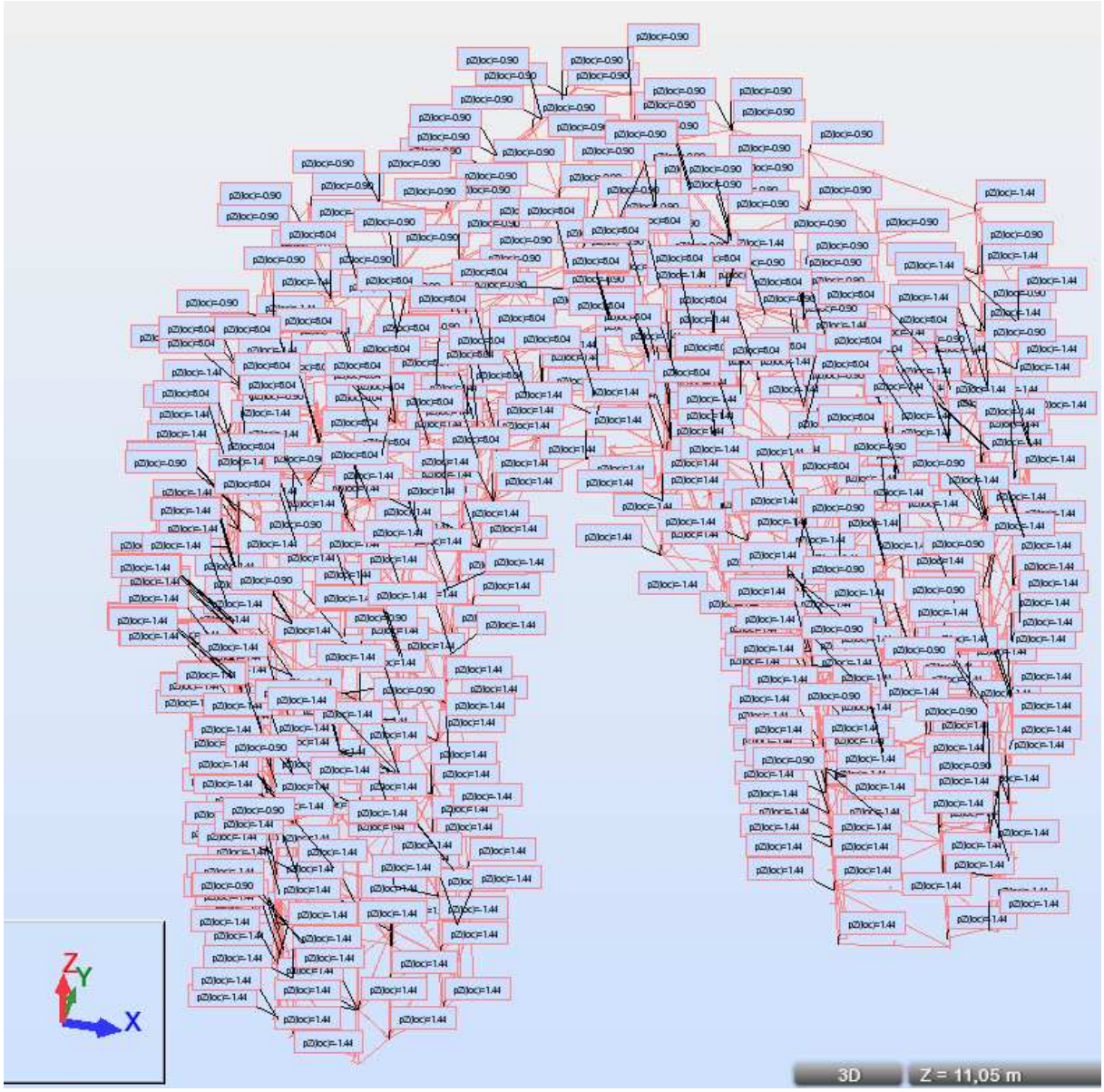
Wind - X


Z
Y
X
3D
Z = 11,05 m

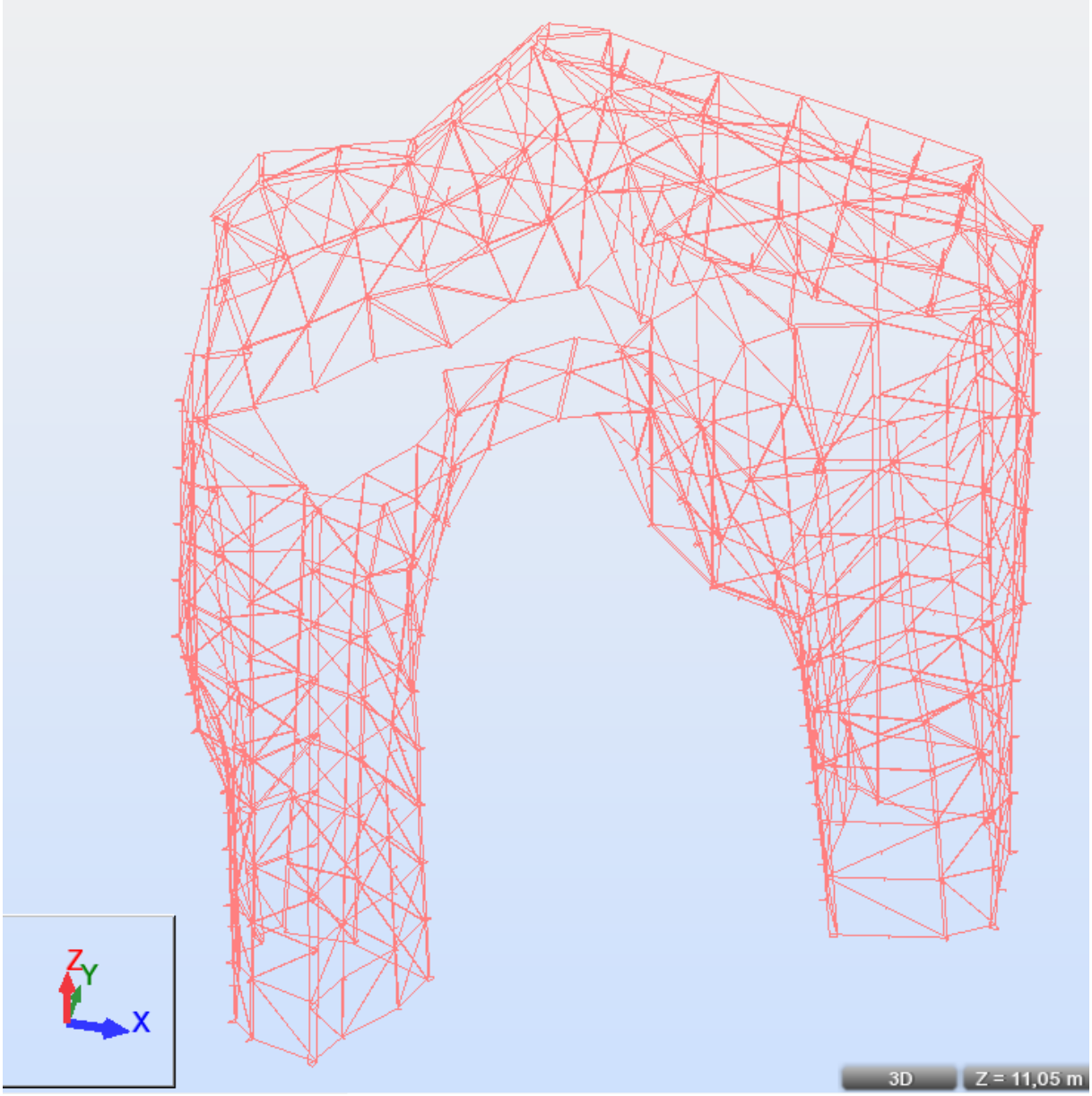

Z
Y
X
3D
Z = 11,05 m

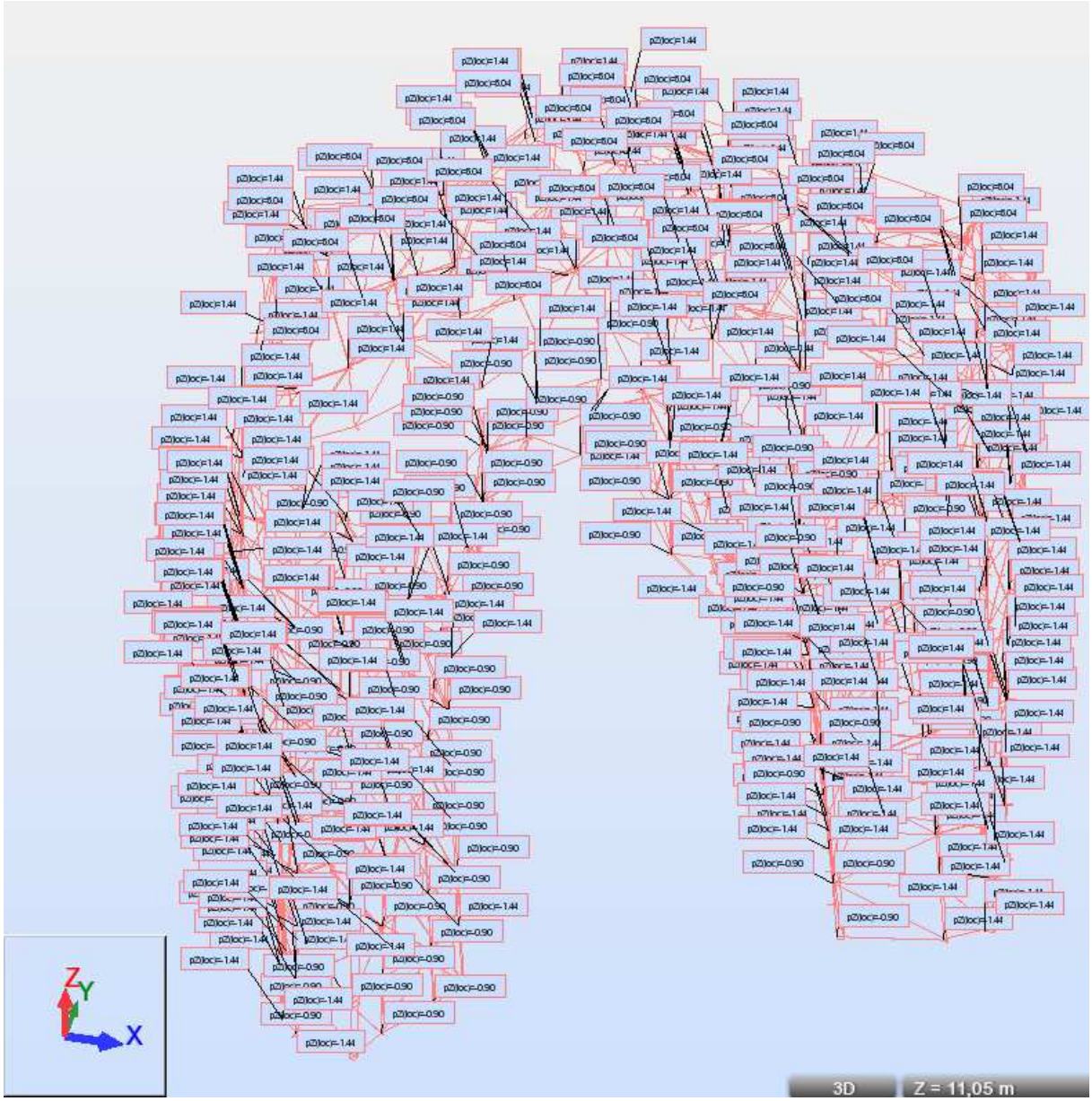
Wind + Y



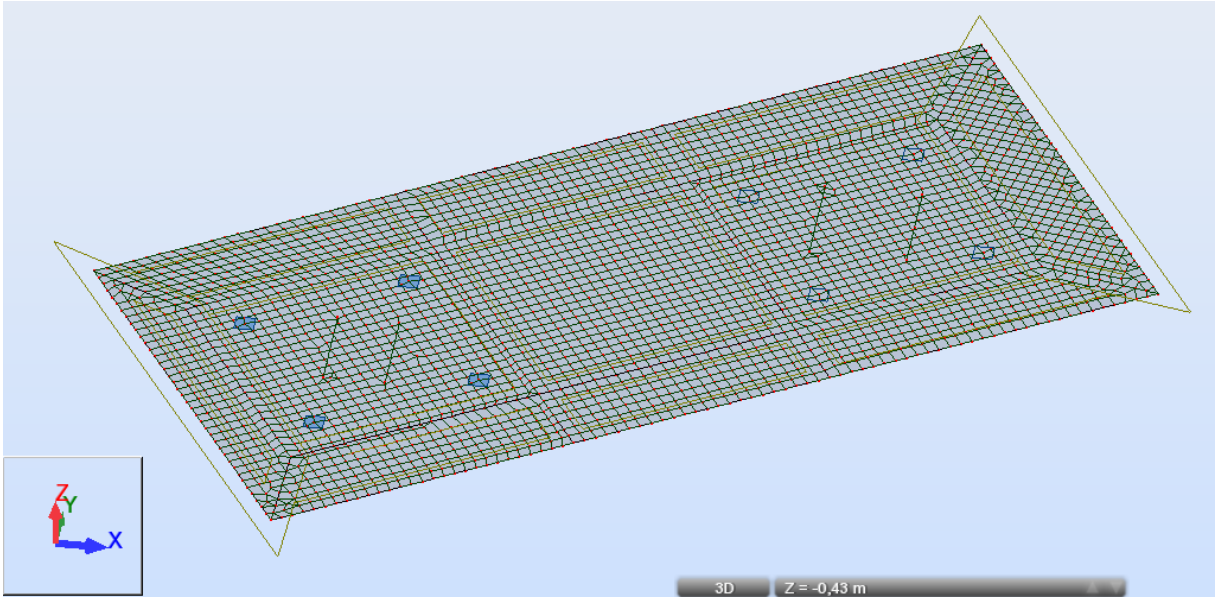

Z
Y
X
3D
Z = 11,05 m

Wind - Y




Z
Y
X
3D
Z = 11,05 m

Foundation FEM Model :



Nodes for reactions on foundation

Maximum Reactions on piles from SLS combinations : (Dead Load)*1 + (Wind or Live load)*1

Pile dimension and rebar is given in the drawings.

