Ingenieurbüro für
Fliegende Bauten
Bühnentechnik
Messebau

Statische Berechnung

Static Analysis

Datum:	25.07.2013
Lieferschein-Nr.:	2013072505
Kunden-Nr.:	51517
Sachbearbeiter/-in:	Andreas Fritz

Auftraggeber:
Customer:

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Betreiber:
User:

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Projekt:
Project:

2013-0698
Statische Berechnung für Line Array
Lautsprecher:
al-4

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1 Terms for safe use

- Suspension points and all slinging mean needs to observe requirement according UVV BGV C1.

- The construction is intrinsically safe. No secondary securing within the construction is required.

- Maximum count of speakers among one another:

Grid AL4-fb	
Hole	min N []
1	**20**
2	**20**
3	**20**
4	**20**
5	**20**

Grid AL4-fb	
Hole	min N []
1	**20**
2	**20**
3	**20**
4	**20**
5	**20**
6	**17**
7	**14**
8	**12**

2 Description of the construction

The construction is used for hanging loudspeakers.
Basically it consists out of two front and one rear connectors. By different hole positions different angles can be adjusted.

3 Basics of calculation

- DIN EN 1993-1 Eurocode 3: Design of steel structures (12/2010)
- DIN 18800 steel constructions (1-3, 11/1990)
- DIN EN 1999-1 Eurocode 9: Design of aluminium structures (05/2010)
- DIN 4113 Aluminium constructions (02/1958, 05/1980 Teil 1, A1 09/2002, 09/2002 Teil 2)
- BGV C1: BG Vorschrift - Veranstaltungs- und Produktionsstätten für szenische Darstellungen (04/1998)

4 Materials

4.1 Aluminium

$E = 7000\ kN/cm^2$

4.1.1 EN AW-6061 T6 with weld material AlMg 5

plates 6mm < t < 100mm
$f_o = 24{,}0\ kN / cm^2$
$f_u = 29{,}0\ kN / cm^2$

4.2 Steel

Structural steel: E = 210000 N/mm²
Stainless steel: E = 170000 N/mm² (for deformation)
E = 200000 N/mm² (for stability)

4.2.1 C45

$f_{u,k}$ = 62,0 kN / cm^2
$f_{y,k}$ = 34,0 kN / cm^2

4.2.2 S355/ Q345

$f_{y,k}$ = 34,5 kN/cm²
$f_{u,k}$ = 51,0 kN/cm²

4.2.3 S235JR

$f_{y,k}$ = 24,0 kN/cm²
$f_{u,k}$ = 36,0 kN/cm²

4.2.4 17-4 PH

X5 CrNiCuNb 16/4 (1.4548.4)
$f_{u,k}$ = 107,0 kN / cm^2
$f_{y.k}$ = 100,0 kN / cm^2

5 Load assumptions

5.1 Snow

none

5.2 Dead loads

G = 0,086 kN - acc. manufacture information

5.3 Live loads

5.3.1 horizontal

none

5.3.2 vertical

Will be determined.

5.4 Wind loads

none

6 Calculation of member forces

see single positions

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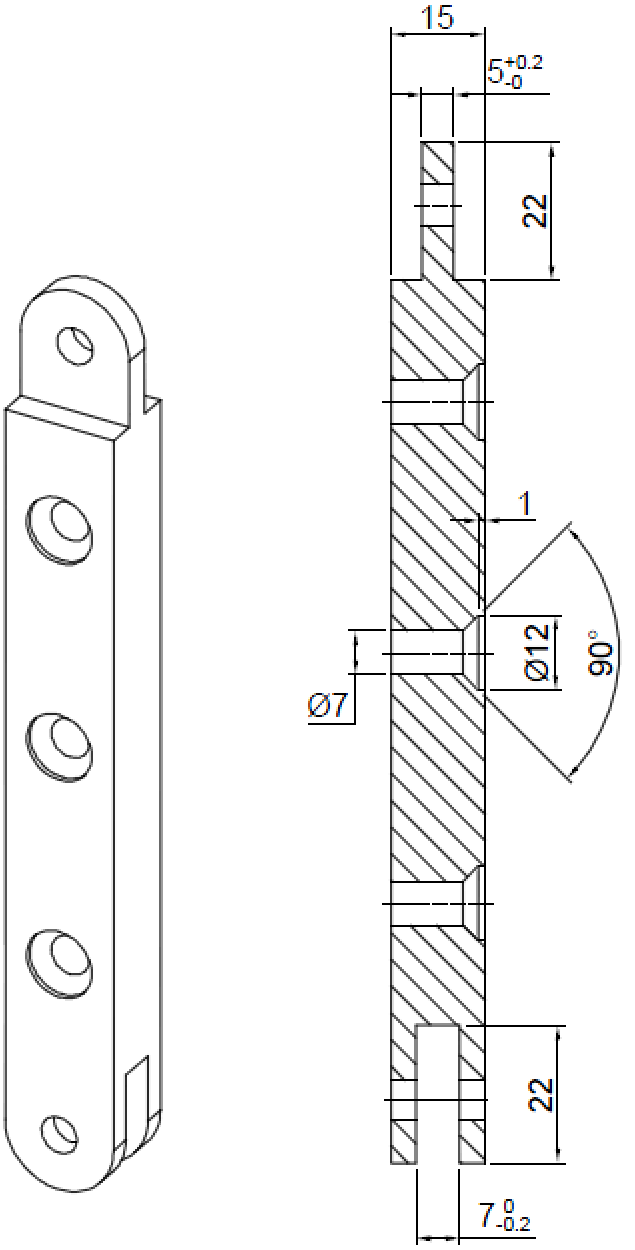
7 Proofs

