Structural Report 1193/2017.27.01 (Revision 3) on

Glass Façades for Rothschild 48, Tel Aviv Hotel

Component: West façade EWS-01, EWS-08

Table of Revisions

Revision	Date	Added pages	Removed pages	Changed pages	Notes
0	July, 7th, 2017	1 to 179	-	-	Preparation of the static report
1	July, 24th, 2017	-	-	1 to 179	- Change of linear line load to 1.5 kN/m - Thread stripping (Pos. 9.3) - Minor changes
2	August, 28th, 2017	1 to 250	1 to 179		- Pos. 2: 3D Finite Element Calculation of SSG joints - Pos. 4.5: Steel frame to reduce vert. deformation at the cantilever - Pos. 5.5: Support of steel frame
3	November 8th, 2018	1 to 272	1 to 250		- Section 4: Change in material param-eters - Section 8: Numerical redesign of the façade concerning a reduced thick-ness of 15 mm for the vertical SSG joint.

Content

[14] DIN 18008-3, Glas im Bauwesen - Bemessungs- und Konstruktionsregeln - Teil 3: Punktförmig gelagerte Verglasungen, Ausgabe Juli 2013.

[15] DIN 18008-4, Glas im Bauwesen - Bemessungs- und Konstruktionsregeln - Teil 4: Zusatzanforderungen an absturzsichernde Verglasungen, Ausgabe Juli 2013.

[16] DIN 18008-5, "Glas im Bauwesen - Bemessungs- und Konstruktionsregeln - Teil 5: Zusatzanforderungen an begehbare Verglasungen; Ausgabe Juli 2013".

[17] DIN 18008-6 (Entwurf), Glas im Bauwesen - Bemessungs- und Konstruktionsregeln - Teil 6: Zusatzanforderungen an zu Instandhaltungsmaßnahmen betretbare Verglasungen; Stand Januar 2014.

[18] Glasscon, Technical Report - Design of cast-in channels on Rothschild 48 Tel Aviv Hotel Revision 1, 16/3/2017.

[19] Halfen Cast-In Channels HTA-CE, Halfen Bolts - Type HSR, 2017.

[20] EN 1990: Eurocode: Basis of structural design.

[21] EN 1991-1-4 Eurocode 1: Actions on structures - General actions - Wind actions.

[22] EN 1999-1-1 Eurocode 9: Design of aluminium structures - General structural rules.

[23] EN 13830 Curtain wailing - Product standard.

[24] EN 1993-1-1 Eurocode 3: Design of steel structures - General rules and rules for building.

[25] EN 1993-1-4 Eurocode 3: Design of steel structures - General rules - supplementary rules for stainless steel.

[26] EN 1993-1-8 Eurocode 3: Design of steel joints.

[27] EN 14351-1 Windows and doors. Product standard, performance characteristics. Windows and external pedestrian doorsets without resistance to fire and/or smoke leakage characteristics.

[28] Front, "Project description Rothschild 48 Tel Aviv Hotel: Section 084413 - Exterior Interior Wall Systems (EWS-IWS)," 15th March 2017.

[29] Sika Technology AG, "Influence of Poisson Ratio and volumetric data in the FE simulation of Sikasil SG-550," Dr. P. Jousset, 10.05.2012.

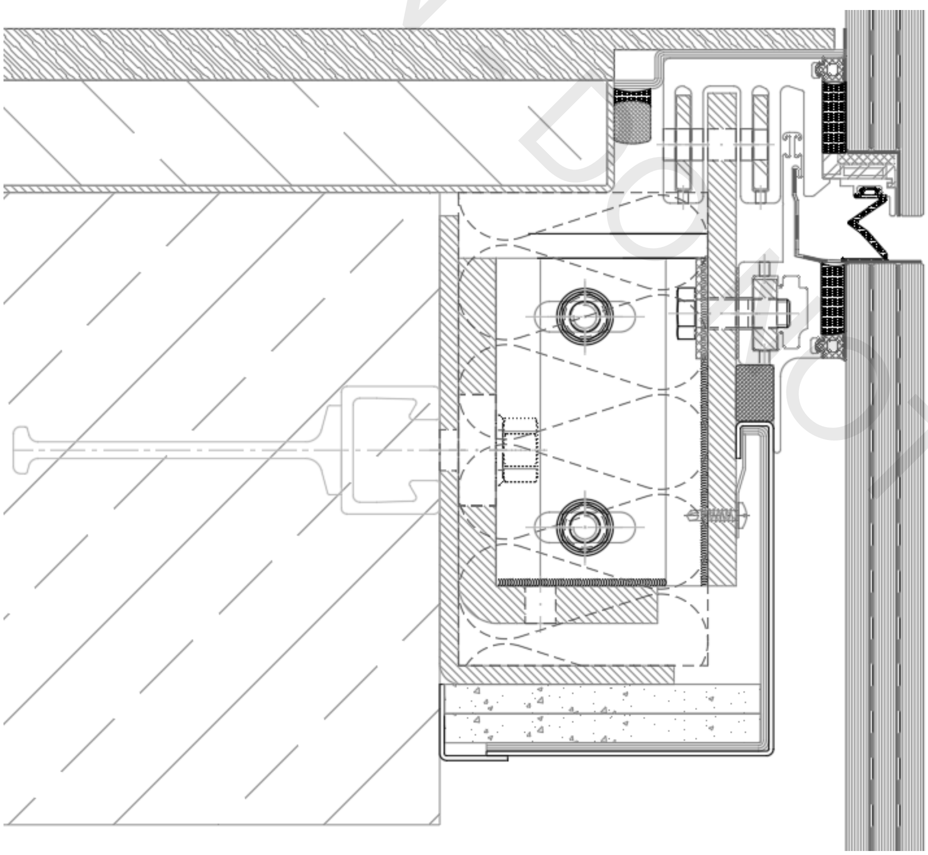
[30] EOTA, European Technical Approval 01/0005 - DC 993 and 995, 06.04.2012.

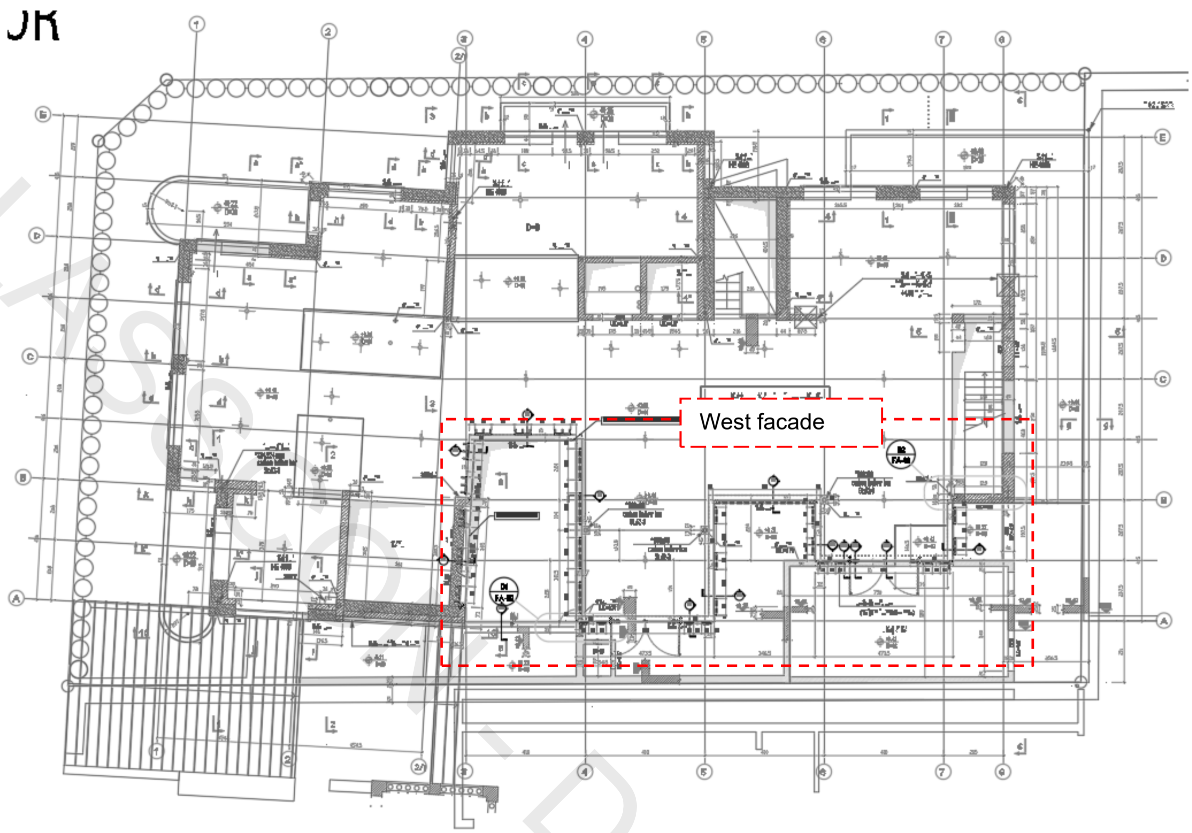
[31] EOTA, European Technical Approval 03/0038 - Sikasil SG 500, 16.03.2014.

