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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User:

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Projekt:
Project:

2013-0698
Statische Berechnung für Line Array Lautsprecher:
al-8

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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.

Nominal loads:

Grid AL8-fb	
Hole	min N []
10	**20**
9	**20**
8	**20**
7	**20**
6	**20**
5	**18**
4	**16**
3	**13**
2	**10**
1	**9**

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)

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4 Materials

4.1 Aluminium

E = 7000 kN/cm²

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 X5 CrNiMo 17-12-2 / 1.4401

$f_{u,k}$ = 50,0 N/mm²
$f_{y,k}$ = 20,0 N/mm²

4.2.2 S355/ Q345

$f_{y,k}$ = 345 N/mm² = 34,5 kN/cm²
$f_{u,k}$ = 510 N/mm² = 51,0 kN/cm²

4.2.3 S235JR

$f_{y,k}$ = 240 N/mm² = 24,0 kN/cm²
$f_{u,k}$ = 360 N/mm² = 36,0 kN/cm²

4.2.4 C45

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

4.2.5 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 = 0,34 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

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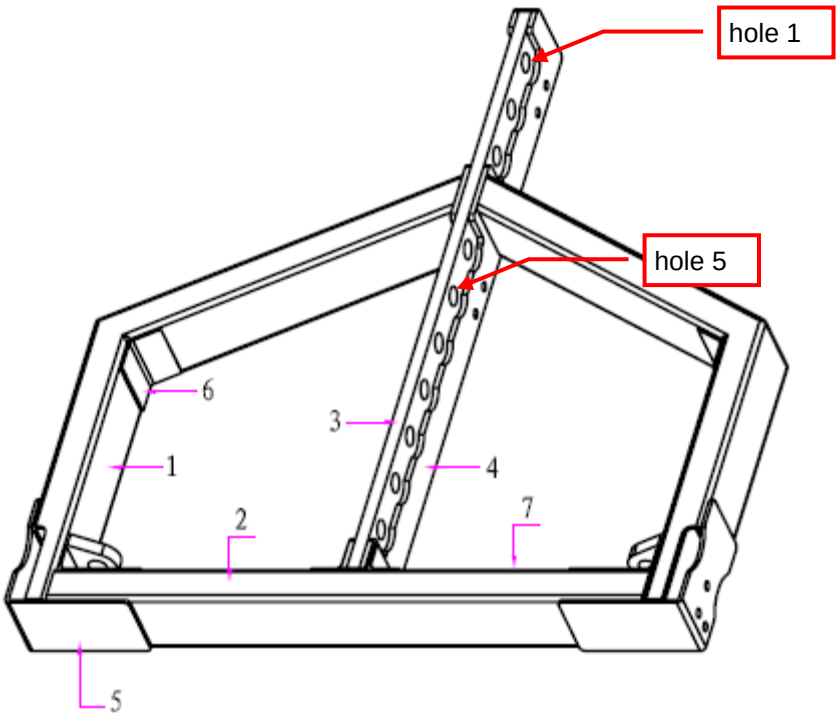
6 Calculation of member forces

