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Structural Report

GeoS12-Serie **0679**

for the system of

Nexo S.A.
154 Allée des Erables

F 95950 Roissy CDG Cedex

Aachen, 27th March 2008

INGENIEURKAMMER-BAU NORDRHEIN-WESTFALEN
BERATENDER INGENIEUR
101448

This structural analysis includes pages 1 - 61

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1 PRELIMINARY NOTES

1.1 Technical Bases

DIN	1055	Design Loads for Buildings
DIN	4112	Temporary structures
DIN 18 800,		Steel structures; design and construction
DIN	3065	Steel wires ropes
User Manuals		GeoS-12 Series, RS15 Series

1.2 Applied Building Materials

Steel	IMEX 701	(S700 acc. to NF EN 10149-2)
	S 235 JR	
Bolts	Ballock pins stainless steel 1.4305	fyk / fuk = 300 / 620
	Socket Head Shoulder srew 12.9	fyk / fuk = 1080 / 1200 N/mm²
	Bolt Inox 304 L	fyk / fuk = 500 / 630 N/mm²
	Srews A70	fyk / fuk = 450 / 700 N/mm²
	Standard bolts and srews in classe	4.6 , 10.9 , 12.9
Wood	Baltic Birch Ply	

1.3 General Description

Subject of this structural calculation is the GeoS12 Tangent Array and the RS15 subwoofer assembly system developed by the Nexo company.

The **GeoS12** Tangent Array has been designed for the deployment of curved vertical, horizontal and groundstacked arrays of GeoS12-10 and GeoS12-30 loudspeakers. There are two kinds of rigging-system. One has been developped for touring-applications and the other for fixed installations.

Ther riggingsystem of the GeoS loudspeakers is a bending resistant system and consists of steel elements which are fixed on two sides of a loudspeaker and connected over 4 locking pins with the appropriate steel elements of the neighbouring cabinet. The system is designed to enable different angle settings between adjacent cabinets. The maximum angle between two cabinets is limited to 10° (GeoS12/10) resp 30° (GeoS12/30). The cluster system can be flown for the touring applictaion with one hanging point. For fixe installations the top-bumpoer is fixed by 4 screws to a substructure or cable mounted with accessories. The substructure is not part of this report.

Additional to the cluster system this report contains the proof of several accessories for touring and fixed installation apllications.

Restrictions concerning the maximum number of cabinets which can be flown together or used in combination with the accesories see next page.

The **RS15** system can be used for an vertical hanging subwoofer-cluster. The rigging system consits of 4 vertical riggings parts which are placed at the four corners of the cabinet. The maximum number is limited to 16 RS15.

This structural report takes as condition that all safety requirements in the User Manuals - GeoS12 Series - and -RS15 series- are respected.

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1.4 Restrictions concerning maximum number of cabinets

GeoS12-Cluster

For all desired configurations an individuel proof of structural integrity like descibed in this report is necessary. It is not sufficient to respect only the maximum allowable number of cabinets. Especially angle seetings with important angles between the cabinets can reduce the maximum allowable number of cabinets which can be flown together.

For practical use the proof of structural integrity like described in this report has been introduced in the programme GeoSoft.

GeoS12- cluster Touring	max. 12 GeoS12

The linkbarVersion TLB can be used without any restrictions for flown touring-cluster in tension mode.

GeoS12-cluster Fixed	Max Number depends on the configuration and allowable loading of the substructure.

Accessories GeoS12

Touring

TCBRK-V2	2 GeoS12
TTC-V2	1 GeoS12
LYRE-V2 in combination with SSBRK-V2	1 GeoS12
LYRE-V2 in combination with PSBRK-V2	2 GeoS12
XHBRK	4 GeoS12 per XHBRK

Fixed installation

UBRK	1 GeoS12
LBRK in horizontal mode, cable mounted	3 GeoS12 per LBRK
2 LBRK with F-Bumper, cable mounted	Cluster with max 10 GeoS12
ABRK in horizontal mode,	4 GeoS12 per ABRK

Groundstack-Mode GeoS12

base angel between -10° and 10° maximum angle setting 10° between two cabinets	6 GeoS12

RS15 - cluster	max 16 RS15

1.5 Loading and safety level

Wind forces for touring apllictaions are applied according to DIN 1055, Part 5, (1986), and DIN 4112 (1983).

According to DIN 4112 the impact pressure can be reduced if the service of the system is stopped at wind force greater beaufort 8 (resp. v = 20,7m/s). In this case the impact pressure can be set as follows

For 0 ÷ 5,00 m over ground q = 0,15 kN/m²
For h > 5,00 m over ground q = 0,25 kN/m²

For wind lower than beaufort 8 the impact pressure can be reduced dependent on the windspeed:

In case of wind lower beaufort 6 (v = 13,8 m/s)

For h > 5,00 m over ground $q = 13{,}8^2 / 20{,}7^2 \cdot 0{,}25 = 0{,}12$ kN/m²

Snow loads are not taken into account because they are very low in relation to the other loads.

For **fixed installations** windloading has to be taken into account in accordance to the national standards.

Selfweight elements GeoS12 Array

Loudspeaker GeoS12/10	including Rigging-parts	Gi = 33 kg
Loudspeaker GeoS12/30	including Rigging-parts	Gi = 32 kg
Touring Bumper		G = 20 kg

Selfweight elements RS15 Array

Subwoofer RS15	including Rigging-parts	Gi = 65 kg
Touring Bumper		G < 60 kg

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Safety level

To cover dynamic effects during lifting the assemblies and faults made during rigging the **safety level concerning loading is set to 4**.

This safety factor includes	a safety factor of	1,5	acc. to DIN 1055-100 By exmaple in combination with DIN18800
	a safety factor of	2,0	acc. to the European Machinery Directive
	a dynamic factor of 1,3		
	Summary	1,5 · 2,0 · 1,3 = 3,9 < 4,0	

The safety level concerning resistance of the steel-components is set according to DIN 18800 Part 1 to **1,1.**

In combination with material-standards which are not based on a semi probalistic safety system the safety factor of 1,5 acc. to DIN 1055-100 must not be taken into account (This safety factor is then allready taken into account in the material specific safety system)

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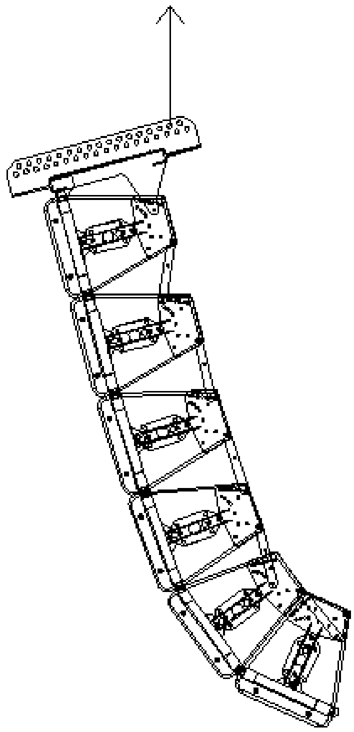
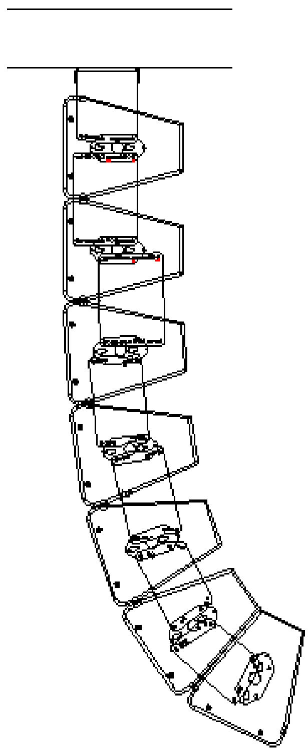
2 SYSTEM COMPONENTS AND ASSEMBLY

vertical-cluster

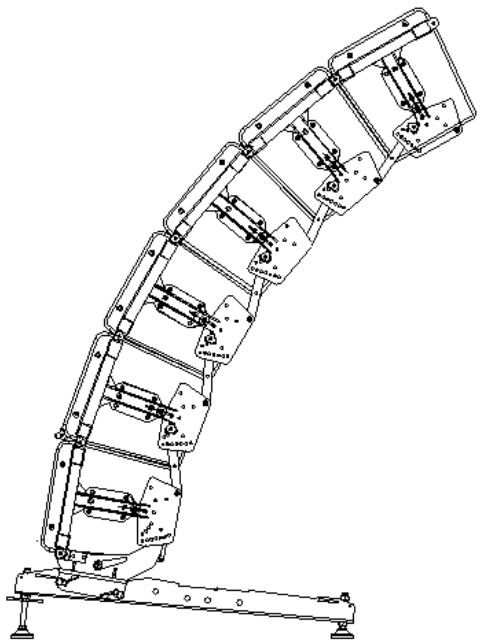
Touring Cluster



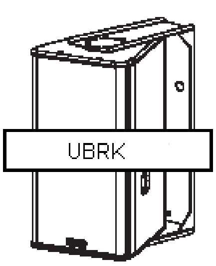
Fixed Cluster

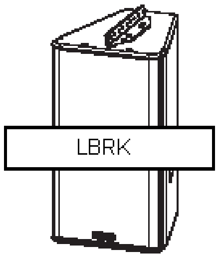


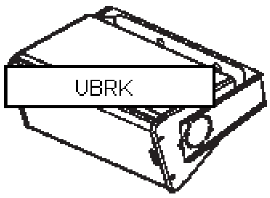
Groundstack Touring cluster

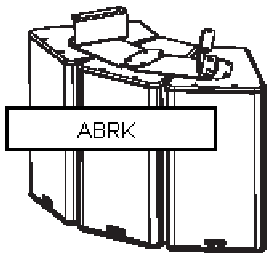


Accessories Fixed installations

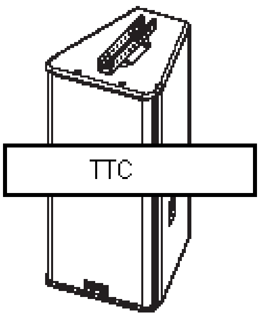


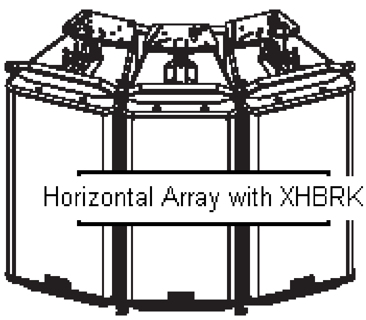


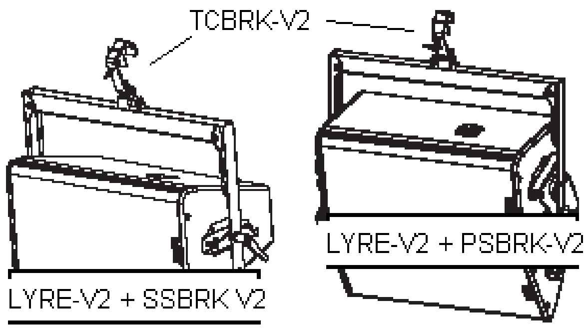




Accessories touring applictaions

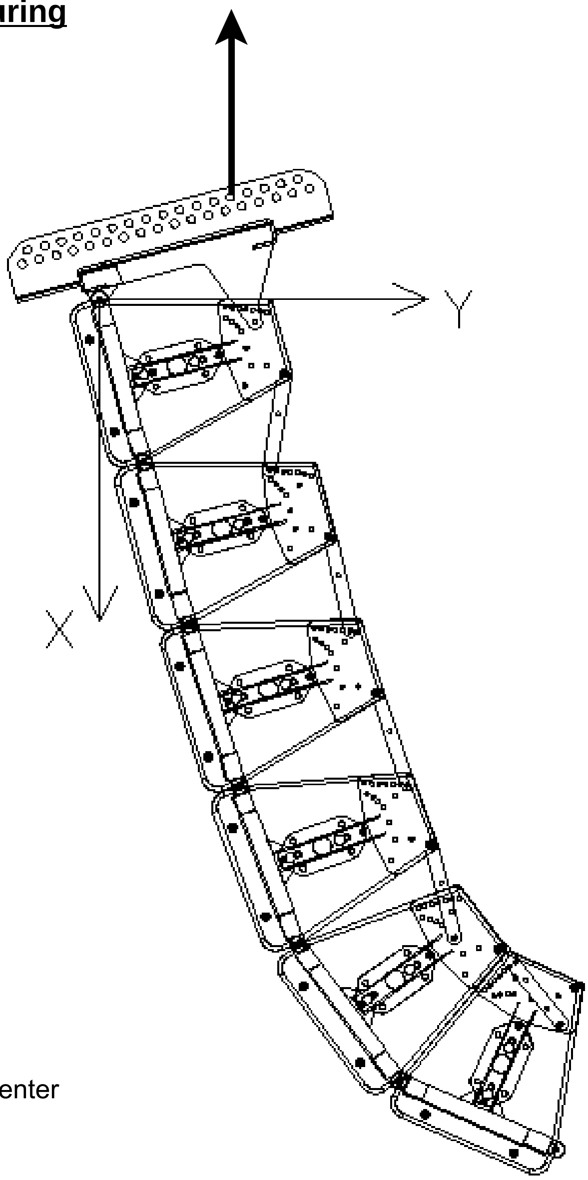




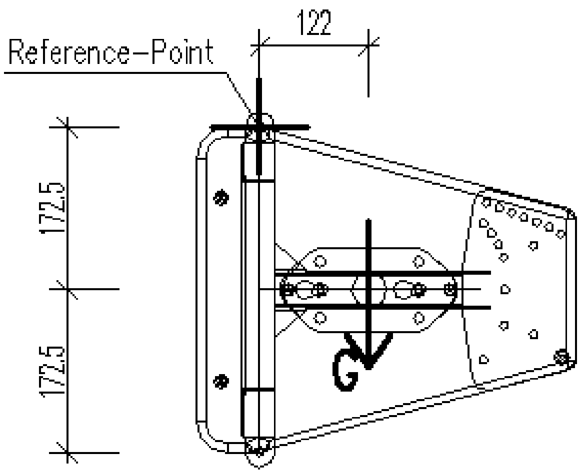


3 GEOS-12/30 ARRAY - Touring

3.1 System overview



Reference-point and local gravity center



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3.2 Center of gravity

The center of gravity of a cluster is calculated by:

Ys =(3Gi· ysi) / 3Gi　　　　Xs =(3Gi· xsi) / 3Gi

with	Gi	= 0,33 kN	weight of loudspeakers
	GB	= 0,20 kN	weight of bumper
	ysi,xsi =		coordinates of gravity center of a loudspeaker / bumper reffering to the base point Y/X = 0/0

The coordinates from the gravity center of the top bumper reffering to the base point is calcualted by

ysi = ex· sinΨo + ey · cos Ψo
xsi = ex· cosΨo - ey · sin Ψo

with　ex = -0,056 m　ey = 0,175 m

The coordinates from the gravity center of a loudspeaker reffering to the base point is calculated by

ysi = yi +ex· sinΨi + ey · cos Ψi
xsi = xi +ex· cosΨi - ey · sin Ψi

with　ex = 0,1725m　ey = 0,122m

and　yi,xi = global coordinates of the front connection point of a loudspeaker

at first box	$y_i = x_i = 0$
for all following boxes	$y_i = y_{i-1} + h_{H,i-1}$
	$x_i = x_{i-1} + h_{V,i-1}$

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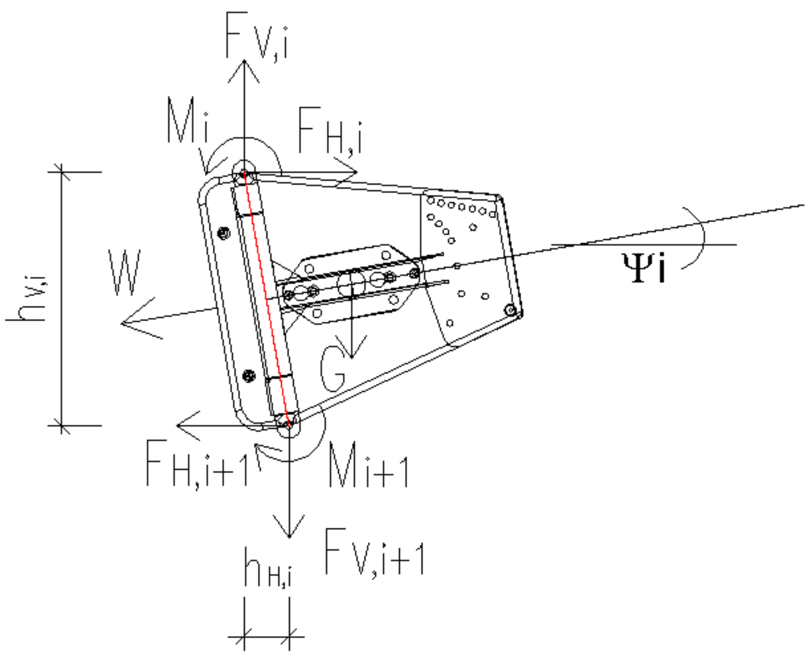
3.3 Internal Forces

3.3.1 General remarks

For the calculation the following notation is used:

n	number of boxes		
i	position of a box	i=1	first box at the top
		i=n	last box
Ψ_i	horizontal angle of a box in postion i		
Ψo	horizontal angle of top bumper		
h_i	height of a box = 0,345m		
$h_{H,i}$	horizontal projection of the height h_i	$h_{H,i} = h_i \cdot \sin \Psi_i$	
$h_{V,i}$	vertical projection of the height h_i	$h_{V,i} = h_i \cdot \cos \Psi_i$	
hhp	total horizontal projection of the cluster		
hvp	total verticla projection of the cluster		
G	total weight of the cluster = 3 Gi		
G_i	selfweight of a loudspeaker		
W_i	resultant wind load on a box		
FV_i	internal global vertical force between boxes at position i and i-1		
FH_i	internal global horizontal force between boxes at position i and i-1		
M_i	internal moment between the boxs at position i and i-1		
FII_i	internal local force parallel to the front side		
FL_i	internal local force rectangular to the front side		



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3.3.2 Internal forces at reference point

The internal forces are calculated allong a curved beam which is defined by the front connection points of the rigging system.