7.1 Parts of front suspension



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7.1.1 Front locking pin

Ø6,2 mm X5 CrNiCuNb 16/4 (1.4548.4)
$A = 0{,}302\ cm^2$
$W = 0{,}0234\ cm^3$

$V_{a,R,d} = 0{,}302 * 0{,}55 * 107{,}0 / 2{,}2 = 8{,}08\ kN$
$M_{R,d} = 0{,}0234 * 100{,}0 / 2{,}2 = 1{,}06\ kNcm$

$F_d = 4{,}78\ kN$
$M_d = 4{,}78 / 8 * (0{,}5 + 2 * 0{,}4 + 4 * 0{,}1) = 4{,}78 * 0{,}2125 = 1{,}016\ kNcm$
$V_d = 4{,}78 / 2 = 2{,}39\ kN$

$M_d / M_{R,d} = 1{,}016 / 1{,}06 = 0{,}96 < 1{,}0$
$V_d / V_{a,R,d} = 2{,}39 / 8{,}08 = 0{,}30 < 1{,}0$
$(M_d / M_{R,d})^2 + (V_d / V_{a,R,d})^2 = 1{,}0 = 1{,}0$

all F = 4,78 / 1,35 = 3,54 kN - BGV C1

7.1.2 front plate

Upper part is decisive.
milled part ENAW 6061 T6

<u>Bearing stress:</u>
$e1 = 1{,}0\ cm = 1{,}61 * D_L$
$e2 = 1{,}0\ cm = 1{,}61 * D_L$

$k1 = 2{,}8 * 1{,}61 - 1{,}7 > 2{,}5$
$\alpha b = 1{,}61 / 3 = 0{,}54$

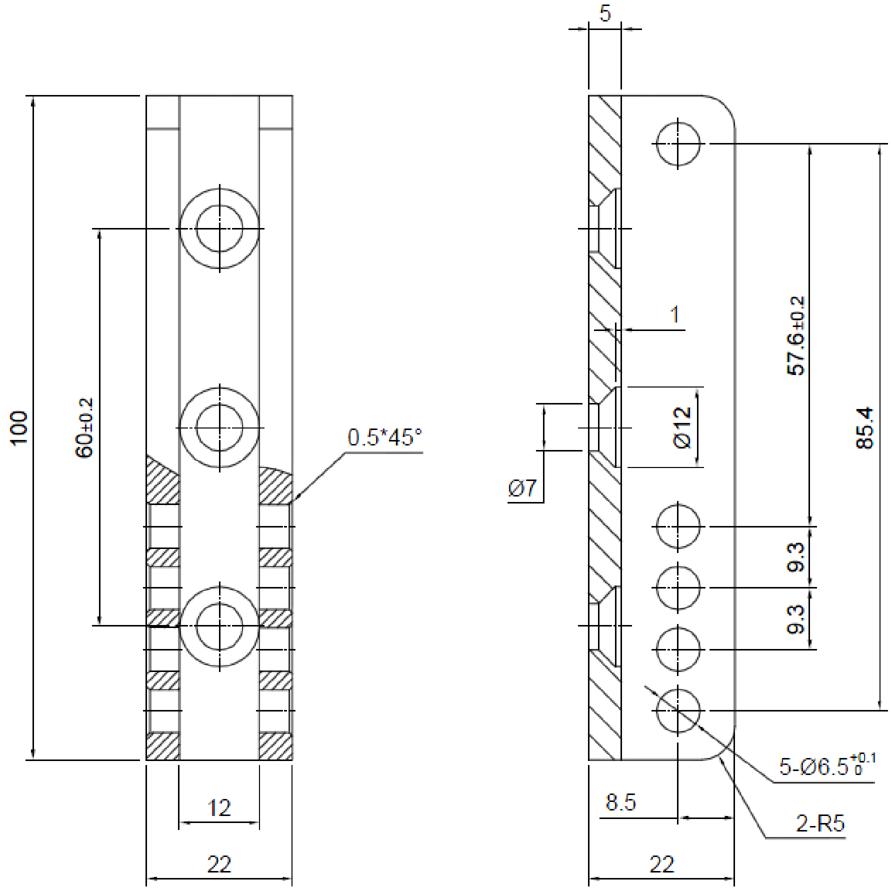
$F_{b,Rd} = 2{,}5 * 0{,}54 * 29{,}0 * 0{,}62 * 0{,}5 / 2{,}5 = 4{,}85\ kN$