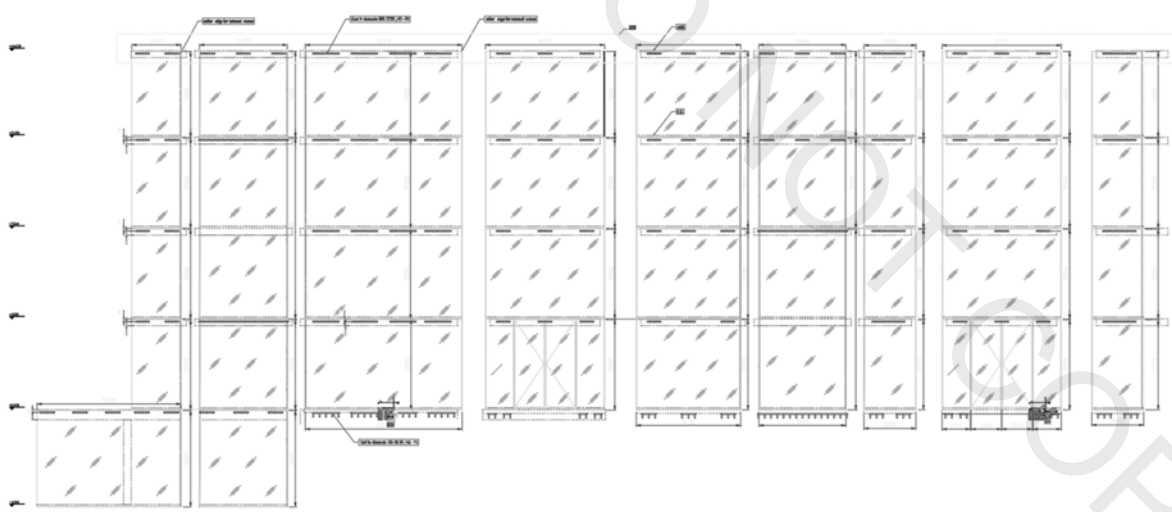
3. Project Description

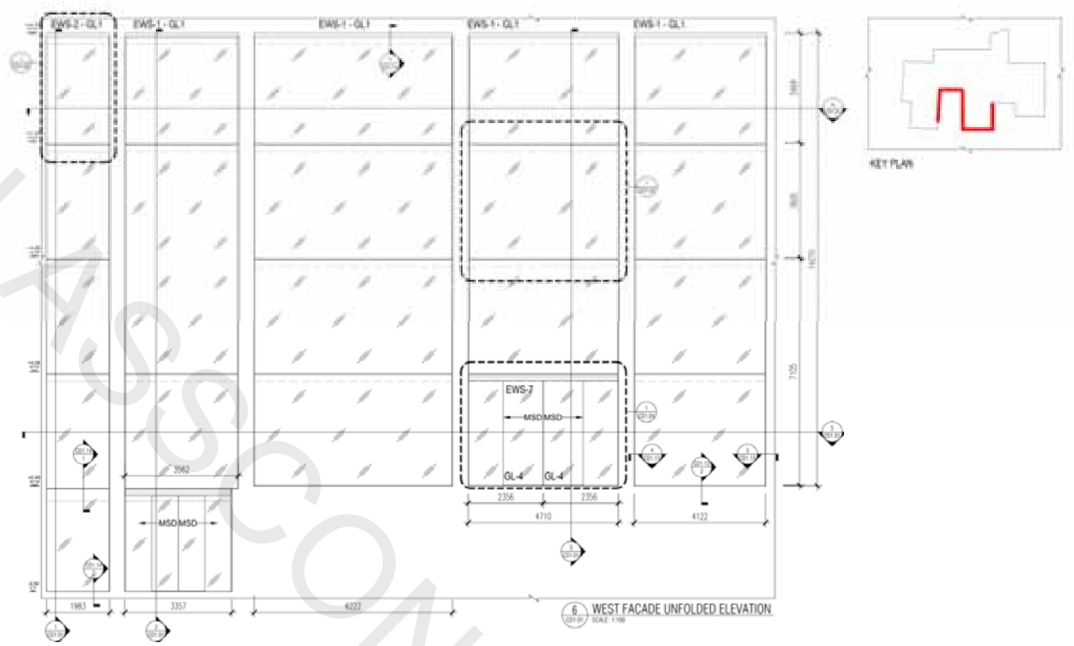
For the project “Tel Aviv Hotel – Rothschild 48”, Tel Aviv, Israel a new façade is planned. The “West Façade”, which is considered within this report, is an all-glass façade. The glasses in the façade are laminated glasses which span between the concrete ceiling and are connected on all vertical edges to the adjacent glasses. For the horizontal support aluminium profiles are arranged parallel in front of the ceiling. The horizontal support and the connection to the adjacent glasses both are planned by structural sealant glazing (SSG). The aluminium profiles are supported by two, three or four mounting brackets.

The self-weight of the glazing is removed by two aluminium corners with glass blocks, which were connected to the aluminium profiles at the mounting brackets. As the outer glass pane is larger to cover the connection detail, the self-weight of the outer glass pane is transferred by the intermediate layer (SGP) to the inner glass panes.

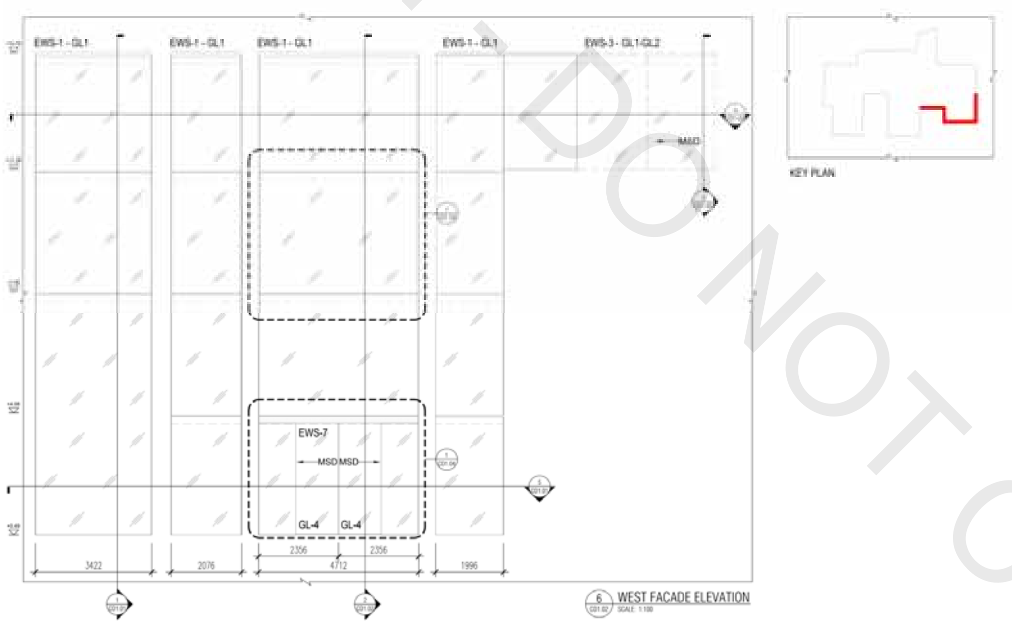



West facade





6 WEST FACADE UNFOLDED ELEVATION



6 WEST FACADE ELEVATION

4. Material Properties

Glas

E-module:	E_{Glas}	=	70 000 N mm^{-2}
G-module:	G_{Glas}	=	29 500 N mm^{-2}
Poisson's ratio:	ν_{Glas}	=	0.23
Specific weight:	γ_{Glas}	=	25.0 kN/m^3
Coefficient of thermal expansion:	α_{TS}	=	$9 \cdot 10^{-5}$ 1/K

Steel S235

E-module:	E_{S235}	=	210 000.00 N mm^{-2}
G-module:	G_{S235}	=	80 800 N mm^{-2}
Poisson's ratio:	ν_{S235}	=	0.30
Specific weight:	γ_{S235}	=	78.5 kN/m^3
Coefficient of thermal expansion:	α_{TS}	=	$12 \cdot 10^{-6}$ 1/K

Aluminium EN-AW 6063 T6

E-module:	E	=	70 000.00 N mm-2
G-module:	G	=	26 900.00 N mm-2
Poisson's ratio: ν	=	0.30	
Specific weight: γ	=	27 kN/m^3	

SGP

Wind (c.f. [1])	E-module:	E_1	=	300.00 N mm^{-2}
	G-module:	G_1	=	100.70 N mm^{-2}
	Poisson's ratio: ν_1	=	0.49	
Horizontal Line Load (c.f. [1])	E-module:	E_2	=	12.00 N mm^{-2}
	G-module:	G_2	=	4.03 N mm^{-2}
	Poisson's ratio: ν_2	=	0.49	
Wind / Horizontal Line Load (c.f. [1])	E-module:	E_3	=	195.00 N mm^{-2}
	G-module:	G_3	=	65.44 N mm^{-2}
	Poisson's ratio: ν_3	=	0.49	

Sikasil SG-550 (Hyperelastic material behaviour: Neo-Hooke):

μ_0 = 0.92 N mm^{-2}

D = 0

Sikasil SG-20 (Hyperelastic material behaviour: Neo-Hooke):

μ_0 = 0.26 N mm^{-2}

D = 0

5. Overview of Components

Pos. 1 Glass

Pos. 1.1: Glass (LG) 3 x 10 mm HSG, SGP

Pos. 2 SSG joint

Pos. 2.1 horizontal SSG joint Sikasil SG550

Pos. 2.1 vertical SSG joint Sikasil SG550

Pos. 3 Aluminium profile

Pos. 3.1 Upper aluminium profile EN-AW 6063 T6

Pos. 3.2 Lower aluminium profile EN-AW 6063 T6

Pos. 4 Mounting bracket

Pos. 4.1 Mounting bracket (front, upper floors)

