Büro für Tragwerksplanung und Ingenieurbau
vom Felde + Keppler GmbH & Co. KG

Lütticher Straße 10-12
52064 Aachen
www.vom-felde.de

Telefon: 0241 / 70 96 96
Telefax: 0241 / 70 96 46
buero@vom-felde.de

Structural Report

PA500 Tower
F34P Truss

15393

for the system by

Global Truss
Furong Industrial Area
Shajing Town

Baoan District Shenzen China

Compiled by: C. Fox

Aachen, 22.09.2015

INGENIEURKAMMER-BAU NORDRHEIN-WESTFALEN
BERATENDER INGENIEUR
101448

This report includes pages 1 – 35 + annex

Büro für Tragwerksplanung und Ingenieurbau
Dipl.-Ing. Ralf-Harald vom Felde
Lütticher Straße 10-12
52064 Aachen
Telefon: 0241 / 70 96 96
Telefax: 0241 / 70 96 46
buero@vom-felde.de

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Lütticher Straße 10-12
52064 Aachen
Telefon: 0241 / 70 96 96
Telefax: 0241 / 70 96 46
buero@vom-felde.de

1 GENERAL REMARKS

1.1 Basics

The currently applicable regulations and standards, in particular:

DIN EN 1991-1	Loadings for buildings (Eurocode 1)
DIN EN 13814	Temporary structures
DIN EN 13782	Temporary structures – Tents
DIN EN 1993-1	Steel structures (Eurocode 3)
DIN EN 1995-1	Wooden Structures (Eurocode 5)
DIN EN 1999-1	Aluminium Structures (Eurocode 9)
DIN 4113	Aluminium Structures
DIN 4114	Stability
DIN 15920	Part 2: Stage and Studio structures
DIN 18800	Part 1: Steel Structures
DIN 2448	Steel tubes
DIN EN 12385	Steelropes

1.2 Materials

EN AW-6082 T6	Alloy of the trusses
EN AW-6061 T6	Alloy of the adapters

1.3 General description / Advices on setup and operation

Subject of this calculation is a tower structure made of trusses F34 P (company Globaltruss) used as speaker tower.

The calculation is done for a temporary setup. The verifications are done according EN 13814.

The height of the tower is approx. 7.5 m above ground.

The tower consists of a pillar, which is inclined 15°, two V-shaped outriggers and two diagonal bracings (tubes 60x5 EN AW 6082-T6).

At the head, payloads of the following max. weight and max. area can be applied:

Weight	max.	500 kg
Area	max.	2 m²

The structure has to be ballasted as shown on the following page.

Loadings can be lifted by by a pulley.

The dynamic effects due to lifting and lowering are covered by a factor of 1.2!

Before reaching windspeed vref = 15 m/s the speakers (PA) have to be removed.

The wind speed of vref = 15 m/s is equal to a gust-windspeed of ~ 18 m/s at the highest point of the tower (for setup in the inland and not obstructed areas).

Lütticher Straße 10-12
52064 Aachen
Telefon: 0241 / 70 96 96
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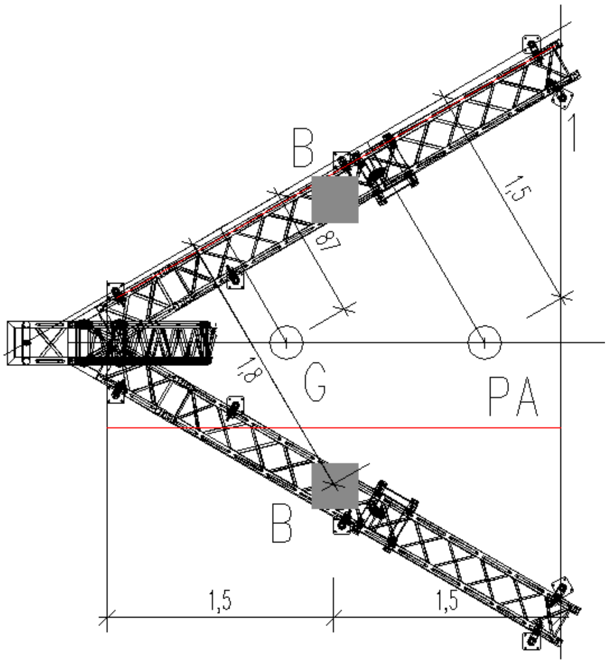
Ballast (see also chapter 5):



Ballast

Setup in regions with wind gust speeds of maximum 28,3 m/s.
Ballast = 75 kg per outrigger (at points "B")
(resulting from case of free-standing tower without PA)

Advice for the case „operation with PA"

Necessary ballast - additionally to the 75 kg - depending on the PA-speakers

Case 1: Area exposed to wind $\leq$ 2 m² and weight of PA $\geq$ 175 kg => no further ballast necessary!

When weight of the PA is lower, the difference to 175 kg has to be applied as ballast!

Case 2: Area exposed to wind $\leq$ 1,5 m² and weight of PA $\geq$ 95 kg => no further ballast necessary!

When weight of the PA is lower, the difference to 95 kg has to be applied as ballast!

Case 3: Area exposed to wind $\leq$ 1,0 m² => no further ballast necessary!

1.4 Loadings

Selfweight

Trusses	F34P + rigging components, spindle Distibtuted equally at the trusses	~ 15,7 kg/m
Bracings	Ø60, t= 5 mm	~ 1,5 kg/m

Payloads:

PA	max. 500 kg 20 % enhancement due to dynamic effects	= 600 kg

Windloads:

Windloads are applied acc. EN 13814 for the case operation (max. vref = 15 m/s).

Before reaching windspeed vref = 15 m/s the speakers (PA) have to be removed.

The wind speed of vref = 15 m/s is equal to a gust-windspeed of ~ 18 m/s at the highest point of the tower (for setup in the inland and not obstructed areas).

Windloads acc. EN 13814 and EN 1991-1-4

The following cases are taken into account:

a. **Operation with PA:**
Acc. EN 13814 the following velocity pressure can be taken into account when the operation is stopped at vref = 15 m/s:

$h < 8{,}0m$ $q = 0{,}2$ kN/m²

b. **Operation stopped (PA removed):**

The stage is calculated with a velocity pressure of qp = 0,5 kN/m². This pressure includes reduction factor acc. the german specimen list of technical building regulations (MLTB) of 0,7 for temporary structures.

The free tower (without PA) can be setup in regions with wind gust speeds of maximum 28,3 m/s.

$qp = 28{,}3^2 / 1600 = 0{,}5$ kN/m²

The maximum allowable basic wind velocity vb,map acc. BS EN 1991-1-4:2005 Fig. NA.1 depends on the height above sealevel and the terrain category.

Example: height above sealevel 50m
altitude factor c,alt = 1,05 (acc. BS EN 1991-1-4)
terrain category III (villages, suburban terrain)
exposure factor 1,5 (acc. EN 1991-1-4 for $z \leq 7m$)
red. factor 0,7 (temporary structures acc. MLTB, see above)
verlocity pressure $qp \leq 0{,}5$ kN/m²
=> allowable $vb,map \leq (0{,}5 / 0{,}7 / 1{,}5 \cdot 1600)^{0{,}5} / 1{,}05 = 26{,}3$ m/s

An adjustment with local authorities is recommended!

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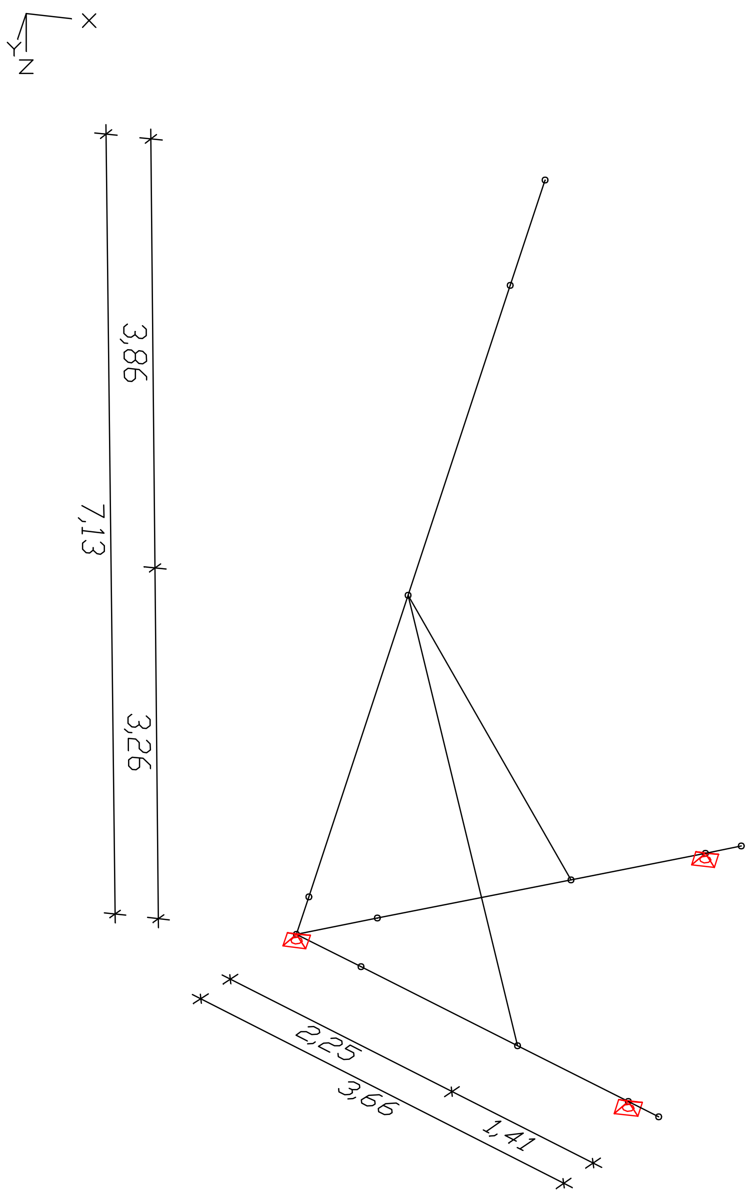
52064 Aachen
Telefon: 0241 / 70 96 96
Telefax: 0241 / 70 96 46
buero@vom-felde.de

2 SYSTEM

Overview isometric drawing:



All dimension refer to the axes of the trusses

Trusses: F34P

Bracings: roundtubes Ø60, t = 5 mm
Length ~3.6 m

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Telefax: 0241 / 70 96 46
buero@vom-felde.de

3 STRUCTURAL CALCULATION

3.1 Loadcases:

Selfweight:

LC1: Trusses F34P
Spindels, Rigging components distributed equally on the trusses
g_1 = 0,157 kN/m

LC 2: Bracings 2 x Ø60, t= 5 mm **g_2 = 0,015 kN/m**

Payloads:

LC3: PA max. 500kg (A = 2m²)
20 % enhancement due to dynamic effects **P_1=6 kN**

PA due to deflection (pulley) **P_1=2x6 kN**

Windloads

LC 10 Wind in x-direction
Wind case „operation with PA“ (max. v_{ref} = 15 m/s)
Acc.EN 13814
$q = 0{,}2$ kN/m²

Shape factor $c_p = 1{,}3$

Wind on PA (Area: max. 2m²)
W_1= 2 x 1,3 x 0,2 =0,52 kN **W_1= 0,52 kN**

LC 11 Wind in y-direction analogue LC 10 **W_2= 0,52 kN**

LC12 Win on free trusses in x-direction
Factor f = 1 – [0,29 - (2 • 0,05 + 2 • 20,5 • 0,02)] / 0,29 = 0,54

w = 1,3 • 0,54 • 0,29 x q = 0,2 x q

w_2 = 0,2 x q = 0,04 **w_2= 0,04 kN/m**

LC 13 Win on free trusses in y-direction analogue LC 12 **w_2= 0,04 kN/m**

Total loads
acc EN 13814: $\gamma_G = 1{,}0$ and $\gamma_Q = 1{,}35$

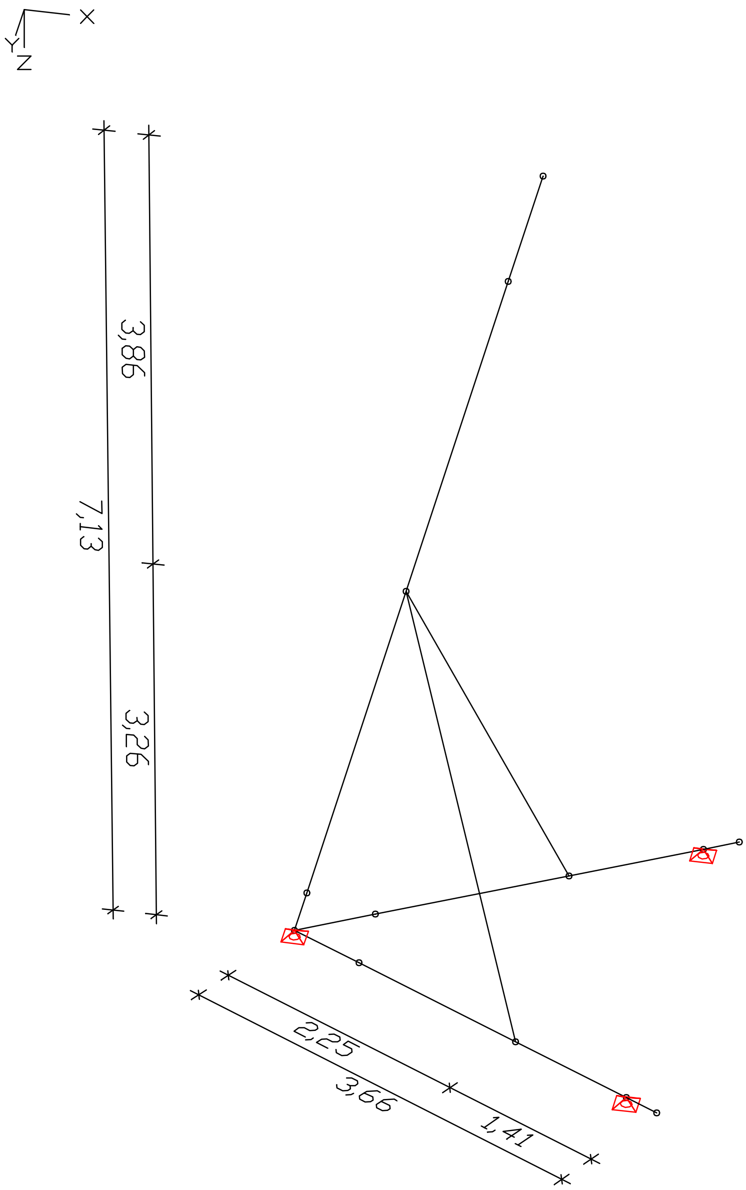
LC100 Totals loads with wind in x-direction

LC101 Totals loads with wind in y-direction

LC102 Totals loads with wind in negative x-direction

3.2 Computer calculation:

Dimension (referring to axes of the trusses)



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vom Felde + Keppler GmbH & Co. KG
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52064 AACHEN
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Telefax: 0241/709646
buero @ vom-felde.de

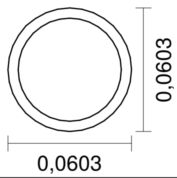
System characteristics

13	Nodes		
14	Elements	14	Beams
3	Supports	0	Slabs
0	Link elements	0	Plains
2	Material properties	0	Shells
2	Section properties	0	Cables
11	Load cases	0	Solids
0	LC Combinations	0	Spring elements
0	Tendon groups		