The calculation has to start at the lowest position (Loudspeaker with index n):

$Fv_n = G_n + W_n \cdot \sin \Psi_n$

$Fh_n = W_n \cdot \cos \Psi_i - FB$

$M_i = G_n \cdot(ex \cdot \sin\Psi_n + ey \cdot \cos\Psi_n) + W_n \cdot h_n / 2 - FB \cdot hv,i$

with $ex = 0{,}1725m \quad ey = 0{,}122m$

and $FB = w \cdot Hv / 2$ Bracingforce in case of Wind Bracing

Hv = total vertical projection of the cluster

w = windloading as distrbuted load [kN/m]

For all following loudspeakers i > n

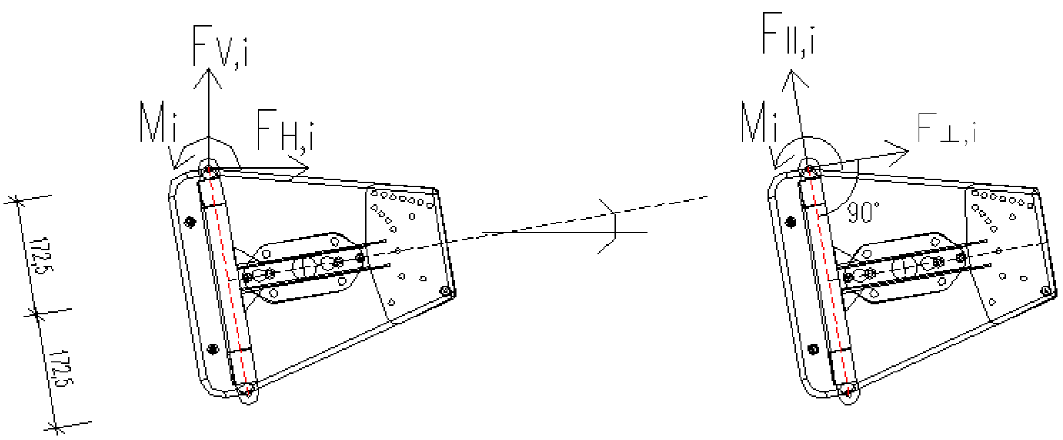
$Fv_i = Fv_{i+1} + G_i + W_i \cdot \sin \Psi_i$

$Fh_i = Fh_{i+1} + Wi \cdot \cos \Psi_i$

$M_i = M_{i+1} + (Fh_{i+1} \cdot\cos\Psi_i + Fv_{i+1} \cdot \sin\Psi_i) \cdot h_i + G_i \cdot(ex \cdot \sin\Psi_i + ey \cdot \cos\Psi_i) + W_i \cdot h_i / 2$

Transformation of F_V and F_H into local direction

$FII_i = F_{Vi} \cdot \cos \Psi i - F_{Hi} \cdot \sin \Psi i$
$FL_i = F_{Vi} \cdot \sin \Psi i + F_{Hi} \cdot \cos \Psi i$



3.3.3 Transformation into local forces at connection points

The forces S1 and S2 are depending on the angle-setting of the link-bar.
For the proof of structural integrity two extreme cases are taken into account

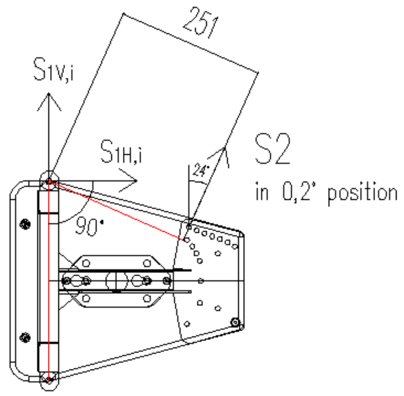
1. S2 inclined by 24° (Link bar on 0,2° position)
2. S2 inclined by 0° (Linkbar on 5° position)
3. S2 inclined by 0° (connection to bumper)

Case 1 S2 inclined by 24° - Link bar on 0,2° position

$S2 = M_i / (2 \cdot 0{,}251)$

$S1V = FII_i \;/\; 2 - S2 \cdot \cos 24°$

$S1H = FL_i / 2 - S2 \cdot \sin 24°$

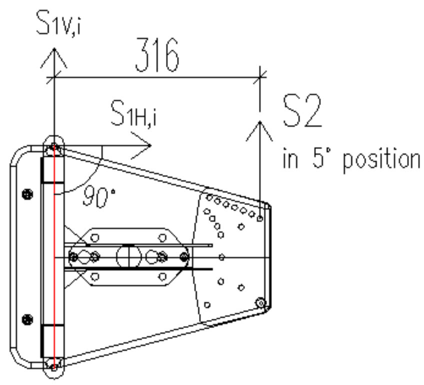


Case 2 S2 inclined by 0° - Linkbar on 5° position

$S2 = M_i / (2 \cdot 0{,}316)$

$S1V = FII_i \;/\; 2 - S2$

$S1H = FL_i / 2$

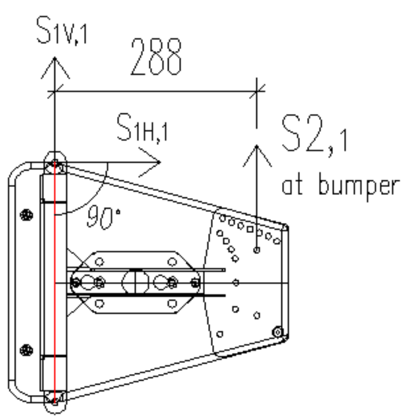


Case 3 S2 inclined by 0° - connection to bumper

$S2 = M_i / (2 \cdot 0{,}288)$

$S1V = FII_i \;/\; 2 - S2$

$S1H = FL_i / 2$



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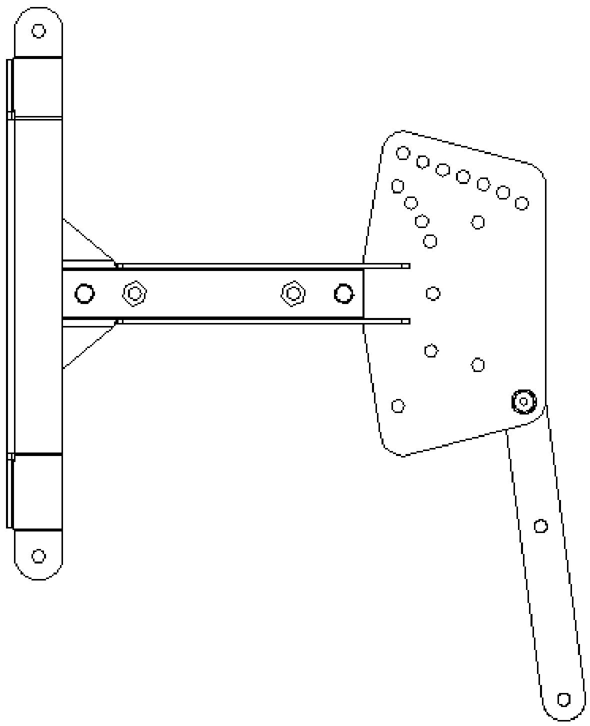
3.4 Allowable Loading

3.4.1 X-BOW V2 Rigging-System



Front connection

by 8mm Ball-lock 1.4305 Nirosta

Shearing acc. to DIN 50141

V = 38 kN

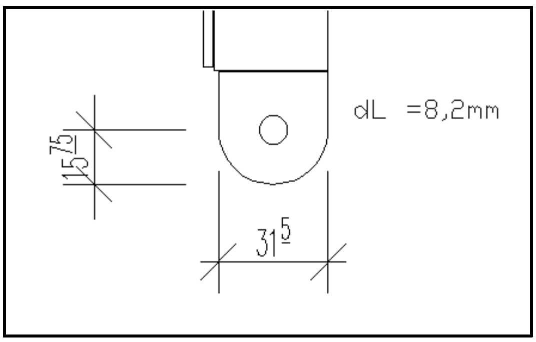
Tear out

e1 = e2 = 15,75 mm = 1,92 · dL

=> a = 1,81

Vlrd = t · dL · a · fyk / 1,1

Vlrd = 2 · 0,3·0,8 ·1,81 · 70 / 1,1 = 55,3 kN



Summary

=> allowable Loading S [kN] including safety factor =4

S < 38 / 4 = 9,5 kN

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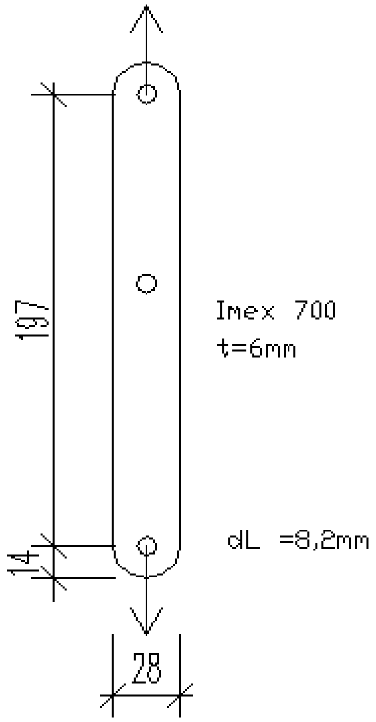
Link bar - standard and Version TLB

Link-bar Version TLB only for flown clusters (in tensions mode)



Tear out at Link bar

e1 = e2 = 14 mm = 1,71 · dL

=> a = 1,58

Vlrd = t · dL · a · fyk / 1,1

Vlrd = 0,6·0,8 ·1,58 · 70 / 1,1 = 48,26 kN

connection to X-Bow

by 8mm Ball-lock 1.4305 Nirosta

Shearing acc. to DIN 50141 V = 38 kN

and Socket Head Shoulder screw M6D8 12.9

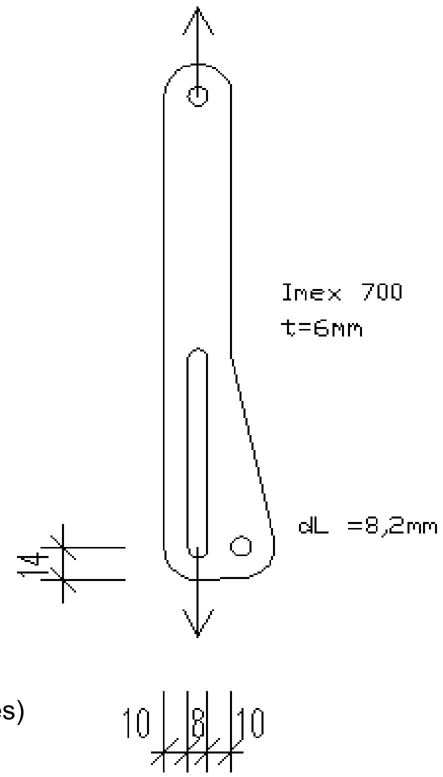
Calculation for srew 10.9

Shearing acc. to DIN 18800 T1

Va,rd =2 · 0,50cm² · 0,44 · 100 /1,1 = 40 kN

=> allowable Loading S [kN] including safety factor =4

S < 38 / 4 = 9,5 kN



Buckling under pressure forces
(only for standard Link-bar in Groundstack-mode)

sk = 19,7-0,82= 18,9 cm   i = 0,289 · 0,6 = 0,173 cm

λ = 18,9 / 0,173 = 109
$\lambda a = \pi\,(210000 / 700)^{0,5}$ = 54,4
λ^*= 109/ 54,4 = 2,01

=> k = 0,195   acc. to DIN 18800

=> Vrd = 0,195 · 2,8·0,6 · 70 /1,1 = 20,85 kN

=> allowable Loading S [kN] including safety factor =4

S = 20,85 / 4 = 5,21 kN (only relevant for pressure forces)

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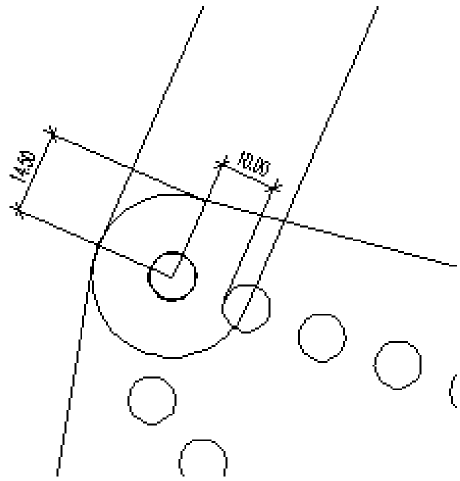
Tear out at Rigging-Plate
(Position for 0,2° angle setting is relevant)



e1 > 14 mm = 1,71 · dL

e2 = 10 mm = 1,22 ·dL

=> a = 1,08

Vlrd = t · dL · a · fyk / 1,1

Vlrd = 0,6·0,8 ·1,08 · 70 / 1,1 = 30,54 kN

=> allowable Loading S [kN] including safety factor =4

S < 30,54 / 4 = 7,64 kN

Summary allowable Loading S [kN] including safety factor =4

under tension forces:	all S = 7,64 kN	
under pressure forces	all S = -5,21 kN	only for standard link-bar

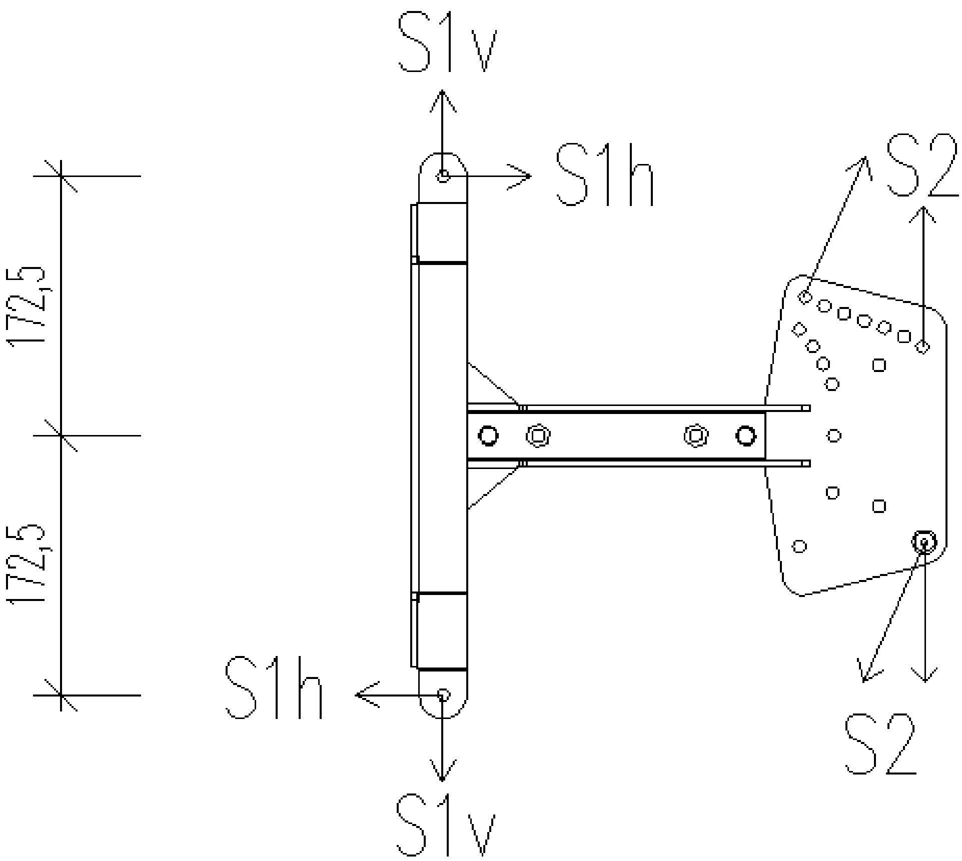
Bending in X-Bow

To cover all theoretic possible combination of internal forces by conditions as simple as possible the limits for the internal forces S1v, S1h and S2 are set as follows.

-5,0 kN < S2 < 5,0 kN

-5,0 kN < S1v < 5,0 kN

-2,0 kN < S1h < 2,0 kN



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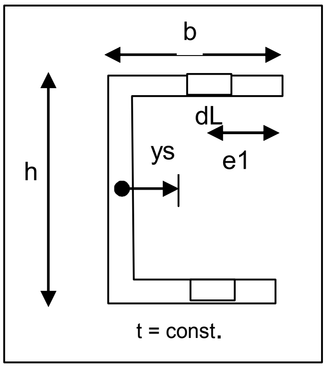
Front - bar U 43x36x3 mm

Cross-Section



h	4,30 [cm]		
b	3,60 [cm]		
th	0,30 [cm]		
tb	0,30 [cm]		
dl	0,00 [cm]		
e1	0,00 [cm]		
h'	4,00 [cm]		
b'	3,45 [cm]		
		Wy	4,60 [cm³]
A	3,27 [cm²]	Wz-1	3,47 [cm³]
ys	1,09 [cm]	Wz-2	1,83 [cm³]
Iyy	9,88 [cm^4]		
Izz	4,31 [cm^4]	(W-pl=2xS)	
Sy	2,67 [cm³]	Wy-pl	5,34 [cm³]
Sz	1,67 [cm³]	Wz-pl	3,34 [cm³]

Maximum bending Moment in Front-bar limited by S1h to

Mmax = 2,0 kN · 17,25 cm = 34,5 kNcm

Maximum Normalforces in Front-bar limited by S1v to

Nmax = 5,0 kN

Stresses

allowable Stress Imex700 including safety acc. to DIN 18800

fyk = 70 / 1,1 = 63,63 kN/cm²

Verification of stress including safety factor of 4

4 ·(5,0kN / 3,27 cm² + 34,5 kNcm / 3,34 cm³) = 47,44 kN/cm² < 63,63

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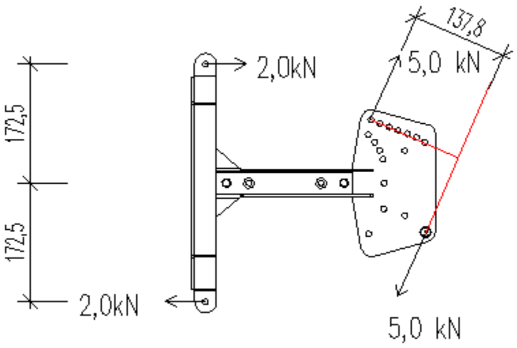
Transverse - bar U 40x36x3 mm

For the maximum bending moments in the transverse bar two independent cases can be possible.