Pos. 4.2 Mounting bracket (front, ground floor)

Pos. 4.3 Mounting bracket (floor, ground floor)

Pos. 4.4 Mounting bracket (floor, door)

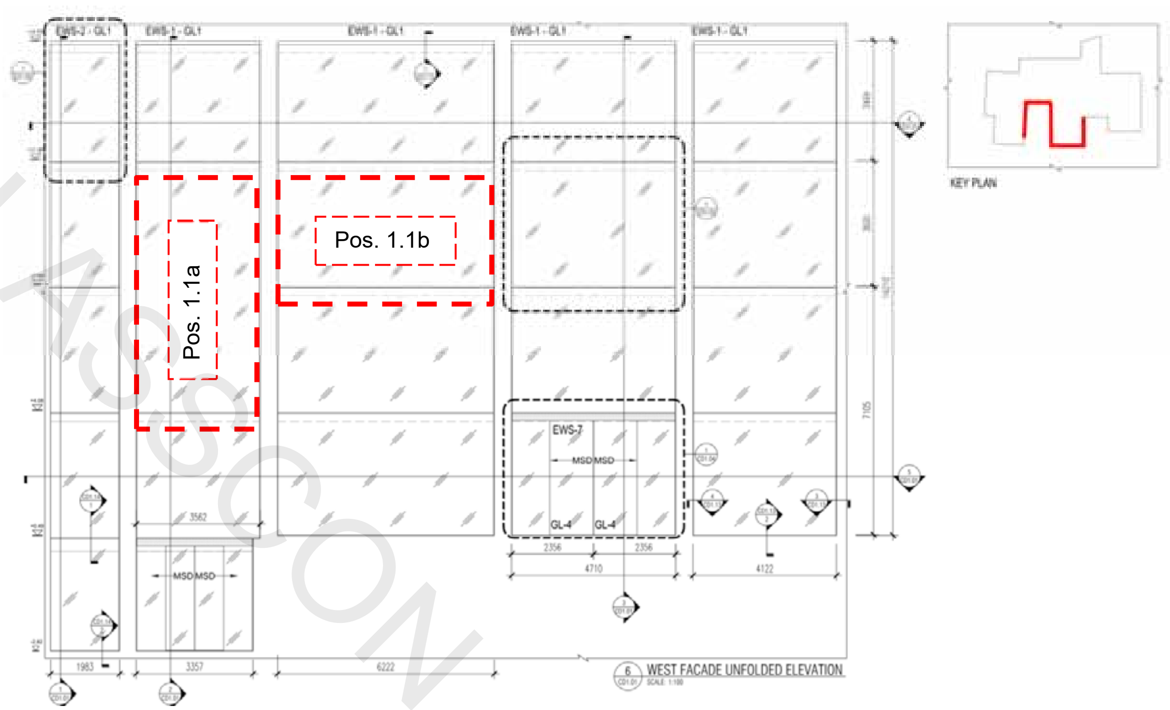
Pos. 5 Halfen anchor channels (front)

Pos. 5.1 Halfen anchor channels (front, upper floors) HTA-CE 55/42 (hot rolled)

Pos. 5.2 Halfen anchor channels (front, upper floors) HTA-CE 55/42 (hot rolled)

Pos. 5.2 Halfen anchor channels (floor, ground floor) HTA-CE 55/42 (hot rolled)

Pos. 5.2 Halfen anchor channels (floor, door) HTA-CE 55/42 (hot rolled)



Pos. 1.1a
Pos. 1.1b
WEST FACADE UNFOLDED ELEVATION
KEY PLAN

6. Load Cases

The static loadings are based on the following load cases.

6.1. Dead Load (LC 1)

The dead load is considered in the finite element calculation by the specification of an acceleration value in gravity direction. The acceleration was set to 9810 mm/s^2.

The specific weight of the used materials is given in section 4 (Material properties).

6.2. Wind (LC 2 and LC 3)

Building and terrain category for the calculation of the wind load:

Tel Aviv:			36 m above sea level
Basic wind velocity:			30 m/s
Basic wind pressure q_b:		0.56 kN/m²	
Building	height h:		18 m
	length d:		17 m
	width b:		28 m
Terrain category:			III
Peak velocity pressure q_p:		=	$1.6 \times q_b \times (z / 10)^{0.31}$
		=	$1.6 \times 0.56\ kN/m^2 \times (18\ m / 10)^{0,31}$
		=	1.08 kN/m²

6.2.1. Wind suction

$h/d \leq 1$

<u>External load:</u>

Zone A $c_{pe,10}$* = 1.2

$w_{k,e}$ = $1.2 \times q_p$ = 1.30 kN/m²

Zone B $c_{pe,10}$* = 0.8

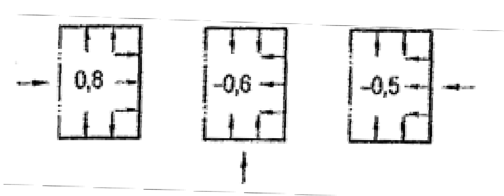
$w_{k,e}$ = $0.8 \times q_p$ = 0.87 kN/m²

Zone C, E $c_{pe,10}$* = 0.5

$w_{k,e}$ = $0.5 \times q_p$ = 0.54 kN/m²

*Since the relevant glass panes have a size of about 20 m², for the verifications $c_{pe,10}$ values are considered.

One side open (according to EN 1055-4):



Zone 1-1 c_{pe} = 0.8

$w_{k,e}$ = $0.8 \times q_p$ = 0.87 kN/m²

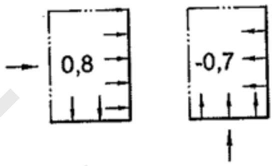
Zone 1-2 c_{pe} = 0.6

$w_{k,e}$ = $0.6 \times q_p$ = 0.65 kN/m²

Zone 1-3 c_{pe} = 0.5

$w_{k,e}$ = $0.5 \times q_p$ = 0.54 kN/m²

Two side open (according to EN 1055-4):



Zone 2-1 c_{pe} = 0.8

$w_{k,e}$ = 0.8 x q_p = 0.87 kN/m²

Zone 2-2 c_{pe} = 0.7

$w_{k,e}$ = 0.7 x q_p = 0.76 kN/m²

Internal load:

- Building without dominant face
- μ_1 = (17 m + 2 x 28 m) / (2 x 17 m + 2 x 28 m) = 0.82

  μ_1 = (28 m + 2 x 17 m) / (2 x 17 m + 2 x 28 m) = 0.68

$c_{pi,1}$ = -0.30

$c_{pi,2}$ = -0.05

chosen +0.20

$w_{k,i}$ = 0.2 x q_p = 0.22 kN/m²

Total load:

w_k = $w_{k,e}$ - $w_{k,i}$

Zone [-]	$w_{k,e}$ [kN/m²]	$w_{k,i}$ [kN/m²]	w_k [kN/m²]	**chosen** [kN/m²]
A	1.30	0.22	1.52	**1.65**
B, 1-1, 2-1	0.87	0.22	1.09	**1.20**
2-2	0.76	0.22	0.98	**1.10**

1-2	0.65	0.22	0.87	**1.00**
C, 1-3	0.54	0.22	0.76	**0.90**

6.2.2. Wind pressure

h/d ≤ 1

External load:

Zone D $c_{pe,10}$* = -0.8

*Since the relevant glass panes have a size of about 20 m², for the verifications $c_{pe,10}$ values are considered.

$w_{k,e}$ = $-0.8 \times q_p$ = -0.87 kN/m²

Internal load:

- Building without dominant face
- $\mu_1 = (17\text{ m} + 2 \times 28\text{ m}) / (2 \times 17\text{ m} + 2 \times 28\text{ m}) = 0.82$

  $\mu_1 = (28\text{ m} + 2 \times 17\text{ m}) / (2 \times 17\text{ m} + 2 \times 28\text{ m}) = 0.68$

  $c_{pi,1}$ = 0.30

  $c_{pi,2}$ = 0.05

$w_{k,i}$ = $0.3 \times q_p$ = 0.33 kN/m²

Total load:

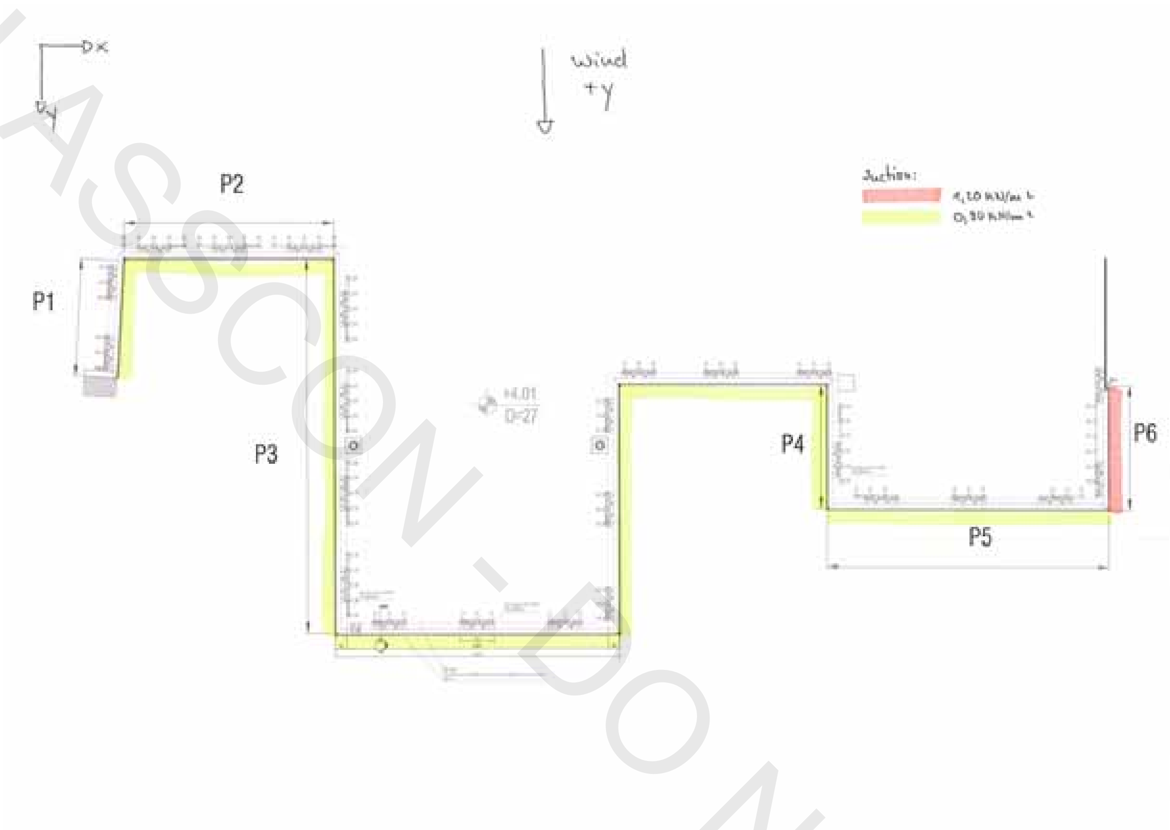
w_k = $w_{k,e} - w_{k,i}$

= -0.87 kN/m² - 0.33 kN/m² = -1.20 kN/m²

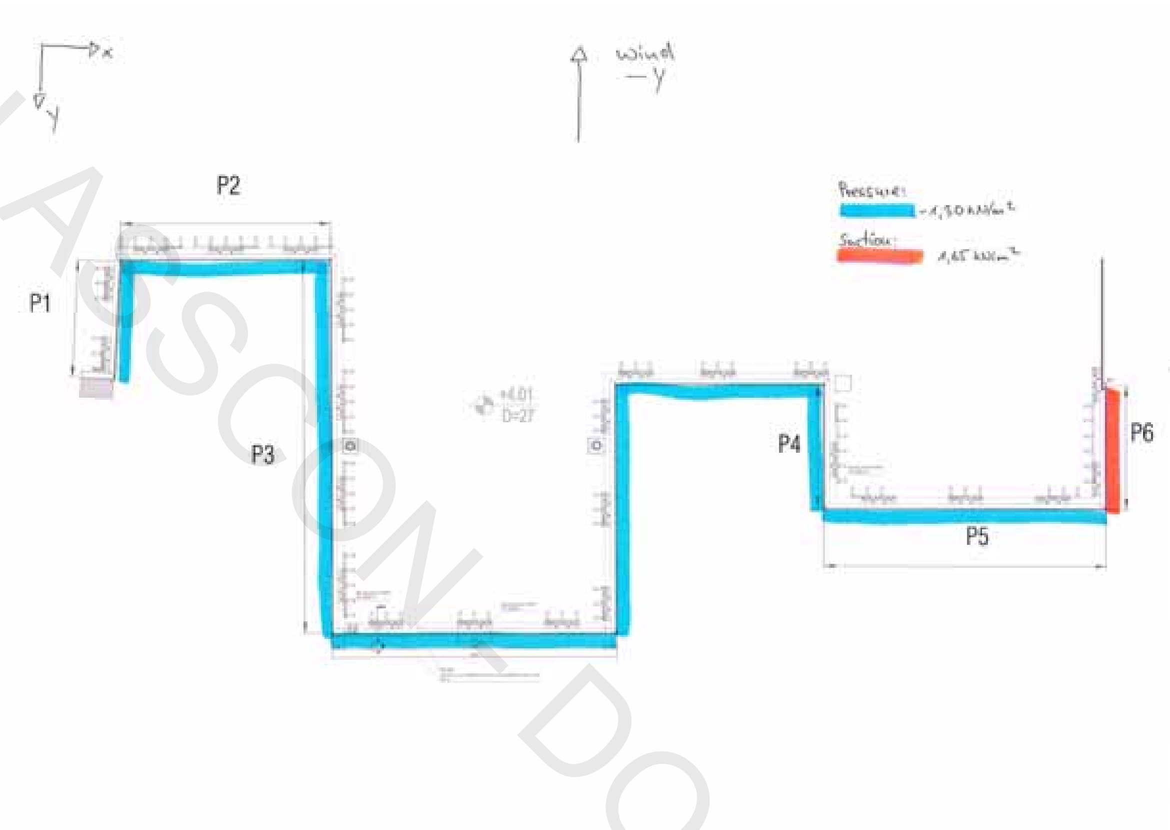
chosen = -1.30 kN/m²

6.2.3. Wind Load Scenarios

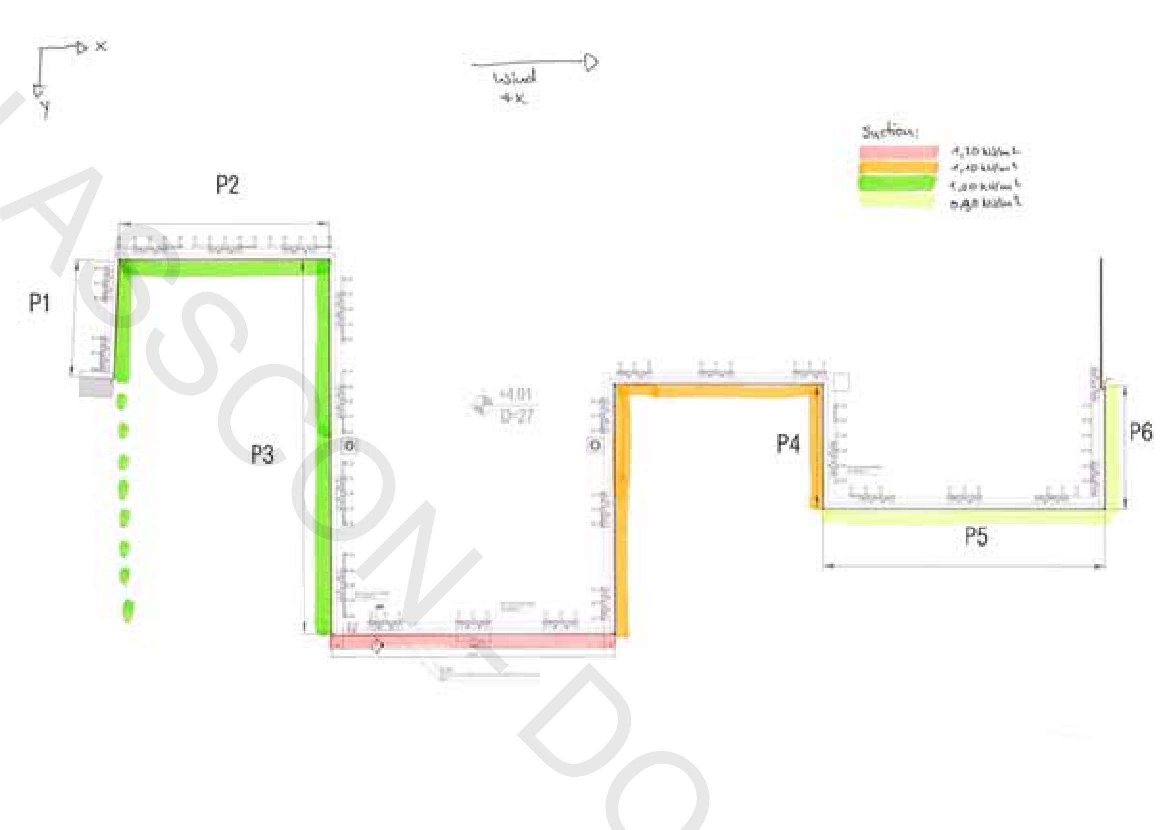
Wind Load Scenario 1 (+Y):