see single positions

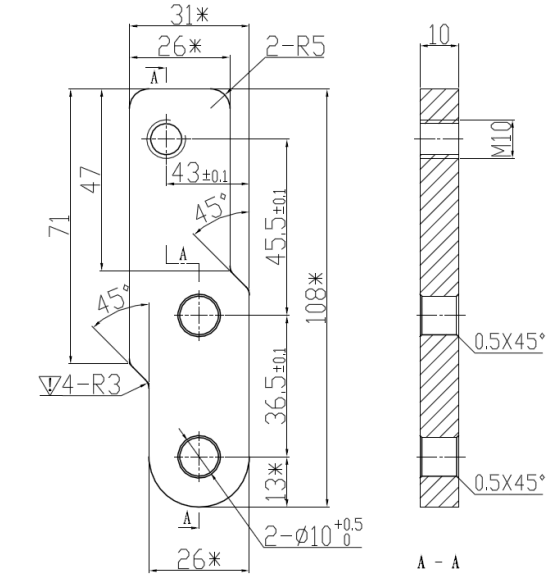


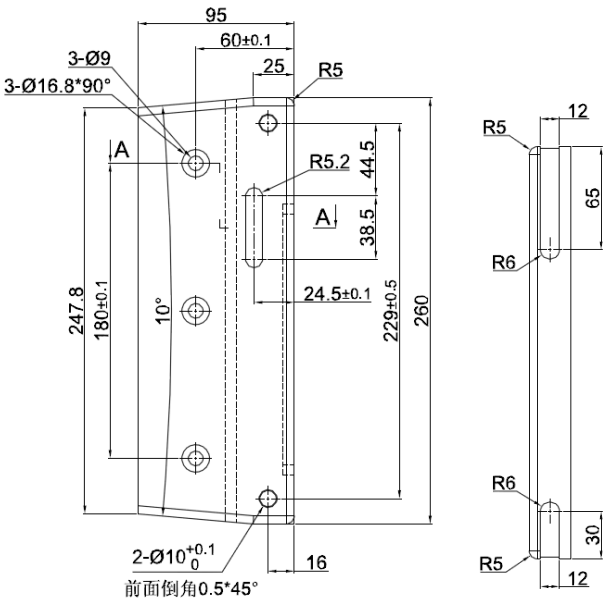
Maximum count of speakers ELX 82 among one another:
without subwoofers, hole position 1-3:
$F_{bb} = F_{ges} * 740 / 442 = F_{ges} * 1,67$
all N = 6,25 / 1,67 / 0,275 = 13 pcs.

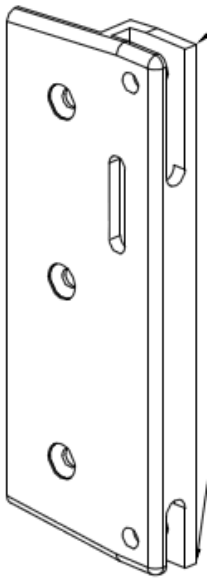
without subwoofers, hole position 4-10:
$F_{bb} = F_{ges} * 500 / 442 = F_{ges} * 1,13$
all N = 6,25 / 1,13 / 0,275 = 20 pcs.

7 Proofs

7.1 Parts of front suspension







7.1.1 Front locking pin

Ø9,8mm X5 CrNiCuNb 16/4 (1.4548.4)
A = 0,75 cm^2
W = 0,0924 cm^3

$V_{a,R,d}$ = 0,55 * 0,75 * 107,0 / 2,2 = 20,18 kN
$M_{R,d}$ = 0,0924 * 100,0 / 2,2 = 4,200 kNcm

F_d = 11,5 kN
M_d = 11,5 / 8 * (1,0 + 2 * 0,7 + 4 * 0,1) = 11,5 * 0,35 = 4,03 kNcm
V_d = 11,5 / 2 = 5,75 kN

$M_d / M_{R,d}$ = 4,03 / 4,20 = 0,96 < 1,0
$V_d / V_{a,R,d}$ = 5,75 / 20,18 = 0,29 < 1,0
$(M_d / M_{R,d})^2 + (V_d / V_{a,R,d})^2$ = 1,0 = 1,0

all F = 11,5 / 1,5 = 7,67 kN - BGV C1

7.1.2 front connector

milled part C45
e1 = 1,3 cm = 1,3 * D_L
e2 = 1,3 cm = 1,3 * D_L
k1 = 2,8 * 1,3 - 1,7 = 1,94
αb = 1,3 / 3 = 0,43
$F_{b,Rd}$ = 1,94 * 0,43 * 62,0 * 0,98 * 1,0 / 2,5 = 20,3 kN / cm^2

all F = 20,3 / 1,5 = 13,5 kN

7.1.3 Front bar

milled part EN AW 6061 T6
e1 = 1,5 cm = 1,49 * D_L
e2 = 1,6 cm = 1,58 * D_L > 1,5 * D_L
k1 = 2,5
αb = 1,49 / 3 = 0,50

$F_{b,Rd}$ = 2,5 * 0,50 * 29,0 * 0,98 * (2*0,7) / 2,5 = 19,9 kN

all F = 19,9 / 1,5 = 13,3 kN

Shear force will be transferred by locking pin and sine lap connecting screw. The Shear force also causes additional force component perpendicular to axial forces. $V_{Bolt} = V_{Box} * 82mm / 45,5mm = 1,80 * V_{Box}$

Because of two front suspensions and only one rear suspension, the shear force transfer will not be proofed. Thus the maximum uptilt is limited to +10°.