Node	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
4813 / MAX	27,46	15,22	470,36	139,29	-10,20	1,45
4822 / MAX	29,99	28,79	405,46	26,94	58,53	0,36
4811 / MAX	24,37	22,17	385,28	174,23	54,41	1,32
4819 / MAX	24,47	21,60	334,23	14,79	50,53	0,35
4820 / MAX	28,16	15,75	319,90	24,61	34,35	0,37
4821 / MAX	20,98	34,00	293,71	25,40	55,45	0,28
4812 / MAX	14,11	16,08	221,94	31,94	15,27	1,03
4811 / MIN	-23,19	-23,32	220,92	18,50	18,02	-1,70
4813 / MIN	-33,18	-13,25	93,61	2,43	-168,78	-1,39
4819 / MIN	-23,72	-13,21	69,05	-19,82	-30,21	-0,29
4814 / MAX	0,0	0,0	0,0	0,0	0,0	0,0
4814 / MIN	0,0	0,0	0,0	0,0	0,0	0,0
4820 / MIN	-23,66	-7,27	-56,20	-40,35	-31,64	-0,29
4822 / MIN	-33,78	-18,95	-57,30	-48,35	-30,78	-0,37
4821 / MIN	-27,19	-18,66	-59,66	-26,30	-49,69	-0,56
4812 / MIN	-19,86	-14,60	-69,87	2,41	-27,96	-1,15

	Bentonite piles:			
	Diameter (cm)	Net length (m)	Allowable **compression**service loads (ton)	Allowable **tension** service loads (ton)
Type C	60	16	41-55	14-18

Pile section design
Desing forces in piles

Node	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
4813 / MAX	40,84	22,67	664,54	197,22	31,49	2,61
4822 / MAX	45,67	43,73	577,75	40,02	87,15	0,55
4811 / MAX	36,38	33,18	535,81	245,52	76,73	2,10
4819 / MAX	36,72	32,67	478,02	23,54	74,19	0,51
4820 / MAX	42,35	23,59	461,09	36,36	52,62	0,55
4821 / MAX	32,27	51,48	415,68	38,41	82,14	0,41
4812 / MAX	21,19	23,96	324,13	44,62	26,70	1,77
4811 / MIN	-35,19	-35,29	190,73	-25,18	10,64	-2,88
4819 / MIN	-35,65	-19,71	26,29	-29,31	-50,75	-0,45
4813 / MIN	-50,65	-20,34	3,45	-35,48	-239,17	-2,19
4814 / MAX	0,0	0,0	0,0	0,0	0,0	0,0
4814 / MIN	0,0	0,0	0,0	0,0	0,0	0,0
4812 / MIN	-29,99	-22,41	-133,83	-7,36	-40,79	-1,88
4820 / MIN	-35,44	-10,97	-145,86	-62,30	-47,14	-0,42
4821 / MIN	-40,55	-27,86	-172,49	-39,36	-78,14	-0,83
4822 / MIN	-50,51	-28,20	-187,74	-73,88	-48,17	-0,55

Tenssion combination

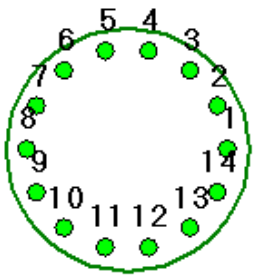
General

Loads: N, Mx, My

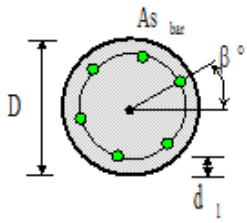
N>0 is compression !

```
Design code:     Eurocode 2
Analysis:        Check section
```

Section




```
Data [cm]

D =60

d1 =5
```



Materials

```
Concrete: C30/37
SSR:  Rectangular

fck = 30.00 MPa
Ec = 31938.77 MPa
ecu = -3.500 o/oo
```

```
Reinforcing steel: S400
SSR:   Standard

fyk = 400.00 MPa
Es = 200000.00 MPa
esu = 10.000 o/oo
```

Factors

```
Concrete:   gama_c = 1.50
Steel:      gama_s = 1.15
```

Reinforcement

```
Bars =14
beta = 0.00 deg
As,bar =3.14cm2
```

Loads

Load	N [kN]	Mx [kNm]	My [kNm]
L1	-187.74	73.88	48.17

Solve data

II order moments: No

Results: Legend

Np, Mp - Maximal permissible loads

Ratio = Applied load / Maximal permissible load

Load	Np [kN]	Mxp[kNm]	Myp[kNm]	Ratio	Permissible
L1	-505.65	198.98	129.74	0.371	Yes

Section properties

Reinforcement :

```
As,tot = 43.96 cm2

Concrete section:

Ac     = 2822.27 cm2
Ic,x   = 633850.86 cm4
Ic,y   = 633850.86 cm4

R/C section:

Ared   = 3053.59 cm2
Ired,x = 706137.35 cm4
Ired,y = 706137.35 cm4
rx     = 15.21 cm
ry     = 15.21 cm
```

Concete grade C30/37 is used for the calculations – the concrete in the final drawing will be with cubic compression strenght 40 Mpa
Rebar steel used B400 , fy = 400Mpa

Compression combination :

General

Loads: N, Mx, My

N>0 is compression !

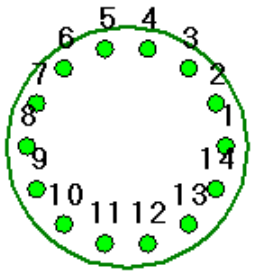
Design code: Eurocode 2
Analysis: Check section

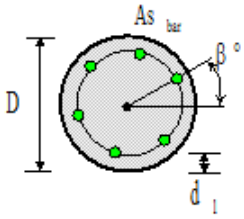
Section

Data [cm]

D =60

d1 =5





Materials

Concrete: C30/37
SSR: Rectangular

fck = 30.00 MPa
Ec = 31938.77 MPa
ecu = -3.500 o/oo

Reinforcing steel: S400
SSR: Standard

fyk = 400.00 MPa
Es = 200000.00 MPa
esu = 10.000 o/oo

Factors

Concrete: gama_c = 1.50
Steel: gama_s = 1.15

Reinforcement

Bars =14
beta = 0.00 deg
As,bar =3.14cm2

Loads

Load	N [kN]	Mx [kNm]	My [kNm]
L1	664	197.22	31.49

Solve data

II order moments: No

Results: Legend

Np, Mp - Maximal permissible loads

Ratio = Applied load / Maximal permissible load

Load	Np [kN]	Mxp[kNm]	Myp[kNm]	Ratio	Permissible
L1	1689.54	501.82	80.13	0.393	Yes

Section properties

Reinforcement :

```
As,tot = 43.96 cm2

Concrete section:

Ac     = 2822.27 cm2
Ic,x   = 633850.86 cm4
Ic,y   = 633850.86 cm4

R/C section:

Ared   = 3053.59 cm2
Ired,x = 706137.35 cm4
Ired,y = 706137.35 cm4
rx     = 15.21 cm
ry     = 15.21 cm
```

Pile Cap Desing : (From ULS combinations – Envelope)

Bending moments

Pile cap punching chek from the piles

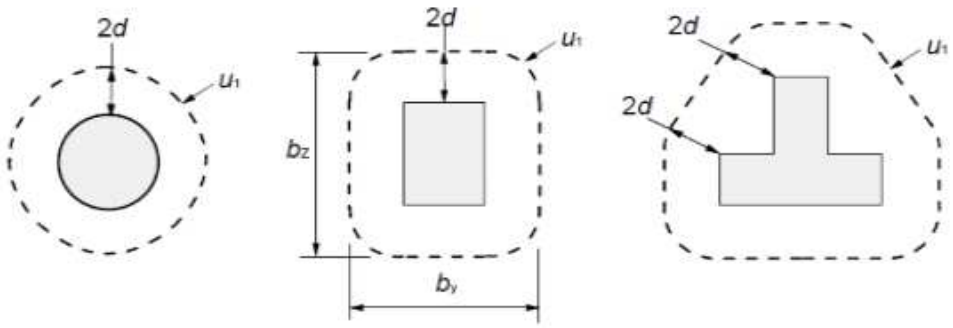
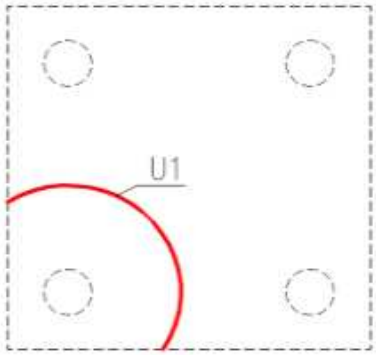