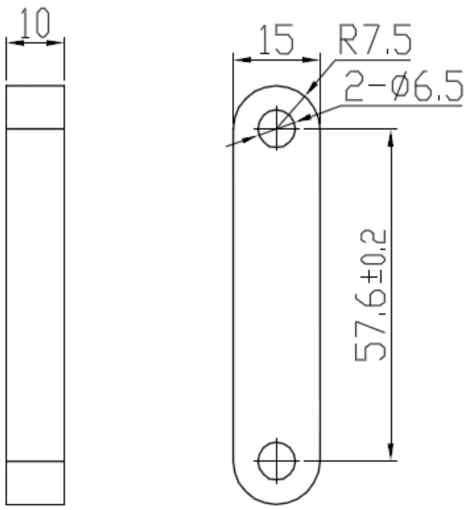
all F = 4,85 / 1,5 = 3,2 kN - BGV C1

<u>Netto section:</u>
$A_{hole} = 1{,}15 * 0{,}7 + 0{,}25 * (0{,}7+1{,}2)/2 + 0{,}1 * 1{,}2 = 1{,}16\ cm^2$
$A_{netto} = 3{,}0 - 1{,}16 = 1{,}84\ cm^2$

$N_{Rd} = 1{,}84 * 24{,}0 / 2{,}2 = 20{,}1\ kN$
all F = 20,1 / 1,5 = 13,4 kN

7.2 Parts of rear suspension





7.2.1 Rear locking pin

Ø6,2mm X5 CrNiCuNb 16/4 (1.4548.4)
$A = 0{,}302\ cm^2$
$W = 0{,}0234\ cm^3$

$V_{a,R,d} = 0{,}302 * 0{,}55 * 107{,}0 / 2{,}2 = 8{,}08$ kN
$M_{R,d} = 0{,}0234 * 100{,}0 / 2{,}2 = 1{,}06$ kNcm

$F_d = 3{,}46$ kN
$M_d = 3{,}46 / 8 * (1{,}0 + 2 * 0{,}5 + 4 * 0{,}1) = 3{,}46 * 0{,}3 = 1{,}04$ kNcm
$V_d = 3{,}46 / 2 = 1{,}74$ kN

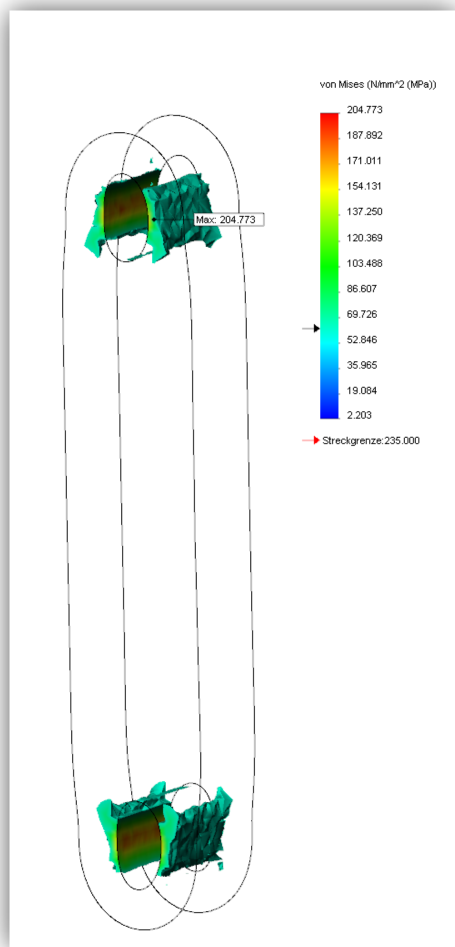
$M_d / M_{R,d} = 1{,}04 / 1{,}06 = 0{,}98 \leq 1{,}0$
$V_d / V_{a,R,d} = 1{,}74 / 8{,}08 = 0{,}22 < 0{,}25 < 1{,}0$
No proof of interaction required.

all F = 3,46 / 1,35 = 2,56 kN   - BGV C1

7.2.2 Rear fish plate

milled part ENAW 6061 T6

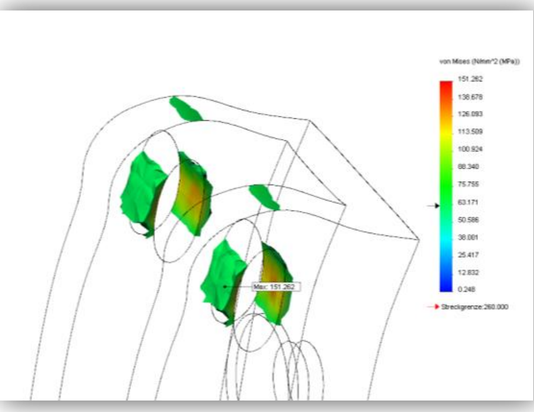
Analysis with F = 4,0 kN



max $\sigma = 20{,}5\ kN / cm^2 < 25{,}7\ kN / cm^2$
The decisive areas strained by bending are beneath the allowed stress.