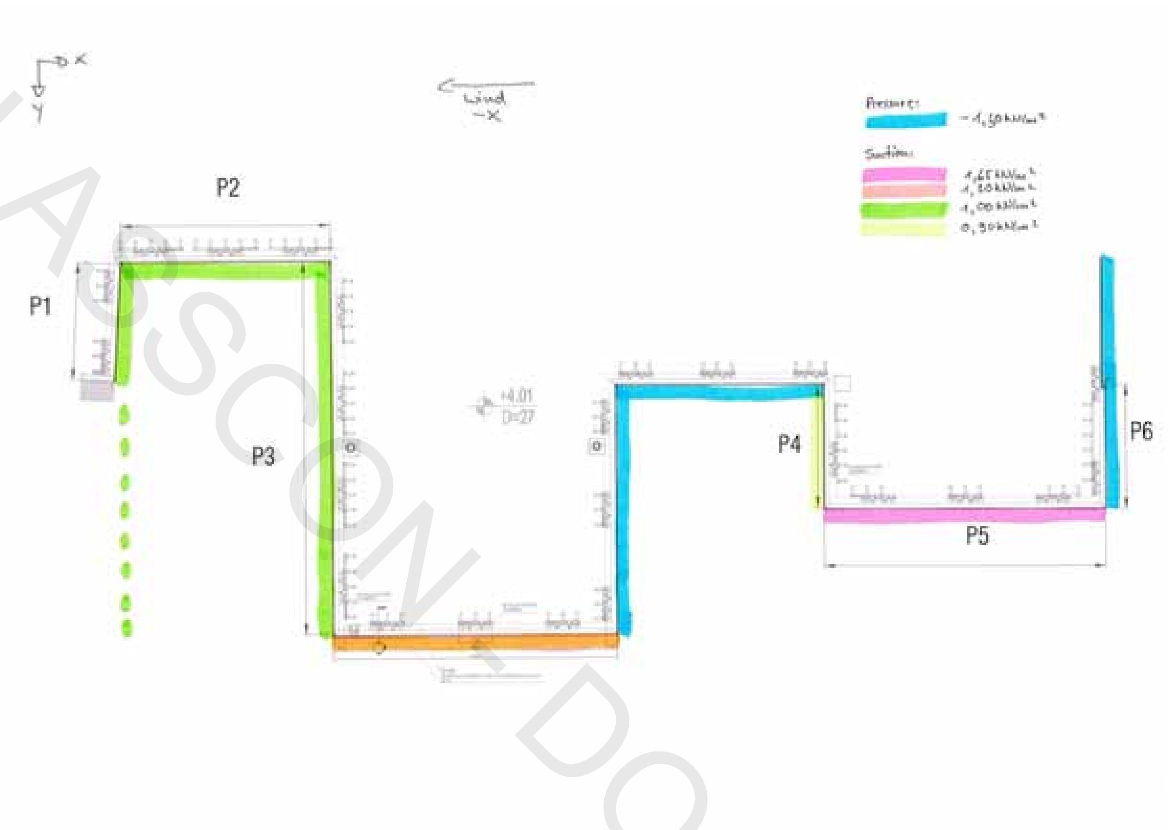
Wind Load Scenario 2 (-Y):



Wind Load Scenario 3 (+X):



Wind Load Scenario 4 (-X):



6.3. Horizontal Line Load / Load from Person (LC 4)

According to EN 1991 [2] the building Rothschild 48 has to be classified as category B2. For this category the following horizontal line load has to be considered for the verification:

$q_{hll,k}$ = 1.5 kN/m (1.2 m above finished floor level)

6.4. Failure Scenario (LC 5)

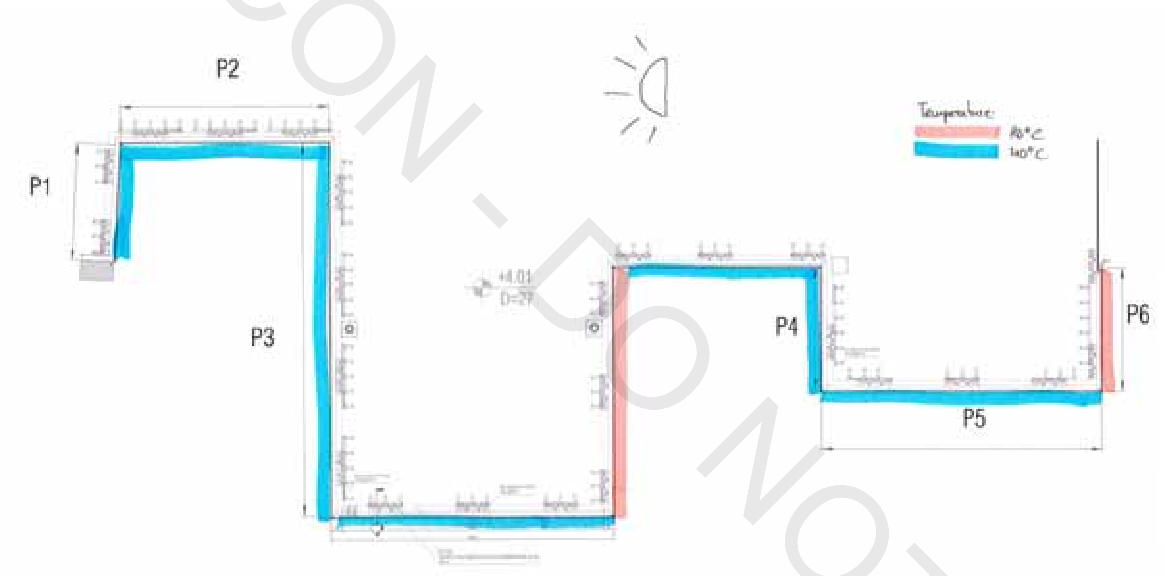
In order to ensure the load-carrying capacity of the components in the event of a failure of the on-site bonding (vertical SSG joints), the failure is computationally investigated. The load case is considered as an exceptional load situation. The load-bearing capacity is determined on the basis of with ψ_0 reduced characteristic loads.

6.5. Temperature (LC 6)

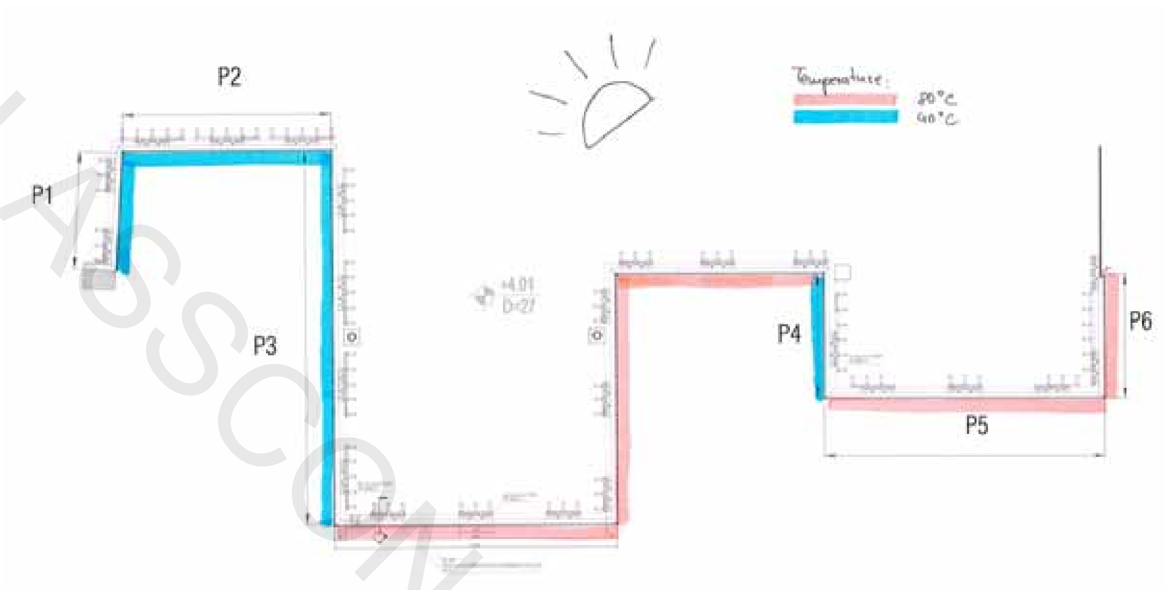
The temperature loads defined in ETAG 002 are investigated for the verification of SSG joints. Due to temperature differential deformation between the horizontal SSG joint and the aluminum profile Δl_H developed, which causes shear deformation in the SSG joint. Based on ETAG 002 the following temperature scenarios are considered in the calculations.

T_{glass} = 80 °C (according to ETAG 002)

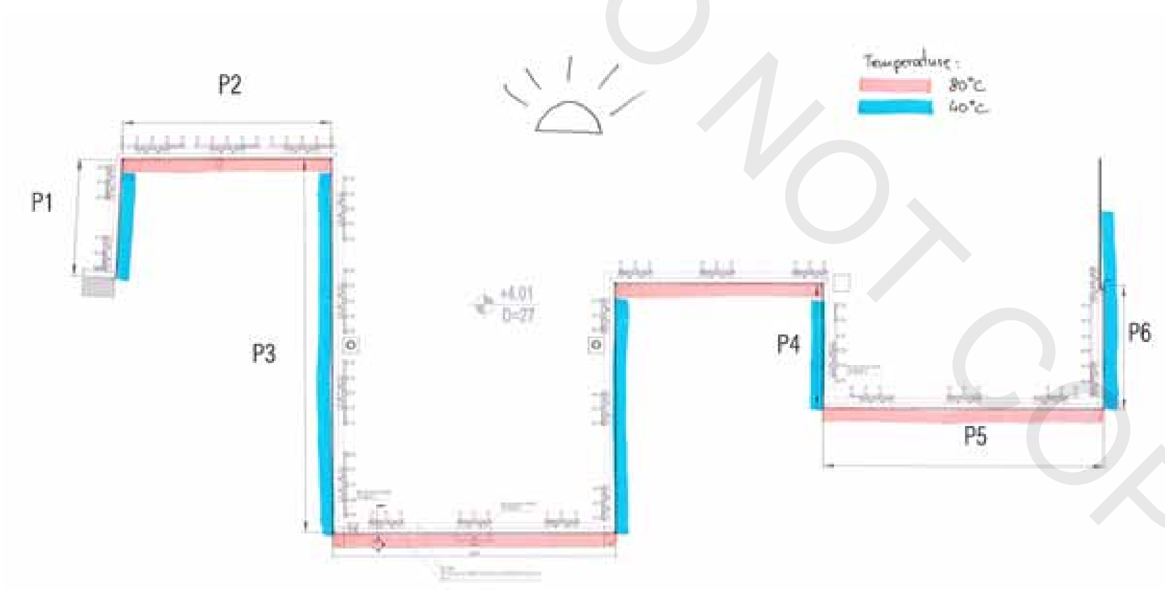
<u>Temperature Scenario 1:</u>



Temperature Scenario 2:



Temperature Scenario 3:



7.1. Pos.1.1 – Glass

7.1.1. General

Glass assembly:

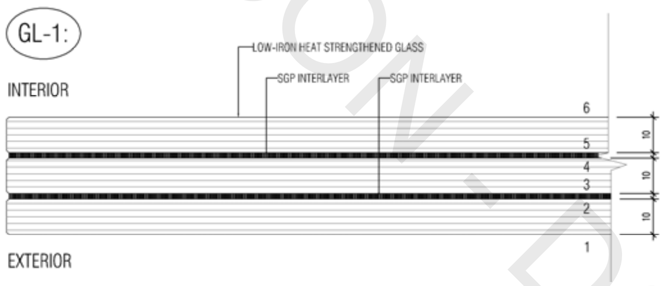
Laminated glass out of 10 mm heat strengthened glass

1.52 mm SGP

10 mm heat strengthened glass

1.52 mm SGP

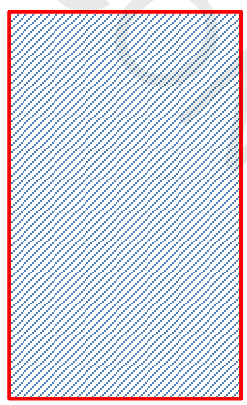
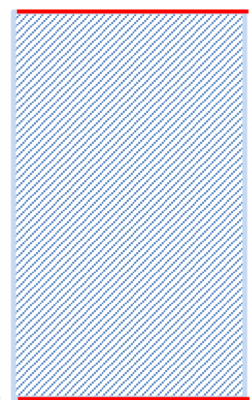
10 mm heat strengthened glass



7.1.2. Static System

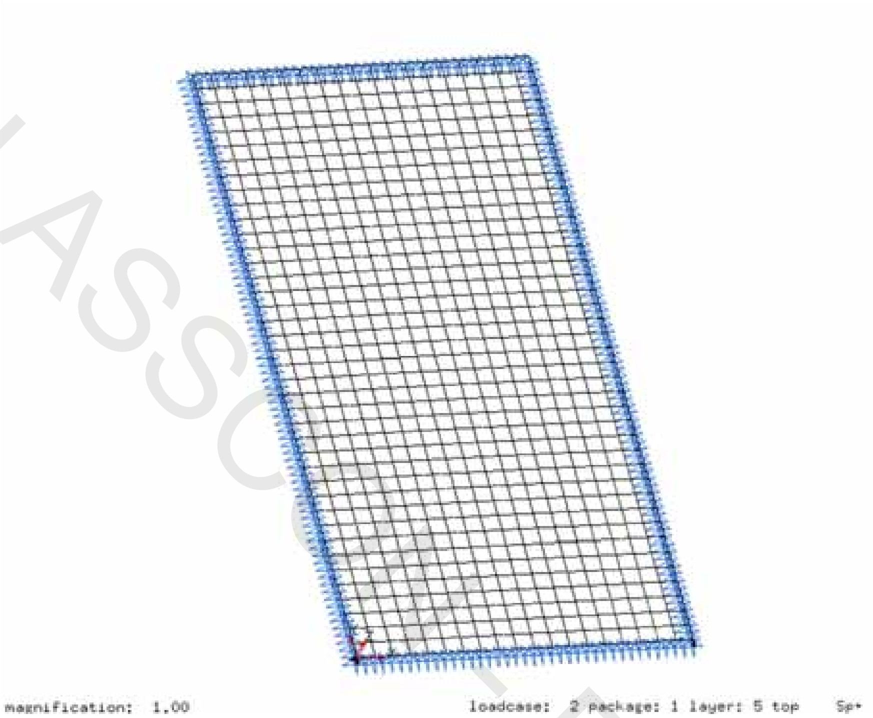
A four side linear support is chosen for the two design situations ULS and SLS. For the calculation of the stresses and deformations occurring in the glass finite element calculations were performed with the finite element software SJ Mepla. The bearing conditions can be taken from the following composition:

- For the verification in ULS and SLS a four side linear support is considered
- For the verification of failure scenario (failure of vertical SSG joint) and during construction a two side linear support is considered

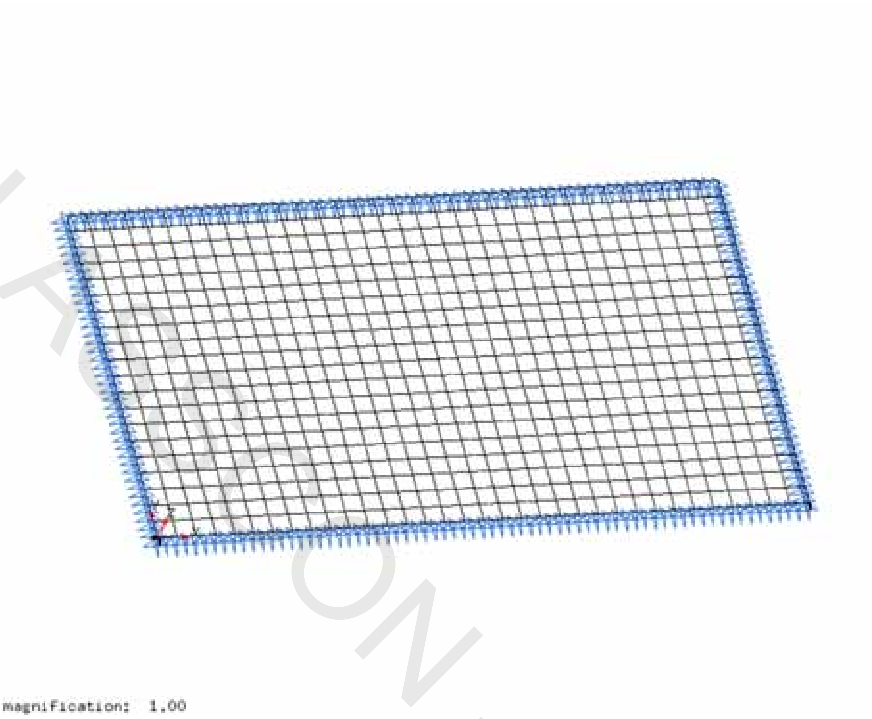
ULS / SLS	Failure scenario
	

Navier-Support

Finite element mesh of Pos. 1a:



Finite element mesh of Pos. 1b:


magnification: 1.00

7.1.3. Load Cases

The glazing is loaded by the loads defined in section 6. The material properties for the glazing were varied due to the load duration (c.f. section 4).

Bezeichnung		außen/oben	innen/unten	
w(1)	= Wind	1.500	0.000	[kN/m²]
q(1)	= Linienlasten		1.50	[kN/m]

LF	Beschreibung
1	Wind Suction
2	Wind Suction / Line Load
3	Line Load
4	Wind Pressure
5	Wind Pressure / Line Load
6	GZG Wind Suction

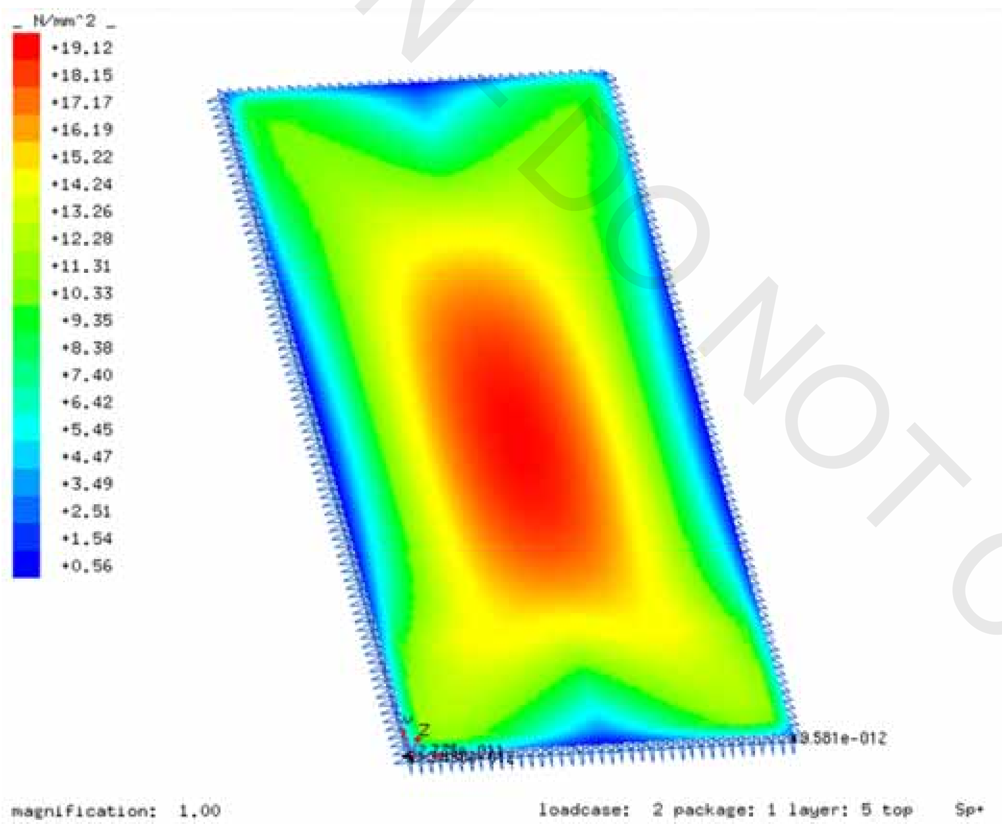
LF	EG	Wind	Schnee	Linie	Punkt		Klima	Schub	Nachweis
1	0.00	1.65	0.00	0.00	0.00	0.00	0.00	1.00	GZT
2	0.00	1.65	0.00	1.05	0.00	0.00	0.00	0.65	GZT
3	0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.04	GZT
4	0.00	1.30	0.00	0.00	0.00	0.00	0.00	1.00	GZT
5	0.00	1.30	0.00	1.05	0.00	0.00	0.00	0.65	GZT
6	0.00	1.65	0.00	0.00	0.00	0.00	0.00	1.00	GZG