Result location in area elements: Node
2 Result locations in beam elements

Rotated element systems
0 Element systems
0 Internal force systems
0 Reinforcement systems

Section properties

1	Beam	F34P				
		Area [m²]	A	= 1,7719e-03		
		Moments of inertia [m4]	Ix	= 4,1085e-06	Iy	= 2,6006e-05
			Iz	= 2,6006e-05	Iyz	= 0,0000e+00
2	Library section	RO 60,3 x 5 (EN 10219-2); Cornerbrakes				
		Centroid [m]	ys	= 0,000	zs	= 0,000
		Area [m²]	A	= 8,6900e-04		
		Moments of inertia [m4]	Ix	= 6,6400e-07	Iyz	= 0,0000e+00
			Iy	= 3,3500e-07	I1	= 3,3500e-07
			Iz	= 3,3500e-07	I2	= 3,3500e-07
		Main axis angle [Grad]	Phi	= 0,000		

Material properties

	No.	Type	E-Modu. [MN/m²]	G-Modu. [MN/m²]	Poiss. ratio	alpha.t [1/K]	gamma [kN/m³]	Miscellaneous
1	1	Frei	70000	27000	0,30	2,300e-06	27,000	
2	2	Frei	70000	27000	0,30	2,300e-06	27,000	fc = 25 [MN/m²] ft = 0

List of load cases

LC.	Label
1	selfweight truss
2	selfweight Cornerbrakes
3	PA
10	Wind PA x

LC.	Label
11	Wind PA y
12	Wind on trusses x
13	Wind on trusses y
100	Total load with wind in +x
101	Total load with wind in +y
102	Total load with wind in -x

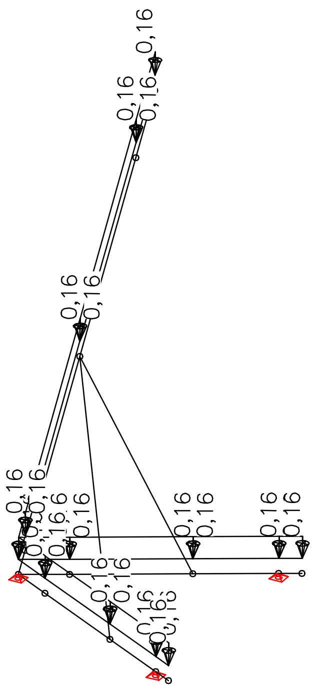
Sum of installed loads and support reactions

LC.	Label	Fx [kN]	Fy [kN]	Fz [kN]
1	selfweight truss	0,000	0,000	2,308
	Support reactions	-0,000	-0,000	2,308
2	selfweight Cornerbrakes	-0,000	0,000	0,108
	Support reactions	-0,000	-0,000	0,108
3	PA	0,000	0,000	6,000
	Support reactions	-0,000	-0,000	6,000
10	Wind PA x	0,520	0,000	0,000
	Support reactions	0,520	-0,000	0,000
11	Wind PA y	0,000	0,520	0,000
	Support reactions	0,000	0,520	-0,000
12	Wind on trusses x	0,588	-0,000	0,000
	Support reactions	0,588	0,000	0,000
13	Wind on trusses y	0,000	0,877	0,000
	Support reactions	0,000	0,877	-0,000
100	Total load with wind in +x	1,496	-0,000	10,516
	Support reactions	1,496	-0,000	10,516
101	Total load with wind in +y	-0,000	1,886	10,516
	Support reactions	-0,000	1,886	10,516
102	Total load with wind in -x	-1,496	0,000	10,516
	Support reactions	-1,496	-0,000	10,516

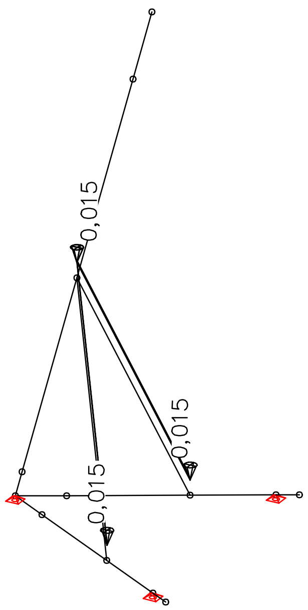
15393–PA500Tower

22.09.2015

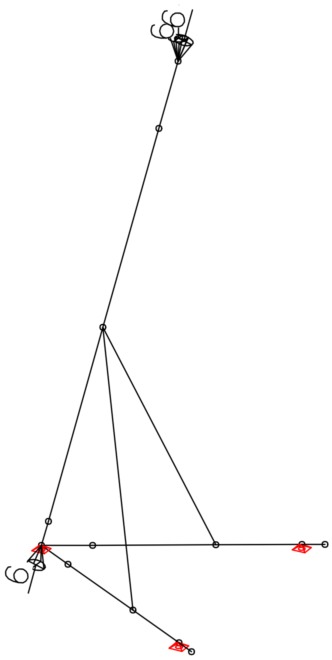
M 1 :



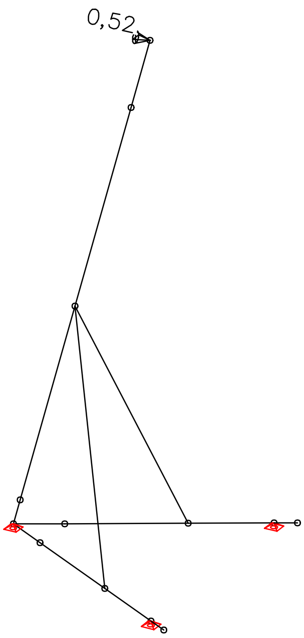
LC 1: Load, selfweight truss



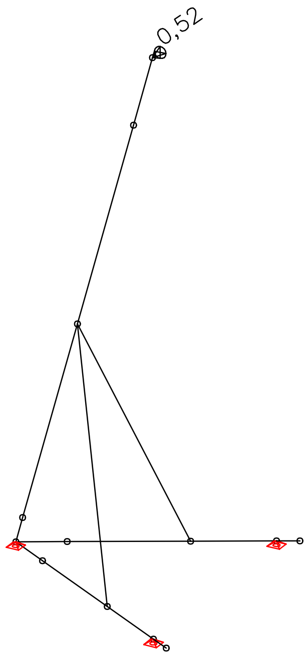
LC 2: Load, selfweight Cornerbrakes



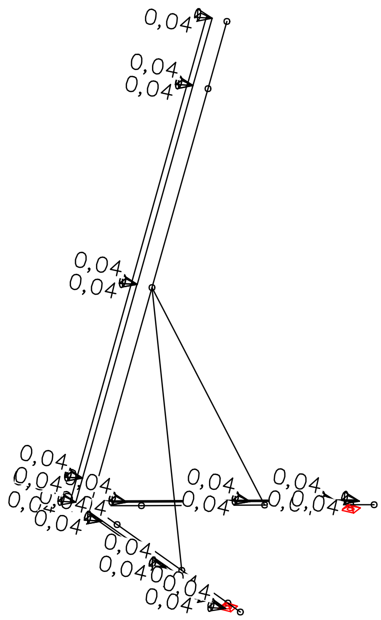
LC 3: Load, PA



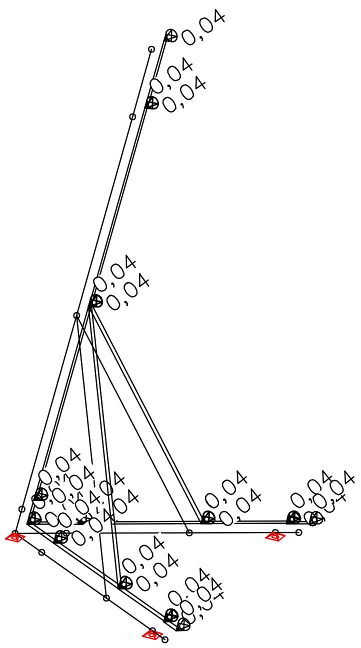
LC 10: Load, Wind PA x



LC 11: Load, Wind PA y



LC 12: Load, Wind on trusses x



LC 13: Load, Wind on trusses y

Load data load case 100: Total load with wind in +x

Load group (GRL)
Theory: 2. order theory
No soil pressure > 0: No; No support reac. < 0: No; Error threshold [%]: 1,00
Additional global load factor: 1,00; Predeformation: 0
Consider concrete creeping in the nonlinear analysis: No

Selected load cases

No.	Label	Factor
1	selfweight truss	1
2	selfweight Cornerbrakes	1
3	PA	1,35
10	Wind PA x	1,35
12	Wind on trusses x	1,35

Load data load case 101: Total load with wind in +y

Load group (GRL)
Theory: 2. order theory
No soil pressure > 0: No; No support reac. < 0: No; Error threshold [%]: 1,00
Additional global load factor: 1,00; Predeformation: 0
Consider concrete creeping in the nonlinear analysis: No

Selected load cases

No.	Label	Factor
1	selfweight truss	1
2	selfweight Cornerbrakes	1
3	PA	1,35
11	Wind PA y	1,35
13	Wind on trusses y	1,35

Load data load case 102: Total load with wind in -x

Load group (GRL)
Theory: 2. order theory
No soil pressure > 0: No; No support reac. < 0: No; Error threshold [%]: 1,00
Additional global load factor: 1,00; Predeformation: 0
Consider concrete creeping in the nonlinear analysis: No

Selected load cases

No.	Label	Factor
1	selfweight truss	1
2	selfweight Cornerbrakes	1
3	PA	1,35
10	Wind PA x	-1,35
12	Wind on trusses x	-1,35

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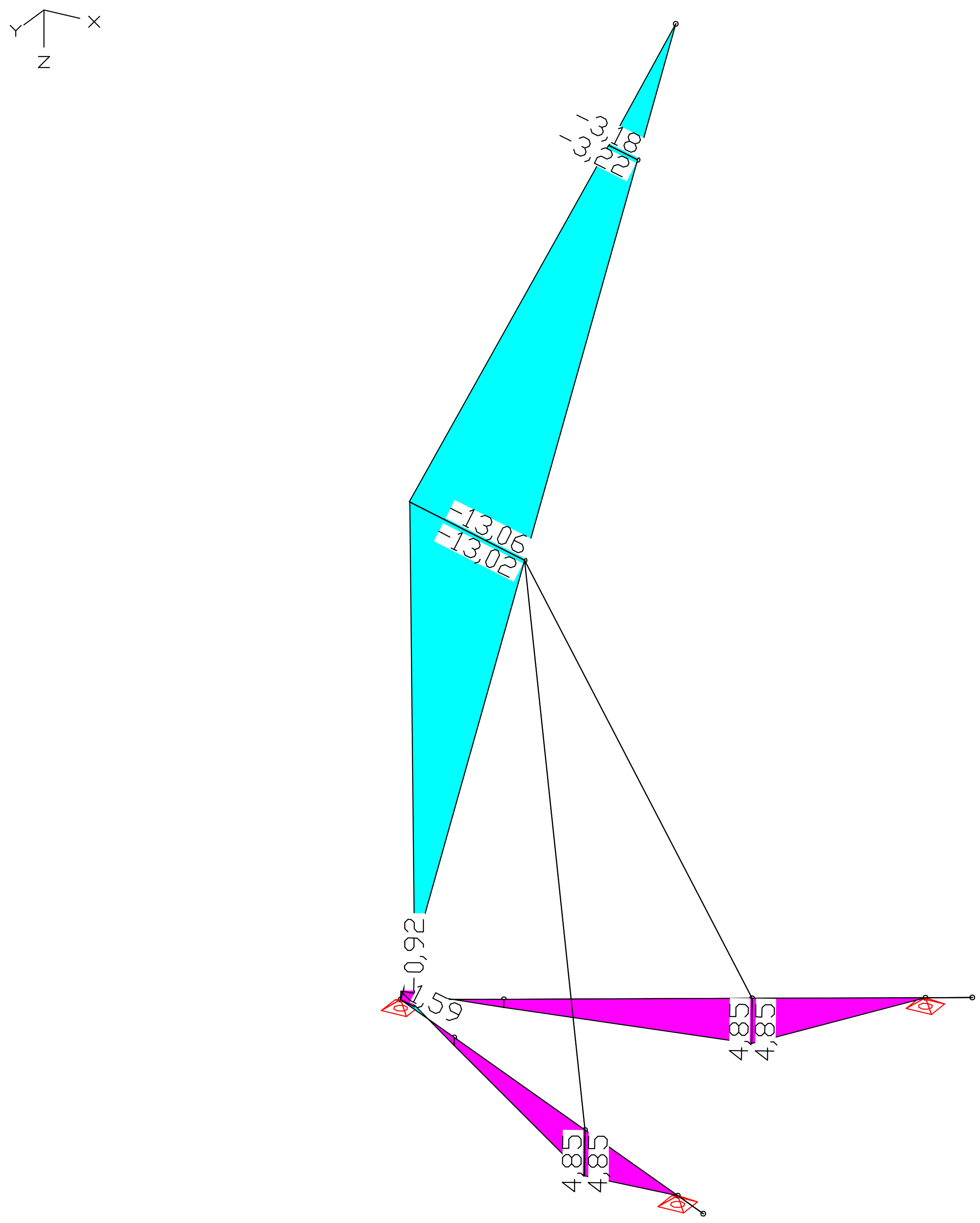
LÜTTICHER STR. 10–12
52064 AACHEN
Telefon: 0241/709696
Telefax: 0241/709646
buero @ vom-felde.de

15393-PA500Tower
Schnittgrößen My; LF 100, Gesamtlast mit Wind x-Richtung

22.09.2015
M 1 : 40



LC 100: Total load with wind in +x
Internal forces My [kNm]
Value range (overall system, min/max): -13,06/4,85 [kNm]