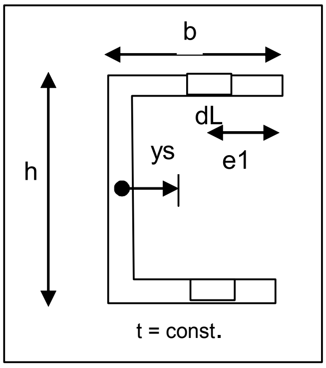
1. Maximum forces S2h => Mmax = 2 · 2,0 · 17,25 = 69 kNcm

2. Maximum forces S2 with maximum lever arm => Mmax = 5,0 · 13,78 = 68,9 kNcm
   (Both Link-bars on 0,2° position)



In both cases there are no Normal-forces in the transverse bar.
Normal froces only appear when one force of the pair is lower then the other and in this case the bending moment is lower => not. relevant

Cross-Section



h	4,00 [cm]		
b	3,60 [cm]		
th	0,30 [cm]		
tb	0,30 [cm]		
dl	0,00 [cm]		
e1	0,00 [cm]		
h'	3,70 [cm]		
b'	3,45 [cm]		
		Wy	4,18 [cm³]
A	3,18 [cm²]	Wz-1	3,30 [cm³]
ys	1,12 [cm]	Wz-2	1,81 [cm³]
Iyy	8,35 [cm⁴]		
Izz	4,20 [cm⁴]	(W-pl=2xS)	
Sy	2,43 [cm³]	Wy-pl	4,86 [cm³]
Sz	1,62 [cm³]	Wz-pl	3,25 [cm³]

allowable Stress Imex700 including safety acc. to IN 18800

fyk = 70 / 1,1 = 63,63 kN/cm²

Verification of stress including safety factor of 4

4 ·69 kNcm / 4,86 cm³ = 56,79 kN/cm² < 63,63

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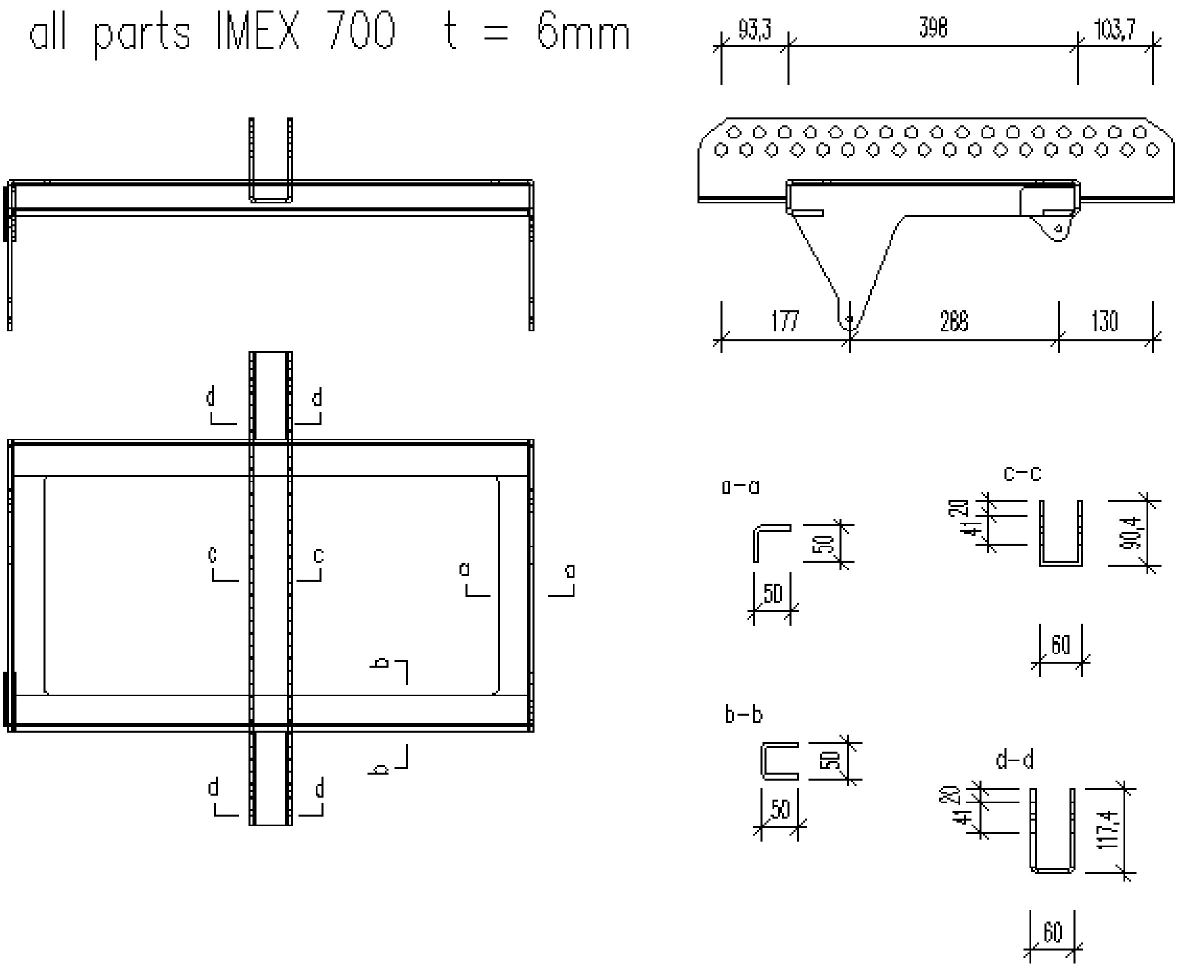
Bumper



internal forces

The internal forces are calculated for a unit force of 10 kN at the hanging point. Three positions of the hanging point are taken into account.

1.+ 2. Hanging point in extreme left and right poistion

3. Hanging Point in the middle of the central bar

Then on the base of the internal forces due to the unit load of 10 kN the allowable total weigth of a cluster is calculated.

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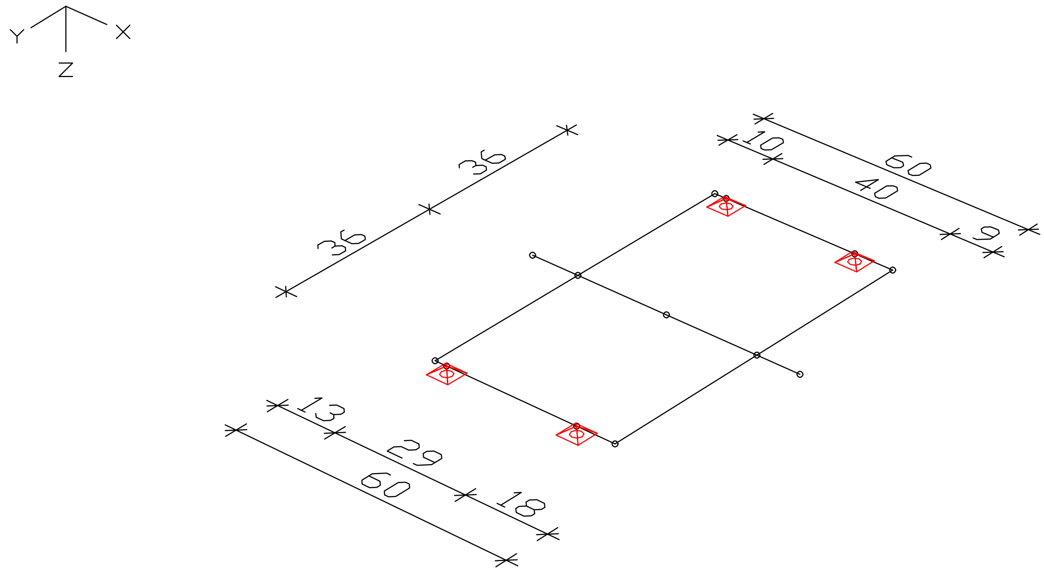
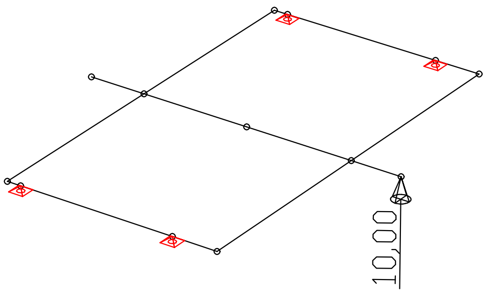
0679 - Bumper GeoS12/30

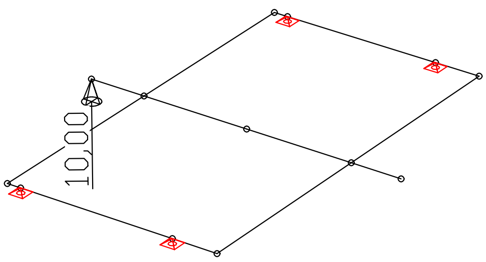
M 1 :



Bem



LC 1: Load



LC 2: Load

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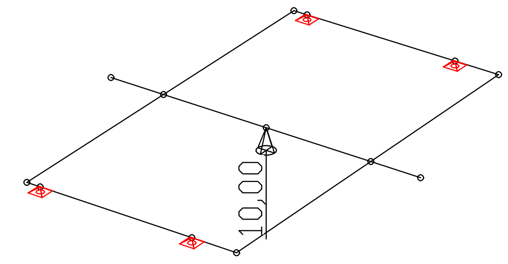
0679 - Bumper GeoS12/30

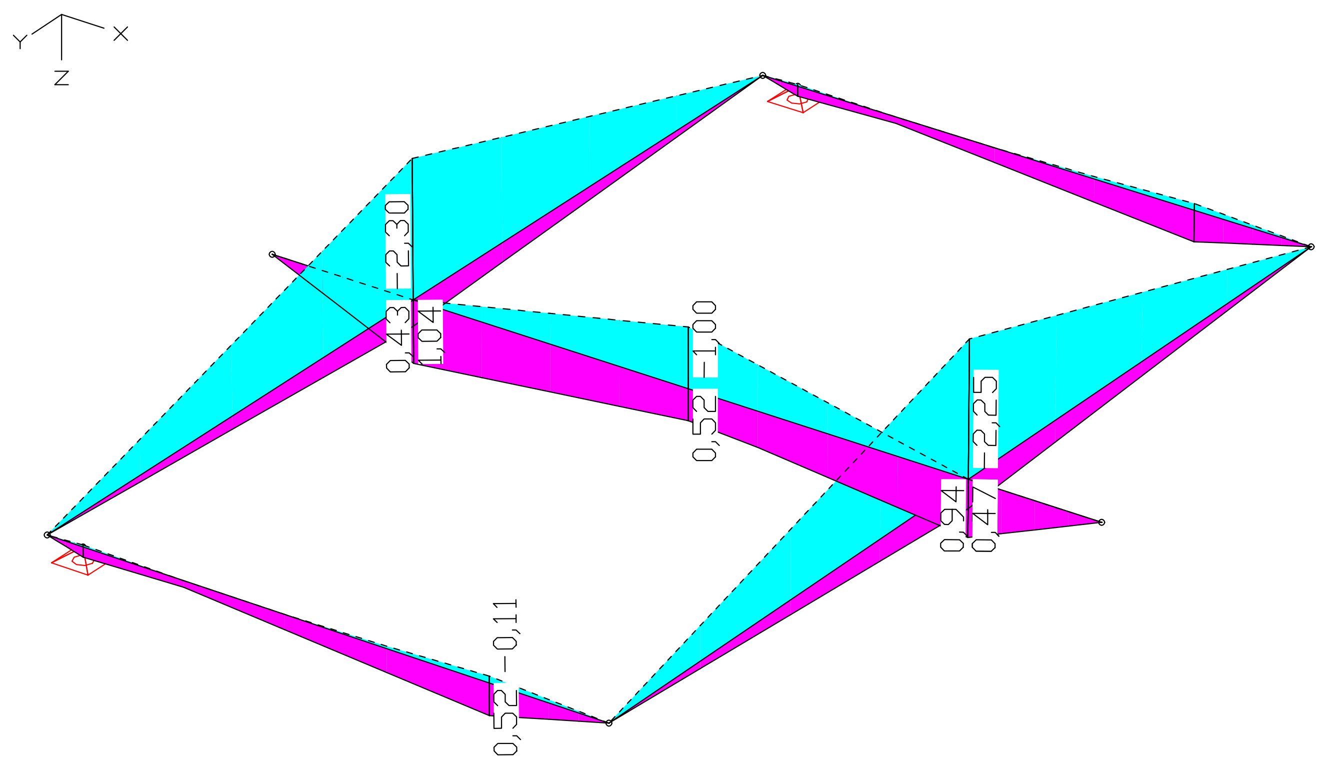
M 1 :



LC 3: Load

Load case combination 10

1. Variable exclusive action	Factor
1	1,000
2	1,000
3	1,000



Internal forces My min, max; K10

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Section a-a L 50x50x6 mm

Max M = 52 kNcm due to 10 kN

Wel = 3,61 cm³

Allowable stress σ = 0,7* · 70 / 1,1 = 44,55 kN/cm²

* reducing allowable stress to 70% acc. to DIN 18800, because calculation of stresses are not done for the principle axes of the section

=> allowable maximum Load incl. safety factor of 4

4· P· 52 kNcm / (10 KN ·3,61cm³) < 44,55 kN/cm² => P< 7,73 kN

Section b-b U 50x50x6 mm

Max M = 230 kNcm

Wel = 12,62 cm³

Allowable stress σ = 70 / 1,1 = 63,63 kN/cm²

=> allowable maximum Load incl. safety factor of 4

4· P· 230 / (10·12,62) < 63,63 => P< 8,7 kN

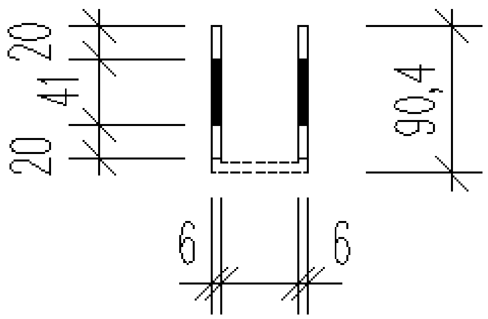
Section c-c and d-d U 60x90x6 resp U 60x117x6

Max M = 104 kNcm

on the safe side the stress calculation is based on the following simplified cross section
Tow rectangular corss setions (6x81) with a hole of 41 mm

Iyy = 0,6 · (8,1³ - 4,1³) / 12 = 23,13 cm4

Wel = 23,13 / 4,05 = 5,711



Allow. stress σ = 70 / 1,1 = 63,63

4 · P · 104 / (10· 5,711) < 63,63

=> P < 8,70 kN

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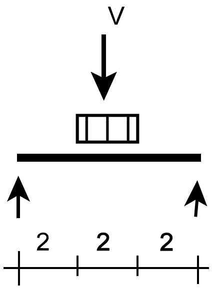
Hanging Points at Bolt M16 fyk / fuk = 500 / 630 N/mm²



Bending

$M_{sd} = V/2 \cdot (3 - 0{,}5) = 1{,}25 \text{ cm} \cdot V$ [kNcm]

$W_{pl} = 4/3 \cdot 0{,}8^3 = 0{,}68 \text{ cm}^3$

$\sigma = 1{,}25 \cdot V / 0{,}68 \quad < \quad \sigma_{rd} = 50 / 1{,}1 = 45{,}4 \text{ kN/cm}^2$

=> $V_{rd} = 45{,}4 \cdot 0{,}68 / 1{,}25 = 24{,}7$ kN

Shearing

$V_{rd} = 2 \cdot 0{,}6 \cdot \pi \cdot 0{,}8^2 \cdot 63 / 1{,}1 = 138$ kN

Tear out

$e_1/d_L = 20 / 16{,}5 = 1{,}2$

$e_2/d_L > 1{,}5 \qquad a = 1{,}1 \cdot 1{,}2 - 0{,}3 = 1{,}02$

$V_{rd} = 2 \cdot 0{,}6 \cdot 1{,}02 \cdot 1{,}6 \cdot 70 / 1{,}1 = 125$ kN

Bending with Vrd = 24,7 kN is relevant

Allowable loading including safety factor of 4

all. P = 24,7 / 4 = 6,18 kN

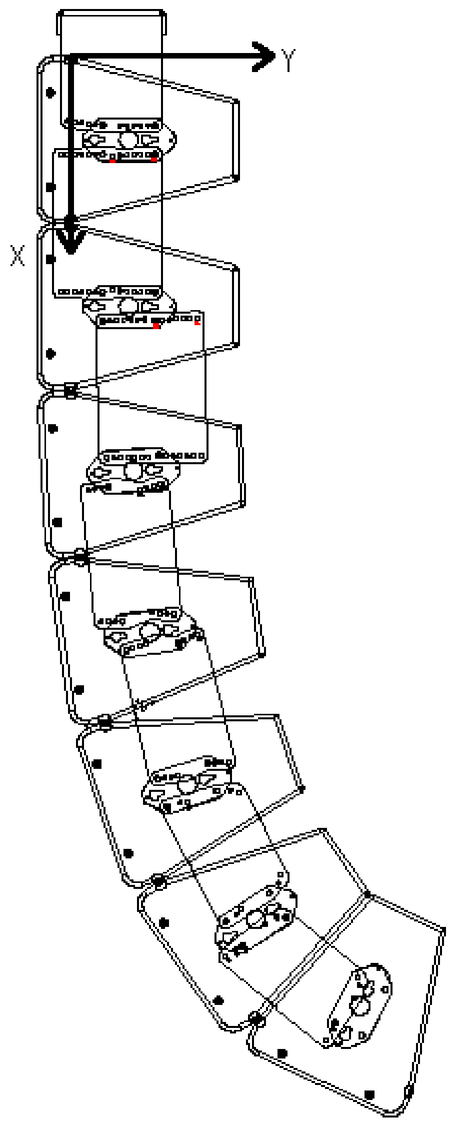
Summary

The total weight of the cluster is limited by bending of the bolt at the hanging point.

Including a safety factor of 4 the total weight of the cluster is limited to 6,18 kN.

4 GEOS12/30-ARRAY Fixed-Installation

4.1 System overview



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4.2 Gravity center

The calculation of the gravity center is equal to the calculation for the Touring - Cluster (see chapter 3.2)

The weight of a loudspeaker including rigging-parts is 33 kg

The weight of the bumper is about 5 kg.

4.3 Internalforce

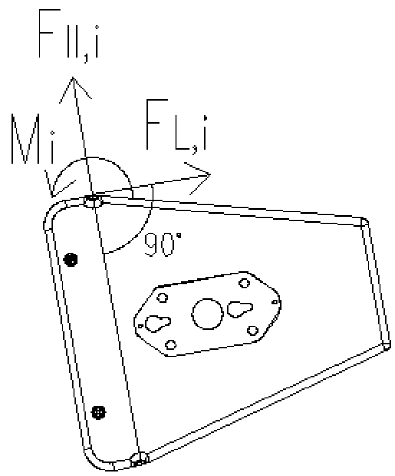
4.3.1 General remarks

In a first step the internal forces are calculated analogue to the touring cluster at the reference point. So the calculation of the internal forces till the point of the internal forces Mi, FII,i and FL,i is equal to the calculation for the touring cluster.