Figure 6.13: Typical basic control perimeters around loaded areas



Punching for round column

U1	=	4374	mm	My,ed	=	173,53	kN.m
Dcol	=	600	mm	Mz,ed	=	219,81	kN.m
d	=	750	mm	Ved	=	665	kN
				Asy	=	1272	mm2
				Asx	=	1272	mm2
Crd,c	=	0,12		ρ	=	0,001696	
k	=	1,52		γ_c	=	1,5	
				fck	=	35	Mpa

$$v_{Ed} = \beta \frac{V_{Ed}}{u_i d} \qquad (6.38)$$

where

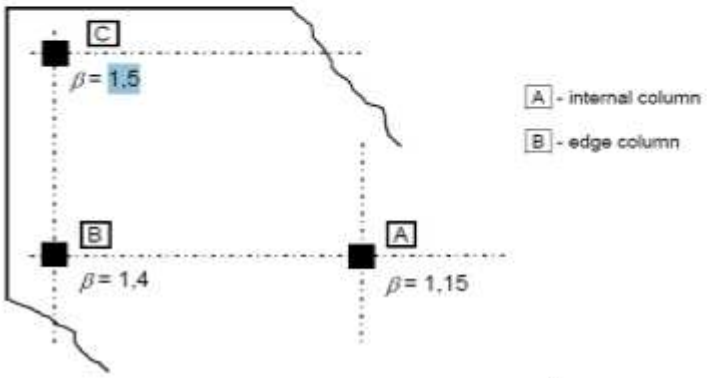
d is the mean effective depth of the slab, which may be taken as $(d_y + d_z)/2$ where:

d_y, d_z is the effective depths in the y- and z- directions of the control section

u_i is the length of the control perimeter being considered

β is given by:

Note: Values of β for use in a Country may be found in its National Annex. Recommended values are given in Figure 6.21N.



r column

Figure 6.21N: Recommended values for β

Choose	β	=	1,5
ved	=	0,30	Mpa

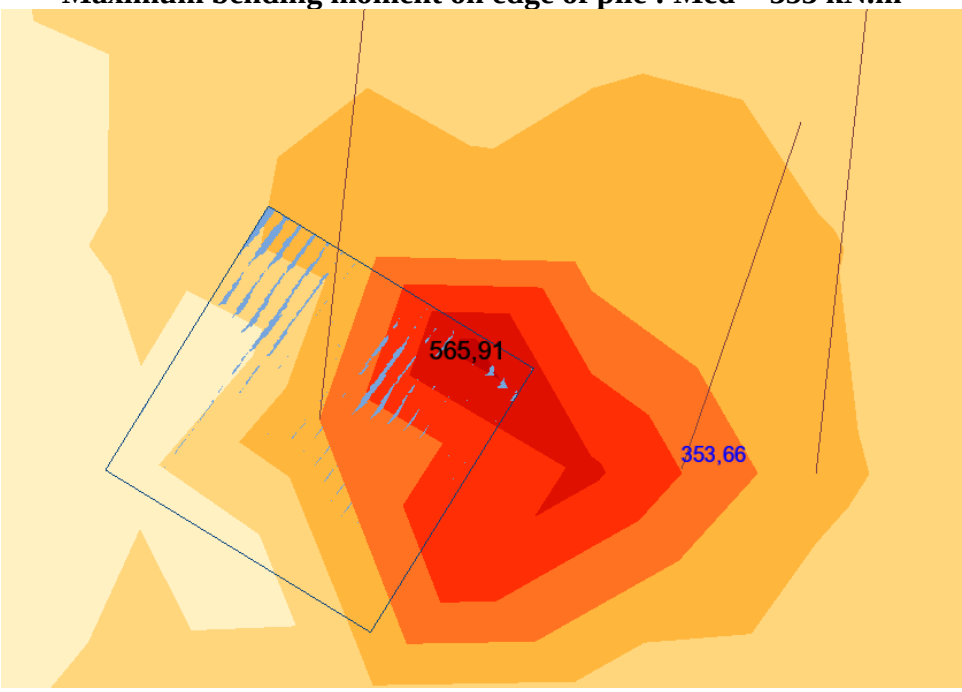
$$v_{Rd,c} = C_{Rd,c}\, k\, (100 \rho_l \; f_{ck})^{1/3}$$

VRd,c	=	0,329477	Mpa

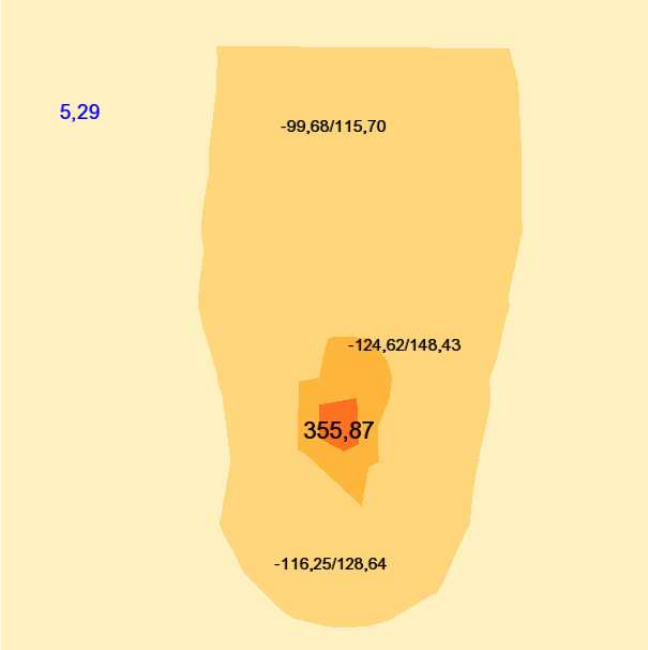
$$v_{min} = 0{,}035\, k^{3/2} \cdot f_{ck}^{1/2}$$

Vmin	=	0,386653	Mpa
Vrd	=	0,386653	Mpa
Vrd	>	ved	
	OK		

Bending design Under Piles :
Maximum bending moment on edge of pile : Med = 353 kN.m



Bending design under steel base:
Maximum bending moment in center of anchor group : Med = 355 kN.m



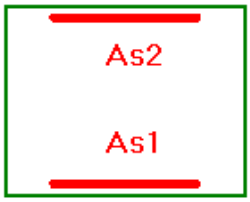
General

Design code: Eurocode 2
Analysis: Check section

Loads: N, Mx

N>0 is compression !

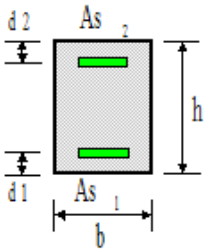
Section



Data [cm]