15393-PA500Tower
Schnittgrößen Mz; LF 100, Gesamtlast mit Wind x-Richtung

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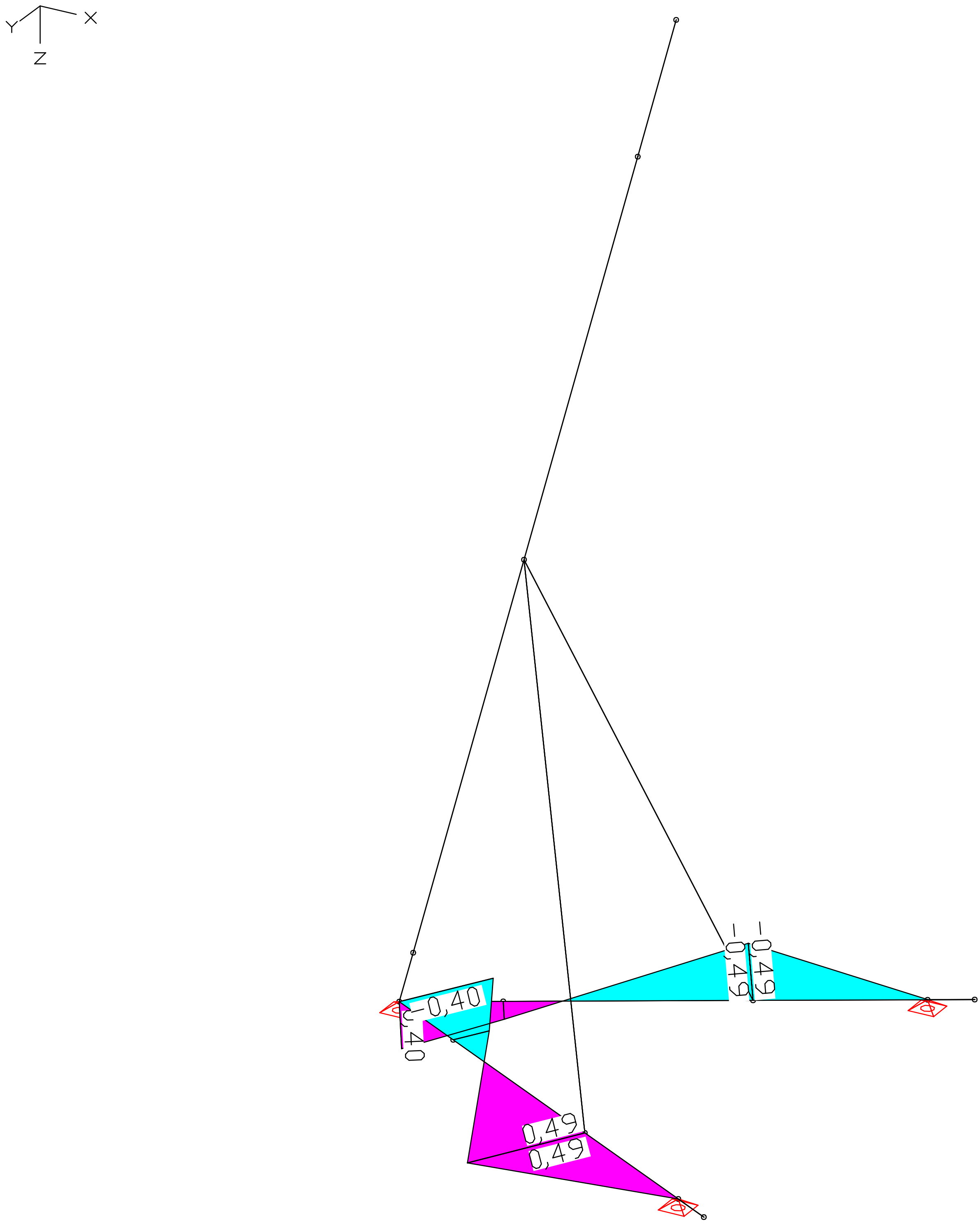
M 1 : 40



LC 100: Total load with wind in +x
Internal forces Mz [kNm]
Value range (overall system, min/max): -0,49/0,49 [kNm]

15393-PA500Tower
Schnittgrößen Nx; LF 100, Gesamtlast mit Wind x-Richtung

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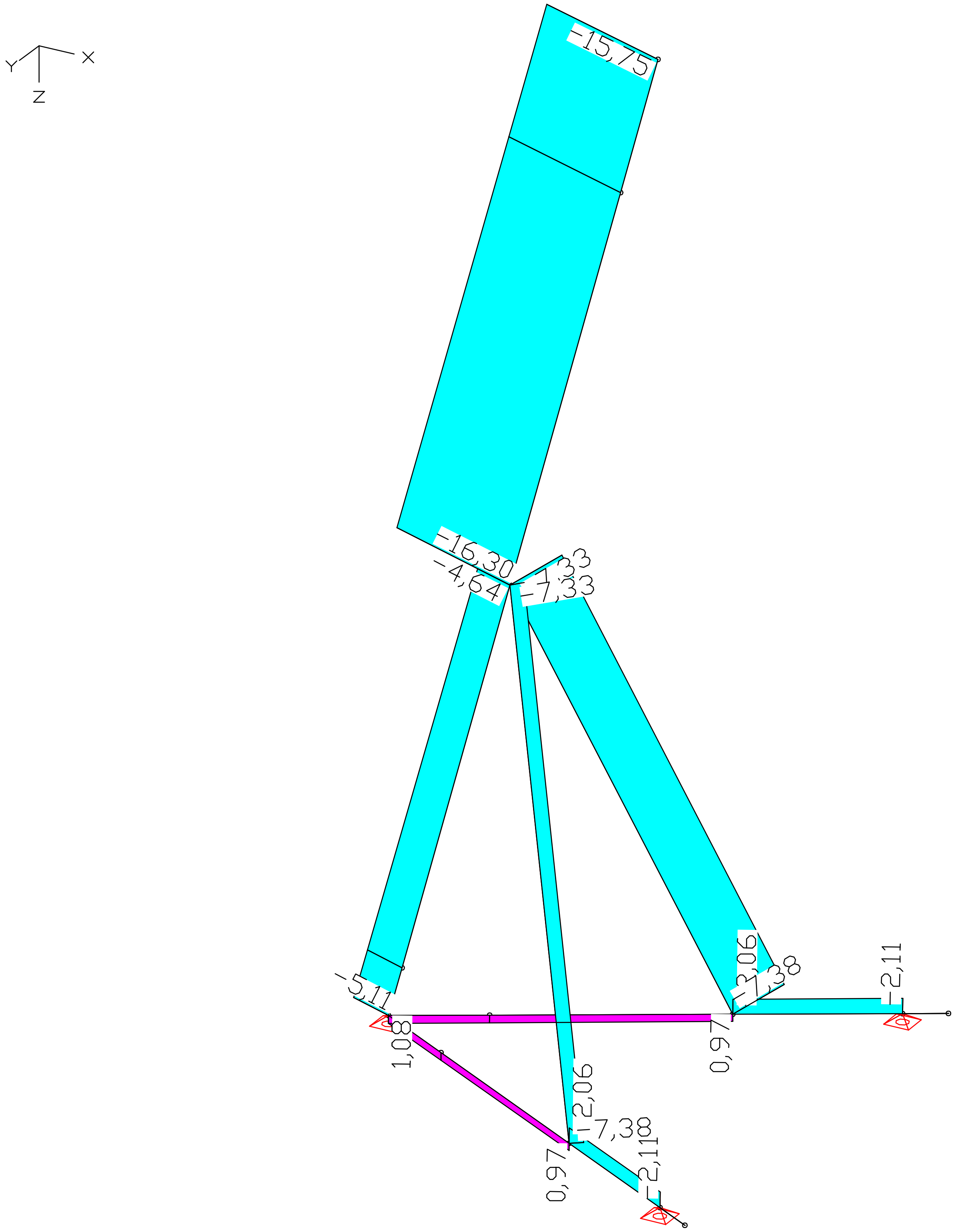
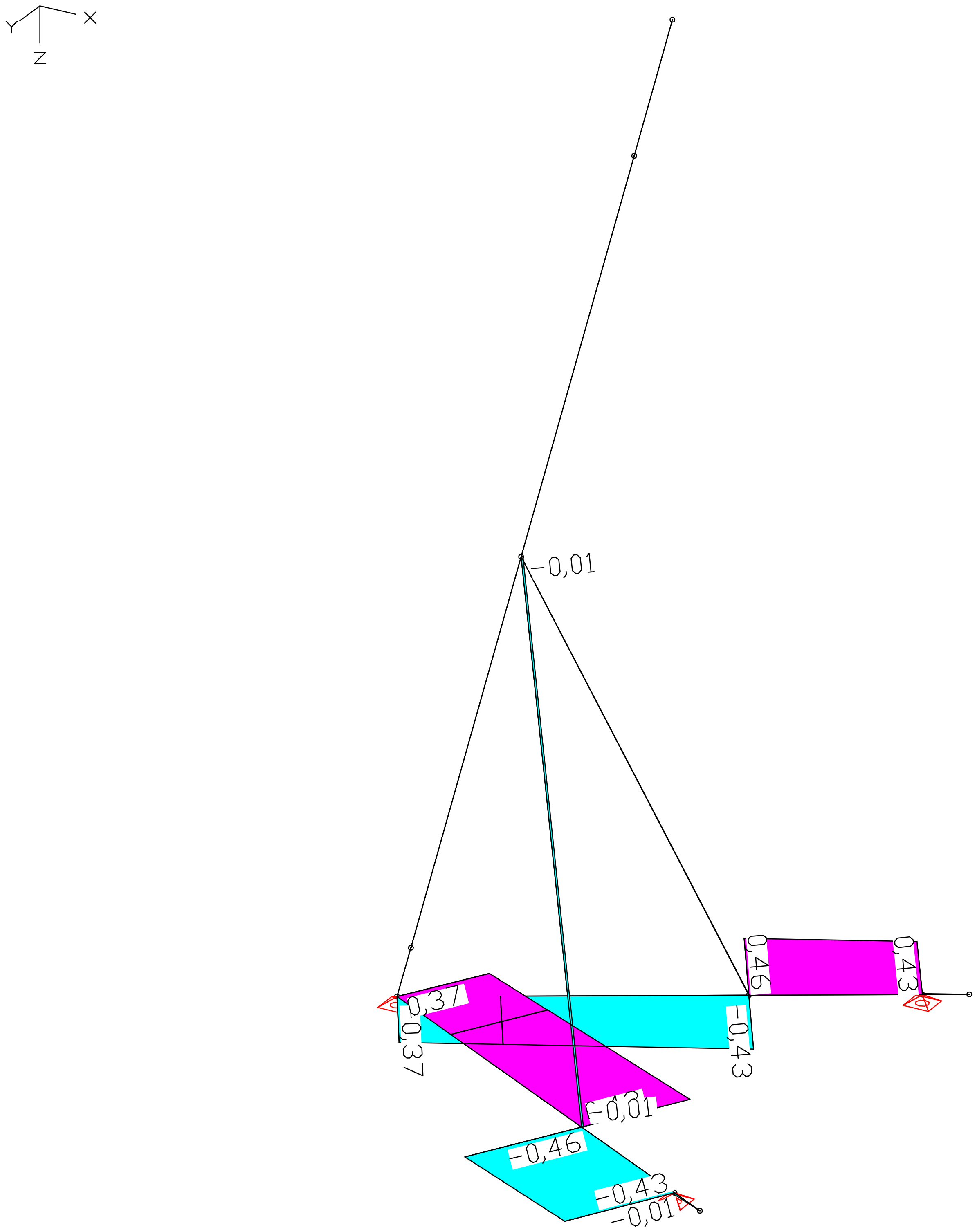
M 1 : 40



LC 100: Total load with wind in +x
Internal forces Nx [kN]
Value range (overall system, min/max): -16,30/1,08 [kN]

15393-PA500Tower
Schnittgrößen Qy; LF 100, Gesamtlast mit Wind x-Richtung

22.09.2015
M 1 : 40



LC 100: Total load with wind in +x
Internal forces Qy [kN]
Value range (overall system, min/max): -0,46/0,46 [kN]

15393-PA500Tower
Schnittgrößen Qz; LF 100, Gesamtlast mit Wind x-Richtung

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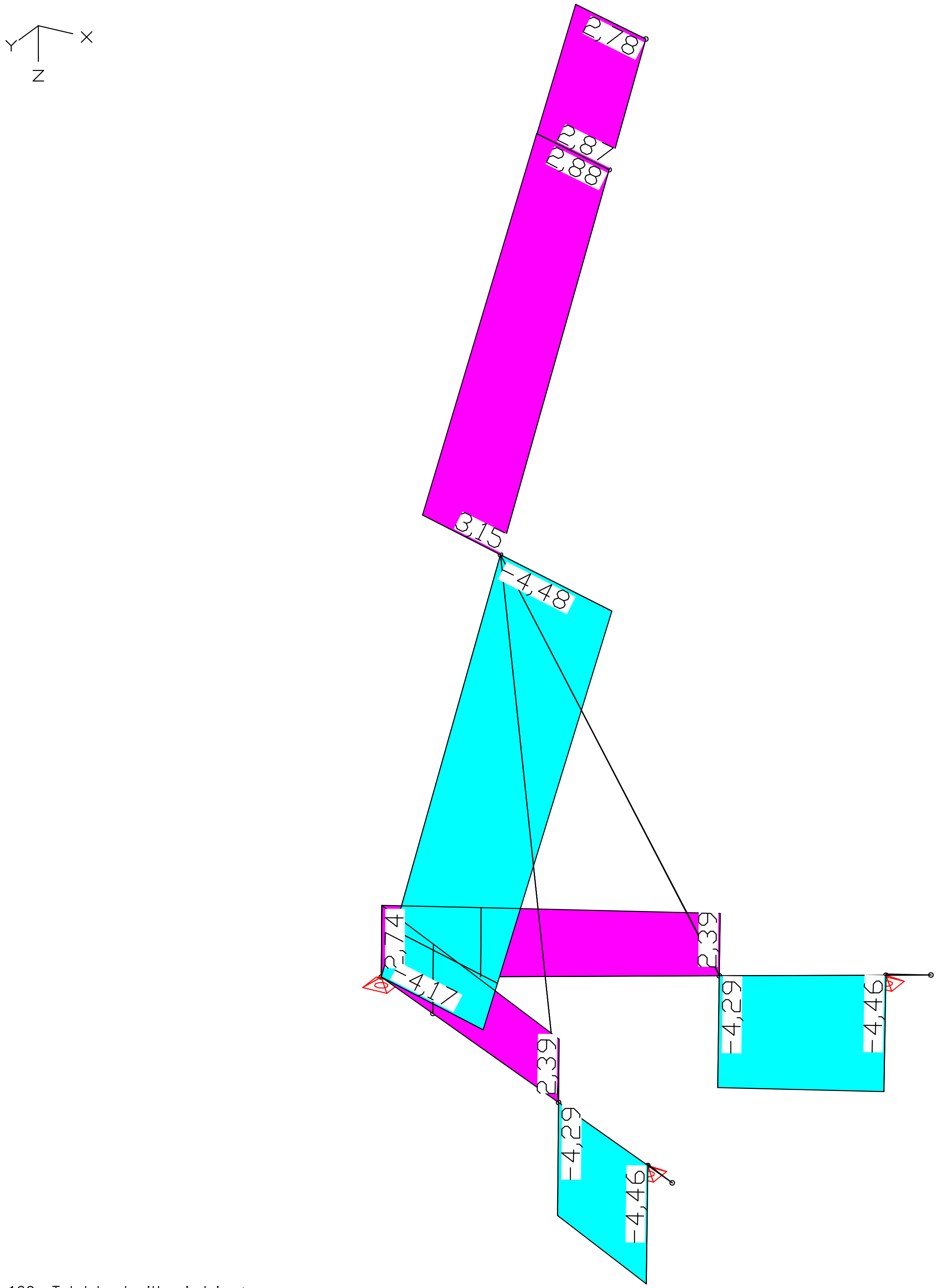
M 1 : 40



LC 100: Total load with wind in +x
Internal forces Qz [kN]
Value range (overall system, min/max): -4,48/3,15 [kN]

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LÜTTICHER STR. 10–12
52064 AACHEN
Telefon: 0241/709696
Telefax: 0241/709646
buero @ vom-felde.de

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Schnittgrößen My; LF 101, Gesamtlast mit Wind y–Richtung