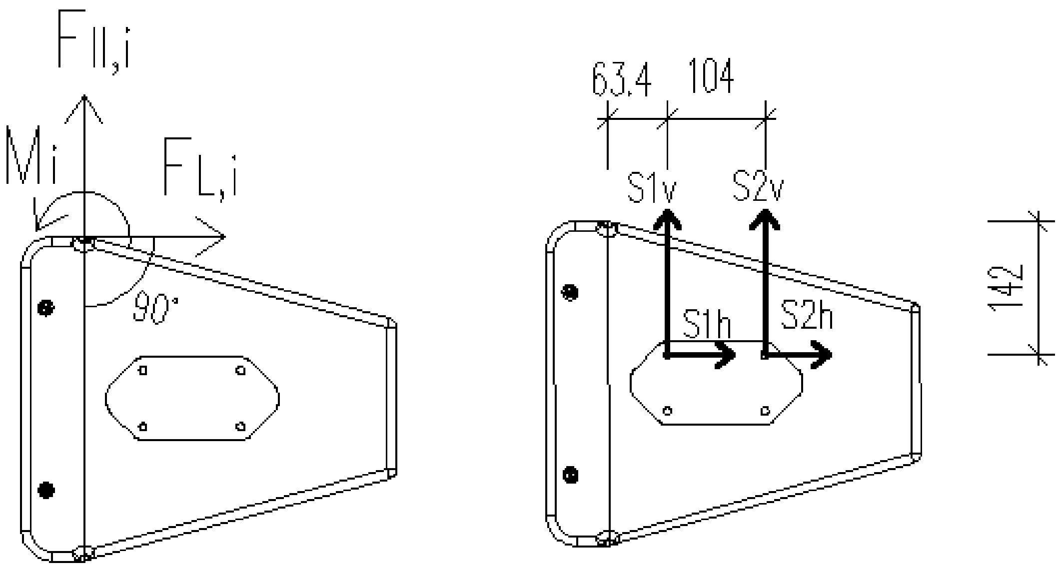
Due to the similar way of calculation the same notation as for the touring cluster is used

4.3.2 Internal forces at reference point

Calculation of Mi, FII,i and FL,i see chapter 3.3.2



4.3.3 Transformation into local forces at connection points

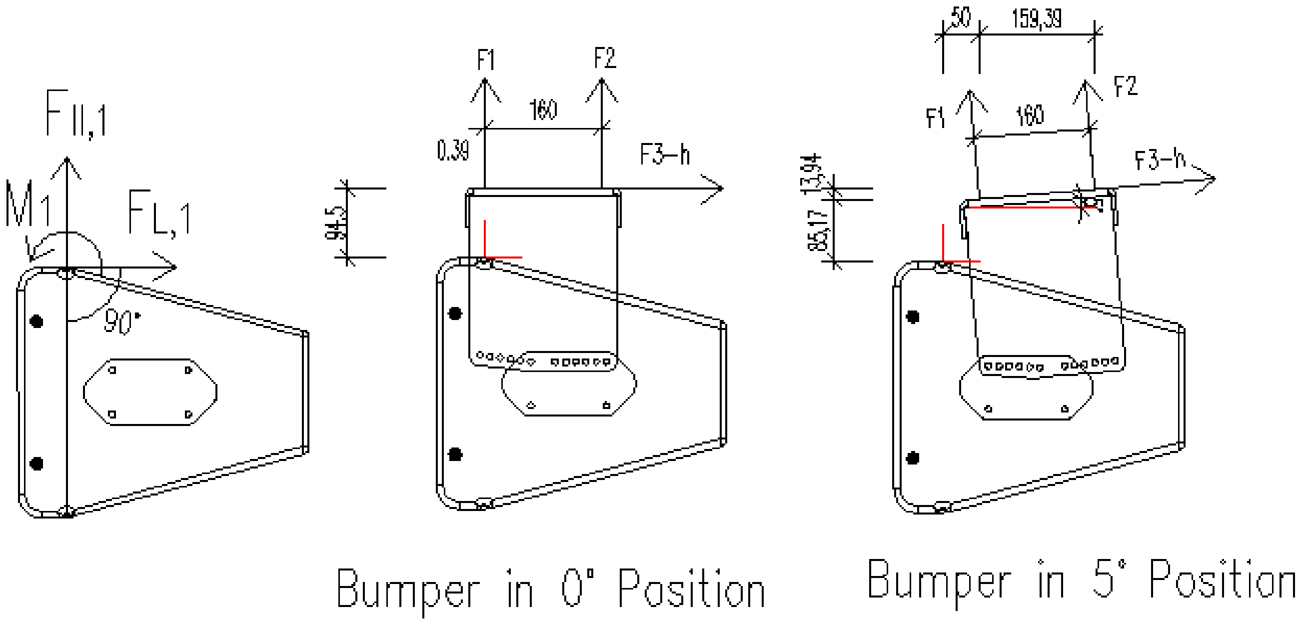


S2v,i = (Mi - FII,i · 0,0634 - FL,i · 0,142) / (2·0,104)

S1v,i = FII;i / 2 - S2v,i

S1h,i = S2h,i = FL,i / 4

4.3.4 Transformation intot local forces at fixation points on top



The forces at the top connection points are calculated from the internal forces at the refernce point of the first loudspeaker. Two extreme cases are taken into account.

1. Bumper in 0° Postion

   F2 = (M1 + FL,1·0,0945) / (2 · 0,160)

   F1 = FII,1 / 2 - F2

   F3-h = FL,1 / 2

2. Bumper in 5° Position

   F2 = (M1+ FL,1·0,085 - FII,1·0,05) / (2 · 0,160)

   F1 = -(M1 + FL,1·0,099 - FII,1·0,209) / (2·0,160)

   F3-h = FL / 2 - (F1+F2) ·sin5°

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4.4 Allowable loading

Rigging- and External Plate

Connection Riggingplate to Externalplate

Conncetion by Socket Head shoulder srew M6D8x20 12.9

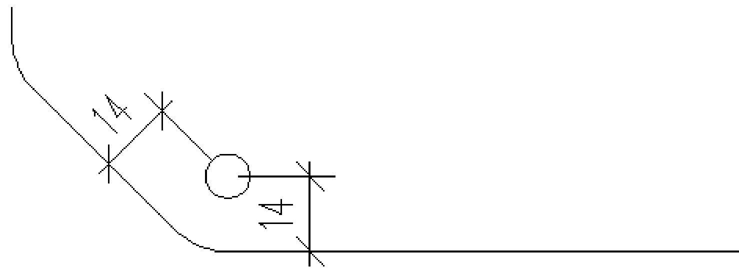
Shearing D 8mm $A = 0{,}5\ cm^3$

Materiel 12.9 $f_{ub,k} = 120\ kN/cm^2$

Shearing acc. to DIN 18800 T1

$V_{a,rd} = 2 \cdot 0{,}50 cm^2 \cdot 0{,}44 \cdot 120 / 1{,}1 = 48\ kN$

Tear out (external and rigging plate)

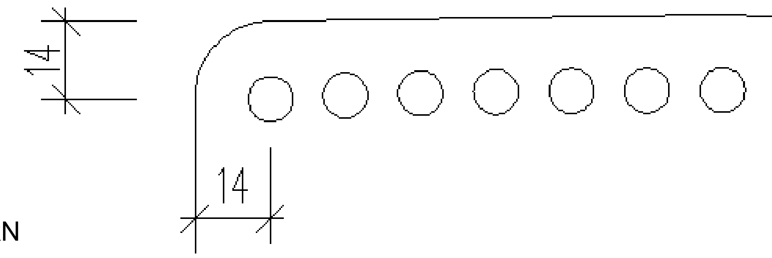


DL = 8,2 mm

e1 = 14 mm = 1,71 dL

e2 >= 14 mm > 1,5 dL

=> a = 1,58



$Vlrd = t \cdot dL \cdot a \cdot fyk / 1{,}1$

$Vlrd = 2 \cdot 0{,}3 \cdot 0{,}8 \cdot 1{,}58 \cdot 70 / 1{,}1 = 48{,}3\ kN$

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Bending of the riggingplate t = 6mm Imex 700

Mmax < 12 kN · 10,4 cm < 124,8 kNcm

Min b > 160 cm => Wel = 0,6 · 16² / 6 = 25,6 cm³

All. Stress acc. To DIN 18800

fy,d = 70 / 1,1 = 63,63 kN/cm²

Stress-proof including safety factor 4,0

σ= 4 · 124,8 / 25,6 = 19,5 kNcm < 63,63 kN/cm²

Bending of External plates t = 2x 3mm Imex 700

Mmax < 124,8 kNcm

min b > 10,4 cm Wel = 0,6 · 10,4² / 6 = 10,8 cm²

All. Stress acc. To DIN 18800

fy,d = 70 / 1,1 = 63,63 kN/cm²

Stress-proof including safety factor 4,0

σ= 4 · 124,8 / 10,8 = 46,22 kNcm < 63,63 kN/cm²

Summary:

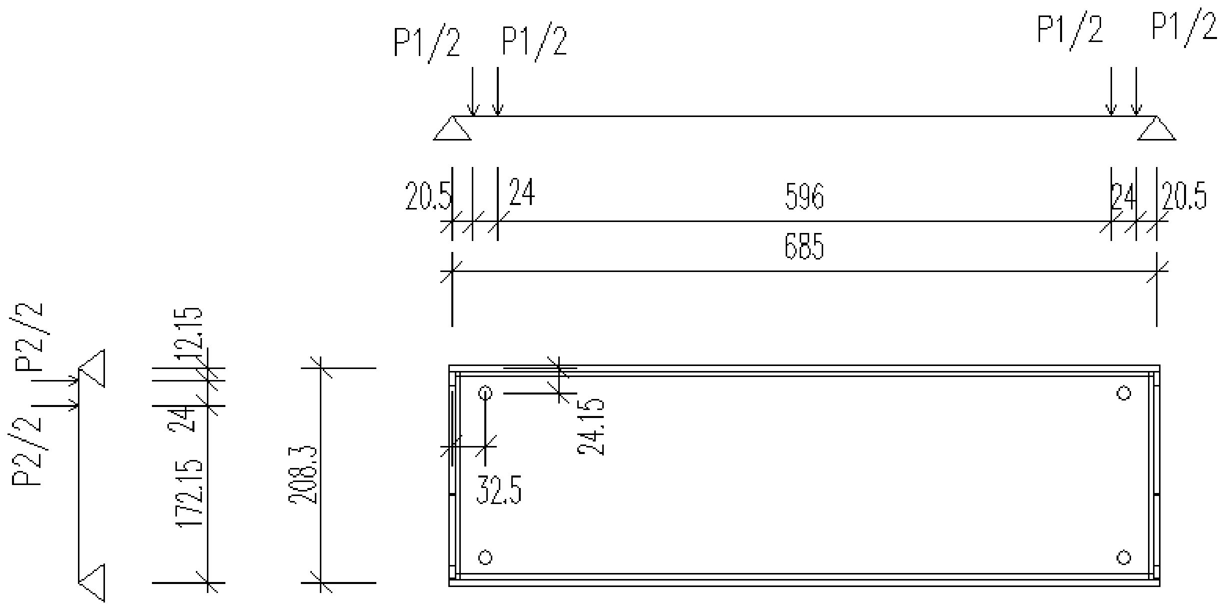
allowable loading at conection point including Safety factor 4,0

all S = 48 / 4 = 12,0 kN

F-Bumper

The allowable Loading on the bumper is limited by the loadintroduction at the fixation points.

To determinatee the allowable loading at one fiaxtion point the loadtransmission from the side-plates to the fiaxtion points is idealised as follows:



The total allowable loading at one fixation point is P = P1+P2:

relevant is bending in the plate in the axe of the hole M12

Plate t= 6mm Imex 700

Fixation is by srews M12 with washer i 24mm , t=8mm.

<u>Determination of P1:</u>

relevant is bending in the plate at the axe of the hole M12 Plate t= 6mm Imex 700

M = P1 · 3,25cm - P1 / 2 · 1,2 cm = P1 · 2,65 cm

effective width: calculation on the base of Heft 240 DAfStb

beff = ty + 2,5 · x (1-x/l) with ty = 2,4cm x = 3,25 cm l = 68,5 cm

=> beff = 2,4 + 2,5 · 3,25 (1 - 3,25 / 68,5) = 10,1 cm

to one side beff is limited by the border of the plate => beff = 10,1 / 2 + 2,715 = 7,76 cm

less the hole M12 the net width is beff - 1,2cm = 6,57 cm

=> Wpl = 6,57 · 0,6² / 4 = 0,59 cm³

The allowable stress σ = 70 / 1,1 = 63,63 kN/cm² and the safety factor of 4 leads to

4· P1 · 2,65 / 0,564 < 63,63 => P1 < 63,63 · 0,59 / (4 · 2,65) = 3,54 kN

<u>Determination of P2:</u>

M = P2 ·(20,8-2,415 /20,8) · 2,415cm - P2 / 2 · 1,2 cm = P1 · 1,53 cm

effective width: calculation on the base of Heft 240 DAfStb

beff = ty + 2,5 · x (1-x/l) with ty = 2,4cm x = 2,415 cm l = 20,8 cm

=> beff = 2,4 + 2,5 · 2,415 (1 - 2,415 / 20,8) = 7,74 cm

to one side beff is limited by the border of the plate => beff = 7,74 / 2 + 3,515 = 7,38 cm

less the hole M12 the net width is beff - 1,2cm = 6,18 cm

=> Wpl = 6,18 · 0,6² / 4 = 0,56 cm³

The allowable stress σ = 70 / 1,1 = 63,63 kN/cm² and the safety factor of 4 leads to

4· P1 · 1,53 / 0,56 < 63,63 => P1 < 63,63 · 0,56 / (4 · 1,53) = 5,82 kN

<u>Summary</u>

Allowable force at a connection point including a safety factor of 4 is :

all F = 3,54 + 5,82 = 9,4 kN

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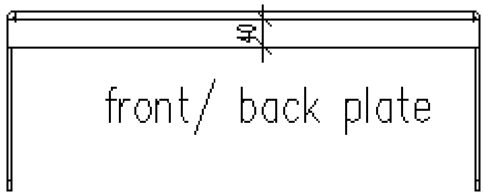

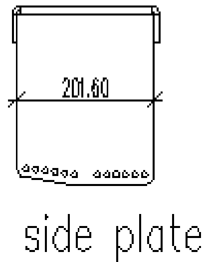

Side plates 6 x 200 mm Imex 700

Conncetion to first loudspeaker by Socket Head shoulder srew M6D8x20 12.9

Concerning Sheraing and tear out see capter rigging-plate

Allowbalew loading including safety fachtor 4

S < 12,0 kN

Bending

Mmax < 9,4 kN · 16 cm < 150,4 kNcm

B =20 cm => Wel = 0,6 · 20² / 6 = 40 cm³

All. Stress acc. To DIN 18800

fy,d = 70 / 1,1 = 63,63 kN/cm²

Stress-proof including safety factor 4,0

σ= 4 · 150,4 / 40 = 15,04 kN/cm² < 63,63 kN/cm²

Front and back -plate 6x40 mm Imex 700

Loading by loadtransmission to fixation point max F = 5,82 kN

leveram e = 3,25 cm

=> M = 5,82 · 3,25 = 18,92 kNcm

Wel = 0,6 ·4² / 6 = 1,6 kNcm

Stress-proof including safety factor 4,0

σ= 4 · 18,92 / 1,6 = 47,3 kNcm < 63,63 kN/cm²

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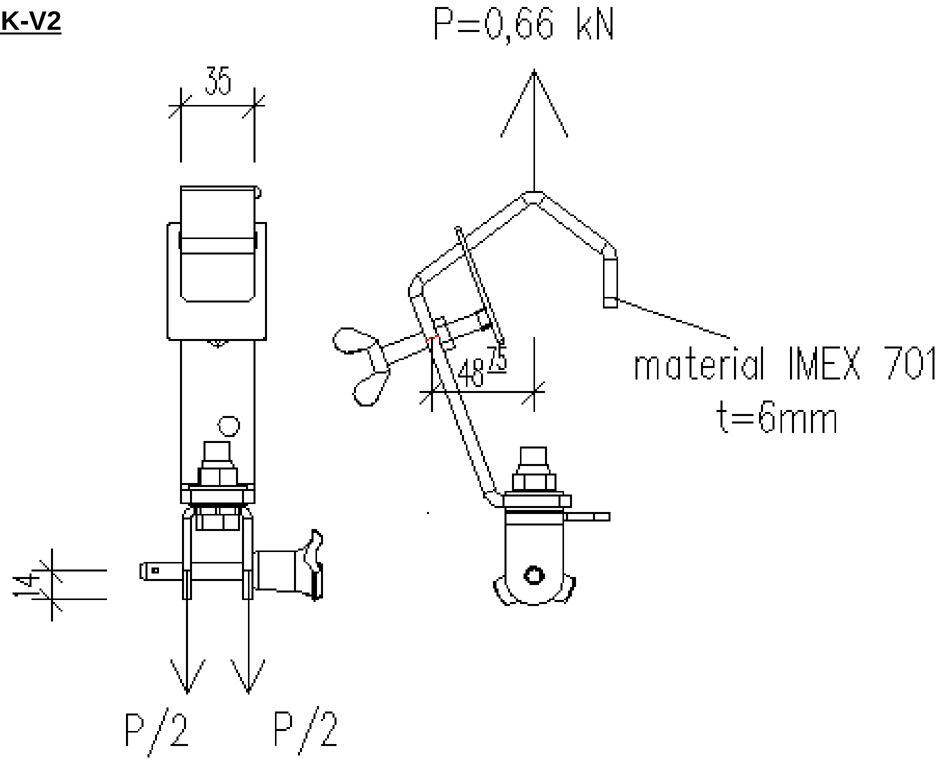
5 TOURING ACCESSORIES

5.1 TCBRK-V2



Coupler to support 2 GEOS12-cabinets including rigging-parts (TTC or LYRE)

Fmax = 2 · 0,33 kN = 0,66 kN

Bending Hook (bending at the side with hole 10,5mm relevant)

e = 4,875cm M = 0,66 · 4,875 =3,22 kNcm N = 0,66 · cos30° = 0,57 kN

Cross-section 35x6 mm with hole 10,5mm material IMEX 700

W_{pl} = (3,5 - 1,05) · 0,6² / 4 = 0,22 cm³
A = (3,5-1,05) · 0,6 = 1,47 cm²

Safety–factor: 4

σ= 4 · (3,22 / 0,22 + 0,57 / 1,47) = 60,1 kN/cm² < 70 / 1,1 = 63,63 kN/cm²

Bracket: Connection to hook by srew M12 material >= 4.6

Nrd = 22,4 kN > 4 · 0,66 kN

Connection to accessories by balllock M8 1.4305

Shearing acc. to DIN 50141 V = 38 kN > 4 · 0,66 kN

Tear out not relevant

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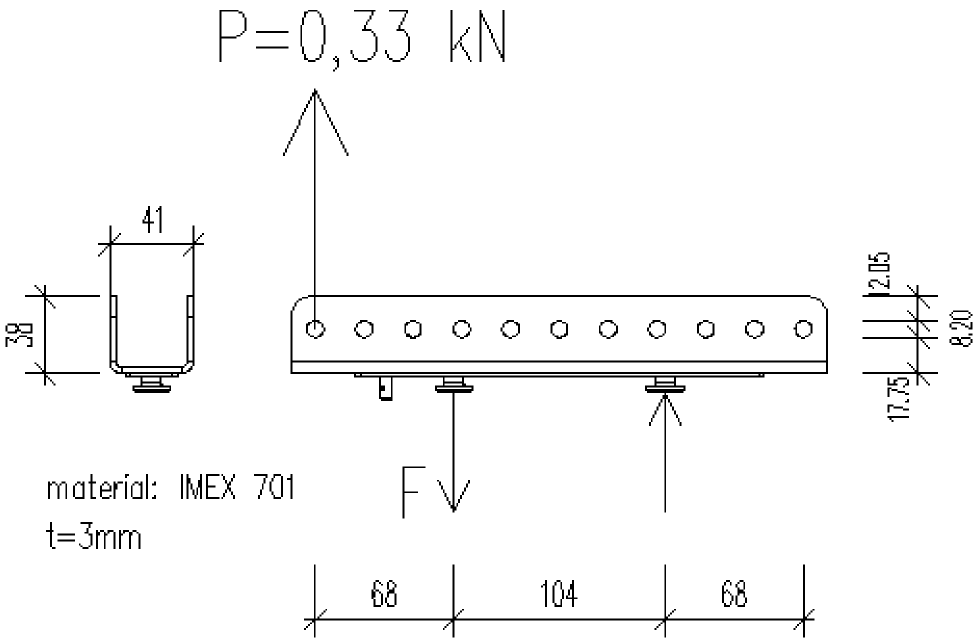
5.2 TTC-V2

maximum Loading 1 GeoS12

=> P = 0,33 kN



maximum Bending in TTC- (U 41x38x3) IMEX 700

Mmax = 0,33kN · 6,8 = 2,24 kNcm

Wpl > 4 · 0,3· 1,205 ·(1,205/2 + 0,82/2)² = 1,48 cm³

Stress-proof incl. Safety factor 4

σ = 4· M/ Wz,el = 4 · 2,24 / 1,48 = 6,05 kN/cm³ << 70 / 1,1

Connection to Hook by 8mm Ball-lock Pin

Maximum loading on the pin V = 0,33 kN

Shearing and Tear out not relevant.