7.2.3 Rear bar

milled part ENAW 6061 T6
Analysis with F = 3,8 kN

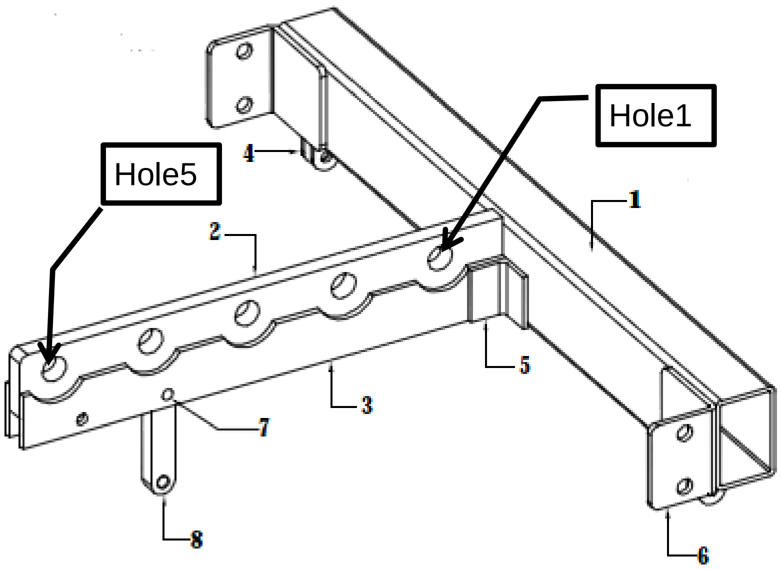


max σ = 15,1 kN / cm^2 < 25,7 kN / cm^2
The decisive areas strained by bending are beneath the allowed stress.

7.3 Summarisation loudspeaker

all F_{bb} = +/- 2,56 kN
all F_{fb} = +/- 3,2 kN

7.4 Grid AL4-fb



7.4.1 front cross beam:

□ 60x40x2,5 Q235
$A = 4{,}59\ cm^2$
$W = 5{,}87\ cm^3$

L = 0,45m = 45,0 cm
$M_{R,d}$ = 24,0 * 5,87 / 2,2 = 64,0 kNcm
$F_{R,d}$ = 4 * 64,0 / 45,0 = 5,69 kN

max F = 5,69 / 1,35 = 4,21 kN

7.4.2 Suspension / speaker connection

Constructed in the same way like aluminium-type.
Here: manufactured in steel – no proof

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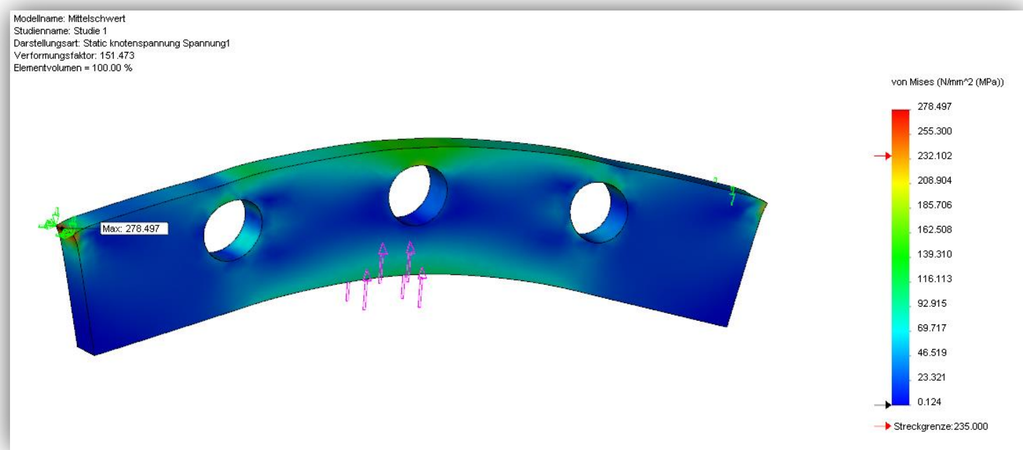
7.4.3 mounting bracket

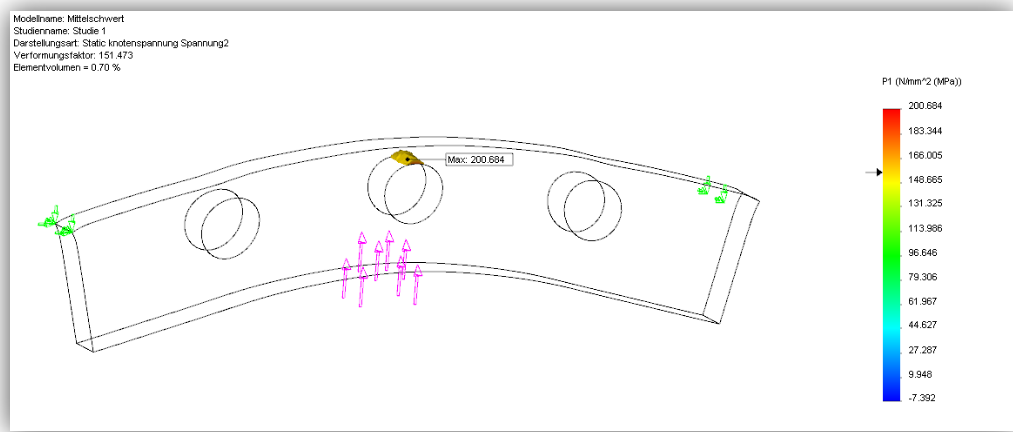
centreboard plate t = 12mm Q345
e1 = 0,8 * d_L
A FEM-Analysis will be done.