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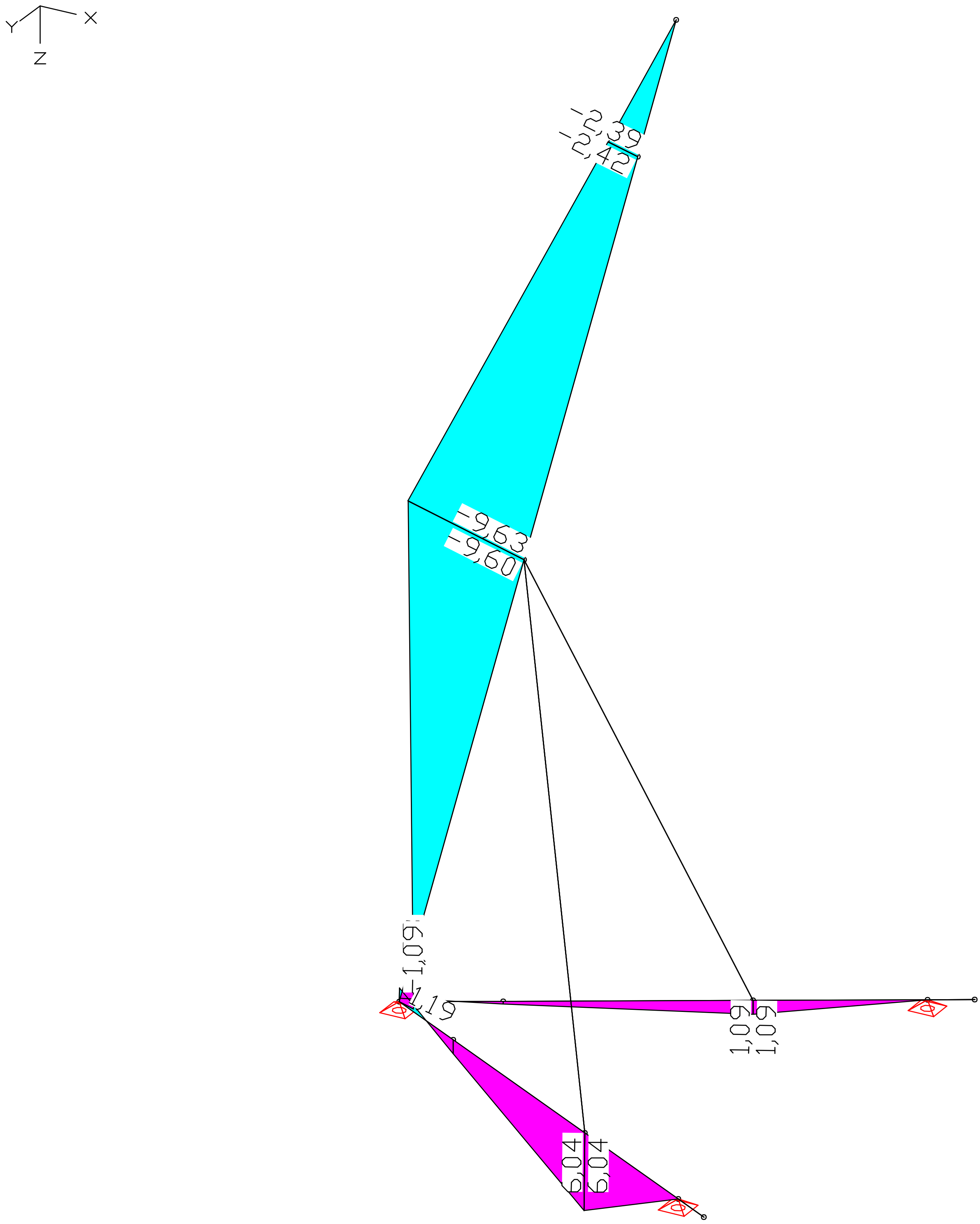
M 1 : 40



LC 101: Total load with wind in +y
Internal forces My [kNm]
Value range (overall system, min/max): –9,63/6,04 [kNm]

15393–PA500Tower
Schnittgrößen Mz; LF 101, Gesamtlast mit Wind y–Richtung

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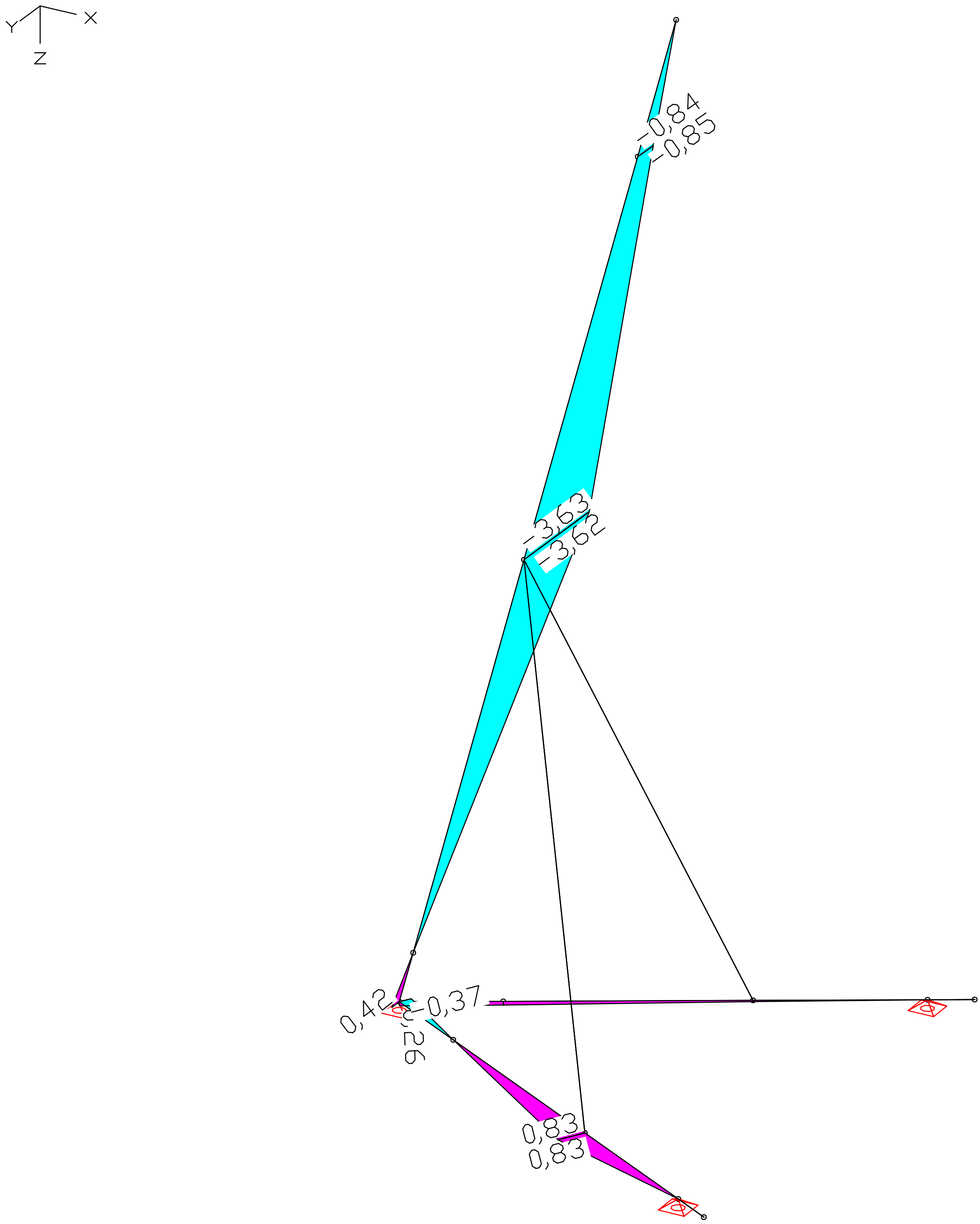
M 1 : 40



LC 101: Total load with wind in +y
Internal forces Mz [kNm]
Value range (overall system, min/max): −3,63/0,83 [kNm]

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Telefax: 0241/709646
buero @ vom–felde.de

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Schnittgrößen Nx; LF 101, Gesamtlast mit Wind y–Richtung
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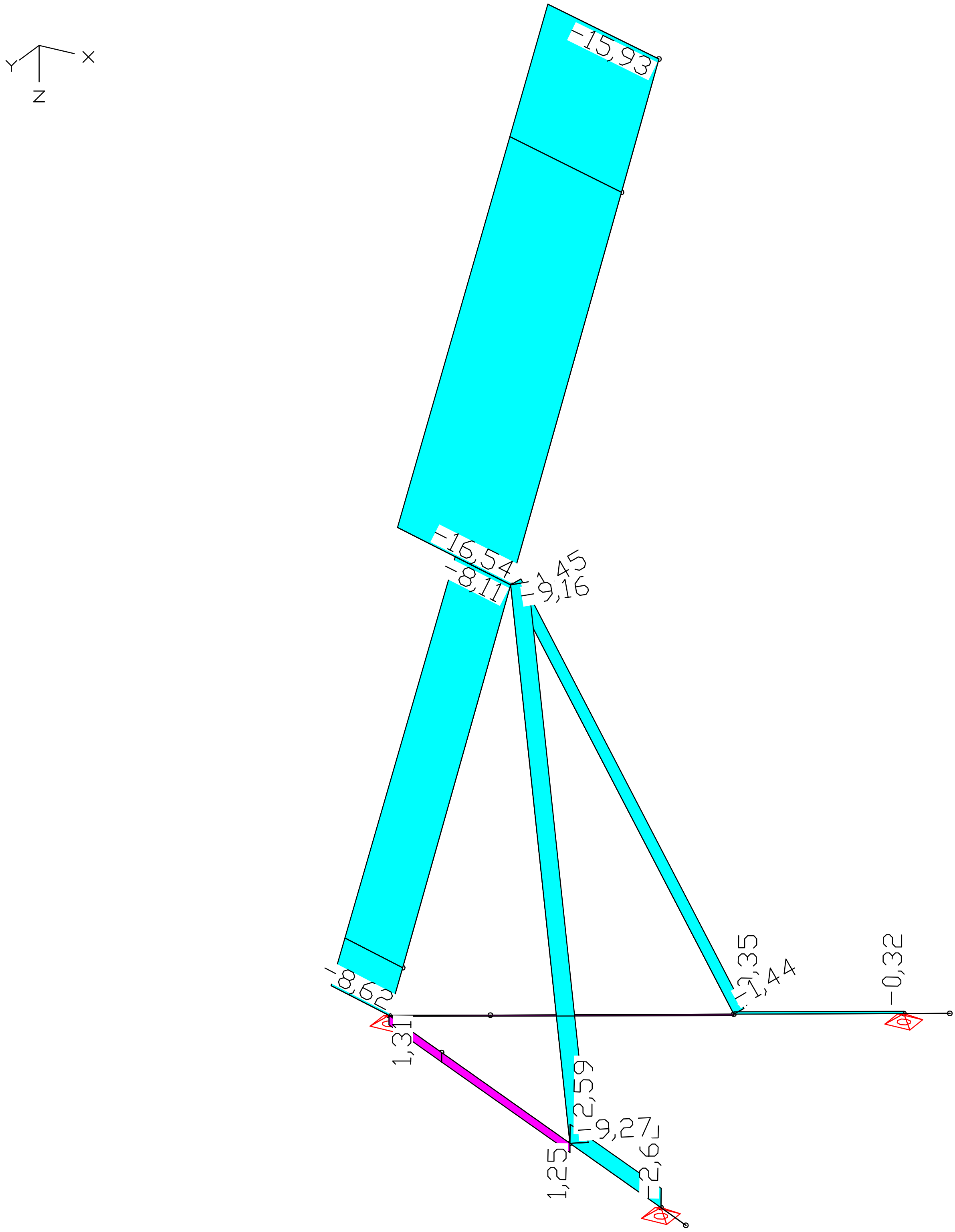

LC 101: Total load with wind in +y
Internal forces Nx [kN]
Value range (overall system, min/max): –16,54/1,31 [kN]

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Schnittgrößen Qy; LF 101, Gesamtlast mit Wind y-Richtung

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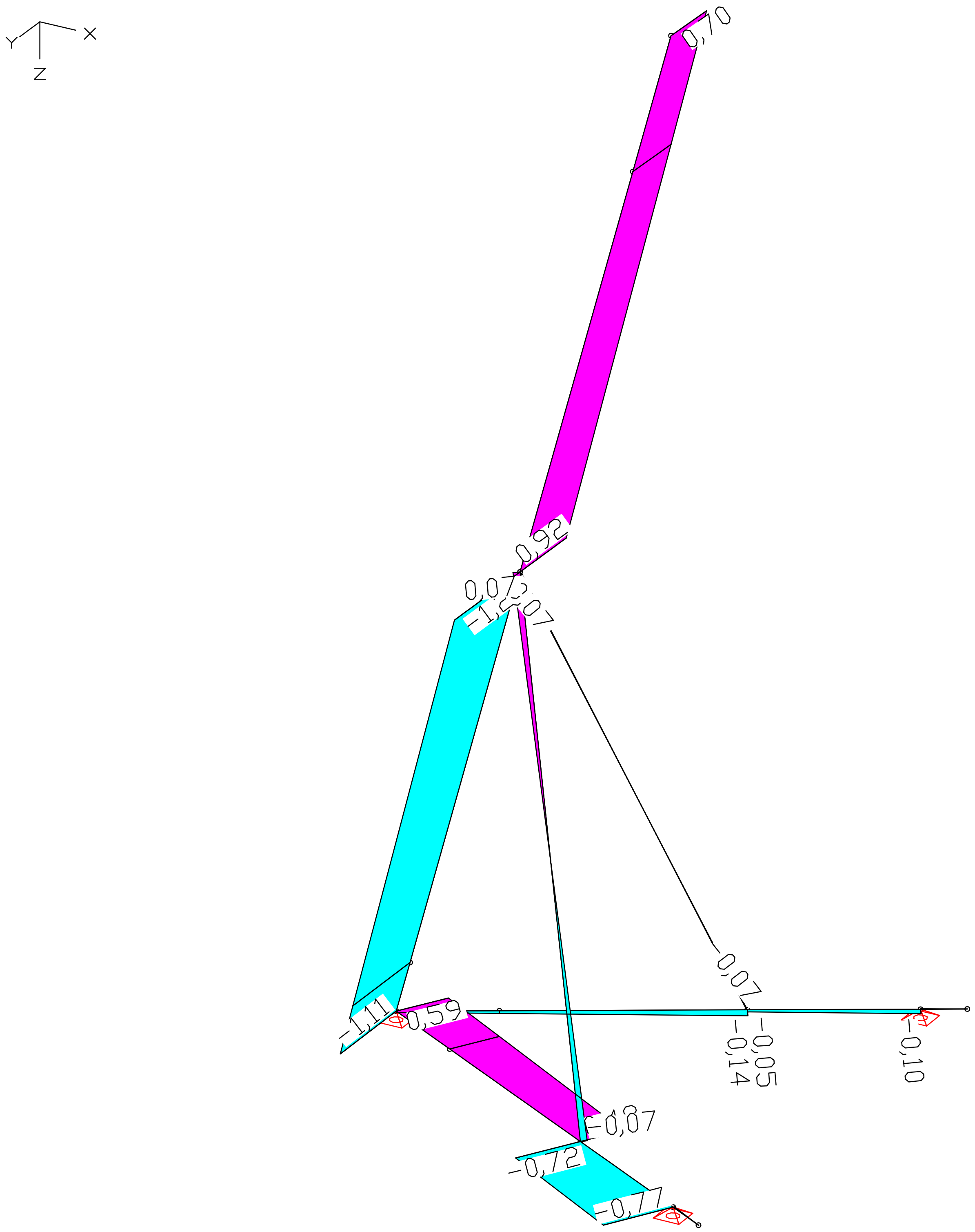