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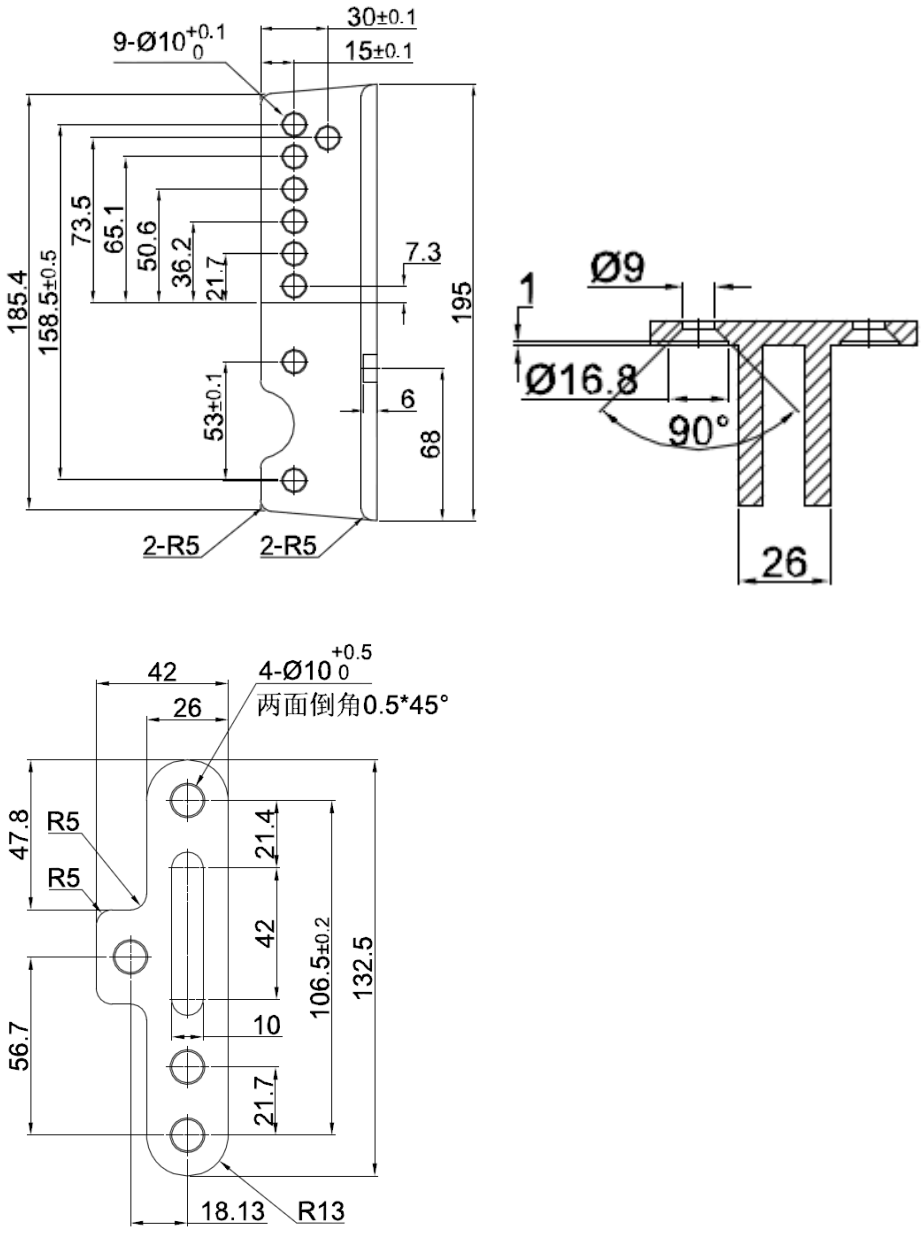
7.2 Parts of rear suspension