b =100
h =80

d1 =5
d2 =5



Materials

Concrete: C30/37
SSR: Rectangular

fck = 30.00 MPa
Ec = 31938.77 MPa
ecu = -3.500 o/oo

Reinforcing steel: S400
SSR: Standard

fyk = 400.00 MPa
Es = 200000.00 MPa
esu = 10.000 o/oo

Factors

Concrete: gama_c = 1.50
Steel: gama_s = 1.15

Reinforcement

Symmetric: As1=As2

As1 =15.71cm2 As2 =15.71cm2

Loads

Load	N [kN]	Mx [kNm]
L1	0	355

Solve data

II order moments: No

Results: Legend

Np, Mp - Maximal permissible loads

Ratio = Applied load / Maximal permissible load

Load	Np [kN]	Mxp[kNm]	Ratio	Permissible
L1	0.00	401.41	0.884	Yes

Section properties

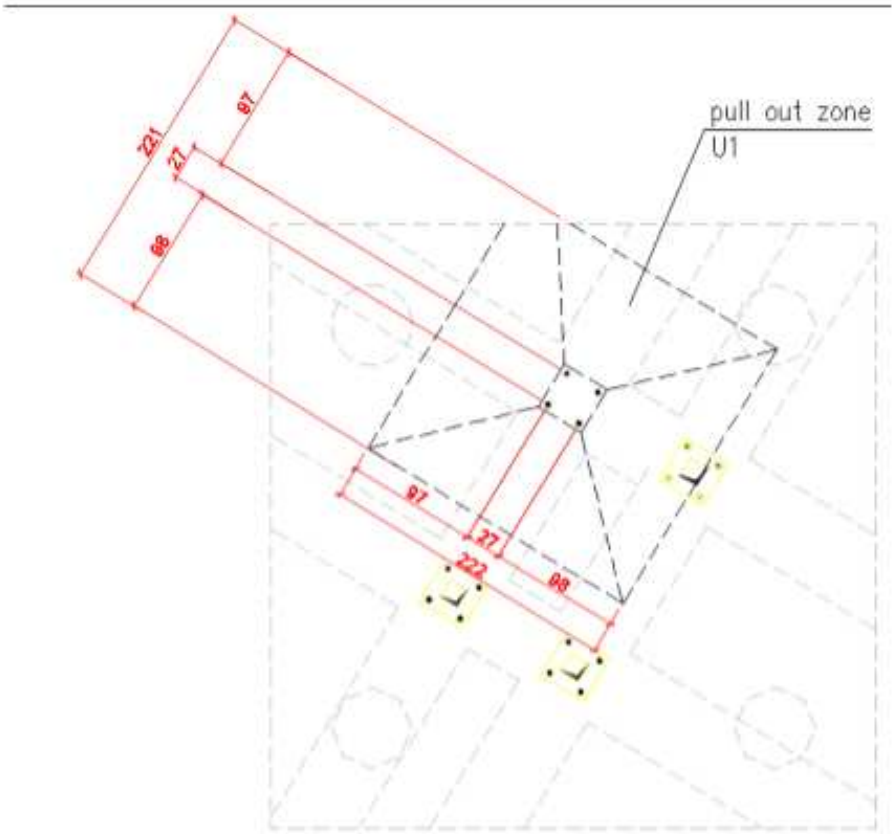
```
Reinforcement :

As,tot = 31.42 cm2

Concrete section:

Ac     = 8000.00 cm2
Ic,x   = 4266666.67 cm4

R/C section:

Ared   = 8165.33 cm2
Ired,x = 4469197.75 cm4
rx     = 23.40 cm
```

Main reinforcement 5ϕ20/м‘

5Φ20 + 4Φ14 is provided in the zone under the steel columns

Concete grade C30/37 is used for the calculations – the concrete in the final drawing will be with cubic compression strenght 40 Mpa
Rebar steel used B400 , fy = 400Mpa

Concrete pullout of the anchor group



Punching for round column

U1	=	8460	mm	My,ed	=	0	kN.m
				Mz,ed	=	0	kN.m
d	=	650	mm	Ved	=	800	kN
				Asy	=	1888	mm2
				Asx	=	1888	mm2
Crd,c	=	0,12		ρ	=	0,002905	
k	=	1,55		γ_c	=	1,5	
				fck	=	35	Mpa

$$v_{Ed} = \beta \frac{V_{Ed}}{u_i d} \qquad (6.38)$$

where

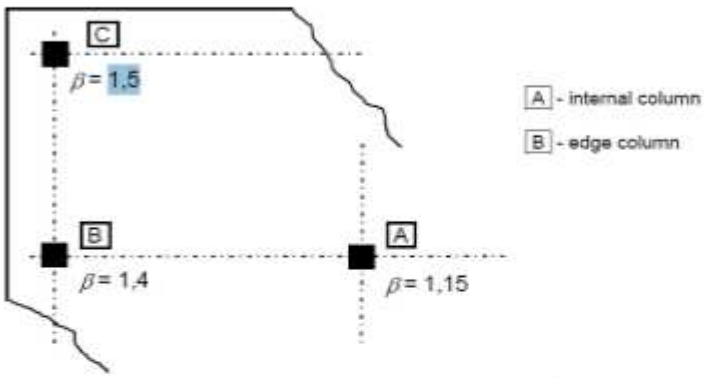
d is the mean effective depth of the slab, which may be taken as $(d_y + d_z)/2$ where:

d_y, d_z is the effective depths in the y- and z- directions of the control section

u_i is the length of the control perimeter being considered

β is given by:

Note: Values of β for use in a Country may be found in its National Annex. Recommended values are given in Figure 6.21N.



r column

Figure 6.21N: Recommended values for β

Choose	β	=	1,15
ved	=	0,17	Mpa

$$v_{Rd,c} = C_{Rd,c}\, k\, (100 \rho_l\ f_{ck})^{1/3}$$

VRd,c	=	0,404154	Mpa

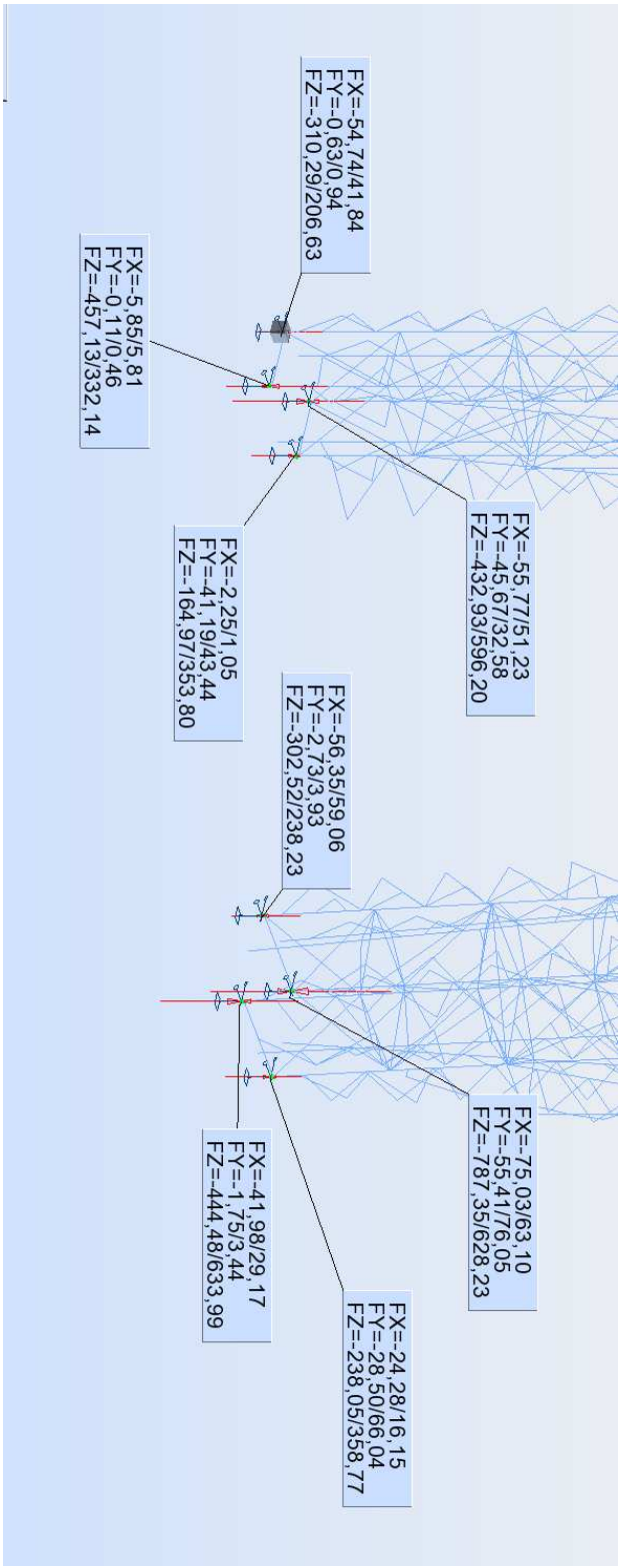
$$v_{min} = 0{,}035\, k^{3/2} \cdot f_{ck}^{1/2}$$

Vmin	=	0,401395	Mpa
Vrd	=	0,404154	Mpa
Vrd	>	ved	
	OK		

Additional inside concrete beam reinforcement is provided under the steel columns.