LC 101: Total load with wind in +y
Internal forces Qy [kN]
Value range (overall system, min/max): -1,29/0,92 [kN]

15393-PA500Tower
Schnittgrößen Qz; LF 101, Gesamtlast mit Wind y-Richtung

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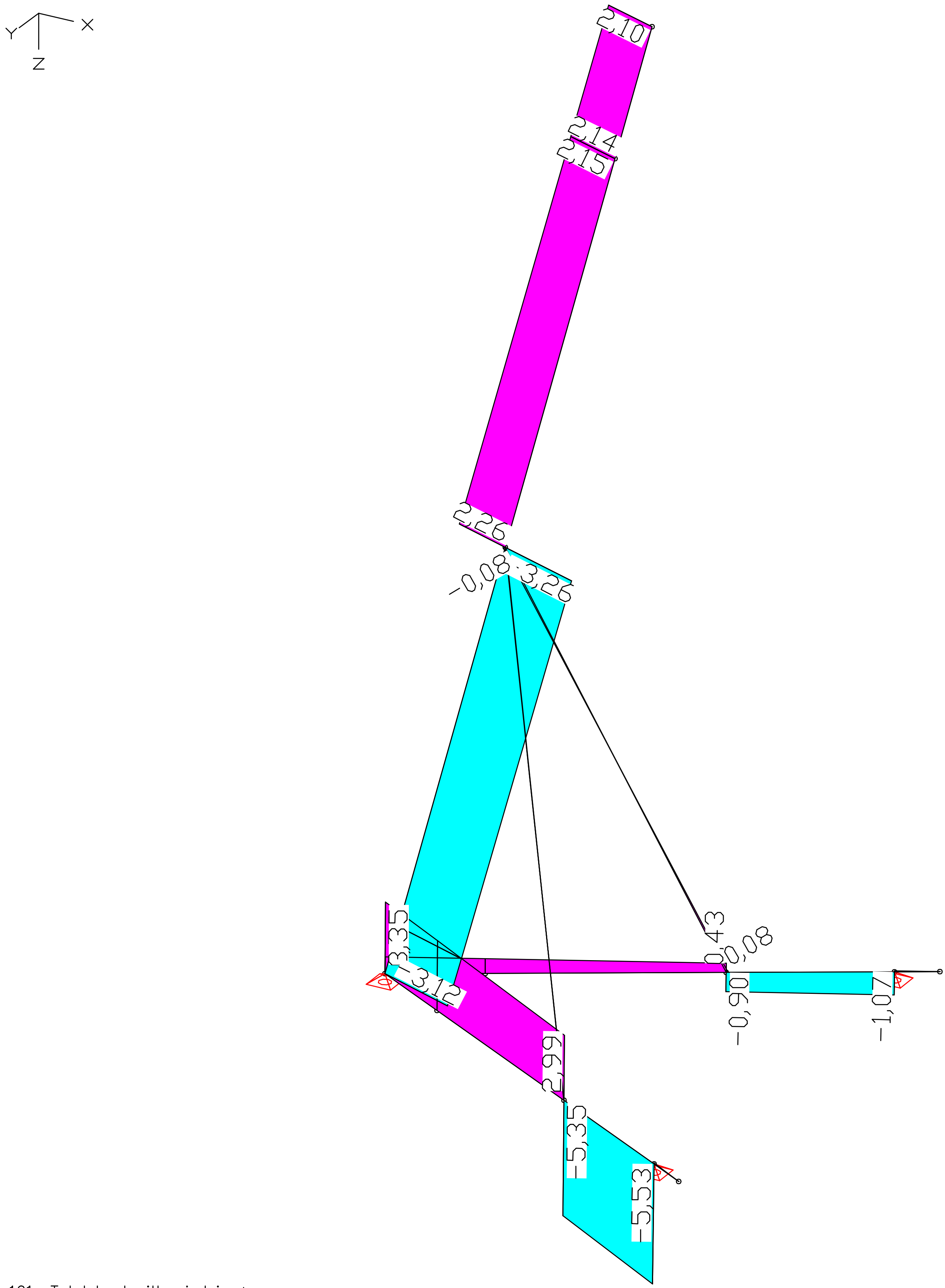
M 1 : 40



LC 101: Total load with wind in +y
Internal forces Qz [kN]
Value range (overall system, min/max): -5,53/3,35 [kN]

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LÜTTICHER STR. 10–12
52064 AACHEN
Telefon: 0241/709696
Telefax: 0241/709646
buero @ vom–felde.de

15393–PA500Tower
Schnittgrößen My; LF 102, Gesamtlast Wind negative x–Richtung

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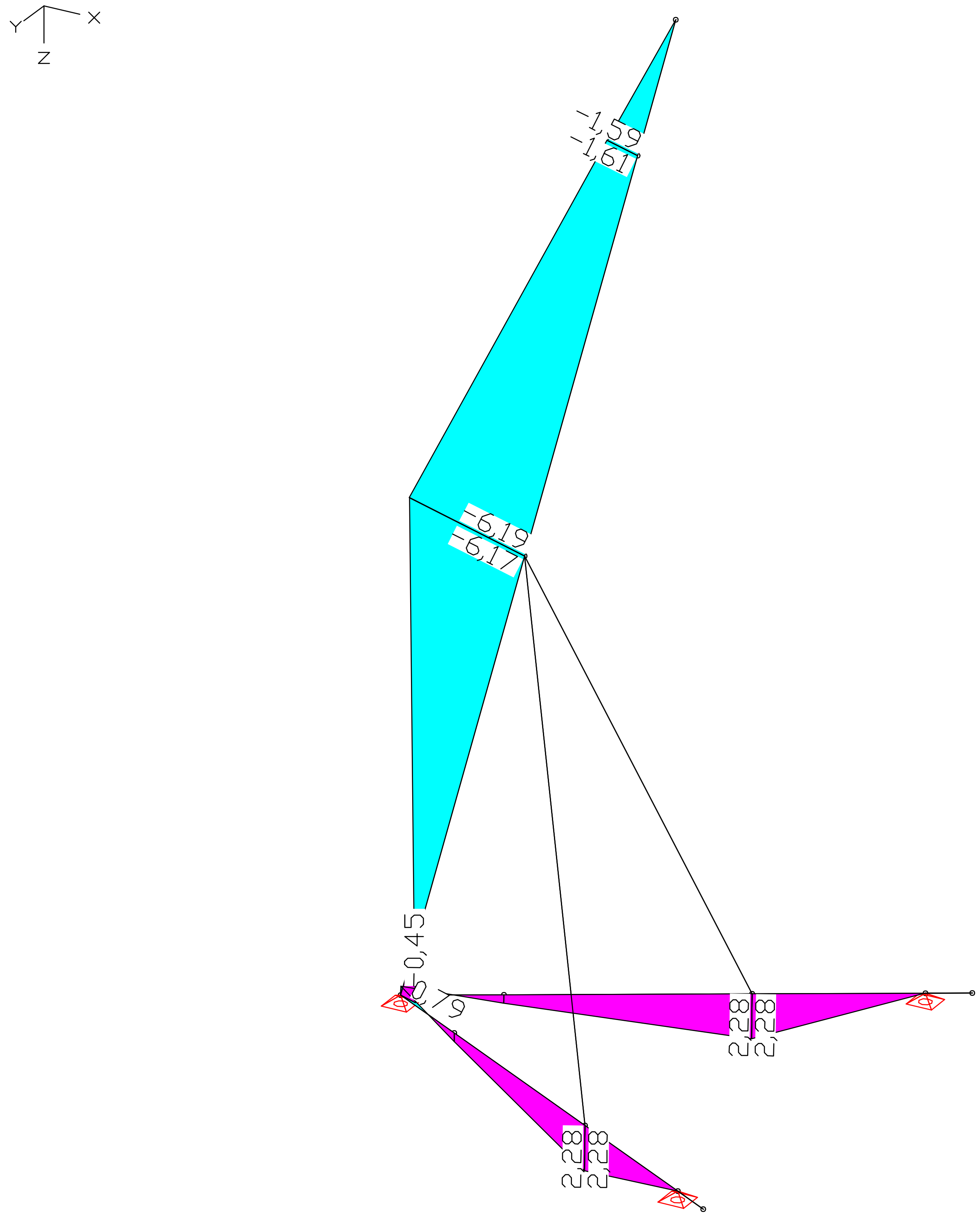
M 1 : 40



LC 102: Total load with wind in –x
Internal forces My [kNm]
Value range (overall system, min/max): –6,19/2,28 [kNm]

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Telefax: 0241/709646
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15393-PA500Tower
Schnittgrößen Mz; LF 102, Gesamtlast Wind negative x-Richtung

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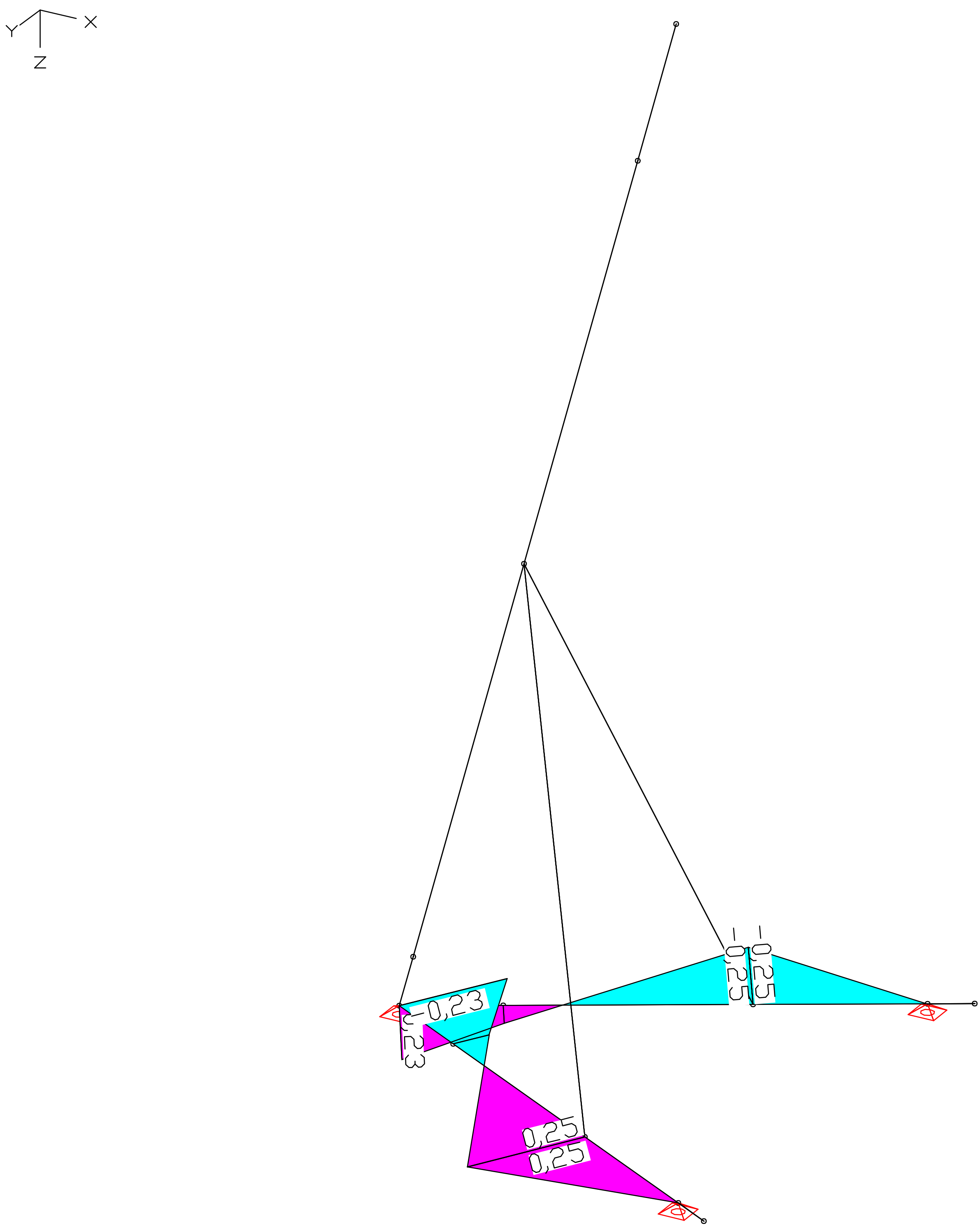
M 1 : 40

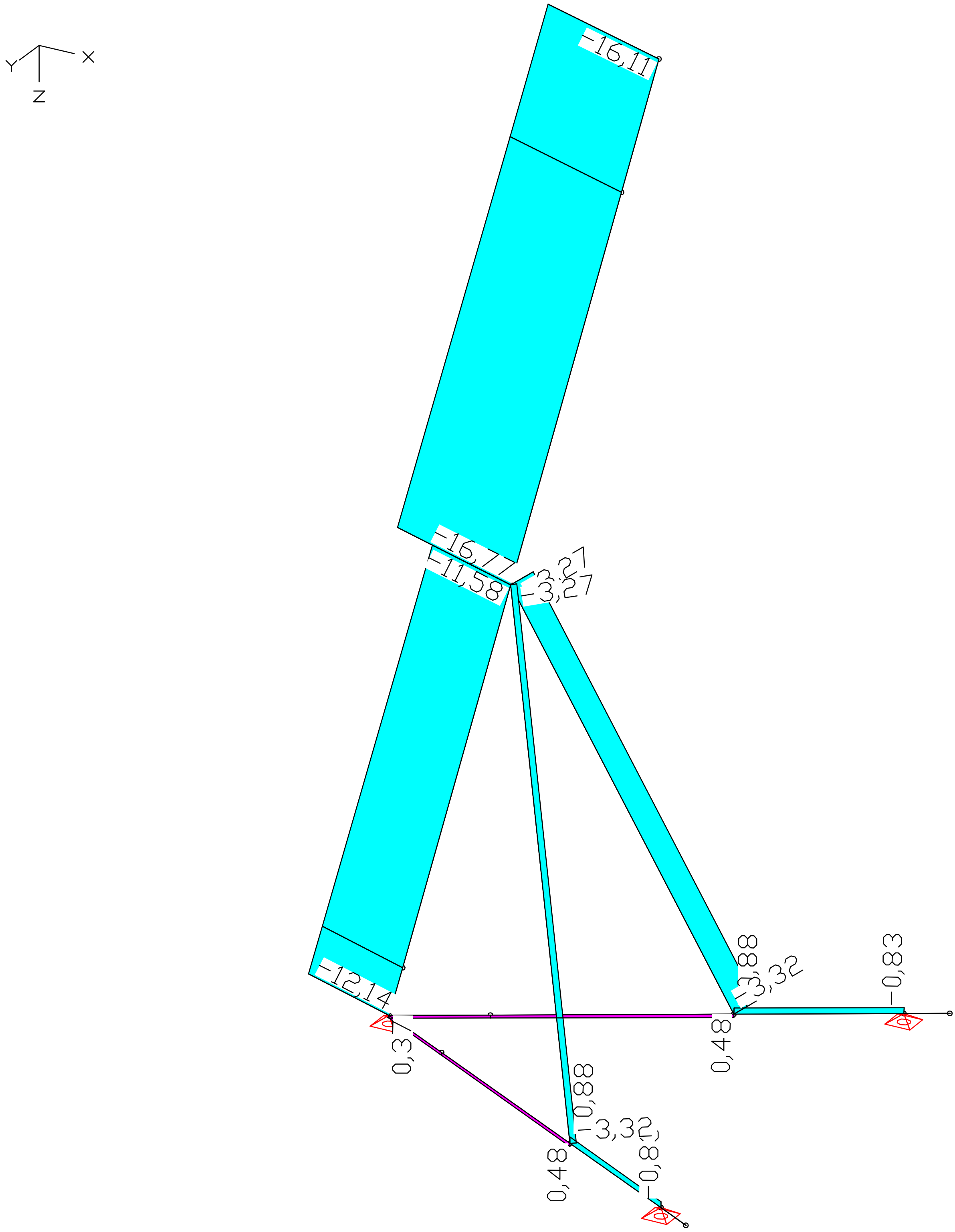


LC 102: Total load with wind in -x
Internal forces Mz [kNm]
Value range (overall system, min/max): -0,25/0,25 [kNm]