Connection to GeoS 12- cabinet by plung M8 1.4305

Maximum loading on plung V = 0,33 ·(6,8 + 10,4) / 10,4 = 0,55 kN

1.4305 fy,k > 190 N/mm² Plung M8 A = 0,50cm²

Nrd = 0,5 · 19 /1,1 = 8,63 kN > 4 · 0,55 = 2,2 kN

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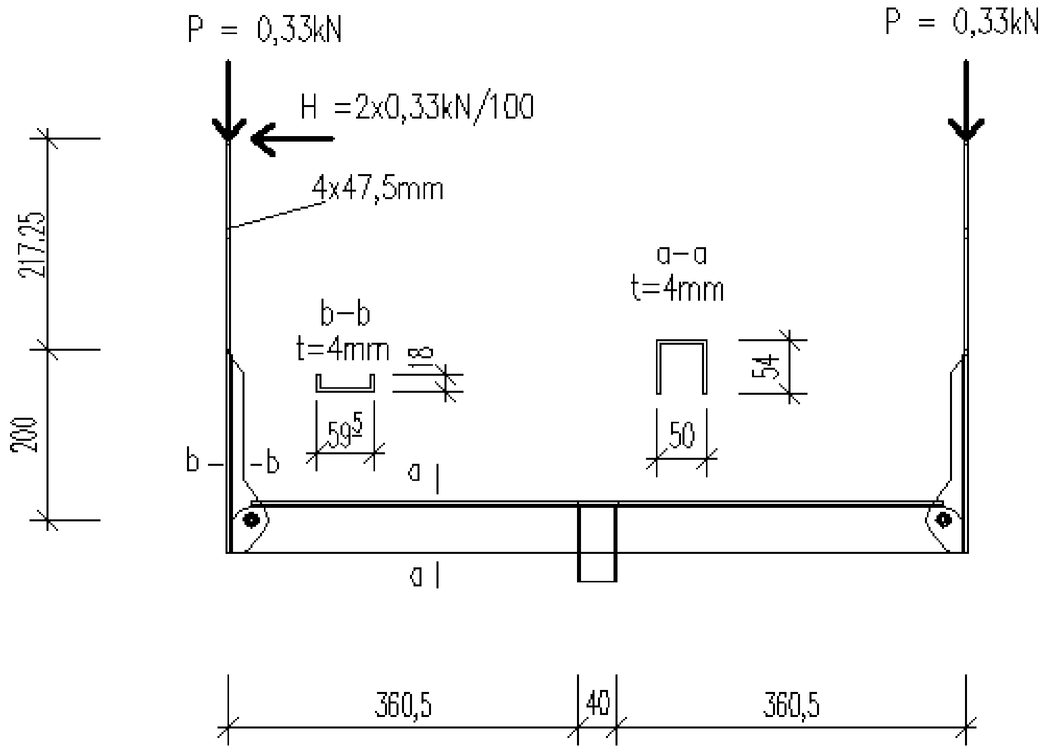
5.3 LYRE-V2

maximum loading by 2 GeoS12 in Hanging- or Groundstack- mode (in combination with GeoS12-SSBRK -V2 and -PSBRK-V2)



=> Loading on one Side-bar — Pv = 2 · 0,33kN / 2 = 0,33 kN

horizontal-Stabilisation force — = V /100 Due to the jointed connection in one direction one side bar has to transmitt the completet horizontal force

=> V = 2 · 0,33 / 100 = 0,0066KN

Materiel Steel S235 JR fyk = 240 N/mm² fy,d = 24 / 1,1 = 21,8 kN/cm²

Buckling in Side bar in section 4x47,5mm

A = 1,90 cm²　　Wel = 4,75 · 0,4² / 6 = 0,127 cm³

N = 0,33 kN　　M = 0,0066 · 21,73= 0,143 kNcm

Buckling:　sk = 2 · 21,73 = 43,46 cm　　i = 0,289 · 0,4 = 0,1156 cm

l = 43,46 / 0,1156 = 376　　l* = 376 / 92,9 = 4,05

k = 1 / (4,05·(4,05+0,49) = 0,054

σ = 4·(0,33 / (1,90·0,054) + 0,143 / 0,127) = 17,36 kN/cm²　　< 21,8 kN/cm²

Buckling in Side bar section b-b

A = 3,5 cm²　　Izz = 0,79 cm4　　Wel,min = 0,61 cm³

N = 0,33 kN　　M = 0,0066 · 41,73 = 0,275 kNcm

Buckling:　sk = 2 · 41,73 = 83,46 cm　　i = $(0,79/3,5)^{0,5}$ = 0,475 cm

l = 83,46 / 0,475 = 176　　l* = 176 / 92,9 = 1,89

k = 0,215

σ = 4·(0,33 / (3,5·0,215) + 0,275 / 0,61) = 3,56 kN/cm²　　< 21,8 kN/cm²

bending in section a-a

on the safe side only the two vertical sheets are taken into account

A = 2 · 0,4 · 5,4 = 4,32cm²　　Wel = 2 · 0,4 · 5,4²/6 = 3,89 cm²

N = 0 kN　　M = 0,33 · 36cm = 11,9 kNcm

σ = 4·(11,9 / 3,89) = 12,2 kN/cm²　　< 21,8 kN/cm²

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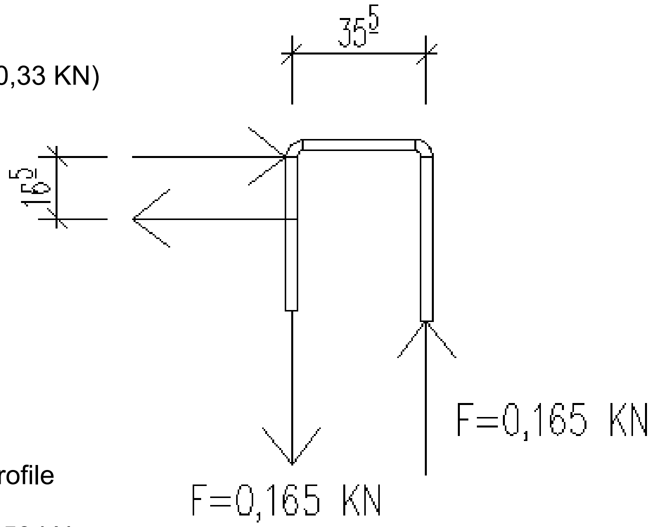
5.4 SSBRK-V2



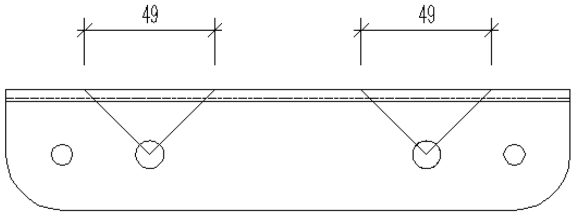
Maximum loading by 1 GeoS12 (G= 0,33 KN)

=> per side F = 0,33 / 2 = 0,165 kN

Bending in transverse direction of U-Profile

Mmax = 0,165 kN · 3,55 cm = 0,59 kNcm

effective breadth concerning bending resistant



per Plung 2 · 24,5 = 49 mm

=> total b = 98 mm

Wpl = 9,8 · 0,3² / 4 = 0,22 cm³ Material S235 fyk = 240 N/mm²

σ = 4 · 0,59 / 0,22 = 10,73 kN/cm² < 24 / 1,1

Connection to Lyre by

Connection to GeoS 12- cabinet by plung M8 1.4305

Maximum loading on plung V = 0,165/2 ·3,55 / 0,165 = 0,18 kN

1.4305 fy,k > 190 N/mm² Plung M8 A = 0,50cm²

Nrd = 0,5 · 19 /1,1 = 8,63 kN > 4 · 0,18 = 0,72 kN

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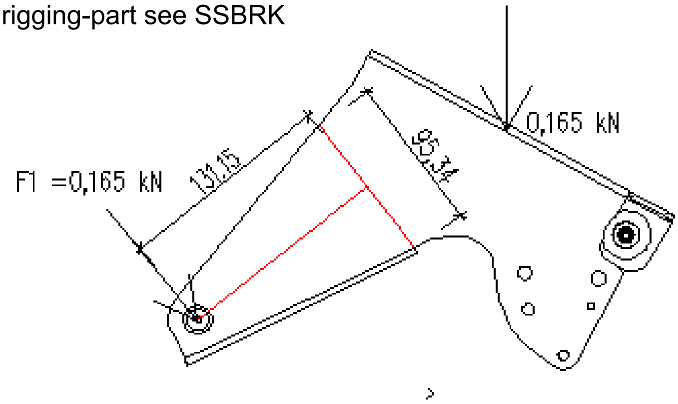
5.5 PSBRK-V2

Maximum loading by 2 x GeoS12   in combination with system LYRE
(1 on the top part and one one the sup-part)

Load-introduction from cabinet on rigging-part see SSBRK

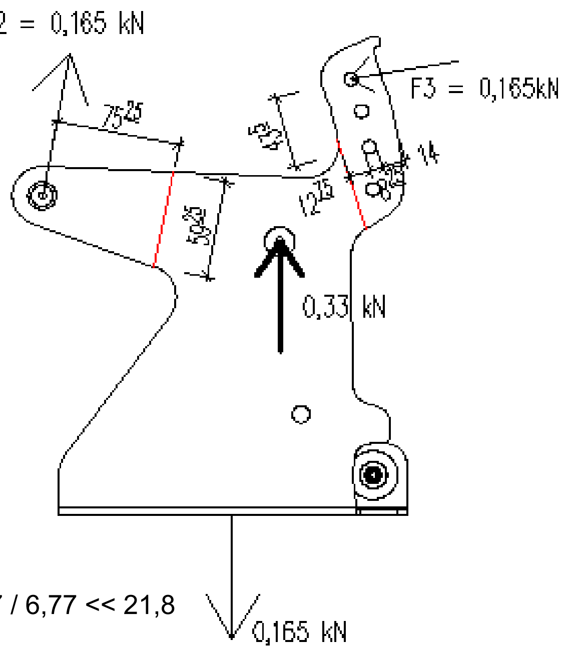


Theoretique worst-case loading

Material :   S235

fy,d = 24 / 1,1 = 21,8 kN/cm²

Thickness: t = 3mm



Proof including safety factor 4

M1 = 4 · 0,165 · 13,15 = 8,7 kNcm

W = 0,3 · 9,5² / 4 = 6,77 cm³   σ = 8,7 / 6,77 << 21,8

M2 = 4 · 0,165 · 7,525 = 4,97 kNcm

W = 0,3 · 5,9² / 4 = 2,61 cm³   σ = 4,97 / 2,61 << 21,8

M3 = 4 · 0,165 · 4,35 = 2,87 kNcm

Wpl > 2· 0,3 ·1,275 · 1,05² = 0,84   σ = 2,87 / 0,84 << 21,8

Connection Top to Sup by Ball-Lock M8   Vsd = 4 · 0,15 kN << Vrd = 38 kN

Connection to LYRE by   Vsd = 4 ·0,33 kN

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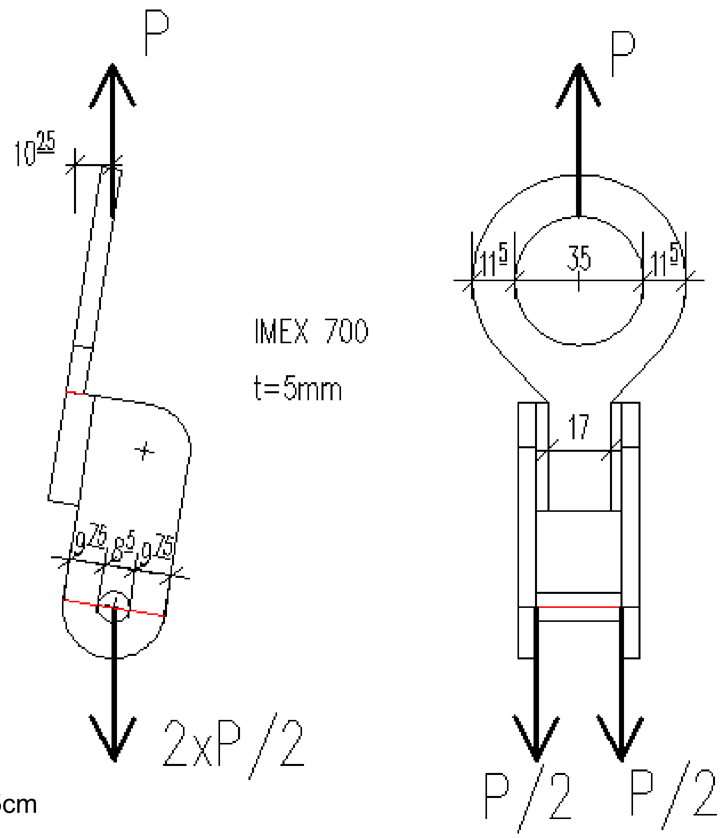
5.6 XHBRK

maximum Loading by 4 GEOS12
(P = 4 · 0,33 = 1,32 kN)

To use in combination with
X-Bow or TTC

All proofs including safety factor 4



Bending in Ring-Part

R = (3,5+1,15) / 2 = 2,325cm

Formulas for internal forces after “Stahlbau-Petersen" page 986

Mmax = 0,2387 · 2,325 · 1,32 = 0,73 kNcm
N = 0,2387 · 1,32 = 0, 32kN

Wpl = 0,5 · 1,15² / 4 = 0,165 cm³
A = 0,5 · 1,15 = 0,575 cm²

σ = 4 · (0,73 / 0,165 + 0,32 / 0,575) = 19,9 < 70 / 1,1

Bending at 2-2

M = 1,32 · 1,025 = 1,35 kNcm
N = 1,32 kN

Wpl 1,7 · 0,5² / 4 = 0,1063 cm³
A = 1,7 · 0,5 = 0,85 cm²

σ = 4 · (1,35 / 0,1063 + 1,32 / 0,85) = 57,01 kN/cm² < 70 / 1,1

Connection to X-Bow

by Ball-lock M8 Vsd = 4 · 1,32 << Vrd = 38 kN
tear out not relevant

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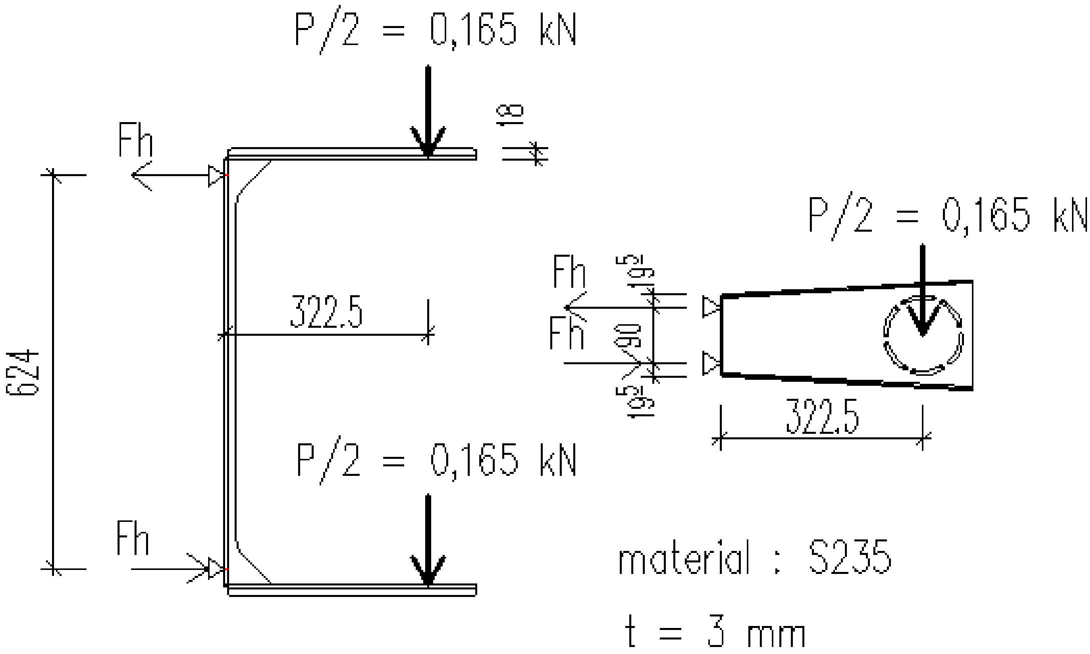
6 FIXED INSTALLATION ACCESSORIES

6.1 UBRK

maximum Load 1 GEOS12 (P= 0,33 kN => 0,165 kN per side)

Two operation modes possible (See draft)



case 1 vertical mode

Moment at corner renfort relevant (e=24,37 cm)