Base detail for climbing tower calculation

Reactions



1.Materials

1.1. Anchors

anchor grade 8.8 $f_{ub} := 80 \frac{kN}{cm^2}$ $f_{yb} := 64 \frac{kN}{cm^2}$

anchor diameter $d := 36mm$

$A_b :=$
- $2.45cm^2$ if $d = 20mm$ $= 8.17 \cdot cm^2$
- $3.53cm^2$ if $d = 24mm$
- $5.61cm^2$ if $d = 30mm$
- $4.59cm^2$ if $d = 27mm$
- $8.17cm^2$ if $d = 36mm$
- $11.2cm^2$ if $d = 42mm$
- $20.3cm^2$ if $d = 56mm$
- $14.7cm^2$ if $d = 48mm$

$nut := d \cdot 1.67 = 60.12 \cdot mm$

1.2. Concrete

Concrete C25/30 $f_{ck} := 2.5 \frac{kN}{cm^2}$ $f_{ck_cube} := 3 \frac{kN}{cm^2}$ $f_{ctk005} := 1.8MPa$ $E_c := 31GPa$

$\gamma_c := 1.5$ partial factor for concrete under compression

$f_{ctd} := 1 \cdot \frac{f_{ctk005}}{\gamma_c} = 0.12 \cdot \frac{kN}{cm^2}$ $f_{bd} := f_{ctd} \cdot 0.7 \cdot 2.25 = 0.189 \cdot \frac{kN}{cm^2}$

1.3. Reinforcement steel $f_{yk} := 500MPa$

For headed fasteners the value of k_{cr} is set to 8.5 according to current experience. $k_{cr} := 8.5$

2. Geometry

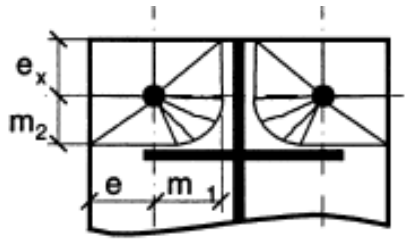
2.1. Anchor plate $b_{anchor_plate} := 390mm$

2.2. Foundation $L_{eff_anchor} := 560mm$

2.3. Base plate $t_p := 35mm$ $m := 60mm$ $l_{eff} := 250mm$ $f_{ypl} := 225MPa$ $\gamma_{m0} := 1.1$

Steel for base plate - S235JR

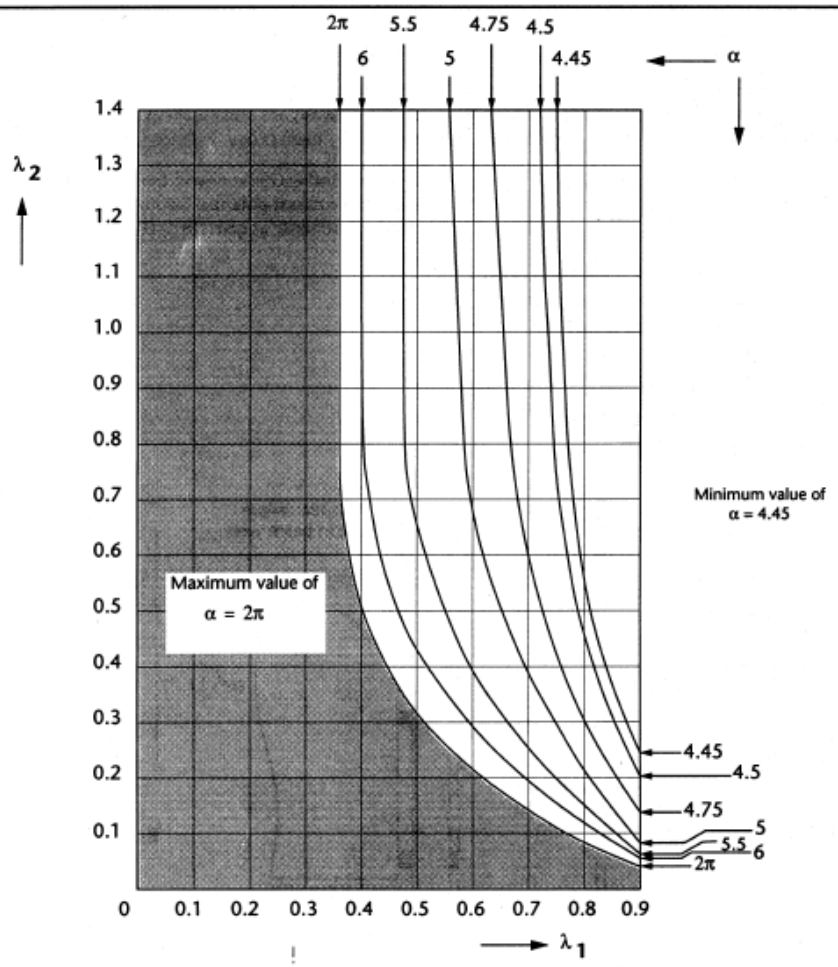
$E := 21000 \frac{kN}{cm^2}$ elastic modulus

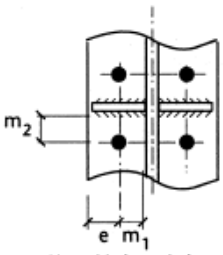


Pattern (vi)
Corner yielding near a stiffener

$$L_{eff} = \alpha m_1 - (2m_1 + 0.625e) + e_x$$

α CHART



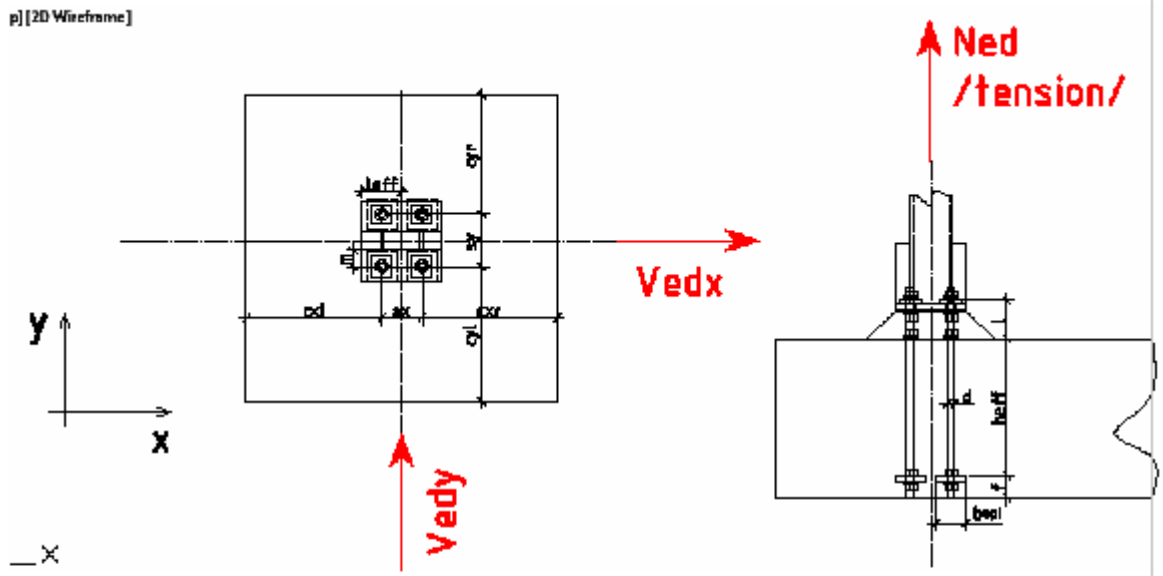


$$\lambda_1 = \frac{m_1}{m_1 + e}$$

$$\lambda_2 = \frac{m_2}{m_1 + e}$$

Note: Mathematical expressions for α are given in Appendix III

Figure 2.16 Values of α for stiffened column flanges and endplates



3. Loads

$N_{ed} := 800kN$

4. Resistance due to base plate bending - no prying effect

$$M_{pl} := \frac{l_{eff} \cdot t_p^{\,2} \cdot f_{ypl}}{4 \cdot \gamma_{m0}} = 15.661 \cdot kN \cdot m \qquad F_{TRd} := \frac{2 \cdot M_{pl}}{m} \cdot 2 = 1044 \cdot kN$$