BÜRO FÜR TRAGWERKSPLANUNG UND INGENIEURBAU
vom Felde + Keppler GmbH & Co. KG
LÜTTICHER STR. 10-12
52064 AACHEN
Telefon: 0241/709696
Telefax: 0241/709646
buero @ vom-felde.de

15393-PA500Tower
Schnittgrößen Nx; LF 102, Gesamtlast Wind negative x-Richtung

22.09.2015
M 1 : 40



LC 102: Total load with wind in -x
Internal forces Nx [kN]
Value range (overall system, min/max): -16,77/0,48 [kN]

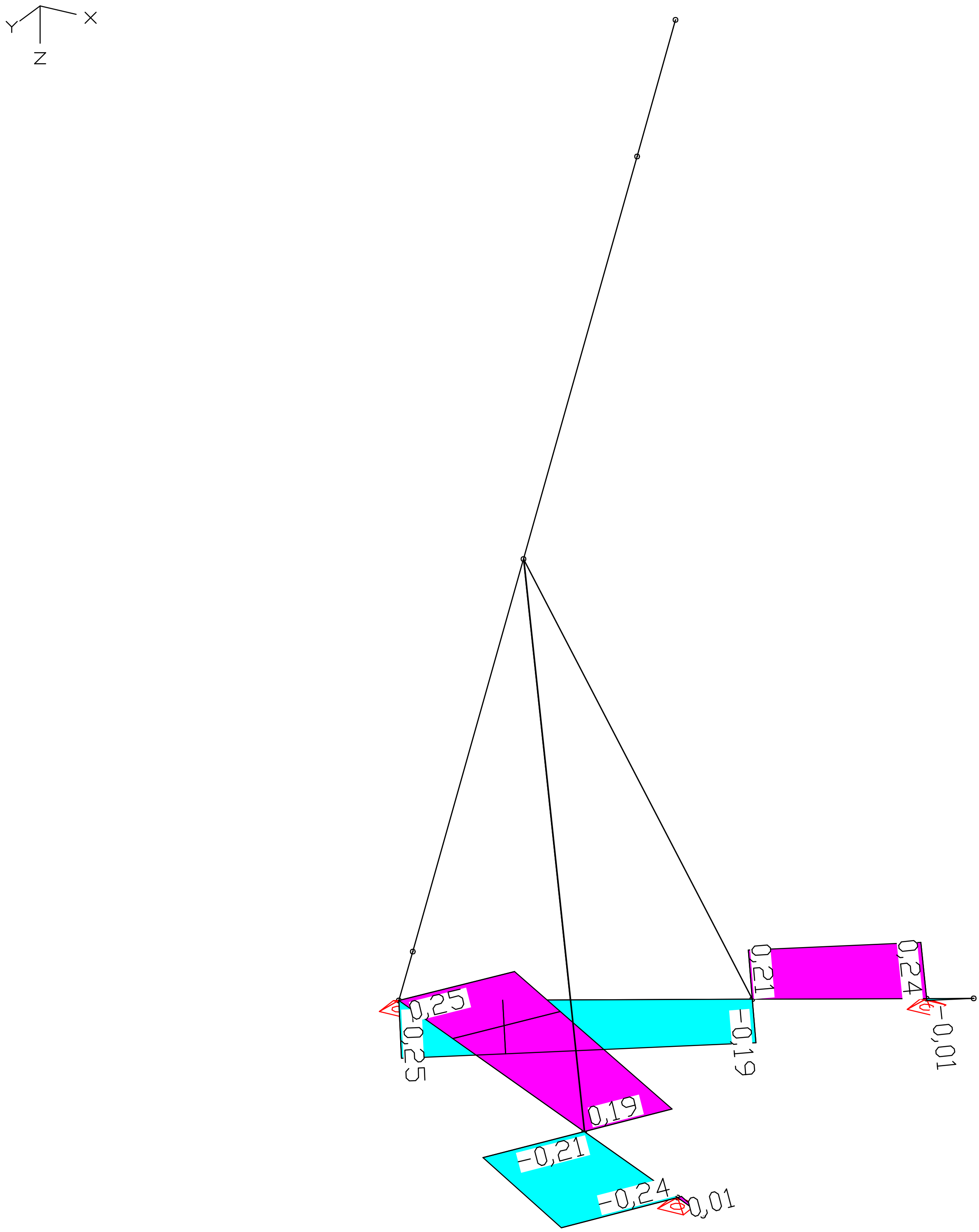
BÜRO FÜR TRAGWERKSPLANUNG UND INGENIEURBAU
vom Felde + Keppler GmbH & Co. KG
LÜTTICHER STR. 10–12
52064 AACHEN
Telefon: 0241/709696
Telefax: 0241/709646
buero @ vom–felde.de

15393–PA500Tower

22.09.2015

Schnittgrößen Qy; LF 102, Gesamtlast Wind negative x–Richtung

M 1 : 40



LC 102: Total load with wind in –x

Internal forces Qy [kN]

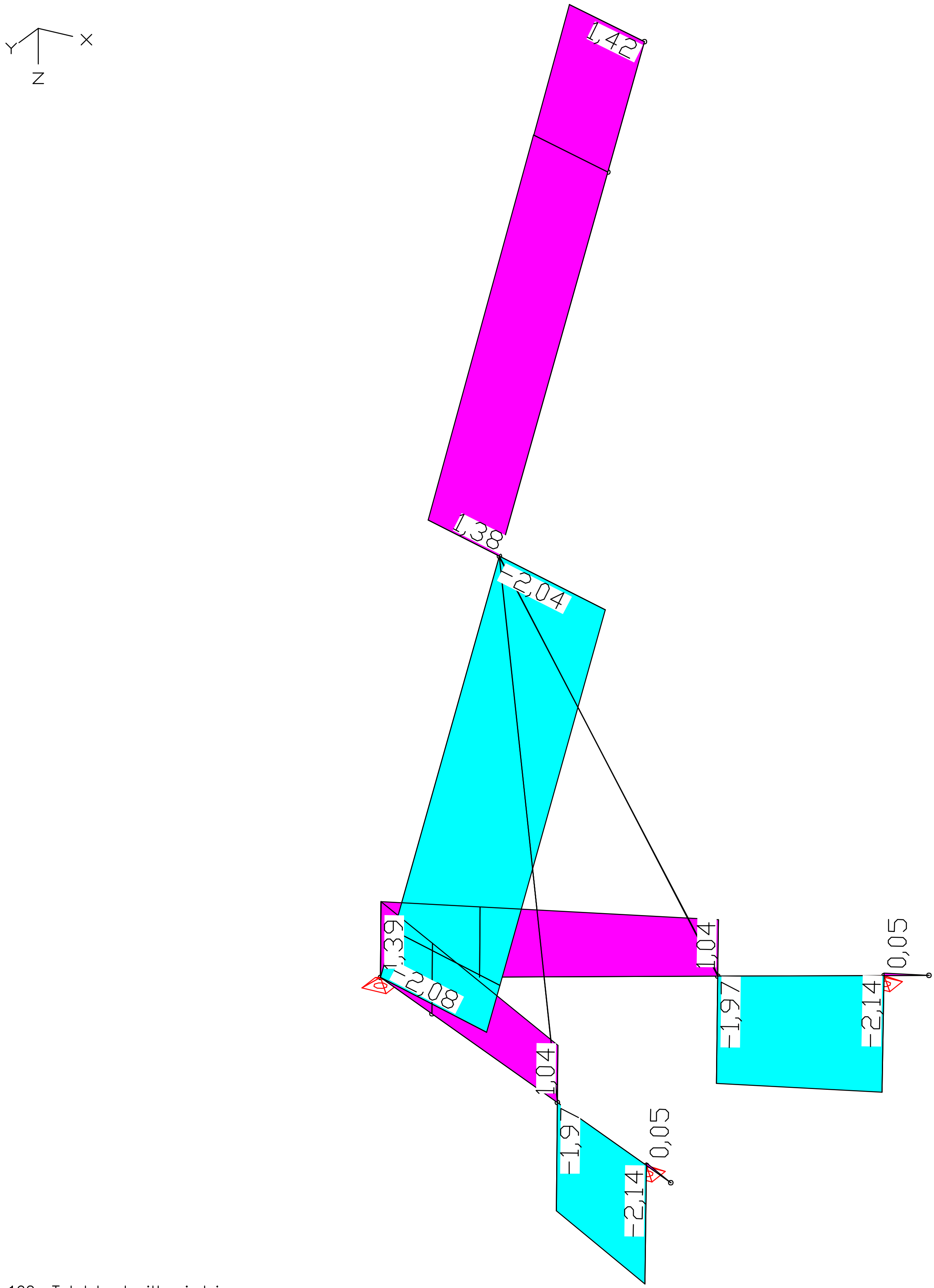
Value range (overall system, min/max): –0,25/0,25 [kN]

BÜRO FÜR TRAGWERKSPLANUNG UND INGENIEURBAU
vom Felde + Keppler GmbH & Co. KG
LÜTTICHER STR. 10-12
52064 AACHEN
Telefon: 0241/709696
Telefax: 0241/709646
buero @ vom-felde.de

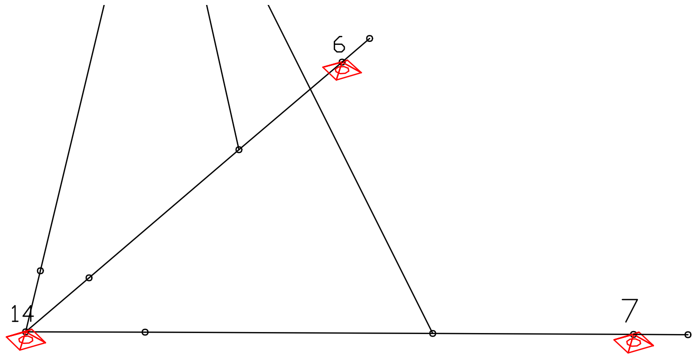
15393-PA500Tower
Schnittgrößen Qz; LF 102, Gesamtlast Wind negative x-Richtung

22.09.2015

M 1 : 40



LC 102: Total load with wind in -x
Internal forces Qz [kN]
Value range (overall system, min/max): -2,14/1,42 [kN]



Support numbers

Support reactions from all load cases

Node	LC	Rx [kN]	Ry [kN]	Rz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
6	1	0,07	-0,06	0,50	0,00	0,00	0,00
	2	0,00	-0,00	0,03	0,00	0,00	0,00
	3	0,72	-0,67	1,97	0,00	0,00	0,00
	10	0,23	-0,22	0,64	0,00	0,00	0,00
	11	-0,39	0,40	-1,10	0,00	0,00	0,00
	12	0,14	-0,07	0,18	0,00	0,00	0,00
	13	-0,15	0,29	-0,45	0,00	0,00	0,00
	100	1,62	-1,43	4,51	0,00	0,00	0,00
	101	0,33	-0,06	1,12	0,00	0,00	0,00
	102	0,58	-0,63	2,19	0,00	0,00	0,00
7	1	0,07	0,06	0,50	0,00	0,00	0,00
	2	0,00	0,00	0,03	0,00	0,00	0,00
	3	0,72	0,67	1,97	0,00	0,00	0,00
	10	0,23	0,22	0,64	0,00	0,00	0,00
	11	0,39	0,40	1,10	0,00	0,00	0,00
	12	0,14	0,07	0,18	0,00	0,00	0,00
	13	0,15	0,29	0,45	0,00	0,00	0,00
	100	1,62	1,43	4,51	0,00	0,00	0,00
	101	1,88	1,99	5,58	0,00	0,00	0,00
	102	0,58	0,63	2,19	0,00	0,00	0,00
14	1	-0,13	-0,00	1,30	0,00	0,00	0,00
	2	-0,01	-0,00	0,06	0,00	0,00	0,00
	3	-1,45	-0,00	2,05	0,00	0,00	0,00
	10	0,05	-0,00	-1,27	0,00	0,00	0,00
	11	-0,00	-0,27	0,00	0,00	0,00	0,00
	12	0,31	-0,00	-0,36	0,00	0,00	0,00
	13	-0,00	0,31	0,00	0,00	0,00	0,00
	100	-1,75	-0,00	1,50	0,00	0,00	0,00
	101	-2,21	-0,04	3,82	0,00	0,00	0,00
	102	-2,66	-0,00	6,14	0,00	0,00	0,00

4 STRUCTURAL INTEGRITY

4.1 F34P - Trusses

Allowable loadings see annex

Normal force in chords	Maxmium loadings	max M_{zd} = 13,06kNm Nd = 16,3 kNm N_{sdG}=(13,06)/(2x0,24)+16,3/4=31,28kN < N_{Rdg} = 52,45 kN
Normal force in bracings	Maxmium loadings	max Q_{yd} = 5,53 kN $N_{dia,z,d}$ = 5,53 kN/(2 sin 39,1 °) = 4,07 kN < $N_{Rd,dia}$ = 13,39 kN
Moment and shear force at coupler	Maxmium loadings	N_{sdG} = 31,28 kN (s.o) max Q_{yd} = 5,53 kN M_{sdG} = 5,53 x 7cm/4=9,68kNcm N_{Rdg} = 52,45 kN M_{Rdg} = 61,63 kNcm $(N_{sdG}/N_{Rdg})^{1,3} + (M_{sdG}/M_{Rdg})$ = 0,64 < 1,0

Lütticher Straße 10-12
52064 Aachen
Telefon: 0241 / 70 96 96
Telefax: 0241 / 70 96 46
buero@vom-felde.de

4.2 Bracing tubes

Buckling

Maxmium loadings

$N_{d,brac.}$ = 9,27kN

$N_{b,Rd} = \chi \times A \times f_y / \gamma_{M1}$
RO 60 x 5   A = 8,64 cm^2
λ^* = 2,6
Φ = 4,14
X = 0,14

N_{bRd} = 8,64 cm^2 x 140 N/mm^2 x 0,14 /1,1
= 14,96 kN

max $N_{d,brac.}$ = 9,27 kN
< N_{bRd} = 14,96 kN

Lütticher Straße 10-12
52064 Aachen
Telefon: 0241 / 70 96 96
Telefax: 0241 / 70 96 46
buero@vom-felde.de

4.3 Local introduction of forces

Connection of bracings

Connection bracings at connecting element — Maxmium loadings

Ned = 9,16 x sin(38°) = 5,68 kN

Rect. Hollow profil 50 x 4mm
Material EN AW-6061 T6
Wpl = 11,7 cm³
fyk = 240 N/mm²