M = 0,165 kN · 24,37 cm = 4,02 kNcm

Wpl > 2· 0,3 ·1,8² / 4 + (9 + 2·1,95) ·0,3² / 4 = 0,78 cm³

σ= 4 ·4,02 / 0,78 = 20,6 kN/cm² < 21,8 kN/cm²

case 2 horizontal mode

M = 0,165 · 32,25 = 5,32 kNcm

Wpl > 0,3 ·(9,0+ 2·1,95)² / 4 = 14,48cm³

σ << 21,8 kN/cm²

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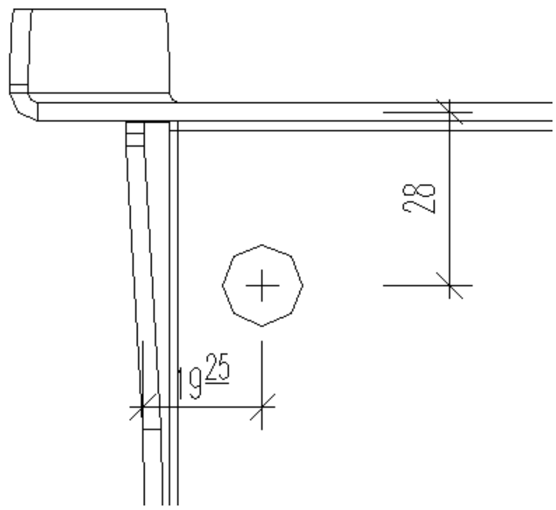
Forces at connection to sub-structure

case 1 Fh = 0,165 · 32,25 / 62,4 = 0,085 kN

case 2 Fh = 0,165 ·32,25 / 9,0 = 0,59 kN

Bending of backplate (case 2 relevant)



Connection by bolt M12 mit washer 24 mm

distance to border

=> e1 = 28 - 24/2 = 1,4 cm b > 2,4 Wpl = 0,054 cm³

=> all P = 21,8 · 0,05 / 1,4 = 0,84 kN

=> e2 = 19,25 - 24/ 2 = 0,725cmb > 2,4cm Wpl = 0,054 cm³

=> all P = 21,8 · 0,054 / 0, 725 = 1,624 KN

Sum P = 0,84 + 1,624 = 2,464 > 4 · 0,59 = 2,36 kN

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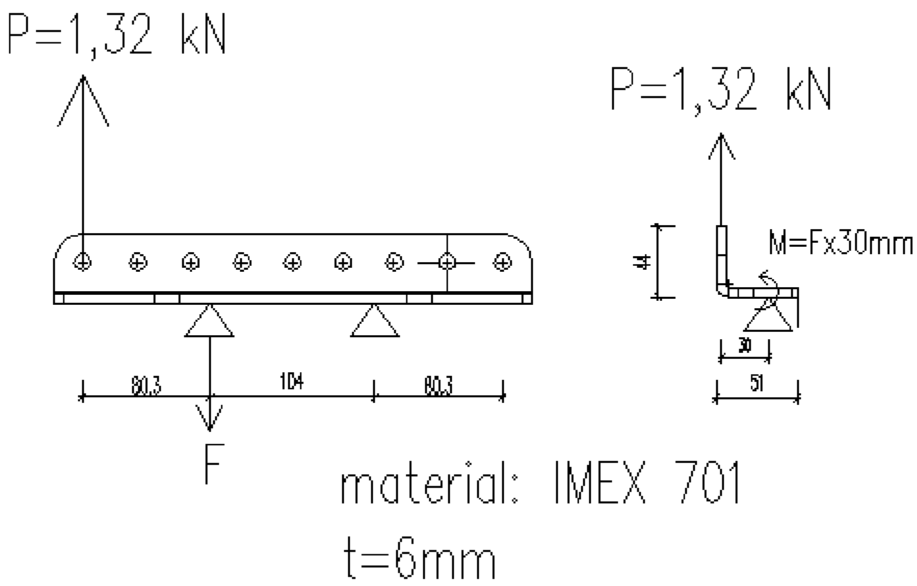
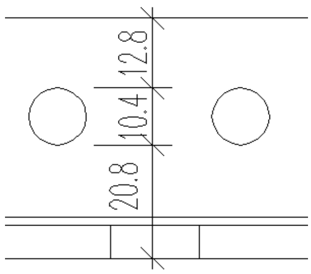
6.2 LBRK

Accessory fo cable mounted arrays (horizontal and vertical)

Horizontal array maximum load by 3 GeoS12 proof for 4 GeoS12
(every third GeoS12 cable mounted)



Bending in longitudinal direction



M max = 1,32 kN · 8,03 cm = 10,6 kNcm

Proof taking only vertical part of cross-section into account

Wpl > 2 · 0,6 · 1,28 · 1,16² = 2,06cm³

σ = 4 · 10,6 / 2,06 = 20,58 << 70/1,1

Bending in transverse direction

F = 1,32 · (8,03 + 10,4) / 10,4 = 2,34 kN

=> M = 2,34 · 3,0 = 7,02 kNcm

Connection to Cabinet by pin M8

Effective Width = 2 ·3 - 0,8 = 5,2 cm Wpl = 5,2 ·0,6² / 4 = 0,468cm³

σ = 4 · 7,02 / 0,468 = 60 kN/cm² < 70 /1,1

Connection to cabinet by Socket Head shoulder srew M6 D8x20 12.9

Nsd = 4 · 2,34 = 9,36 kN < Nrd = 0,201cm² · 100 / (1,1,125) = 14,61 kN

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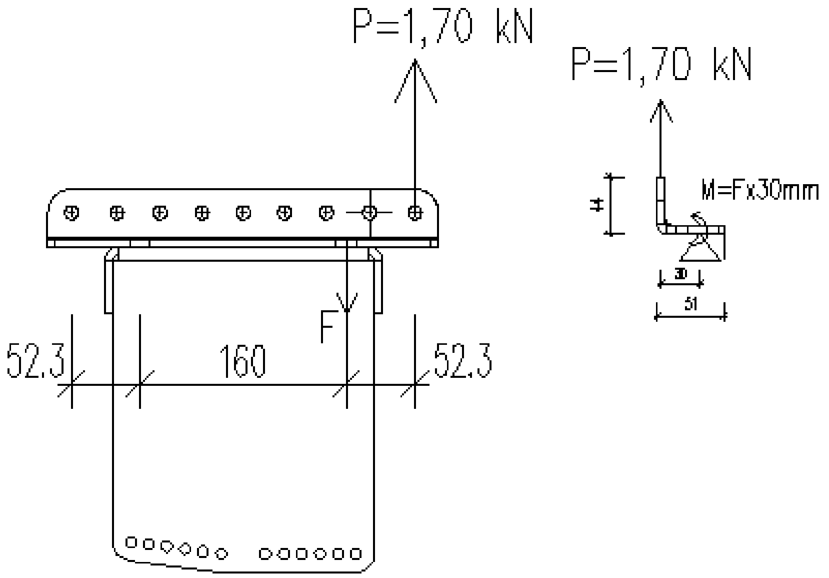
Fixation on F-Bumper with maximum cluster of 10 GeoS12

Loading per LBRK = 10 · 0,33 / 2 = 1,65 kN + 0,05 kN Bumper

Fixation of LBRK at substructure is **only allowed** by cables

(a clamped support , for example by fixing it with two srews at at subtsructure is not allowed)



Bending in longitudinal direction

M max = 1,70 kN · 5,23 cm = 8,89 kNcm

Not relevant see horizontal mode

Bending in transverse direction

F = 1,70 · (5,23 + 16) / 16 = 2,25 kN

Proof see horizontal mode with F = 2,34 kN

Connection to cabinet by Socket Head shoulder srew M6 D8x20 12.9

Nsd = 4 · 2,25 = 9,0 kN < Nrd = 0,201cm² · 100 / (1,1,125) = 14,61 kN

At LBRK cable-mounted fixed cluster system the LBRK-part is allways the limiting part of the cluster. Proof of structural integrity of rigging-plates and F-Bumper is not necessary.

Maximum possible excentricity of gravity center in cable moounted mode ys < 0,3 m
Compare with examples in Annex.

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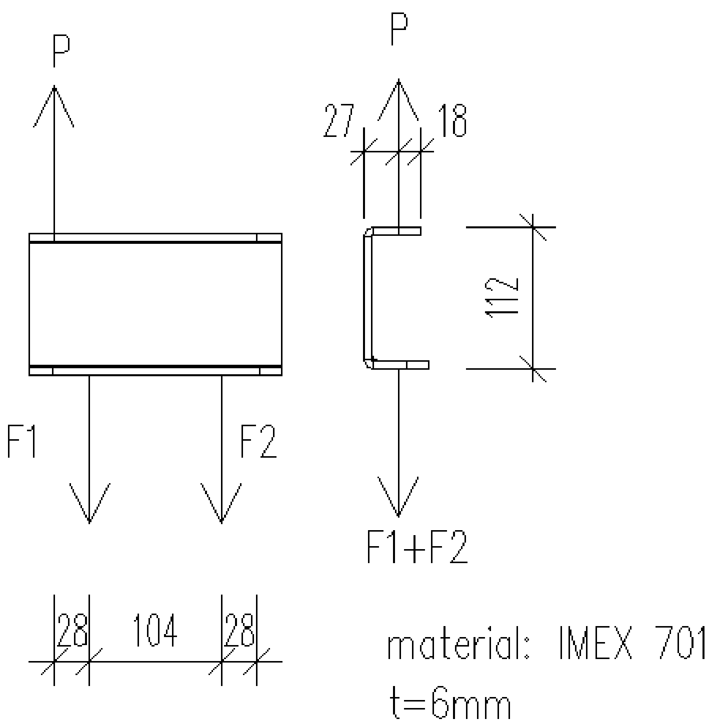
6.3 ABRK

ABRK in combinatiuon with **Horizontal array maximum load by 3 GeoS12** (every third GeoS12 fixed over ABRK). Claclualations are done for 4 GeoS12.

Loading by the weight of 4 GEOS12 (P = 4 · 0,33 kN = 1,32)

Theoretique worst case loading



Bending in transverse relevant

P = 1,32 kN => F1 = P ·(2,8+10,4) / 10,4 = 1,68 kN

M = 1,68 · 2,7cm = 4,53 kNcm

effective width b = 1,2 + 2 · 2,7 = 6,6 cm Wpl = 6,6·0,6² / 4 = 0,594 cm³

Proof including safety 4

s = 4 ·4,53 / 0,594 = 30,5 kN/cm² < 70 /1,1 = 63,6 kN/cm²

Fixation to sub-structure and cabinets by Socket Head shoulder srew M6D8x20 12.9

Nsd = 4 · 1,68 = 6,72 kN < Nrd = 0,201cm² · 100 / (1,1,125) = 14,61 kN

7 GROUNDSTACK MODE

7.1 Proof of stability

Two cases of horizontal forces are taken into account

1. Impact forces by Persons

   Impact force H = 0,3 kN (corresponding to DIN15920-11.)

   Height 1,20 m over groundlevel (maximum height in DIN 1055-3)

2. Windforces due to wind beaufort 8

   width GeoS12 b = 0,675 m

   wind (beaufort 8) q = 0,25 kN/m²

   Shape factor cp = 1,3 => $w = 1{,}3 \cdot 0{,}25 \cdot 0{,}675 = 0{,}22$ kN/m

For the proof of stability the forces due to wind or impact are taken as exclusive acting forces

=> either wind forces are acting or impact forces.

Impact forces are only applied on clusters with more then 3 cabinets. Clusters with 3 or less cabinets don't attempt a height of near 1,20 and it is assumed that impact forces can not act in a form which could be relevant for the stabiltity of the system.

Security-level: the security level is set in accordance to DIN 4112 to

1,2	towards wind
1,3	toward impact

Geomteric properties for calculations:

Height bumper 0,167 m

weight stabilizers Gstab = 25 kg = 0,25 kN

Retilting moment by bumperweight Ms = $0{,}25 \cdot 0{,}97/2 = 0{,}12$ kNm

Height per GeoS12/10 0,345 m weight GeoS12 = 33 kg = 0,33 kN

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Formulas for proof of stabilitiy

Tilt-Moment: Due to wind Mk-w = 0,22 kN/m · hvp · (hvp/2 + 0,167m)
Due to impact Mk-iF = 0,30 kN · min(1,20m, hvp+0,167)

Re-Tilting Moment Due to selfweight Ms = GgeS12 · ec,min · Gstab· 0,97 /2

with ec, min = minimum distance between gravity center of cluster and tilt-point

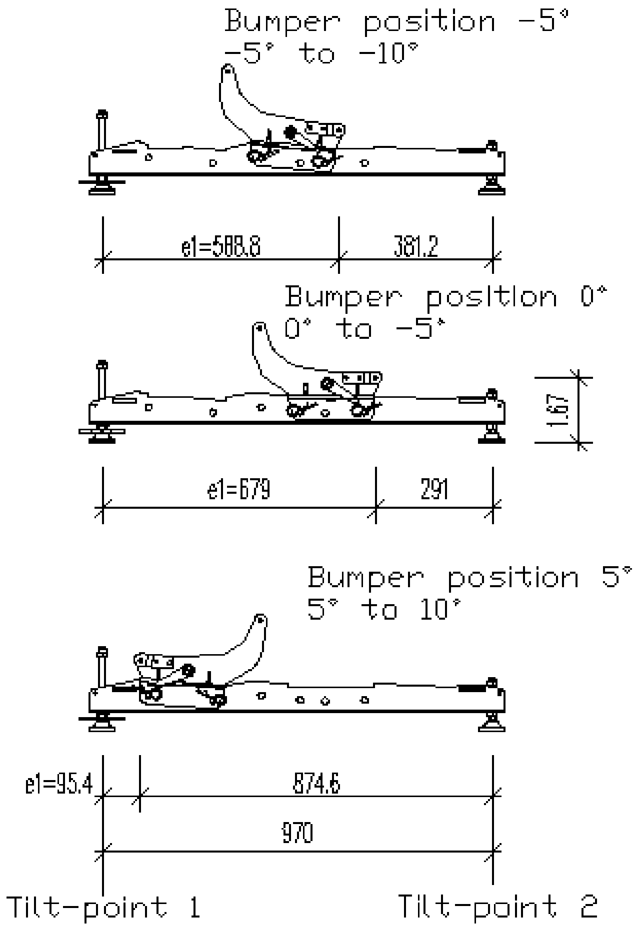
Calculation of gravity-center ys analogue to chapter 3 with reference point at front connection of 1st cabinet.

Distance between front conncetion point and possible tilt points:

ec-1 = e1+ ys for bumper position 5°
ec-1 = e1 - ys for bumper postion -5° and 0°

ec2 = 0,97m - ec1

ec-min = min (ec1;ec2)



Proof of stabiltiy: Ms / Mk-w > 1,2

resp. Ms / Mk-iF > 1,3

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Calculations cluster with 6 cabinets for Bumper position 5°
Bumper 10°, angle setting 10° min ec-2 and max wind or impact

GeoS12 Geometry			
	height	0,345	[m]
	width	0,68	[m]
Weight	GeoS12/10	0,32578	[kN]
	GeoS12/30	0,31328	[kN]
GC	eys /10	0,122118	[m]
	exs /10	0,1725	[m]
	eys /30	0,122402	[m]
	exs /30	0,1725	[m]
Qty	GeoS12/10	6	[-]
	GeoS12/30	0	[-]
Total	Qty	6	[-]
	Weight	1,95	[kN]

GeoS12 Cluster gravity center		
Ys1 [m]	0,523	[m]
Xs1 [m]	0,842	[m]

GSTK-Stabilizers		
weight	0,25	[kN]
Ys-Bumper	0,0000	[m]
Xs-Bumper	0,0000	[m]
Bumper Position		
5; 0 ; -5	5	
e1	0,095	
e2	0,875	

Distance Cluster-GC to tilt points
ec-1 0,618055
ec-2 0,351945
min ec 0,351945
Re-Tilting moment Ms 0,8092 [kNm]

Cluster Height and Depth (projection)		
h-HP	6,022	[m]
h-VP	1,621	[m]

Wind-Load	(0,25 = beaufort 8 ; 0,12=beaufort 6)	
impact pressure	0,25	[kN/m²]
w	0,2194	[kN/m]

Impact forces
H 0,3 [KN]
for clusters with less then 4 cabinets the proof of stability under an impact force is not seen as relevant

Tilt moment	Mk	MS/Mk	
due to wind	0,34771	2,327	> 1,2
due to impact force	0,36	2,25	> 1,3

Notice: Bumper angle are set positive when directing upwards

GeoS12-Cluster			Geometric properties				Projection		local GC of a box			global Coord. Of a box		global G-Offset	
Box-Nr.	Box on / off	Position GeoS12/30	phi(i,j) [°]	psi-0 [°]	psi [rad]	hi [m]	hH,i [m]	hv,i [m]	Gi [kN]	eys [m]	exs [m]	Y[m]	X[m]	ys x G [kNm]	xs x G [kNm]
1	1	0	10	10	0,1745	0,345	0,06	0,34	0,33	0,1221177	0,1725	0,0000	0,0000	0,049	0,048
2	1	0	10	20	0,3491	0,345	0,12	0,32	0,33	0,1221177	0,1725	0,0599	0,3398	0,076	0,150
3	1	0	10	30	0,5236	0,345	0,17	0,30	0,33	0,1221177	0,1725	0,1779	0,6640	0,121	0,245
4	1	0	10	40	0,6981	0,345	0,22	0,26	0,33	0,1221177	0,1725	0,3504	0,9627	0,181	0,331
5	1	0	10	50	0,8727	0,345	0,26	0,22	0,33	0,1221177	0,1725	0,5722	1,2270	0,255	0,405
6	1	0	10	60	1,0472	0,345	0,30	0,17	0,33	0,1221177	0,1725	0,8365	1,4488	0,341	0,466

Calculations cluster with 6 cabinets for Bumper position 5°
Bumper 5°, angle setting 0,2° min ec-1 and max wind

GeoS12 Geometry			
	height	0,345	[m]
	width	0,68	[m]
Weight	GeoS12/10	0,32578	[kN]
	GeoS12/30	0,31328	[kN]
GC	eys /10	0,122118	[m]
	exs /10	0,1725	[m]
	eys /30	0,122402	[m]
	exs /30	0,1725	[m]
Qty	GeoS12/10	6	[-]
	GeoS12/30	0	[-]
Total	Qty	6	[-]
	Weight	1,95	[kN]

GeoS12 Cluster gravity center		
Ys1 [m]	0,217	[m]
Xs1 [m]	1,019	[m]

GSTK-Stabilizers		
weight	0,25	[kN]
Ys-Bumper	0,0000	[m]
Xs-Bumper	0,0000	[m]
Bumper Position		
5; 0 ; -5	5	
e1	0,095	
e2	0,875	

Distance Cluster-GC to tilt points
ec-1 0,312256
ec-2 0,657744
min ec 0,312256
Re-Tilting moment Ms 0,7316 [kNm]

Cluster Height and Depth (projection)		
h-HP	3,739	[m]
h-VP	2,060	[m]

Wind-Load	(0,25 = beaufort 8 ; 0,12=beaufort 6)	
impact pressure	0,25	[kN/m²]
w	0,2194	[kN/m]

Impact forces
H 0,3 [KN]
for clusters with less then 4 cabinets the proof of stability under an impact force is not seen as relevant

Tilt moment	Mk	MS/Mk	
due to wind	0,54115	1,352	> 1,2
due to impact force	0,36	2,03	> 1,3