2. Material partial safety factors

2.1. Partial factors for steel

$$\gamma_{mst} := \max\left(1.2 \cdot \frac{f_{ub}}{f_{yb}}, 1.4\right) = 1.5$$

tension loading on fasteners, anchors

$$\gamma_{mss} := \begin{cases} \max\left(\frac{f_{ub}}{f_{yb}}, 1.25\right) & \text{if } \frac{f_{yb}}{f_{ub}} \le 0.8 \;\; f_{ub} \le 80 \frac{kN}{cm^2} \\ 1.5 & \text{if } f_{ub} > 80 \frac{kN}{cm^2} \\ 1.5 & \text{if } \frac{f_{yb}}{f_{ub}} > 0.8 \end{cases} = 1.25$$

shear loading on fasteners

$$\gamma_{m2} := 1.25$$

2.2. Partial factors for concrete

partial factor taking in account instalation safety of the fastenings system.
For post installed anchors the values are:

$\gamma_{inst} := 1$ tension loading

$\gamma_{inss} := 1$ shear loading

For cast-in place fasteners then if the conditions of 4.5 and of EN 1992-1-2:2004, 4.5.5 are fulfilled high installation safety may be assumed for all load directions

$\gamma_{mc} := \gamma_c \cdot \gamma_{inst} = 1.5$ partial factor that cover break-out failure modes (cone failure, blow-out failure, pry-out failure, edge failure)

$\gamma_{mp} := \gamma_{mc} = 1.5$ partial factor that cover pull-out failure

$\gamma_{msp} := \gamma_{mc} = 1.5$ partial factor that cover splitting failure.

Design resistance
A. Tension resistance

1. Steel failure

$$F_{Rds1} := \frac{1 \cdot f_{ub} \cdot A_b}{\gamma_{mst}} = 436 \cdot kN$$

$$F_{Rds} := 4 \cdot F_{Rds1} = 1743 \cdot kN$$

2. Pull-out failure

$$A_h := b_{anchor_plate}^{2} - \frac{nut^{2} \cdot \pi}{4} = 1.493 \times 10^{3} \cdot cm^{2}$$

load bearing area

$$N_{Rkp} := 6 \cdot f_{ck_cube} \cdot A_h = 26867 \cdot kN$$

$$N_{Rdp} := \frac{4 \cdot N_{Rkp}}{\gamma_{mp}} = 71645 \cdot kN$$

3. Concrete cone failure

- supplementary reinforcement is provided

4. Concrete splitting failure

5.6.3.4 Concrete splitting failure

According to the *CEN/TS 1992-4-2, Section 6.2.6.1* splitting failure during the installation of fasteners can be avoided by complying with minimum values for internal anchor spacing (s_{min}), edge distance (c_{min}), concrete member thickness (h_{min}) and for reinforcement of the concrete member. An illustration of the concrete splitting failure mode can be seen in Figure 5.8.

Verification of splitting failure due to loading is not required if one of the following conditions is satisfied.

1. Edge distance in all directions exceeds $1.0 * c_{cr,sp}$ for one anchor or $1.2 * c_{cr,sp}$ for an anchor group.
2. Concrete cone and pull-out failure modes are calculated with regard to cracked concrete and the reinforcement resists splitting forces and limits the crack width to $w_k \leq 0.3$ mm.

5.6.3.4 (2) is satisfied

5. Blow-out failure

Verification of blow-out failure is not required if the edge distance in all directions exceeds $c = 0{,}5\ h_{ef}$. If a verification is required, the characteristic resistance in case of blow-out failure is:

$$N_{Rk,cb} = N^0_{Rk,cb} \cdot \frac{A_{c,Nb}}{A^0_{c,Nb}} \cdot \psi_{s,Nb} \cdot \psi_{g,Nb} \cdot \psi_{ec,Nb} \cdot \psi_{ucr,N} \quad [N] \qquad (20)$$

The different factors of Equation (20) are given below:

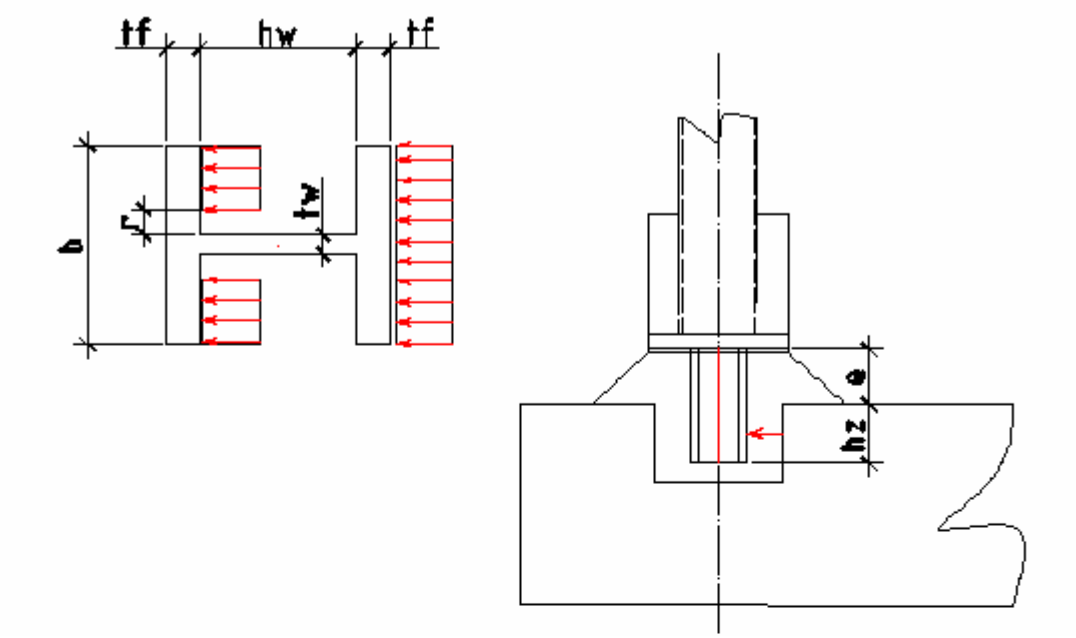
NOTE For groups of fasteners perpendicular to the edge, which are loaded uniformly, verification is only required for the fasteners closest to the edge.

The edge distance is satisfied.