$F_{R,d}$ = 6,5 kN

Comparison stress:



Normal stress ISO- clipping 156,8 N / mm^2:

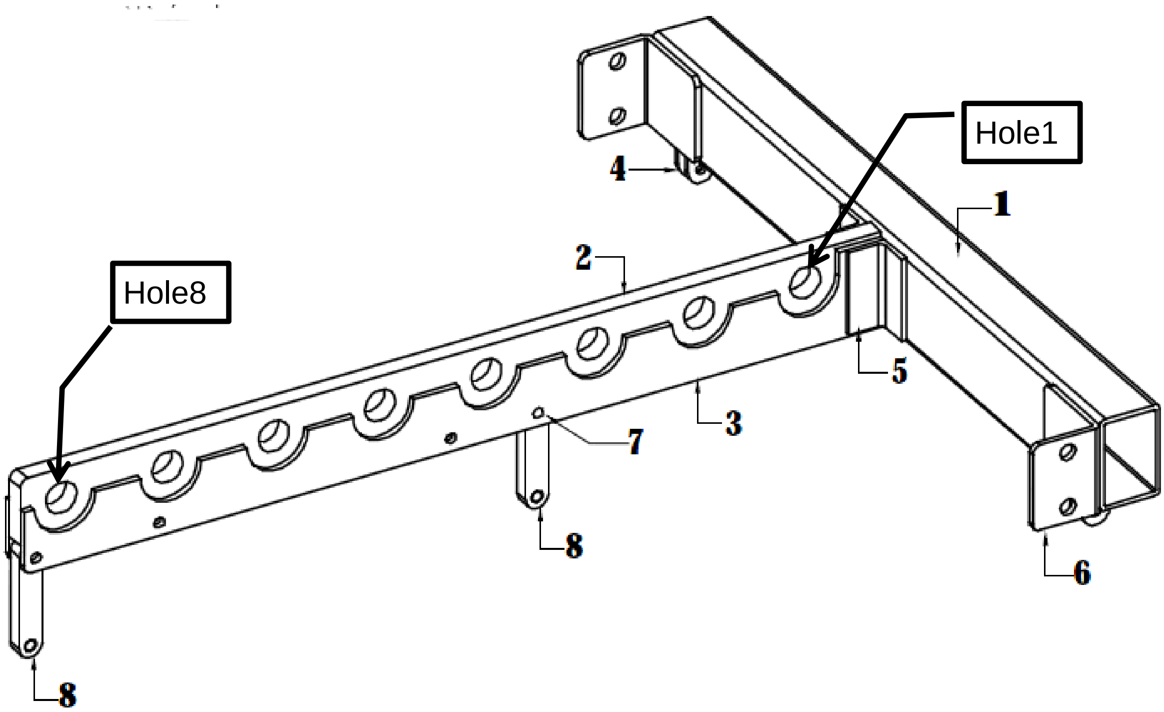


max σ_b < 15,68 kN / cm^2
max F = 6,5 / 1,35 = 4,81 kN

7.4.4 Allowed amount of speakers at AL4-fb Grid

Grid AL4-fb								
Hole	a [mm]	b [mm]	L [mm]	X(Ffb) []	X(Fbb) []	N(Ffb) []	N(Fbb) []	min N []
1	53	186	239	0,39	0,22	62	134	**20**
2	118	121	239	0,25	0,49	96	60	**20**
3	183	56	239	0,12	0,77	208	38	**20**
4	248	-9	239	-0,02	1,04	1299	28	**20**
5	313	-74	239	-0,15	1,31	158	22	**20**

7.5 Grid AL4-fbl



7.5.1 front cross beam

see above

7.5.2 Suspension

No proof

7.5.3 mounting bracket

plate 12mm C45

M(8) = 12 * 0,086 * 31,2 cm = 32,2 kNcm

M(7) = 14 * 0,086 * 24,2 cm = 29,1 kNcm < 32,2 kNcm

$W = 1{,}2 * 4{,}3^2 / 6 = 3{,}70\ cm^3$

$\sigma = 32{,}2 / 3{,}70 = 8{,}70\ kN / cm^2$

$\sigma_d = 1{,}5 * 8{,}7 = 13{,}05\ kN / cm^2$

$\eta = 13{,}05 / (34{,}0 / 2{,}2) = 0{,}84 < 1{,}0$

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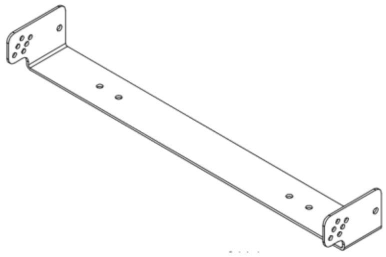
7.5.4 Allowed amount of speakers at AL4-fbl Grid