Notice: Bumper angle are set positive when directing upwards

GeoS12-Cluster			Geometric properties				Projection		local GC of a box			global Coord. Of a box		global G-Offset	
Box-Nr.	Box on / off	Position GeoS12/30	phi(i,j) [°]	psi-0 [°]	psi [rad]	hi [m]	hH,i [m]	hv,i [m]	Gi [kN]	eys [m]	exs [m]	Y[m]	X[m]	ys x G [kNm]	xs x G [kNm]
1	1	0	5	5	0,0873	0,345	0,03	0,34	0,33	0,1221177	0,1725	0,0000	0,0000	0,045	0,053
2	1	0	0,2	5,2	0,0908	0,345	0,03	0,34	0,33	0,1221177	0,1725	0,0301	0,3437	0,055	0,164
3	1	0	0,2	5,4	0,0942	0,345	0,03	0,34	0,33	0,1221177	0,1725	0,0613	0,6873	0,065	0,276
4	1	0	0,2	5,6	0,0977	0,345	0,03	0,34	0,33	0,1221177	0,1725	0,0938	1,0307	0,076	0,388
5	1	0	0,2	5,8	0,1012	0,345	0,03	0,34	0,33	0,1221177	0,1725	0,1275	1,3741	0,087	0,500
6	1	0	0,2	6	0,1047	0,345	0,04	0,34	0,33	0,1221177	0,1725	0,1623	1,7173	0,098	0,611

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Calculations cluster with 4 cabinets for Bumper position 5°

Bumper 5°, angle setting 0,2° min ec-1 in comb. with min selfweight under impact

GeoS12 Geometry			
	height	0,345	[m]
	width	0,68	[m]
Weight	GeoS12/10	0,32578	[kN]
	GeoS12/30	0,31328	[kN]
GC	eys /10	0,122118	[m]
	exs /10	0,1725	[m]
	eys /30	0,122402	[m]
	exs /30	0,1725	[m]
Qty	GeoS12/10	4	[-]
	GeoS12/30	0	[-]
Total	Qty	4	[-]
	Weight	1,30	[kN]

GeoS12 Cluster gravity center		
Ys1 [m]	0,184	[m]
Xs1 [m]	0,676	[m]

GSTK-Stabilizers		
weight	0,25	[kN]
Ys-Bumper	0,0000	[m]
Xs-Bumper	0,0000	[m]

Bumper Position	
5; 0 ; -5	5
e1	0,095
e2	0,875

Distance Cluster-GC to tilt points

ec-1	0,278831		
ec-2	0,691169		
min ec	0,278831		
Re-Tilting moment	Ms	0,4846	[kNm]

Tilt moment	Mk	MS/Mk	
due to wind	0,25744	1,882	> 1,2
due to impact force	0,36	1,35	> 1,3

Cluster Height and Depth (projection)		
h-HP	1,949	[m]
h-VP	1,374	[m]

Wind-Load	(0,25 = beaufort 8 ; 0,12=beaufort 6)	
impact pressure	0,25	[kN/m²]
w	0,2194	[kN/m]

Impact forces		
H	0,3	[KN]

for clusters with less then 4 cabinets the proof of stability under an impact force is not seen as relevant

Notice: Bumper angle are set positive when directing upwards

			Geometric properties				Projection		local GC of a box			global Coord. Of a box		global G-Offset	
GeoS12-Cluster			phi(i,j)	psi-0	psi	hi	$h_{H,i}$	hv,i	Gi	eys	exs	Y[m]	X[m]	ys x G	xs x G
Box-Nr.	Box on / off	Position GeoS12/30	[°]	[°]	[rad]	[m]	[m]	[m]	[kN]	[m]	[m]	[m]	[m]	[kNm]	[kNm]
1	1	0	5	5	0,0873	0,345	0,03	0,34	0,33	0,1221177	0,1725	0,0000	0,0000	0,045	0,053
2	1	0	0,2	5,2	0,0908	0,345	0,03	0,34	0,33	0,1221177	0,1725	0,0301	0,3437	0,055	0,164
3	1	0	0,2	5,4	0,0942	0,345	0,03	0,34	0,33	0,1221177	0,1725	0,0613	0,6873	0,065	0,276
4	1	0	0,2	5,6	0,0977	0,345	0,03	0,34	0,33	0,1221177	0,1725	0,0938	1,0307	0,076	0,388
5	0	0	0	0	0,0000	0	0,00	0,00	0,00	0	0	0,0000	0,0000	0,000	0,000
6	0	0	0	0	0,0000	0	0,00	0,00	0,00	0	0	0,0000	0,0000	0,000	0,000

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Calculations cluster with 6 cabinets for Bumper position 0°
Bumper 0°, angle setting 10° min ec-1 and max wind

GeoS12 Geometry			
	height	0,345	[m]
	width	0,68	[m]
Weight	GeoS12/10	0,32578	[kN]
	GeoS12/30	0,31328	[kN]
GC	eys /10	0,122118	[m]
	exs /10	0,1725	[m]
	eys /30	0,122402	[m]
	exs /30	0,1725	[m]
Qty	GeoS12/10	6	[-]
	GeoS12/30	0	[-]
Total	Qty	6	[-]
	Weight	1,95	[kN]

GeoS12 Cluster gravity center		
Ys1 [m]	0,369	[m]
Xs1 [m]	0,920	[m]

GSTK-Stabilizers		
weight	0,25	[kN]
Ys-Bumper	0,0000	[m]
Xs-Bumper	0,0000	[m]
Bumper Position		
5; 0 ; -5	0	
e1	0,679	
e2	0,291	

Distance Cluster-GC to tilt points
ec-1 0,310076
ec-2 0,659924
min ec 0,310076
Re-Tilting moment Ms 0,7273 [kNm]

Tilt moment	Mk	MS/Mk	
due to wind	0,41865	1,737	> 1,2
due to impact force	0,36	2,02	> 1,3

Cluster Height and Depth (projection)		
h-HP	4,946	[m]
h-VP	1,794	[m]

Wind-Load	(0,25 = beaufort 8 ; 0,12=beaufort 6)	
impact pressure	0,25	[kN/m²]
w	0,2194	[kN/m]

Impact forces
H 0,3 [KN]
for clusters with less then 4 cabinets the proof of stability under an impact force is not seen as relevant

Notice: Bumper angle are set positive when directing upwards

			Geometric properties				Projection		local GC of a box			global Coord. Of a box		global G-Offset	
GeoS12-Cluster			phi(i,j)	psi-0	psi	hi	hH,i	hv,i	Gi	eys	exs	Y[m]	X[m]	ys x G	xs x G
Box-Nr.	Box	Position	[°]	[°]	[rad]	[m]	[m]	[m]	[kN]	[m]	[m]	[m]	[m]	[kNm]	[kNm]
	on / off	GeoS12/30													
1	1	0	0	0	0,0000	0,345	0,00	0,35	0,33	0,1221177	0,1725	0,0000	0,0000	0,040	0,056
2	1	0	10	10	0,1745	0,345	0,06	0,34	0,33	0,1221177	0,1725	0,0000	0,3450	0,049	0,161
3	1	0	10	20	0,3491	0,345	0,12	0,32	0,33	0,1221177	0,1725	0,0599	0,6848	0,076	0,262
4	1	0	10	30	0,5236	0,345	0,17	0,30	0,33	0,1221177	0,1725	0,1779	1,0090	0,121	0,357
5	1	0	10	40	0,6981	0,345	0,22	0,26	0,33	0,1221177	0,1725	0,3504	1,3077	0,181	0,444
6	1	0	10	50	0,8727	0,345	0,26	0,22	0,33	0,1221177	0,1725	0,5722	1,5720	0,255	0,518

Calculations cluster with 6 cabinets for Bumper position 0°
Bumper -5°, angle setting 0,2° min ec-2 and max wind

GeoS12 Geometry			
	height	0,345	[m]
	width	0,68	[m]
Weight	GeoS12/10	0,32578	[kN]
	GeoS12/30	0,31328	[kN]
GC	eys /10	0,122118	[m]
	exs /10	0,1725	[m]
	eys /30	0,122402	[m]
	exs /30	0,1725	[m]
Qty	GeoS12/10	6	[-]
	GeoS12/30	0	[-]
Total	Qty	6	[-]
	Weight	1,95	[kN]

GeoS12 Cluster gravity center		
Ys1 [m]	0,037	[m]
Xs1 [m]	1,041	[m]

GSTK-Stabilizers		
weight	0,25	[kN]
Ys-Bumper	0,0000	[m]
Xs-Bumper	0,0000	[m]
Bumper Position		
5; 0 ; -5	0	
e1	0,679	
e2	0,291	

Distance Cluster-GC to tilt points
ec-1 0,641966
ec-2 0,328034
min ec 0,328034
Re-Tilting moment Ms 0,7625 [kNm]

Tilt moment	Mk	MS/Mk	
due to wind	0,54269	1,405	> 1,2
due to impact force	0,36	2,12	> 1,3

Cluster Height and Depth (projection)		
h-HP	2,161	[m]
h-VP	2,064	[m]

Wind-Load	(0,25 = beaufort 8 ; 0,12=beaufort 6)	
impact pressure	0,25	[kN/m²]
w	0,2194	[kN/m]

Impact forces
H 0,3 [KN]
for clusters with less then 4 cabinets the proof of stability under an impact force is not seen as relevant

Notice: Bumper angle are set positive when directing upwards

			Geometric properties				Projection		local GC of a box			global Coord. Of a box		global G-Offset	
GeoS12-Cluster			phi(i,j)	psi-0	psi	hi	hH,i	hv,i	Gi	eys	exs	Y[m]	X[m]	ys x G	xs x G
Box-Nr.	Box	Position	[°]	[°]	[rad]	[m]	[m]	[m]	[kN]	[m]	[m]	[m]	[m]	[kNm]	[kNm]
	on / off	GeoS12/30													
1	1	0	-5	-5	-0,0873	0,345	-0,03	0,34	0,33	0,1221177	0,1725	0,0000	0,0000	0,035	0,059
2	1	0	0,2	-4,8	-0,0838	0,345	-0,03	0,34	0,33	0,1221177	0,1725	-0,0301	0,3437	0,025	0,171
3	1	0	0,2	-4,6	-0,0803	0,345	-0,03	0,34	0,33	0,1221177	0,1725	-0,0589	0,6875	0,016	0,283
4	1	0	0,2	-4,4	-0,0768	0,345	-0,03	0,34	0,33	0,1221177	0,1725	-0,0866	1,0314	0,007	0,395
5	1	0	0,2	-4,2	-0,0733	0,345	-0,03	0,34	0,33	0,1221177	0,1725	-0,1131	1,3753	-0,001	0,507
6	1	0	0,2	-4	-0,0698	0,345	-0,02	0,34	0,33	0,1221177	0,1725	-0,1383	1,7194	-0,009	0,619

Calculations cluster with 4 cabinets not relavant because less cabinets will remove gravity center to the middle (ec-min > 0,31 > ec-min = 0,2788 for bumper position5°)

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Calculations cluster with 6 cabinets for Bumper position -5°

Bumper -5°, angle setting 10° min ec-1 and max wind

GeoS12 Geometry			
	height	0,345	[m]
	width	0,68	[m]
Weight	GeoS12/10	0,32578	[kN]
	GeoS12/30	0,31328	[kN]
GC	eys /10	0,122118	[m]
	exs /10	0,1725	[m]
	eys /30	0,122402	[m]
	exs /30	0,1725	[m]
Qty	GeoS12/10	6	[-]
	GeoS12/30	0	[-]
Total	Qty	6	[-]
	Weight	1,95	[kN]

GeoS12 Cluster gravity center		
Ys1 [m]	0,287	[m]
Xs1 [m]	0,949	[m]

GSTK-Stabilizers		
weight	0,25	[kN]
Ys-Bumper	0,0000	[m]
Xs-Bumper	0,0000	[m]
Bumper Position		
5; 0 ; -5	-5	
e1	0,588	
e2	0,382	

Distance Cluster-GC to tilt points
ec-1 0,300652
ec-2 0,669348
min ec 0,300652
Re-Tilting moment Ms 0,7089 [kNm]

Tilt moment	Mk	MS/Mk	
due to wind	0,44755	1,584	> 1,2
due to impact force	0,36	1,97	> 1,3

Cluster Height and Depth (projection)		
h-HP	4,342	[m]
h-VP	1,860	[m]

Wind-Load	(0,25 = beaufort 8 ; 0,12=beaufort 6)	
impact pressure	0,25	[kN/m²]
w	0,2194	[kN/m]

Impact forces
H 0,3 [KN]
for clusters with less then 4 cabinets the proof of stability under an impact force is not seen as relevant

Notice: Bumper angle are set positive when directing upwards

			Geometric properties				Projection		local GC of a box			global Coord. Of a box		global G-Offset	
GeoS12-Cluster			phi(i,j)	psi-0	psi	hi	hH,i	hv,i	Gi	eys	exs	Y[m]	X[m]	ys x G	xs x G
Box-Nr.	Box on / off	Position GeoS12/30	[°]	[°]	[rad]	[m]	[m]	[m]	[kN]	[m]	[m]	[m]	[m]	[kNm]	[kNm]
1	1	0	-5	-5	-0,0873	0,345	-0,03	0,34	0,33	0,1221177	0,1725	0,0000	0,0000	0,035	0,059
2	1	0	10	5	0,0873	0,345	0,03	0,34	0,33	0,1221177	0,1725	-0,0301	0,3437	0,035	0,164
3	1	0	10	15	0,2618	0,345	0,09	0,33	0,33	0,1221177	0,1725	0,0000	0,6874	0,053	0,268
4	1	0	10	25	0,4363	0,345	0,15	0,31	0,33	0,1221177	0,1725	0,0893	1,0206	0,089	0,367
5	1	0	10	35	0,6109	0,345	0,20	0,28	0,33	0,1221177	0,1725	0,2351	1,3333	0,141	0,458
6	1	0	10	45	0,7854	0,345	0,24	0,24	0,33	0,1221177	0,1725	0,4330	1,6159	0,209	0,538

Calculations cluster with 6 cabinets for Bumper position -5°

Bumper -10°, angle setting 0,2° min ec-2 and max wind

GeoS12 Geometry			
	height	0,345	[m]
	width	0,68	[m]
Weight	GeoS12/10	0,32578	[kN]
	GeoS12/30	0,31328	[kN]
GC	eys /10	0,122118	[m]
	exs /10	0,1725	[m]
	eys /30	0,122402	[m]
	exs /30	0,1725	[m]
Qty	GeoS12/10	6	[-]
	GeoS12/30	0	[-]
Total	Qty	6	[-]
	Weight	1,95	[kN]

GeoS12 Cluster gravity center		
Ys1 [m]	-0,054	[m]
Xs1 [m]	1,040	[m]

GSTK-Stabilizers		
weight	0,25	[kN]
Ys-Bumper	0,0000	[m]
Xs-Bumper	0,0000	[m]
Bumper Position		
5; 0 ; -5	-5	
e1	0,588	
e2	0,382	

Distance Cluster-GC to tilt points
ec-1 0,641845
ec-2 0,328155
min ec 0,328155
Re-Tilting moment Ms 0,7627 [kNm]

Tilt moment	Mk	MS/Mk	
due to wind	0,53197	1,434	> 1,2
due to impact force	0,36	2,12	> 1,3

Cluster Height and Depth (projection)		
h-HP	2,056	[m]
h-VP	2,042	[m]

Wind-Load	(0,25 = beaufort 8 ; 0,12=beaufort 6)	
impact pressure	0,25	[kN/m²]
w	0,2194	[kN/m]

Impact forces
H 0,3 [KN]
for clusters with less then 4 cabinets the proof of stability under an impact force is not seen as relevant

Notice: Bumper angle are set positive when directing upwards

			Geometric properties				Projection		local GC of a box			global Coord. Of a box		global G-Offset	
GeoS12-Cluster			phi(i,j)	psi-0	psi	hi	hH,i	hv,i	Gi	eys	exs	Y[m]	X[m]	ys x G	xs x G
Box-Nr.	Box on / off	Position GeoS12/30	[°]	[°]	[rad]	[m]	[m]	[m]	[kN]	[m]	[m]	[m]	[m]	[kNm]	[kNm]
1	1	0	-10	-10	-0,1745	0,345	-0,06	0,34	0,33	0,1221177	0,1725	0,0000	0,0000	0,029	0,062
2	1	0	0,2	-9,8	-0,1710	0,345	-0,06	0,34	0,33	0,1221177	0,1725	-0,0599	0,3398	0,010	0,173
3	1	0	0,2	-9,6	-0,1676	0,345	-0,06	0,34	0,33	0,1221177	0,1725	-0,1186	0,6797	-0,009	0,283
4	1	0	0,2	-9,4	-0,1641	0,345	-0,06	0,34	0,33	0,1221177	0,1725	-0,1762	1,0199	-0,027	0,394
5	1	0	0,2	-9,2	-0,1606	0,345	-0,06	0,34	0,33	0,1221177	0,1725	-0,2325	1,3603	-0,045	0,505
6	1	0	0,2	-9	-0,1571	0,345	-0,05	0,34	0,33	0,1221177	0,1725	-0,2877	1,7008	-0,063	0,616

Calculations cluster with 4 cabinets not relavant because less cabinets will remove gravity center to the middle (ec-min > 0,30 > ec-min = 0,2788 for bumper position5°)

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Transverse direction:

Impact forces on cluster with 4 GeoS12 relevant
(cluster with minimum selfweight in relation to possible horizontal forces)

Mk-iF = 1,2· 0,3 = 0,36 kNm

Weight cluster + bumper G = 1,32 + 0,25 = 1,57 kN

distance to tilt point = 1/2 width of bumper e = 0,675 / 2 = 0,34 m

Ms = 0,34 · 1,57 = 0,534 kNm

Proof: Ms / Mk = 0,534 / 0,36 = 1,48 > 1,30

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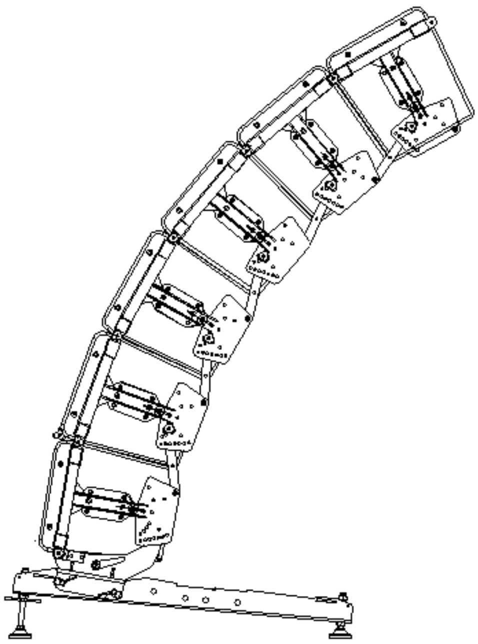
7.2 Strcutural integrity of rigging parts

Maximum internalforces due to selfweight for cluster with 6 GeoS12 , base angle 10° , angle-setting 10° between all cabinets.