7.2.1 Rear locking pin at box

Ø9,8mm X5 CrNiCuNb 16/4 (1.4548.4)
$A = 0{,}75\ cm^2$
$W = 0{,}0924\ cm^3$

$V_{a,R,d} = 0{,}55 * 0{,}75 * 107{,}0 / 2{,}2 = 20{,}18\ kN$
$M_{R,d} = 0{,}0924 * 100{,}0 / 2{,}2 = 4{,}200\ kNcm$

$F_d = 11{,}5\ kN$
$M_d = 11{,}5 / 8 * (1{,}0 + 2 * 0{,}7 + 4 * 0{,}1) = 11{,}5 * 0{,}35 = 4{,}03\ kNcm$
$V_d = 11{,}5 / 2 = 5{,}7\ kN$

$M_d / M_{R,d} = 4{,}03 / 4{,}2 = 0{,}96 < 1{,}0$
$V_d / V_{a,R,d} = 5{,}7 / 20{,}18 = 0{,}28 < 1{,}0$
INT: $0{,}96^2 + 0{,}28^2 = 1{,}0$

all F = 11,5 / 1,5 = 7,67 kN - BGV C1

7.2.2 Rear hinge pin

Ø9,8mm X5 CrNiCuNb 16/4 (1.4548.4)
$A = 0{,}75\ cm^2$
$W = 0{,}0924\ cm^3$

$V_{a,R,d} = 0{,}55 * 0{,}75 * 107{,}0 / 2{,}2 = 20{,}18\ kN$
$M_{R,d} = 0{,}0924 * 100{,}0 / 2{,}2 = 4{,}200\ kNcm$

$F_d = 11{,}5\ kN$
$M_d = 11{,}5 / 8 * (1{,}0 + 2 * 0{,}7 + 4 * 0{,}1) = 11{,}5 * 0{,}35 = 4{,}03\ kNcm$
$V_d = 11{,}5 / 2 = 5{,}75\ kN$

$M_d / M_{R,d} = 4{,}03 / 4{,}20 = 0{,}96 < 1{,}0$
$V_d / V_{a,R,d} = 5{,}75 / 20{,}18 = 0{,}29 < 1{,}0$
$(M_d / M_{R,d})^2 + (V_d / V_{a,R,d})^2 = 1{,}0 = 1{,}0$

all F = 11,5 / 1,5 = **7,67 kN** - BGV C1

7.2.3 Rear connector

milled part C45
e1 = 1,3 cm = 1,3 * D_L
e1 = 1,3 cm = 1,3 * D_L
k1 = 2,8 * 1,3 - 1,7 = 1,94
αb = 1,3 / 3 = 0,43
$F_{b,Rd}$ = 1,94 * 0,43 * 62,0 * 0,98 * 1,0 / 2,5 = 20,3 kN / cm^2

all F = 20,3 / 1,5 = 13,5 kN

7.2.4 Rear Bar

milled part ENAW 6061 T6

reduced section:
A = 9,45 cm^2
$W_{y,el}$ = 4,61 cm^3
$W_{y,pl}$ = 4,725 * (0,31 + 1,40) = 8,08 cm^3 α = 1,75

$N_{o,Rd}$ = 9,45 * 24,0 / 2,2 = 103,1 kN
$M_{u,Rd}$ = 4,61 * 29,0 / 2,5 = **53,5 kNcm**
$M_{o,Rd}$ = 8,08 * 24,0 / 2,2 = 88,1 kNcm

e = 3,27 cm
M = N * 3,27cm

$N / N_{Rd} + M / M_{Rd} < 1,0$
N / 103,1 + N * 3,27 / 53,5 < 1,0
N * [1 / 103,1 + 3,27 / 53,5] < 1,0
N * [0,0708] < 1,0
N_{Rd} = 1,0 / 0,0708 = 14,12 kN

zul N = 14,12 / 1,5 = 9,41 kN

7.3 Summarisation loudspeaker

all F_{bb} = +/- 7,67 kN
all F_{fb} = +/- 7,67 kN

7.4 Grid

7.4.1 Profile

□ 80x40x3,8 Q235

A = 8,17 cm^2

Wy = 15,62 cm^3

$W_{y,pl}$ = 20,08 cm^3 α_{pl} = 1,29

L = 0,79 m = 79,0 cm

$M_{R,d}$ = 24,0 * 1,25 * 15,62 / 2,2 = 213,0 kNcm

$F_{R,d}$ = 4 * 213,0 / 79,0 = 10,78 kN

max F = 10,78 / 1,5 = 7,2 kN

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7.4.2 Suspension / speaker connection