Grid AL4-fb								
Hole	a [mm]	b [mm]	L [mm]	X(Ffb) []	X(Fbb) []	N(Ffb) []	N(Fbb) []	min N []
1	61	178	239	0,37	0,26	65	116	**20**
2	131	108	239	0,23	0,55	108	54	**20**
3	201	39	240	0,08	0,84	301	35	**20**
4	271	-30	241	-0,06	1,12	393	26	**20**
5	341	-99	242	-0,20	1,41	119	21	**20**
6	411	-172	239	-0,36	1,72	68	17	**17**
7	481	-242	239	-0,51	2,01	48	14	**14**
8	551	-312	239	-0,65	2,31	37	12	**12**

7.6 Pole Mount al-4-uf

Maximum load: 4x0,086 = 0,344 kN

7.6.1 U Bracket



3mm Q235

<u>Bending</u>

M = 0,344 / 2 * (53-48)/2 = 0,43 kNcm
W = 6,2 * $0,3^2$ / 6 = 0,093 cm^3
σ = 0,43 / 0,093 = 4,6 kN / cm^2
η = 1,5 * 4,6 / (24,0 / 2,2) = 0,64 < 1,0

<u>Bearing pressure:</u>

Only the M8 hole will be proofed.
4*t+40 = 52 mm
e1 / D_L= 3,0 / 0,8 = 3,75
e2 / D_L= 1,0 / 0,8 = 1,25

k1 = 2,8 * 1,25 - 1,7 = 1,8
αb = 3,75 / 3 = 1,25 > 1,0

$F_{b,Rd}$ = 1,8 * 1,0 * 36,0 * 0,8 * 0,3 / 2,5 = 6,2 kN
η = 0,344 / 6,2 = 0,06 < 1,0

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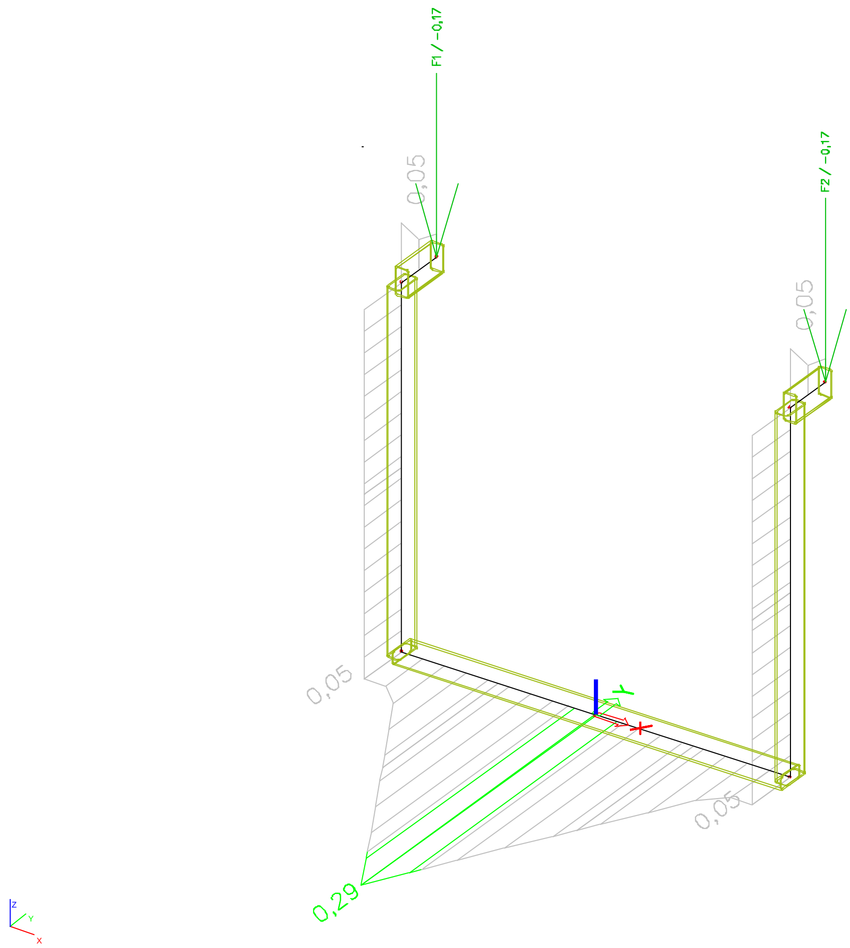
7.6.2 Swing mount

Profile 40x20x2   S235



max η = 0,29 < 1,0

8 Final demands

The construction was check statically according DIN 4113 and DIN 18800 in consideration of UVV: BGV C1.
It has a sufficient load capacity and stability, in case of observing the terms of safe use. The construction is intrinsically safe.