MplRd = 11,7 x fy / 1,1 = 256 kNcm
Med = Ned x 50/4 = 71 kNcm
< MplRd

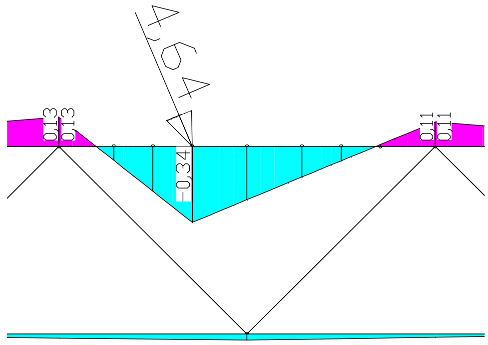
Connection bracings at trusses

Case a: bottom — Maxmium normal force

Normal force in bracings
max $N_{dbrac.}$ = 9,27/2 = 4,64 kN
Global forces in trusses
Md = 6,04 kNm
Nd = 2,59 kN

Normal force in chords
N_{sdG} = 2,59/4 + 6,04/ 0,48 = 13,23 kN

Bending moment in the chord
(see sketch)
M_{sdG} = 34 kNcm
N_{RdG} = 52,45 kN
M_{RdG} = 61,63 kNcm
$(N_{sdG}/N_{Rdg})^{1,3} + (M_{sdG}/M_{Rdg})$ = 0,72 < 1,0



Case b: top — Maxmium normal force

Normal force in bracings

max $N_{dbrac.}$ = 9,16/2 = 4,6 kN

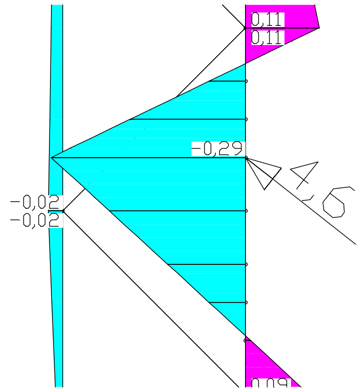
Global forces in trusses
Md = 9,63 kNm
Nd = 16,54 kN

Lütticher Straße 10-12
52064 Aachen
Telefon: 0241 / 70 96 96
Telefax: 0241 / 70 96 46
buero@vom-felde.de

Normal force in chords
N_{sdG} = 16,54/4 + 9,63/ 0,48 = 24,20 kN

Bending moment in the chord
(see sketch)
M_{sdG} = 29 kNcm

N_{RdG} = 52,45 kN
M_{RdG} = 61,63 kNcm
$(N_{sdG}/N_{Rdg})^{1,3} + (M_{sdG}/M_{Rdg}) = 0,84 < 1,0$



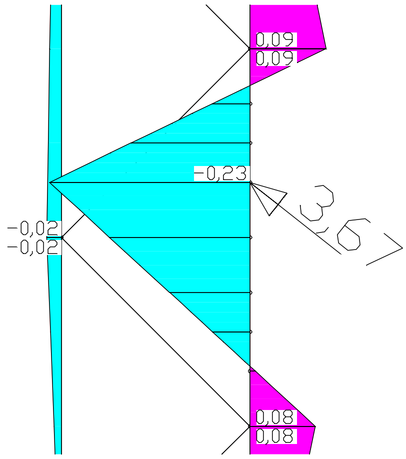
Case c: top Maximum Moment

Normal force bracings
$N_{dbrac.}$ = 7,33/2 = 3,67 kN

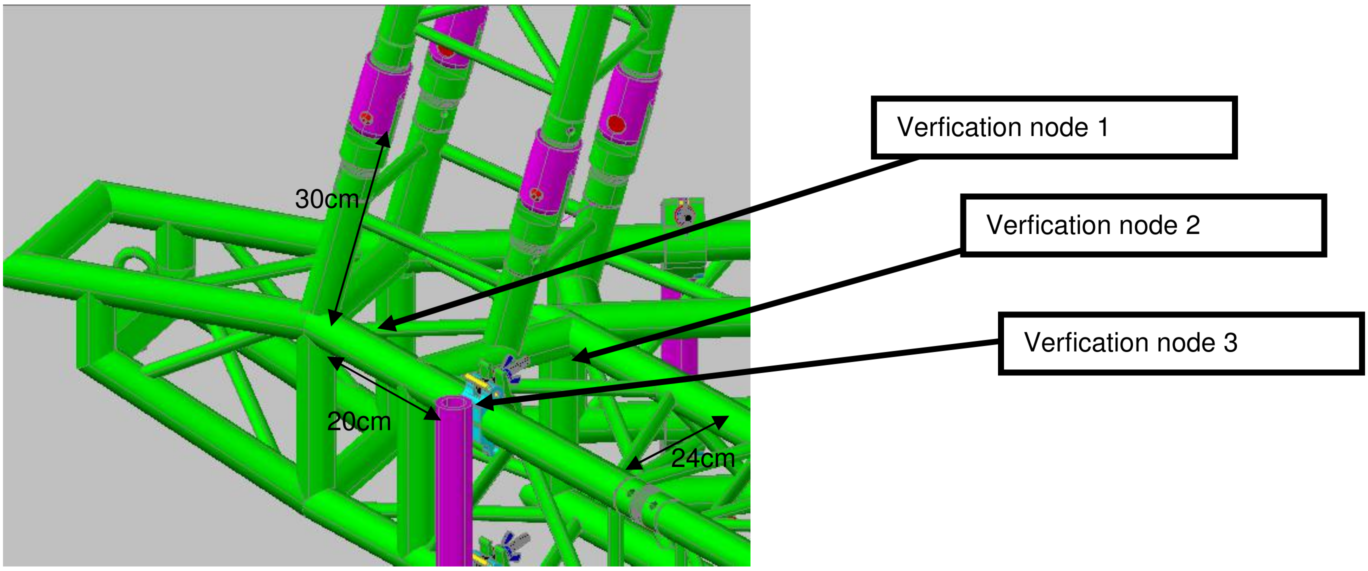
Global forces in trusses
max Md = 13,06 kNm
Nd = 16,3 kN

Normal force in chords
N_{sdG} = 16,3/4 + 13,06/ 0,48 = 31,28 kN

Bending moment in the chord (see sketch)
M_{sdG} = 23 kNcm
N_{Rdg} = 52,45 kN
M_{Rd} = 61,63 kNcm
$(N_{sdG}/N_{Rdg})^{1,3} + (M_{sdG}/M_{Rdg}) = 0,80 < 1,0$



Corner Element



Verifications
Node 1 Maximum loading Global forces truss

max Qd = 4,17 kN
Nd = 5,11kN
Md = 1,59 kNm

Forces in chord
max N_{sdG} = 5,11/4 + 1,59/0,48 = 4,59 kN
max M_{sdG} = 4,17/4 x 30cm = 31,28 kNcm

M_{RdG} = 61,63 kNcm
N_{Rdg} = 52,45 kN

$(N_{sdG}/N_{Rdg})^{1,3} + (M_{sdG}/M_{Rdg})$ = 0,55 < 1,0

Verifications
Node 2 Maximum loading Global forces truss

max Nd = 12,14 kN
Md = 0,79 kNm

Forces in chord
M_{sdG} = (12,14/4 + 0,79/0,48) x 24cm/4
= 28,09 kNcm
< M_{RdG} = 61,63kNcm

Verifications
Node 3 Maximum loading Global forces truss

max Nd= 12,14
Zugh. Md = 0,79 kNm

Forces in chord
N_{sdG} = 12,14/4 + 0,79/0,48 = 4,68 kN
M_{sdG} = 4,68 x cos(15°) x 20cm /2
=45,21 kNcm

< M_{RdG} = 61,63 kNcm

Lütticher Straße 10-12
52064 Aachen
Telefon: 0241 / 70 96 96
Telefax: 0241 / 70 96 46
buero@vom-felde.de

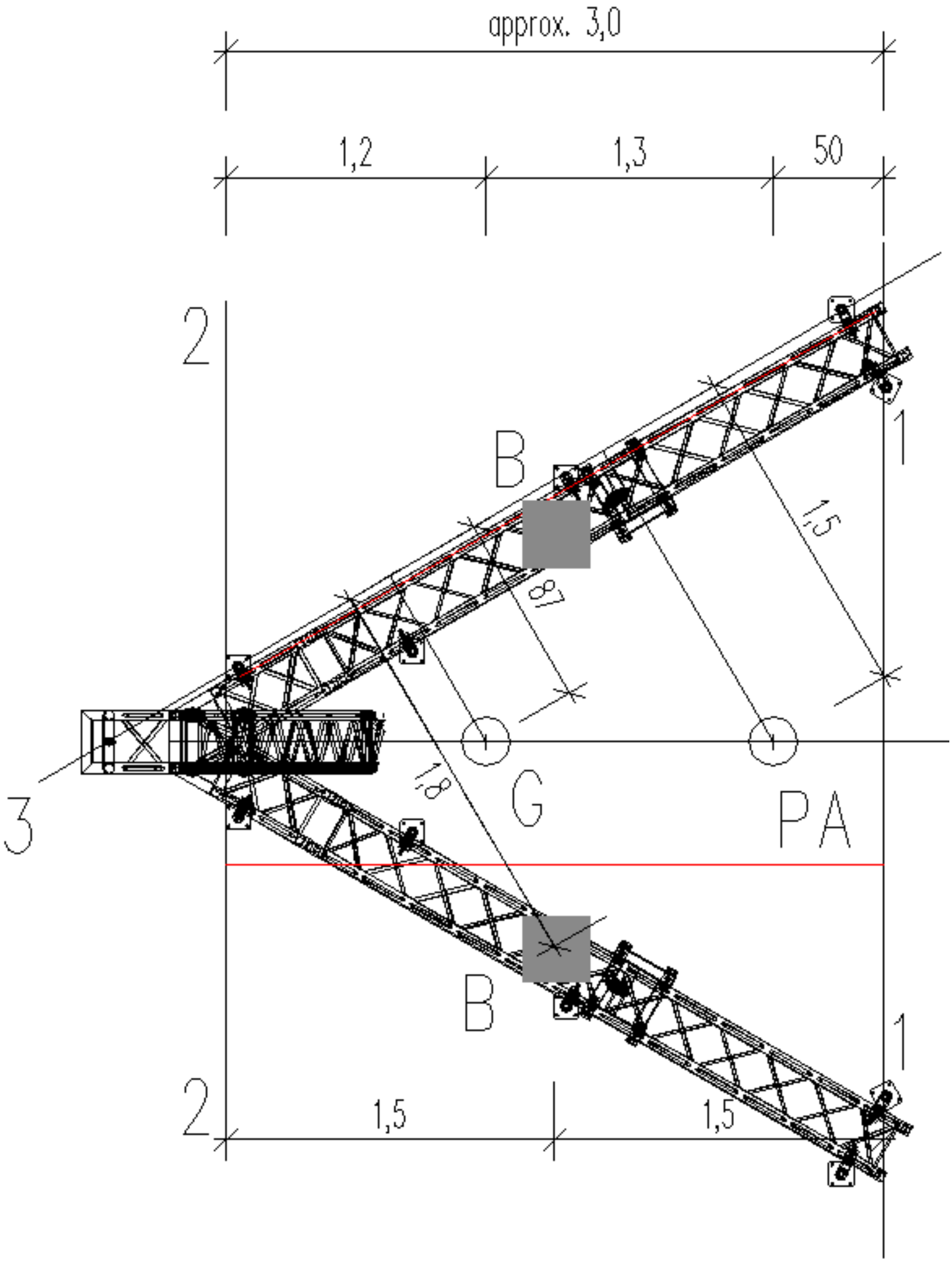
5 STABILITY

Total height of the tower above ground approx. 7.5 m.

Total weight of the tower ~ 240 kg without PA (see load sums computer calculation)

Balance point of the tower xs = 1,2 m (see sktech)

Ballast: Case wind „operation stopped" (PA-speakers removed)



Ballast is calulcated for regions with **in regions with wind gust speeds of maximum 28,3 m/s.**

In regions with higher windpeeds further vertifications are necessary.

Velocity pressure $qp = 28{,}3^2 / 1600 = 0{,}5$ kN/m²

Wind on free trusses

$w = 0{,}5 \times 0{,}2 = 0{,}10$ kN/m

On the safe side a reduction factor due to temporary setup (see chapter 1.4) is not taken into account.

Tilting moment
Tilting over axis 3 is relevant: $Mk = 1{,}2 \times (0{,}10 \cdot 7{,}5^2 / 2) = 3{,}38$ kNm

Necessary ballast $B = (Mk-2{,}4 \times 0{,}87)/1{,}8 = 0{,}72$ kN = approx. 75 kg

=> 2 x 75 kg

Ballast of 75 kg in the middle of each outrigger

Lütticher Straße 10-12
52064 Aachen
Telefon: 0241 / 70 96 96
Telefax: 0241 / 70 96 46
buero@vom-felde.de

Ballast in case „operation“ (with PA)

Case 1 - A = 2m²
Operation with PA

Tilting moment | Wind on tower | $h \leq 8$ m | w1 = 0,2 · 0,2 = 0,04 kN/m

Wind on PA | W = 1,3 · 0,2 · 2,0 = 0,52 kN

Mk = 1,2 x (0,04 · 7,5² / 2 + 0,52·7,5) = 6,03 kNm

Stabilising moment | Tilting over axis 3 is relevant

Ms = 0,87x 2,4 + 1,8 x 0,75 = 3,44 kNm

Necessary weight of PA

➔ **P** = (Mk – Ms)/ 1,5 = (6,03-3,44)/1,5 = 1,73 kN = ~ 175 kg

Case 2 - A = 1,5m²
Operation with PA

Tilting moment | Wind on tower | $h \leq 8$ m | w1 = 0,04 kN/m

Wind on PA | W = 1,3 · 0,2 · 1,5 = 0,39 kN

Mk = 1,2 x (0,04 · 7,5² / 2 + 0,39·7,5) = 4,86 kNm

Stabilising moment | Tilting over axis 3 is relevant

Ms = 3,44 kNm

Necessary weight of PA

➔ **P** = (Mk – Ms)/ 1,5 = (4,86-3,44)/1,5 = 0,95 kN = ~95 kg

Case 3 - A = 1m²
Operation with PA

Tilting moment | Wind on tower | $h \leq 8$ m | w1 = 0,04 kN/m

Wind on PA | W = 1,3 · 0,2 · 1,0 = 0,26 kN

Mk = 1,2 x (0,04 · 7,5² / 2 + 0,26·7,5) = 3,69 kNm

Stabilising moment | Tilting over axis 3 is relevant

Ms = 0,87x 2,4 + 1,8 x 0,75 = 3,44 kNm

Necessary weight of PA

➔ **P** = (Mk – Ms)/ 1,5 = (3,69-3,44)/1,5 = neggigible

For a PA with an area $\leq$ 1 m² the stability is given by the ballast.

When the weight of the PA is smaller, then the difference has to be compensated by additional ballast!

Tilting over axes 1 and 2 is not relevant.