On the safe side the proof of structural integrity is done for windforces on the theoretique maximum height of a cluster Hvp < 6 · 0,345 = 2,07m

Geometric properties see calculations on stability proof page..



Loading on bumper due to selfweight and wind:

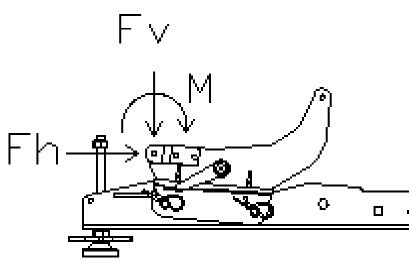
G-Cluster = 1,95 kN   ys1 = 0,523 m   hvp < 2,07 m

Mg = 1,95 · 0,523 = 1,02 kNm due to G

Mw = 0,22 ·2,07² / 2 = 0,47 kNm due to W

Fv = 1,95 KN due to G

Fh = 0,46 kN due to W



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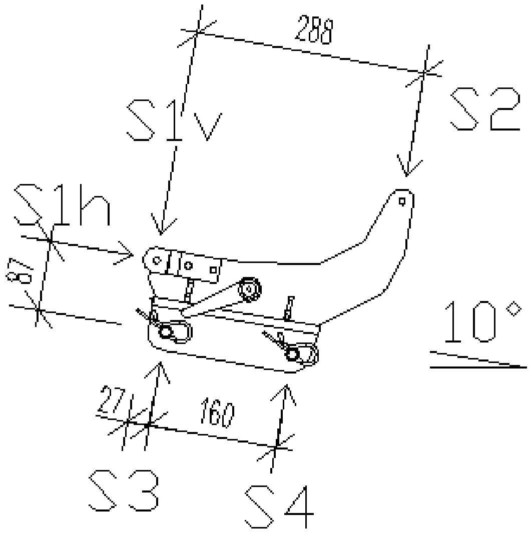
Internal forces at connection points:



S2 = M / (2·0,288)

=> due to G S2 = 1,77 kN

due to W S2 = 0,82 KN

S1v = Fv/2 · cos 10° - Fh/2 ·sin10° - S2

=> due to G S1v = -0,81 kN

due to W S1v = -0,90 kN

S1h = Fv/2 · sin10° +Fh / 2 · cos 10°

=> due to G S1h = 0,17 kN

due to W S1h = 0,45 kN

S3+S4 = S1v + S2

=> S3 = 0,96 - S4 due to G

S3 = -0,08 - S4 due to W

S4 · 0,187 + S3 · 0,027 = M/2

=> due to G S4 ·0,187 + (0,96-S4) 0,027 = 0,51 kNm

S4 = (0,51 - 0,027·0,96) / (0,187-0,027) = 3,03 kN

S3 = 0,96 - 3,03 = -2,07 kN

due to W S4 = (0,235 + 0,027·0,08) / (0,187 - 0,027) = 1,48 KN

S3 = -0,08 - 1,48 = -1,56 kN

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Allowable Loading + proof of structural integrity

All parts S235 JR (Except X-Bow V2)

conncetion points to X-Bow:

Tear out at Front connection (S1)

Bumperpart relevant (materiel S235 JR)
dL=8,3 mm

e1 = e2 = 15 mm = 1,81 · dL

=> a = 1,69

Vlrd = t · dL · a · fyk / 1,1

Vlrd = 0,6·0,8 ·1,61 · 24 / 1,1 = 16,86 kN

Tear out at back connection

Nearly identic geometric properties Vlrd = 16,86

connection to X-Bow

by 8mm Ball-lock 1.4305 Nirosta

Shearing acc. to DIN 50141 V = 38 kN

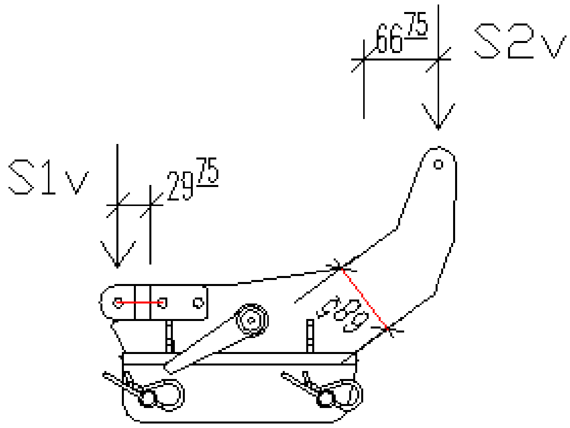
Summary + Proof

tear out relevant

=> allowable Loading S [kN] including safety factor =4

all S = 16,86 / 4 = 4,215 kN > S max = 1,77 + 0,82 = 2,59 kN (S2)

Bending



Female adapter front

distance to welding-axe e < 3 cm

S1v max = 1,71KN M= 3 · 1,71 = 5,13 kNcm

section b/h = 2 x 0,3 / 3,15 cm Wpl = 0,6·3,15² / 4 = 1,49 cm³

σ = 4 ·5,13 / 1,49 = 13,77 kN/cm² < 24,0 / 1,1 = 21,8 kN/cm²

Male adapter back

e < 7 cm

S2 max = 2,59 KN M= 7 · 2,59 = 19,13 kNcm

section b/h = 0,6 / 6,8 cm Wpl = 0,6·6,8² / 4 = 6,93 cm³

σ = 4 ·19,13 / 6,93 = 11,04 kN/cm² < 24,0 / 1,1 = 21,8 kN/cm²

Connection to stabilizer

Tear out at Connection (S4)

Tear out at U-Section relevant (min e1)

dL= 16,2mm

e1 = e2 = 21 mm = 1,29 · dL

=> a = 0,87

Vlrd = t · dL · a · fyk / 1,1

Vlrd = 2 ·0,6· 1,6 ·0,87 · 24 / 1,1 = 36,44 kN

connection by 16mm Bolts > 4.6

Vrd > 2 · 43,9 kN not relevant

Summary + Proof

tear out relevant

=> allowable Loading S [kN] including safety factor =4

all S = 36,44 / 4 = 9,11 kN > S max = 3,03 + 1,48 = 4,51 kN (S4)

Bending stabilizers

Max bending-moment:

max M = 0,5 ·(Mg + Mw + Fh · 0,15) = 0,5·(1,02+0,47 + 0,46·0,15) = 0,78 kNm

Cross section closed rectangular tube 5,8x5,3x0,4 cm

$Iyy = 2 \cdot 0{,}4 \cdot 4{,}9^3 / 12 + 2 \cdot 5{,}4 \cdot 0{,}4 \cdot 2{,}45^2 = 33{,}8\ cm^4$

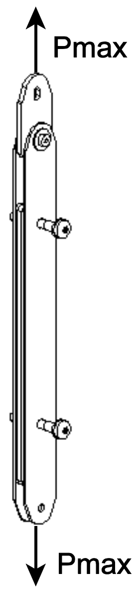
$Sy = 5{,}4 \cdot 0{,}4 \cdot 2{,}45 + 2 \cdot 0{,}4 \cdot 2{,}45^2 / 2 = 7{,}69 cm^3$

$Wpl = 2 \cdot 7{,}69 = 15{,}38\ cm^3$

Proof incl. Safety factor = 4

$4 \cdot 78 / 15{,}38 = 20{,}28\ kN/cm^2 < 24 / 1{,}1 = 21{,}8\ kN/cm^2$

8 RIGGING SYSTEM RS15



Vertical cluster with maximum 16 Subwoofer RS15

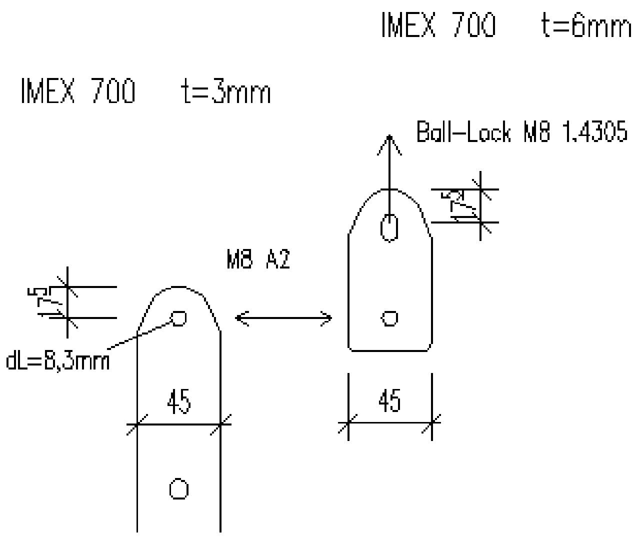
per cabinet 4 rigging-parts (one at each corner)

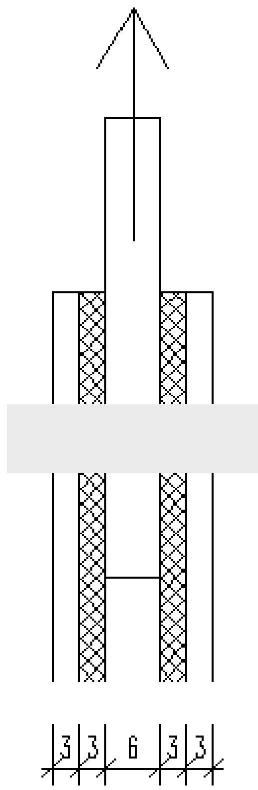
Weight of one cabinet incl. Rigging parts G = 65 kg

Maximum loading on one rigging part

Pmax = 16 · 0,65 /4 = 2,6 kN

Connections and plates





between 2 cabinets by 8mm Ball-lock
material: 1.4305 Nirosta fyk = 300 n/mm²

between plates by Socket Head shoulder
srew M6D8x20 material: 12.9

Ball-Lock is relevant:

shearing Ball-Lock

Vsd = 4 · 2,6 = 10,4 kN (safety factor =4)

allowable Shearing (in acc. to DIN 50141)

Vrd = 38 kN > Vsd = 10,4 kN

bending Ball-Lock

$Msd = 4 \cdot 2{,}6 / 2 \cdot 0{,}30$ cm = 1,56 kNcm

Ball-Lock M8 with inside hole 3,5mm , fyk = 30 kN/cm²

$Wpl = 4/3\ (0{,}4^3 - 0{,}175^3) = 0{,}078$ cm³

$Mrd = 0{,}078 \cdot 30 / 1{,}1 = 2{,}12$ kNcm > Msd = 1,56 kNcm

interaction

$(10{,}4 / 38)^2 + (1{,}56/2{,}12)^2 = 0{,}62 < 1{,}0$

Tear out plates

e1 = e2 = 17,5 mm = $2{,}11 \cdot dL$

=> a = 2,02

$Vlrd = t \cdot dL \cdot a \cdot fyk / 1{,}1$

$Vlrd = 2 \cdot 0{,}3 \cdot 0{,}8 \cdot 2{,}02 \cdot 70 / 1{,}1 = 61{,}7$ kN > Vsd = 10,4 kN

Stresses in plates

$Anet = 2 \cdot 0{,}3 \cdot (4{,}5 - 1{,}0) = 2{,}1$ cm²

Nsd = 10,4 kN

$\sigma = 10{,}4 / 2{,}1 \ll 70 / 1{,}1 = 63{,}63$ kN/cm²

Connection plates to cabinet

connection to cabinet by 2x M10 A70 per rigging part

Loading per rigging part P = 0,65 / 4 = 0,1625 kN

Loading per screw: Ps = 0,1625 / 2 = 0,08125 kN

excentricity e = 15/2 + 3 + 3 + 6/2 = 16,5mm = 1,65cm

Bending-moment in screw $M = 0{,}08125 \cdot 1{,}65 = 0{,}134$ kNcm

Screw M10 $Wpl = 4/3 \cdot 0{,}5^3 = 0{,}167$ cm³

material A70 fyk = 450 N/mm² ; fubk = 700 N/mm²

$\sigma = 4 \cdot 0{,}134 / 0{,}167 = 3{,}2$ kN/cm² << 45 / 1,1

Shearing not relevant

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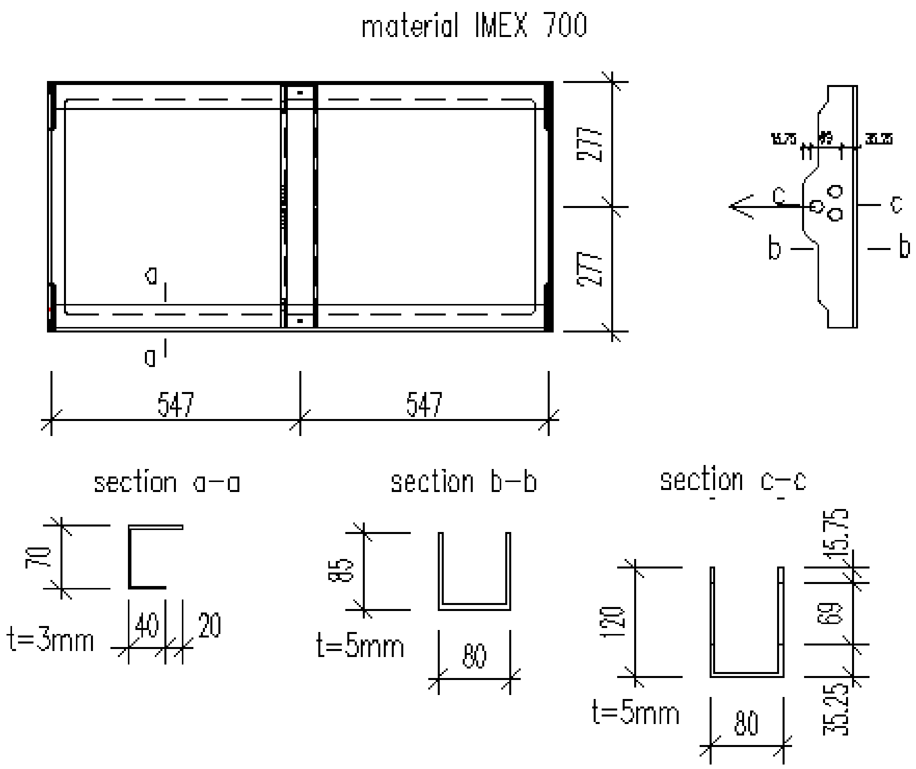
Bumper

Total maximum Weight: Clsuter 16 · 0,65 = 10,4 kN

Bumper < 60 kg = 0,60 kN

Total G = 11 kN

Total load distributed on the four corner points Pi = 11 / 4 = 2,75 kN



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Proof including safety factor = 4

Section a-a

$M = 4 \cdot 2{,}75\ \text{kN} \cdot 54{,}7\text{cm} = 601{,}7\ \text{kNcm}$

$W_{pl} > 0{,}3 \cdot 7^2 / 4 + 2 \cdot 0{,}3 \cdot 3{,}7 \cdot 3{,}35 = 11{,}11\ \text{cm}^3$

$\sigma = 601{,}7 / 11{,}11 = 54{,}15\ \text{kN/cm}^2 < 70 / 1{,}1 = 63{,}63\ \text{kN/cm}^2$

Section b-b

$M < 4 \cdot 5{,}5 \cdot 27{,}7 = 609{,}4\ \text{kNcm}$

$W_{pl} > 2 \cdot 0{,}5 \cdot 8{,}5^2 / 4 = 18{,}06\ \text{cm}^3$

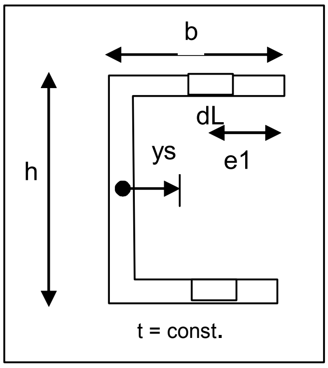
$\sigma = 609{,}4 / 18{,}06 = 33{,}7 < 70 / 1{,}1$

Section c-c

$M = 4 \cdot 5{,}5 \cdot 27{,}7 = 609{,}4\ \text{kNcm}$

Cross-section properties

Cross-Section

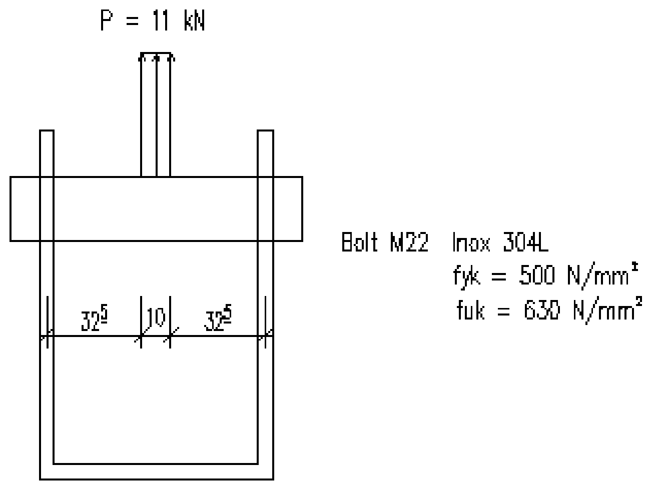


h	8,00 [cm]		
b	12,00 [cm]		
th	0,50 [cm]		
tb	0,50 [cm]		
dl	6,90 [cm]		
e1	5,03 [cm]		
h'	7,50 [cm]		
b'	11,75 [cm]		
		Wy	21,45 [cm³]
A	8,60 [cm²]	Wz-1	58,71 [cm³]
ys	2,63 [cm]	Wz-2	18,55 [cm³]
Iyy	85,78 [cm^4]		
Izz	169,15 [cm^4]	(W-pl=2xS)	
Sy	12,61 [cm³]	Wy-pl	25,22 [cm³]
Sz	13,33 [cm³]	Wz-pl	26,66 [cm³]

Wz-2 relevant

$\sigma = 609{,}4 / 18{,}55 = 32{,}85 < 70/1{,}1\ \text{kN/cm}^2$

Bolt at Hanging point Bolt M22 fyk / fuk = 50 / 63 kN/cm²



Wpl = 4/3 · 1,1³ = 1,775 cm³ => Mrd = 1,775 · 50 / 1,1 = 80,68 kNcm

A = p · 1,1² = 3,8 cm² => Vrd = 3,8 · 0,4 · 63 / 1,1 = 87 kN

Proof incl. safety = 4

Msd = 4 · 5,5 kN · 3,25 cm = 71,5 kNcm < Mrd

Vsd = 4 · 5,5 = 22 kN < Vrd

Interaction: (71,5 / 87)² + (22/ 87)² = 0,77 < 1,0

Tear out in centrale bar

dL = 22 ,5 mm

e1 = 27 mm = 1,2· dL

e2 > 1,5 dL

=> a = 1,02

Vlrd = t · dL · a · fyk / 1,1

Vlrd = 0,5·2,2 ·1,02 · 70 / 1,1 =71,4 kN > Vsd = 4 · 5,5 = 22 kN