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Project	Speaker Connection GmbH
Part	Swing mount
Description	2013-0698
Author	Fritz
Date	24. 07. 2013

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2. Project

Licence name	-
National code	DIN
Structure	Frame XYZ
No. of nodes :	7
No. of beams :	5
No. of slabs :	0
No. of used profiles :	1
No. of load cases :	2
No. of used materials :	1
Project filename	2013-0698 Esa1 - AL-4-uf.esa
Project file path	C:\Users\Andreas.Fritz\Projekte\Speaker Connection GmbH\2013-0698 Lautsprecheraufhängungen\Berechnungen\TOP AL-4\
Project	Speaker Connection GmbH
Part	Swing mount
Description	2013-0698
Author	Fritz
Date	24. 07. 2013
Acceleration of gravity [m/sec^2]	9,810
Version	Scia Engineer 11.0.1223
Functionality	Steel

3. Solver and mesh setup

Run one nonlinear combination	×
Neglect shear force deformation (Ay, Az >> A)	×
Division on haunches and arbitrary members	5
Apply the nodal refinement	Only 2D members
Type of solver	Direct
Number of sections on average member	10
Maximal acceptable translation [mm]	1000,0
Maximal acceptable rotation [mrad]	100,0
Maximum iterations	50
Minimal distance between two points [m]	0,001
Average size of 2D element/curved element [m]	1,000
Average number of tiles of 1D element	1
Minimal length of beam element [m]	0,100
Maximal length of beam element [m]	100,000
Average size of cables, tendons, elements on subsoil, nonlinear soil spring [m]	1,000
Generation of nodes in connections of beam elements	✓
Generation of nodes under concentrated loads on beam elements	✓
Generation of eccentric elements on members with variable height	×
Coefficient for reinforcement	1
Hanging nodes for prestressing	✓

4. Cross-sections

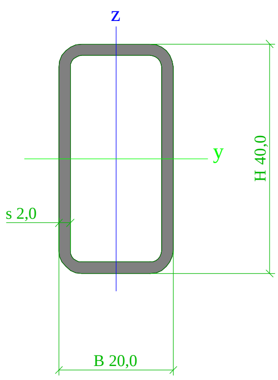
4.1. Cross-sections

4.1.1. Cross-sections - CS1

Name	CS1
Type	RHS
Detailed	40,0; 20,0; 2,0; 4,0
Item material	St 37-2
Fabrication	gewalzt
Buckling y-y	a
Buckling z-z	a

A [cm²]	2,14	
A y, z [cm²]	0,71	1,42
I y, z [cm⁴]	4,04	1,34
It [cm⁴]	3,12	
Iw [cm⁶]	3,20	
Wel y, z [cm³]	2,02	1,34
Wt [cm³]	0,00	
Wpl y, z [cm³]	2,61	1,60
d y, z [mm]	0,0	0,0
c YLKS, ZLKS [mm]	10,0	20,0
Alpha [deg]	0,00	
AL [m²/m]	1,1310e-01	
i y, z [cm]	1,38	0,79

Picture



4.2. Materials

Name	St 37-2
Type	Steel
Thermal exp [m/mK]	0,00
Unit mass [kg/m³]	7850,00
E-Mod [kN/cm²]	21000,00
Poisson - nu	0,3
Independent G modulus	×
G mod [kN/cm²]	8076,92
Log. decrement	0,025
Therm. exp. (fire) [m/mK]	0,00
Specific heat [J/gK]	6,0000e-01
Thermal conductivity [W/mK]	4,5000e+01
Fu [kN/cm²]	36,00
Fy [kN/cm²]	24,00

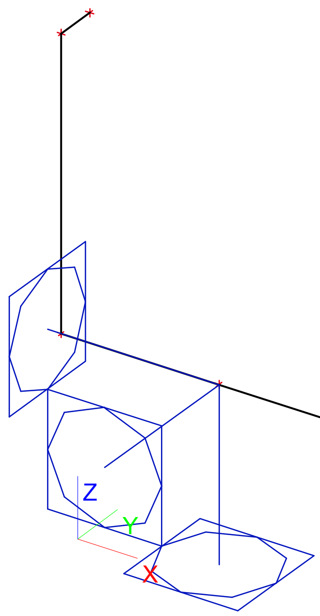
5. Loads

5.1. Loads

5.1.1. Loads - LC1

Name	Action type	LoadGroup	Load type	Direction
LC1	Permanent	LG1	Self weight	-Z

5.1.1.1. Loads



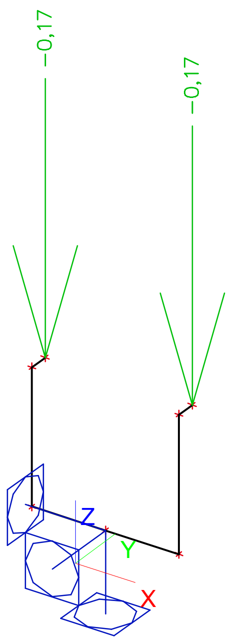
5.1.2. Loads - LC2

Name	Action type	LoadGroup	Load type	Spec	Duration	Master load case
LC2	Variable	LG2	Static	Standard	Short	None

5.1.2.1. Point forces in node

Name	Node	Load case	System	Dir	Type	Value - F [kN]
F1	N5	LC2	GCS	Z	Force	-0,17
F2	N6	LC2	GCS	Z	Force	-0,17