Result

A. Tension resistance		Ratio
1. Steel failure	$F_{Rds} = 1743 \cdot kN$	$ratio_{T_1} := N_{ed} \div F_{Rds} = 0.459$
2. Pull-out failure	$N_{Rdp} = 71645 \cdot kN$	$ratio_{T_2} := N_{ed} \div N_{Rdp} = 0.011$
3. Resistance due to base plate bending - no prying effect	$F_{TRd} = 1044 \cdot kN$	$ratio_{T_4} := \frac{N_{ed}}{F_{TRd}} = 0.766$
4. Resistance due to steel failure of the supplementary reinforcement	$N_{Rd_re} = 1472 \cdot kN$	$ratio_{T_5} := \frac{N_{ed}}{N_{Rd_re}} = 0.543$

Shear connector design



1.Materials

1.1. Concrete

Concrete C25/30 $f_{ck} := 2.5 \frac{kN}{cm^2}$

1.2. Steel - S235 $f_y := 23.5 \frac{kN}{cm^2}$ $f_u := 36 \frac{kN}{cm^2}$

Partial safety factors

$\gamma_{m0} := 1.1$ $\gamma_c := 1.5$

2. Geometry

Section for shear connector :

$b := 100mm$ $r := 16mm$ $t_w := 16mm$ $t_f := 16mm$ $h := 100mm$ $h_w := h - 2 \cdot t_f = 0.068\,m$

$e := 50mm$ $h_z := 100mm$ $W_{y_pl} := 190cm^3$ $A_s := 53.2cm^2$

3. Load

$V_{ed} := 75kN$

3. Design

$$f_{cd} := f_{ck} \cdot \frac{0.85}{\gamma_c} = 1.417 \cdot \frac{kN}{cm^2} \qquad f_{jd} := f_{cd} \cdot \min\left(3, \sqrt{\frac{A_{c1}}{A_{c0}}}\right) = 3.47 \cdot \frac{kN}{cm^2}$$

Stress in flange due to flange bending

$$\sigma_{red_fl} := \sqrt{\left[\frac{\left(\frac{f_{ed} \cdot c_s^2}{2}\right)}{\frac{t_f^2}{6}}\right]^2 + 3 \cdot \left(\frac{f_{ed} \cdot c_s}{t_f}\right)^2} = 6.063 \cdot \frac{kN}{cm^2}$$

stress in beam

$$M_{plRd} := \frac{W_{y_pl} \cdot f_y}{\gamma_{m0}} = 4059 \cdot kN \cdot cm \qquad M_{ed1} := V_{ed} \cdot \left(\frac{h_z}{2}\right) = 375 \cdot kN \cdot cm \qquad M_{ed2} := V_{ed} \cdot \left(e + \frac{h_z}{2}\right) = 750 \cdot kN \cdot cm$$

$$A_{vg} := A_s - 2 \cdot b \cdot t_f + (t_w + 2 \cdot r) \cdot t_f = 28.88 \cdot cm^2$$

$$V_{plRd} := \frac{A_{vg} \cdot f_y}{\sqrt{3} \cdot \gamma_{m0}} = 356.215 \cdot kN$$

$$M_{VRD} := \begin{cases} M_{plRd} & \text{if } V_{ed} \cdot 2 \le V_{plRd} \\ M_{plRd} \cdot \left[1 - \left(2 \frac{V_{ed}}{V_{plRd}} - 1\right)^2\right] & \text{otherwise} \end{cases} = 4.059 \times 10^3 \cdot kN \cdot cm$$

5. Result

$$RATIO_{SH_CON1} := \frac{M_{ed1}}{M_{VRD}} + \frac{\sigma_{red_fl}}{\frac{f_y}{\gamma_{m0}}} = 0.376$$

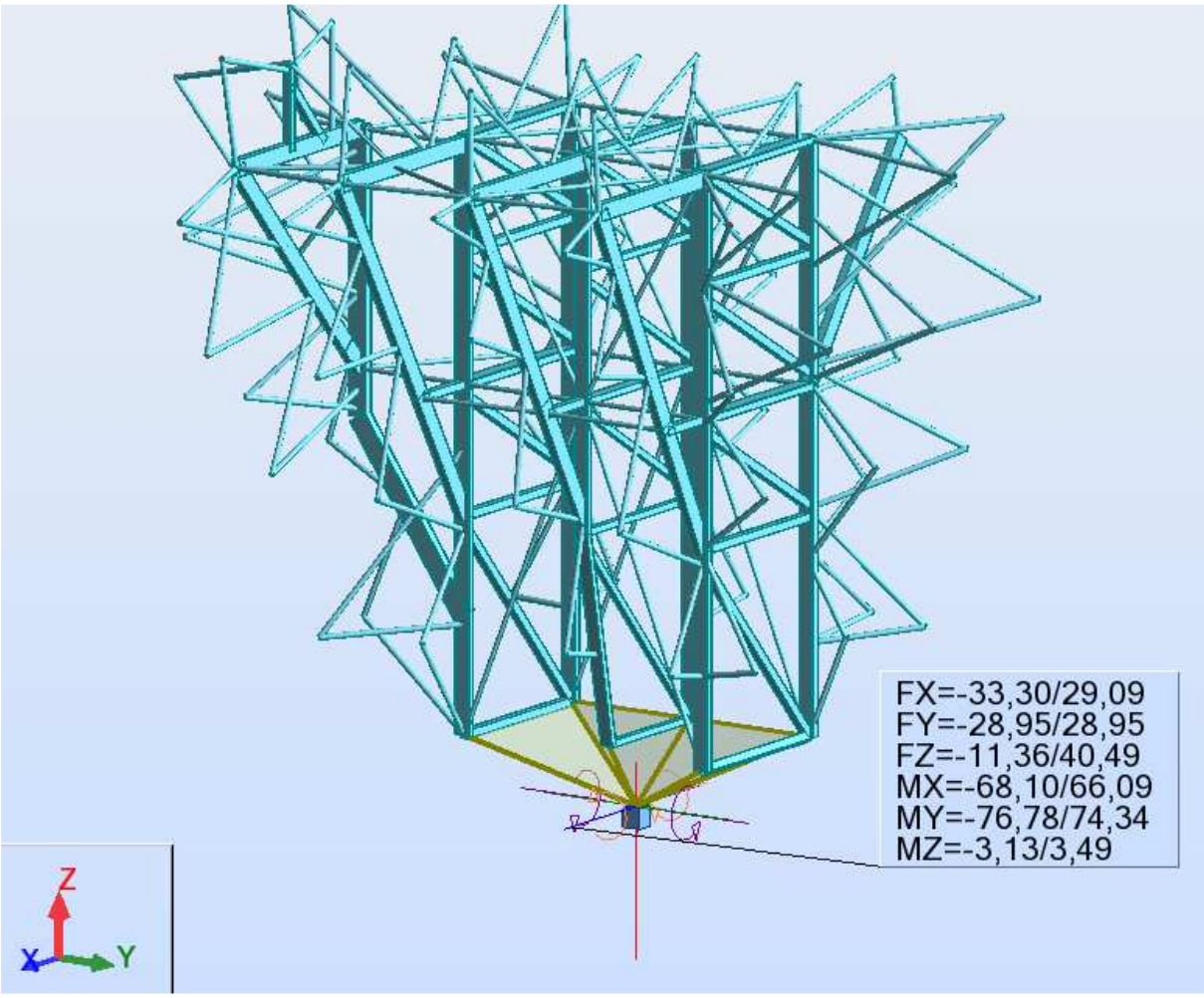
$$RATIO_{SH_CON2} := \frac{M_{ed2}}{M_{VRD}} = 0.185$$

$$RATIO_{concrete} := \max\left(\frac{f_{ed}}{f_{cd}}, 2 \cdot \frac{f_{ed}}{f_{jd}}\right) = 0.509$$

$$RATIO_{shear} := \frac{V_{ed}}{V_{plRd}} = 0.211$$

III. Large bouder foundation

Reaction on pile



Node	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
1 / MAX	29,09	28,95	40,49	66,09	74,34	3,49
1 / MIN	-33,30	-28,95	-11,36	-68,10	-76,78	-3,13

Pile allowable loads

	Diameter (cm)	Net length (m)	Allowable **compression**service loads (ton)	Allowable **tension** service loads (ton)
Type D	60	10	16-25	7-8,5