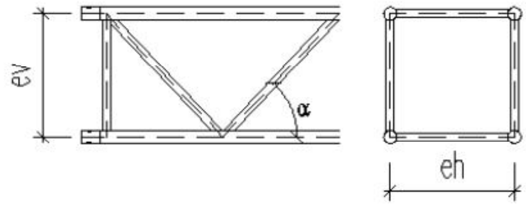
Lütticher Straße 10-12
52064 Aachen
Telefon: 0241 / 70 96 96
Telefax: 0241 / 70 96 46
buero@vom-felde.de

Anhang F34P / Annex F34P

Querschnittswerte Rohre / properties Tubes

	D	t	A	I	Wel	i
	[mm]	[mm]	[cm²]	[cm⁴]	[cm³]	[cm]
Gurtrohre / main chords	50,0	3	4,43	12,28	4,91	1,67
vertikal Diagonalen / Bracing	20	2	1,13	0,46	0,46	0,64
horizontal Diagonalen / Bracing	20	2	1,13	0,46	0,46	0,64

Geometrie Traverse / truss geometry



Achsabstand Gurtrohre	vertikal	ev	24	[cm]
distance axes main chords	horizontal	eh	24	[cm]
min. Neigung Diagonalen	vertikal	α	39,1	[°]
min. gradient bracing	horizontal	α	39,1	[°]

Kennwerte Gesamttraverse / properties truss-Section

A	$= 4 \times A_G$	=	17,72	[cm²]
Iyy	$= 4 \times I_G + 4 \times A_G \times (ev/2)^2$	=	2600,60	[cm⁴]
Izz	$= 4 \times I_G + 4 \times A_G \times (eh/2)^2$	=	2600,60	[cm⁴]
It	= Näherung aus Erfahrungswerten	=	410,85	[cm⁴]
iy	$= (Iyy/A)^{1/2}$	=	12,11	[cm]
iz	$= (Izz/A)^{1/2}$	=	12,11	[cm]

Index G : Querschnittseigenschaft Gurtrohr
section properties main chord

Büro für Tragwerksplanung und Ingenieurbau
vom Felde + Keppler GmbH & Co. KG
Lütticher Straße 10-12
52064 Aachen
Telefon: 0241 / 70 96 96
Telefax: 0241 / 70 96 46
buero@vom-felde.de

Material

Gurtrohre + Diagonalen EN AW 6082 T6 (AlMgSi1)
chords and bracing

zulässige Spannungen nach EN-1999-1-1 / allowable stress acc. to EN-1999-1-1

Teilsicherheitsbeiwerte Material / partial safety factors material

γ_{M1}=	1,10	Beulklasse / BC=	A
γ_{M2}=	1,25		

0,2%-Dehngrenze / 0,2%-Proof Strength		Zugfestigkeit / ultimate tensile strength	
fo t≤5mm=	250 [N/mm²]	fu t≤5mm=	290 [N/mm²]
fo t>5mm=	260 [N/mm²]	fu t>5mm=	310 [N/mm²]
fo,haz=	125 [N/mm²]	fu,haz=	185 [N/mm²]

Festigkeit der Schweißnaht fw= 190 [N/mm²]
Strength of welding seams

Faktor für die WEZ-Werte beim WIG-Schweißen: 0,8
Factor for HAZ-values for TIG-welding:

Bolzen / Bolt min. grade 8.8

Verbinder / Connector EN AW 2011 (AlCuBiPb F37)

0,2%-Dehngrenze / 0,2%-Proof Strength		Zugfestigkeit / ultimate tensile strength	
fo>	230 [N/mm²]	fu>	310 [N/mm²]

Hülse / Female fitting EN AW 6082 T6

zulässige Spannungen nach EN-1999-1-1 / allowable stress acc. to EN-1999-1-1

Teilsicherheitsbeiwerte Material / partial safety factors material

γ_{M1}= 1,10
γ_{M2}= 1,25

0,2%-Dehngrenze / 0,2%-Proof Strength		Zugfestigkeit / ultimate tensile strength	
fo=	250 [N/mm²]	fu=	290 [N/mm²]

Lütticher Straße 10-12
52064 Aachen
Telefon: 0241 / 70 96 96
Telefax: 0241 / 70 96 46
buero@vom-felde.de

Querschnitts- und Materialeigenschaften der Gurtrohre / Section- and material properties of the chord tubes

Material	E=	70000	[N/mm²]	
	fo=	250,00	[N/mm²]	
	fo/YM1=	227,27	[N/mm²]	
	fo,haz=	125,00	[N/mm²]	
	fu=	290,00	[N/mm²]	
	fu/YM2=	232,00	[N/mm²]	
	fu,haz=	185,00	[N/mm²]	
	fu,haz/YM2=	148,00	[N/mm²]	
Querschnitt	D0=	50,00	[mm]	
cross section	A=	4,43	[cm²]	
	I=	12,28	[cm^4]	
	i=	1,67	[cm]	
Bestimmung der QS-Klasse	β=	12,25	[-]	$3 \cdot (D0 / t)^{0,5}$ nach 6.10
Determination of section-class	ε=	1,00	[-]	$(250 / fo)^{0,5}$
	QS-Klasse=	2		nach Kap. 6.1.4.4
				acc. chapter 6.1.4.4
Beiwerte Biegeknicken	BC=	A	[-]	
Coefficients for buckling	α=	0,20	[-]	
	λo=	0,10	[-]	
teff im Bereich der WEZ	red-Faktor=	0,8	[-]	(WIG $_{TIG}$)
teff in heat affected zone				

Knotenpunkt mit 1 Diagonalen / node with 1 bracing

	D1=	20,00	[mm]	
	U_{WEZ}=	80,00	[mm]	$D1 + 2 \cdot 30$
	U_{Total}=	157,08	[mm]	
	teff,o/t=	0,69	[-]	$[1 - (1 - \text{red-Faktor} \cdot fo,haz / fo) \cdot U_{WEZ} / U_{Total}]$
	teff,u/t=	0,75	[-]	$[1 - (1 - \text{red-Faktor} \cdot fu,haz / fu) \cdot U_{WEZ} / U_{Total}]$

Knotenpunkt mit 2 Diagonalen / node with 2 bracing

	D1=	20,00	[mm]	
	D2=	20,00	[mm]	
	U_{WEZ}=	119,27	[mm]	$\pi / \mathbf{4} \cdot D0 + D1 / 2 + D2 / 2 + 2 \cdot 30$
	U_{Total}=	157,08	[mm]	
	teff,o / t=	0,54	[-]	$[1 - (1 - \text{red-Faktor} \cdot fo,haz / fo) \cdot U_{WEZ} / U_{Total}]$
	teff,u / t=	0,63	[-]	$[1 - (1 - \text{red-Faktor} \cdot fu,haz / fu) \cdot U_{WEZ} / U_{Total}]$

Gurtrohr im Bereich der WEZ an der Kupplung
main chord in heat affected zone at coupler

$N_{Rd} = A \times 0{,}8^{*} \times f_{u,haz} / \gamma_{M2}$=	**52,45**	[kN]	*(WIG $_{TIG}$) örtliche Schweißnaht nach Kap. 6.2.9.3 (1) local welding seam acc. chapter 6.2.9.3 (1)

Gurtrohr im Bereich der WEZ
main chord in heat affected zone Knotenpunkt mit 1 Diagonalen / node with 1 bracing

$N_{Rd} = A_{eff} \times f_o / \gamma_{M1}$= (mit A_{eff}= $t_{eff,o}$ / t x A)	**69,91**	[kN]	örtliche Schweißnaht nach Kap. 6.2.9.3 (2) local welding seam acc. Chapter 6.2.9.3 (2)

Knotenpunkt mit 2 Diagonalen / node with 2 bracing

$N_{Rd} = A_{eff} \times f_o / \gamma_{M1}$= (mit A_{eff}= $t_{eff,o}$ / t x A)	**54,81**	[kN]	örtliche Schweißnaht nach Kap. 6.2.9.3 (2) local welding seam acc. Chapter 6.2.9.3 (2)

Knicken Gurtrohr zw. Knoten mit 1 Diagonale in der Mitte buckling main chord bewteen nodes with 1 bracing in the middle				
	sk=	48,00	[cm]	
	Ncr=	368,26	[kN]	
	λ^{*}=	0,55	[-]	
	ϕ=	0,70	[-]	
	X=	0,89	[-]	
	A1=	2,99	[cm²]	nach Tab. 6.5
	κ=	0,83	[-]	acc. table 6.5
	$N_{Rd} = X \times \kappa \times A_{eff} \times f_o / \gamma_{M1}$=	**74,03**	[kN]	nach Gl. 6.49 acc. equation 6.49

(mit A_{eff}=A für QSK 1,2 und 3, s. EN 1999-1-1 Kap. 6.3.1.1)

Knicken Gurtrohr zw. Knoten ohne Diagonale in der Mitte buckling main chord bewteen nodes without bracing in the middle				
	sk=	48,00	[cm]	
	Ncr=	368,26	[kN]	
	λ^{*}=	0,55	[-]	
	ϕ=	0,70	[-]	
	X=	0,89	[-]	
	$N_{Rd} = X \times A \times f_o / \gamma_{M1}$=	**89,69**	[kN]	nach Gl. 6.49 acc. equation 6.49

Schweißnaht zwischen Gurtrohr und Hülse
welding seam between chord and female conical coupler

fw=	190,00	[N/mm²]	
γ_{Mw}=	1,25	[-]	
$N_{Rd} = A \times f_w / \gamma_{M1}$=	**67,33**	[kN]	nach Gl. 8.29 acc. equation 8.29

Lokale Biegung Gurtrohr Knotenpunkt mit 1 Diagonalen
Local bending of chord

örtliche Schweißnaht nach Kap. 6.2.9.3 (2)
local welding seam acc. Chapter 6.2.9.3 (2)

	α=	0,94	[-]	nach Tab. 6.4 acc. table 6.4
Nebenrechnung QS-Kl. 3	D=	50,0	[mm]	
Auxiliary calculation for class 3	red-Faktor=	0,8	[-]	(WIG TIG)
	po,haz=	0,5	[-]	
	to,eff=	2,08	[mm]	
	Wel,haz= π x R² x to,eff=	3,61	[cm³]	R = D / 2 - t / 2
	Wel=	4,91	[cm³]	
	Wpl,haz= 4 x R² x to,eff=	4,60	[cm³]	R = D / 2 - t / 2
	β3=	18		nach Kap. 6.1.4.4
	β2=	13		acc. Chapter 6.1.4.4
	α,3w=	0,97	[-]	
	MoRd = α · Wel · fo / γM1=	**104,59**	[kNcm]	nach Gl. 6.24 acc. equation 6.24

Lokale Biegung Gurtrohr Knotenpunkt mit 2 Diagonalen
Local bending of chord

örtliche Schweißnaht nach Kap. 6.2.9.3 (2)
local welding seam acc. Chapter 6.2.9.3 (2)

	α=	0,73	[-]	nach Tab. 6.4
Nebenrechnung QS-Kl. 3	D=	50,0	[mm]	
Auxiliary calculation for class 3	red-Faktor=	0,8	[-]	(WIG TIG)
	po,haz=	0,5	[-]	fo,haz / fo
	to,eff=	1,63	[mm]	teff,o / t · t
	Wel,haz= π x R² x to,eff=	2,83	[cm³]	mit R = D / 2 - t / 2
	Wel=	4,91	[cm³]	
	Wpl,haz= 4 x R² x to,eff=	3,61	[cm³]	mit R = D / 2 - t / 2
	β3=	18	nach Ka|	nach Kap. 6.1.4.4
	β2=	13	nach Ka|	nach Kap. 6.1.4.4
	α,3w=	0,76	[-]	
	MoRd = α · Wel · fo / γM1=	**82,00**	[kNcm]	nach Gl. 6.24 acc. equation 6.24

Lokale Biegung Gurtrohr Knotenpunkt vollst. in WEZ
Local bending of chord

örtliche Schweißnaht nach Kap. 6.2.9.3 (1)
local welding seam acc. Chapter 6.2.9.3 (1)

D=	50	[mm]	
red-Faktor=	0,8	[-]	(WIG TIG)
po,haz=	0,64	[-]	fu,haz / fu
tu,eff=	1,53	[mm]	red-Faktor · ρu,haz · t
Wnet= π x R² x tu,eff=	2,66	[cm³]	mit R = D / 2 - t / 2
MuRd = Wnet · fu / γM2=	**61,63**	[kNcm]	nach Gl. 6.24 acc. equation 6.24

Querschnitts- und Materialeigenschaften der Diagonalen / Section- and material properties of the bracing

Material	E=	70000	[N/mm²]
	fo=	250,00	[N/mm²]
	fo/YM1=	227,27	[N/mm²]
	BC=	A	[-]
	α=	0,20	[-]
	λo=	0,1	[-]
Querschnitt / cross section	D0=	20	[mm]
	A=	1,13	[cm²]
	I=	0,46	[cm^4]
	i=	0,64	[cm]

Diagonale im Bereich der WEZ
bracing in heat affected zone

NRd = A x 0,8* x fu,haz / YM2=	**13,39**	[kN]	*(WIG TIG) örtliche Schweißnaht nach Kap. 6.2.9.3 (1) local welding seam acc. chapter 6.2.9.3 (1)

Knicken Diagonale
buckling bracing

sk=	25,50	[cm]	
	(Knicklänge = 0,75 x l)		
Ncr=	49,27	[kN]	
λ*=	0,76	[-]	
ϕ=	0,85	[-]	
X=	0,80	[-]	
NRd = X x AG x fo / YM1=	**20,66**	[kN]	nach Gl. 6.49 acc. equation 6.49

Schweißnaht zwischen Diagonale und Gurtrohr
welding seam between chord and female conical coupler

fw=	190,00	[N/mm²]	
Ymw=	1,25	[-]	
NRd = A x fw / YM1=	**17,19**	[kN]	nach Gl. 8.29 acc. equation 8.29

Bolzen / Bolt

Material / material min grade 8.8	fy,bk=	64,00 [kN/cm²]
	fu,bk=	80,00 [kN/cm²]
Geometrie / geometry	Db=	1,08 [cm]
	Ab=	0,91 [cm²]

zul Normalkraft aus Abscheren n. EN 1999-1-1
allow able loading due to shearing acc. to EN 1999-1-1

N_{Rd} = 2 x 0,60 x Ab x fub,k / 1,25= **69,71** [kN]

Verbinder / Connector

Material / material EN AW 2011 (AlCuBiPb F37)

Geometrie / geometry	Dm=	29 [mm]
<u>Lochleibung in Verbinder</u>	fu / γ_{M2}=	248,00 [N/mm²]
Bearing stress in connector	do=	11 [mm]
	t=	29 [mm]
	e_1=	17,1 [mm]
	αb=	0,52 [-]
	e2=	14,5 [mm]
	k_1=	1,99 [-]

NRd = k1 x αb x fu x d x t / γ_{M2}= 81,62 [kN]

Nachweis Restquerschnitt auf Zug
Remaining section under tension

NRd = 0,9 x A,net x fu / γ_{M2}= **76,23** [kN]

Hülse / Female Fitting

Geometrie / geometry	DH=	50 [mm]
	Di-1=	29 [mm]
	Di-2=	35 [mm]
	Di-m=	32 [mm]
<u>Lochleibung in Hülse</u>	fu / γ_{M2}=	232 [N/mm²]
Bearing stress in female fitting	do=	13 [mm]
	t = DH - Di-m=	18 [mm]
	e1>	23 [mm]
	αb=	0,59
	e2>	20 [mm]
	k1=	2,5

NRd = k1 x αb x fu x d x t / γ_{M2}= **80,04** [kN]