5.1.2.2. Loads



5.2. Load groups

Name	Load	Relation	Type
LG1	Permanent		
LG2	Variable	Standard	Cat A : Domestic

5.3. Combinations

Name	Type	Load cases	Coeff. [-]
CO1	Envelope - ultimate	LC1	1,00
		LC2	1,00

6. Structure

6.1. Node

Name	Coord X [m]	Coord Y [m]	Coord Z [m]
N1	-0,276	0,000	0,000
N2	0,276	0,000	0,000
N3	-0,276	0,000	0,500
N4	0,276	0,000	0,500
N5	-0,276	0,075	0,500
N6	0,276	0,075	0,500
N7	0,000	0,000	0,000

6.2. Member 1D

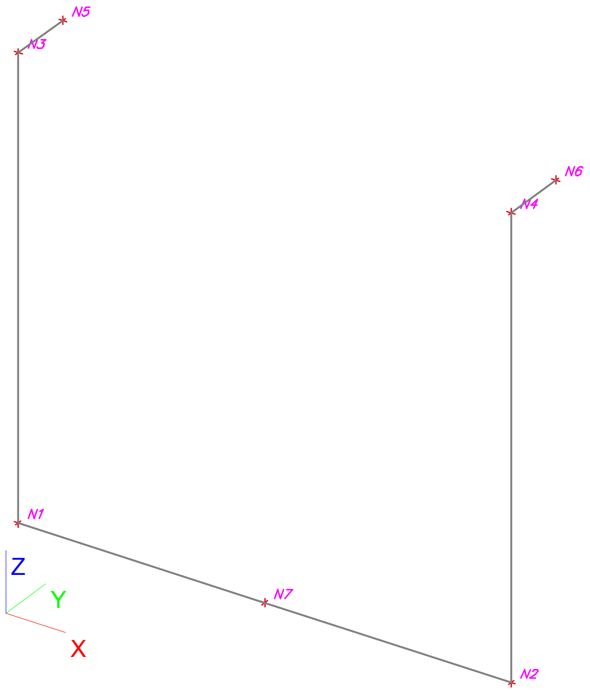
Name	CrossSection	Length [m]	Shape	Anf.Kn	Endkn	Type	FEM type	Layer
B1	CS1 - RHS (40,0; 20,0; 2,0; 4,0)	0,552	Line	N1	N2	general (0)	standard	Layer1
B2	CS1 - RHS (40,0; 20,0; 2,0; 4,0)	0,500	Line	N1	N3	general (0)	standard	Layer1
B3	CS1 - RHS (40,0; 20,0; 2,0; 4,0)	0,500	Line	N2	N4	general (0)	standard	Layer1
B4	CS1 - RHS (40,0; 20,0; 2,0; 4,0)	0,075	Line	N3	N5	general (0)	standard	Layer1
B5	CS1 - RHS (40,0; 20,0; 2,0; 4,0)	0,075	Line	N4	N6	general (0)	standard	Layer1

6.3. Gelenke

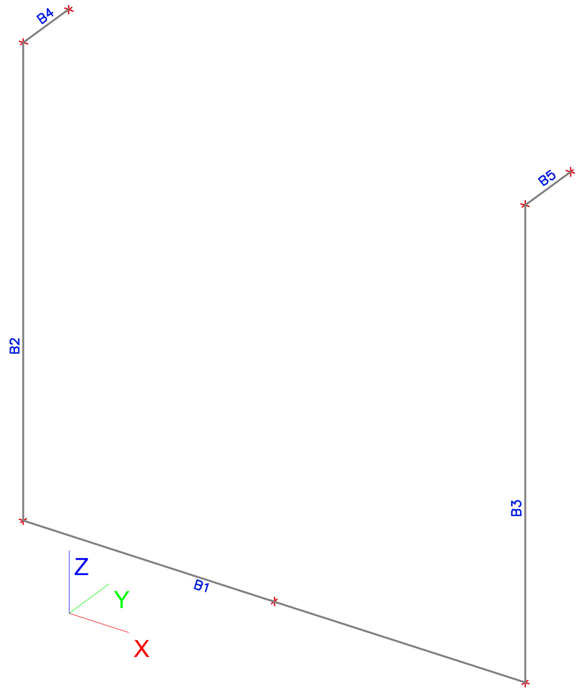
6.4. Supports in node

Name	Node	System	Type	X	Y	Z	Rx	Ry	Rz
Sn1	N7	GCS	Standard	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid

6.5. Nodes



6.6. Beams



7. Results

7.1. Internal forces

7.1.1. Internal forces - CS1

Name	CS1
Type	RHS
Detailed	40,0; 20,0; 2,0; 4,0
Item material	St 37-2
Fabrication	gewalzt
Buckling y-y	a
Buckling z-z	a

A [cm²]	2,14	
A y, z [cm²]	0,71	1,42
I y, z [cm⁴]	4,04	1,34
It [cm⁴]	3,12	
Iw [cm⁶]	3,20	
Wel y, z [cm³]	2,02	1,34
Wt [cm³]	0,00	
Wpl y, z [cm³]	2,61	1,60
d y, z [mm]	0,0	0,0
c YLKS, ZLKS [mm]	10,0	20,0
Alpha [deg]	0,00	
AL [m²/m]	1,1310e-01	
i y, z [cm]	1,38	0,79

Picture