Rear suspension:
bolt Ø 0,98cm - C45+QT
$A = 0{,}754\ cm^2$
$W = 0{,}0924\ cm^3$

proof according EC3:
$V_{a,R,d} = 0{,}754 * 0{,}55 * 70{,}0 / 2{,}5 = 11{,}61\ kN$
$M_{R,d} = 1{,}5 * 0{,}0924 * 49{,}0 / 2{,}0 = 3{,}40\ kNcm$

$F_d = 8{,}4\ kN$
$M_d = 8{,}4 / 8 * (1{,}0 + 2 * 0{,}6 + 4 * 0{,}2) = 8{,}4 * 0{,}375 = 3{,}15\ kNcm$
$V_d = 8{,}4 / 2 = 4{,}20\ kN$

$M_d / M_{R,d} = 3{,}15 / 3{,}40 = 0{,}93 < 1{,}0$
$V_d / V_{a,R,d} = 4{,}20 / 11{,}61 = 0{,}36 < 1{,}0$
INT: $0{,}93^2 + 0{,}36^2 = 1{,}0$

all F = 8,4 / 1,5 = 5,6 kN - BGV C1

Front suspension:
bolt Ø 0,98cm - C45
$A = 0{,}754\ cm^2$
$W = 0{,}0924\ cm^3$

proof according EC3:
$V_{a,R,d} = 0{,}754 * 0{,}55 * 70{,}0 / 2{,}5 = 11{,}61\ kN$
$M_{R,d} = 1{,}5 * 0{,}0924 * 49{,}0 / 2{,}0 = 3{,}40\ kNcm$

$F_d = 7{,}9\ kN$
$M_d = 7{,}9 / 8 * (1{,}0 + 2 * 0{,}4 + 4 * 0{,}35) = 7{,}9 * 0{,}40 = 3{,}16\ kNcm$
$V_d = 7{,}9 / 2 = 3{,}95\ kN$

$M_d / M_{R,d} = 3{,}16 / 3{,}40 = 0{,}93 < 1{,}0$
$V_d / V_{a,R,d} = 3{,}95 / 11{,}61 = 0{,}34 < 1{,}0$
INT: $0{,}93^2 + 0{,}34^2 = 1{,}0$

all F = 7,9 / 1,5 = 5,3 kN - BGV C1

7.4.3 Mounting bracket

plate t = 14mm - C45
max F = 5,0 kN → F_d = 6,75 kN

$e1/D_L$ = 1,0 < 1,2
Anyhow $V_{l,R,d}$ will be calculated with equation 50a for 1,2*D_L for estimating mounting brackets load capacity.
$\alpha 1$ = 1,1 * 1,0 - 0,3 = 0,8
$V_{a,R,d}$ = 1,4 * 2,0 * 0,8 * 49,0 / 2,2 = 50,0 kN >> 6,75 kN

No further proof.

7.5 Summarisation Grid

all F_{bb} = +/- 5,6 kN
all F_{fb} = +/- 3,6 kN

Grid AL8-fb								
Hole	a [mm]	b [mm]	L [mm]	X(Ffb) []	X(Fbb) []	N(Ffb) []	N(Fbb) []	min N []
1	80	332	412	0,40	0,19	26	84	**20**
2	137	275	412	0,33	0,33	31	49	**20**
3	194	218	412	0,26	0,47	40	34	**20**
4	251	161	412	0,20	0,61	54	27	**20**
5	308	104	412	0,13	0,75	83	22	**20**
6	365	47	412	0,06	0,89	185	18	**18**
7	422	-10	412	-0,01	1,02	872	16	**16**
8	501,5	-89,5	412	-0,11	1,22	97	13	**13**
9	627	-215	412	-0,26	1,52	40	10	**10**
10	684	-272	412	-0,33	1,66	32	9	**9**

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.