7.1.4. Calculated Stresses and Deformations

Pos.1.1.a

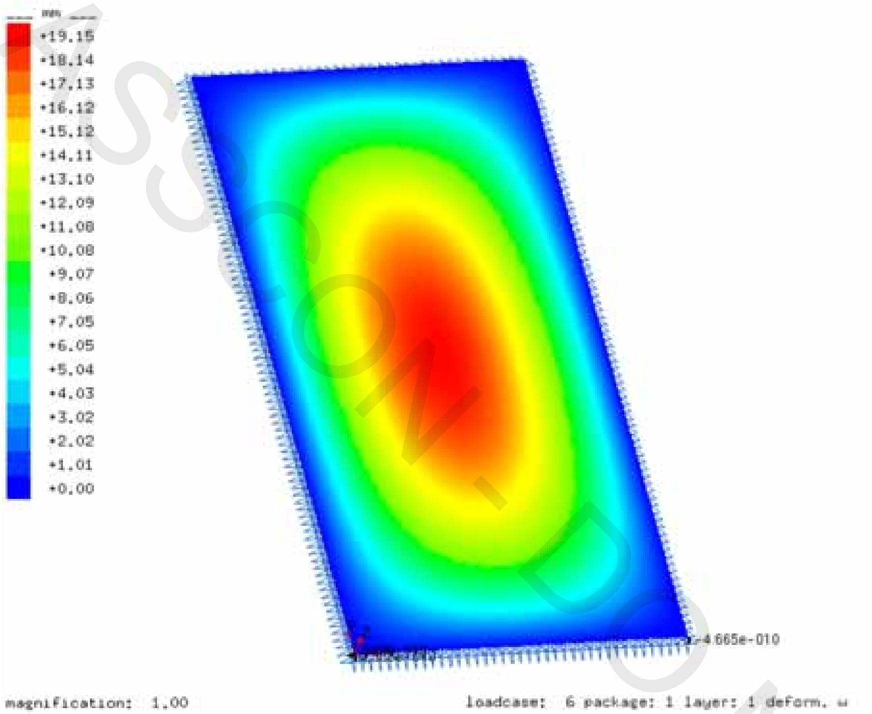
Stress

	Paket	Schicht	Seite	Bereich	Lastfall	σ
✔	1	5	(oben)	Feld	2	19.12
✔			(unten)	Feld	2	7.51
✔	1	3	(oben)	Feld	2	5.90
✔			(unten)	Feld	2	3.59
✔	1	1	(oben)	Feld	2	3.64
✔			(unten)	Feld	2	10.28



Deformation

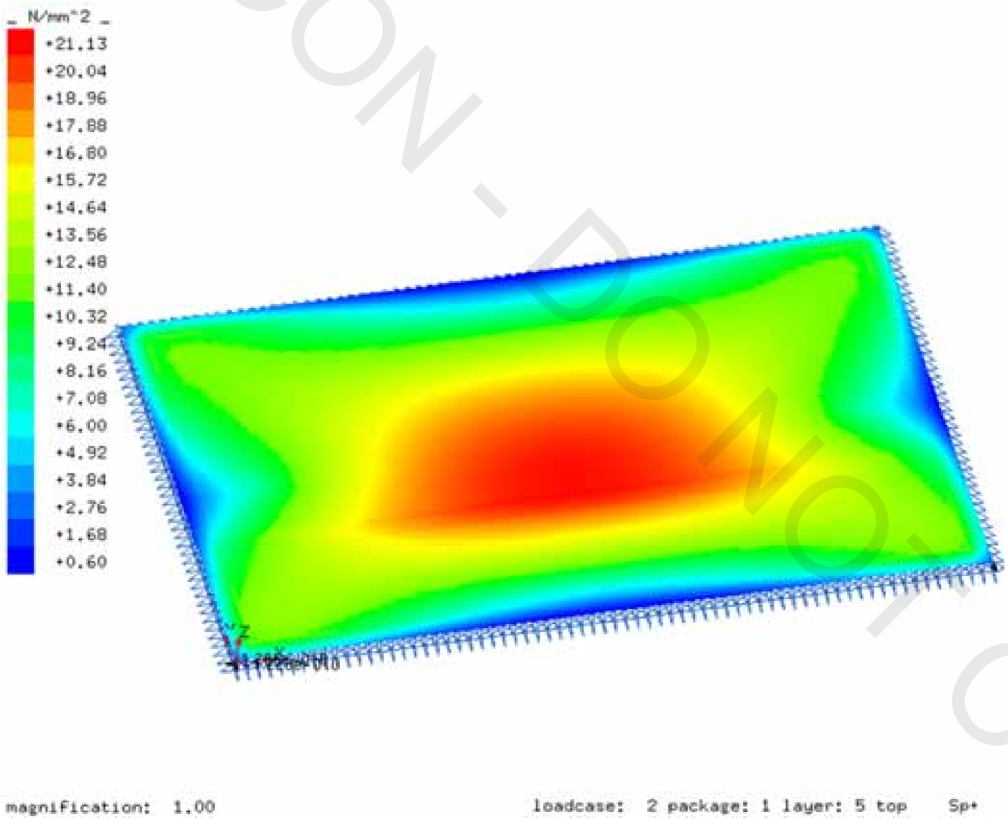
Paket	Lastfall		x	y	mm
1	6	(max)	1781.00	3600.00	19.15
	6	(min)	0.00	0.00	0.00



Pos.1.1.b

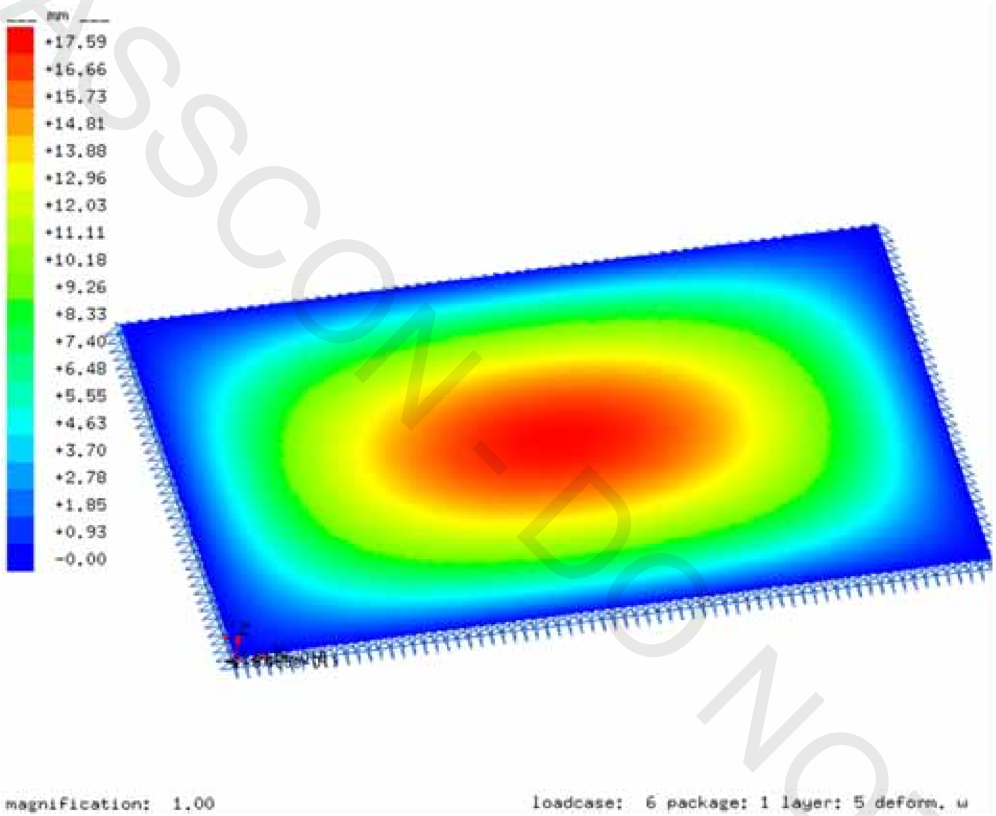
Stress

Paket	Schicht	Seite	Bereich	Lastfall	σ
✔ 1	5	(oben)	Feld	2	21.12
✔		(unten)	Feld	2	8.44
✔ 1	3	(oben)	Feld	2	6.88
✔		(unten)	Feld	2	3.73
✔ 1	1	(oben)	Feld	2	3.79
✔		(unten)	Feld	2	10.66



Deformation

Paket	Lastfall		x	y	mm
1	6	(max)	3111.00	1800.00	17.59
	6	(min)	0.00	0.00	0.00



7.1.5. Verification

The design resistance value for heat strengthened glass is calculated as follows:

R_d = $k_c \times f_k / \gamma_M$ (c.f. [3])

k_c : 1.0 (c.f.. [4])

f_k : 70 N/mm²

γ_M : 1.5

R_d = (1.0 x 70 N/mm² / 1.5) = 46.66 N/mm²

Pos. 1.1.a

Stress

Paket	Schicht	Seite	Bereich	Lastfall	σ	σ_grenz	%	OK/NO
1	5	(oben)	Feld	2	19.12	46.67	40.98	✔
		(unten)	Feld	2	7.51	46.67	16.09	✔
1	3	(oben)	Feld	2	5.90	46.67	12.64	✔
		(unten)	Feld	2	3.59	46.67	7.69	✔
1	1	(oben)	Feld	2	3.64	46.67	7.81	✔
		(unten)	Feld	2	10.28	46.67	22.03	✔

Deformation

Paket	Lastfall		x	y	mm	%	OK/NOK
1	6	(max)	1781.00	3600.00	19.15	76.59	✔
	6	(min)	0.00	0.00	0.00	0.00	✔

Pos. 1.1.b

Stress

Paket	Schicht	Seite	Bereich	Lastfall	σ	σ_grenz	%	OK/NO
1	5	(oben)	Feld	2	21.12	46.67	45.27	✔
		(unten)	Feld	2	8.44	46.67	18.08	✔
1	3	(oben)	Feld	2	6.88	46.67	14.74	✔
		(unten)	Feld	2	3.73	46.67	7.99	✔
1	1	(oben)	Feld	2	3.79	46.67	8.13	✔
		(unten)	Feld	2	10.66	46.67	22.85	✔

Deformation

Paket	Lastfall		x	y	mm	%	OK/NOK
1	6	(max)	3111.00	1800.00	17.59	70.34	✔
	6	(min)	0.00	0.00	0.00	0.00	✔

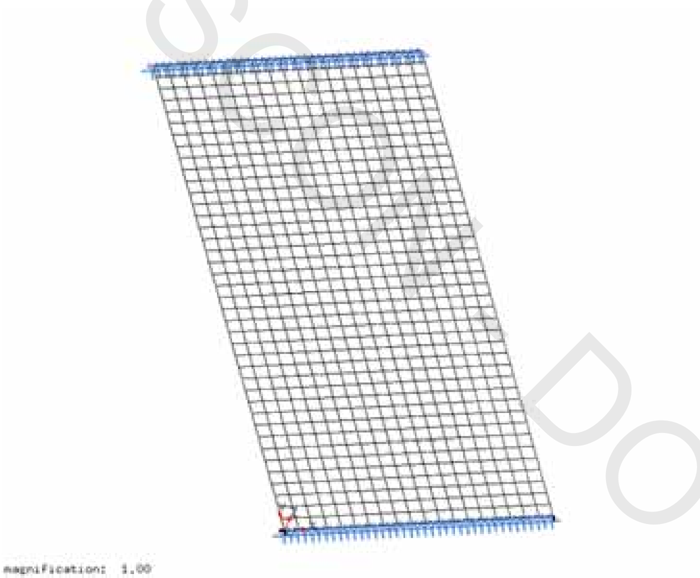
7.1.6. Verification – Failure scenario

Bezeichnung		außen/oben	innen/unten	
w(1)	= Wind	0.600	0.000	[kN/m²]
q(1)	= Linienlasten		1.00	[kN/m]

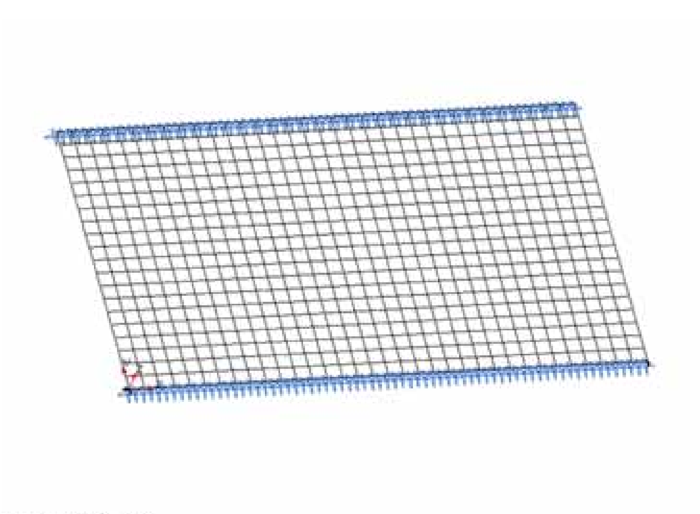
LF	Beschreibung
1	Wind Suction

LF	EG	Wind	Schnee	Linie	Punkt		Klima	Schub	Nachweis
1	0.00	1.65	0.00	0.00	0.00	0.00	0.00	1.00	GZT

Finite element mesh of Pos. 1a (failure scenario):



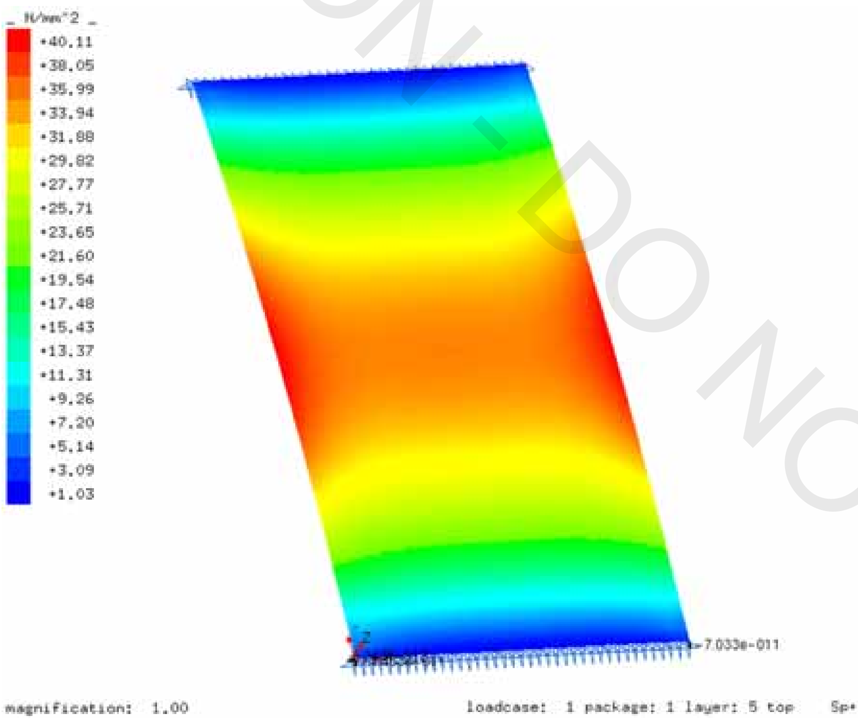
Finite element mesh of Pos. 1b (failure scenario):



Pos. 1.1.a

Stress

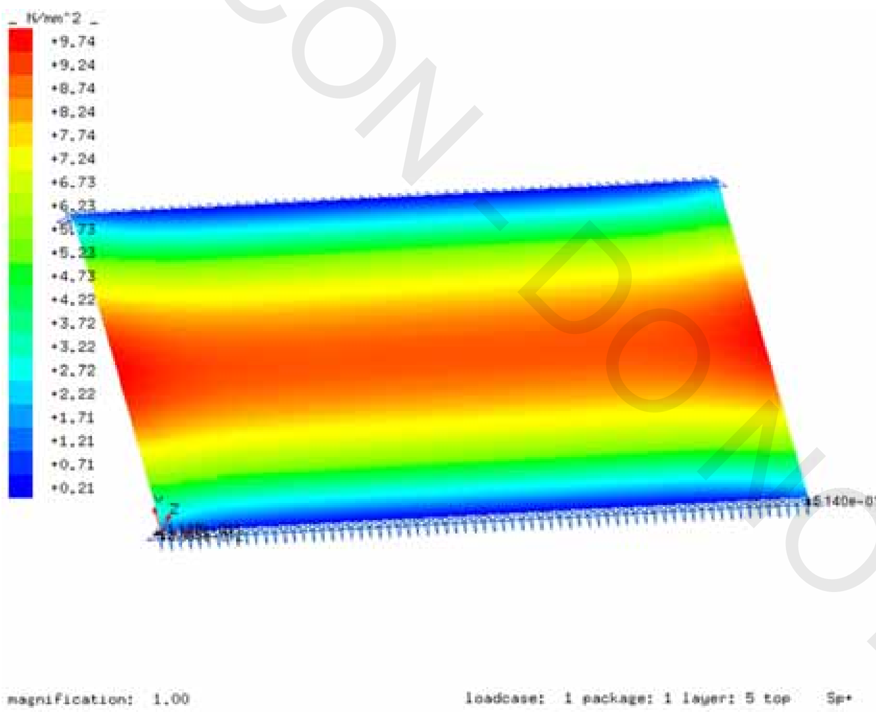
Paket	Schicht	Seite	Bereich	Lastfall	σ	σ_grenz	%	OK/NO
1	5	(oben)	Feld	1	40.11	46.67	85.95	✔
		(unten)	Feld	1	18.70	46.67	40.07	✔
1	3	(oben)	Feld	1	15.50	46.67	33.21	✔
		(unten)	Feld	1	1.27	46.67	2.72	✔
1	1	(oben)	Feld	1	1.32	46.67	2.83	✔
		(unten)	Feld	1	1.81	46.67	3.88	✔



Pos. 1.1.b

Stress

Paket	Schicht	Seite	Bereich	Lastfall	σ	σ_grenz	%	OK/NO
1	5	(oben)	Feld	1	9.75	46.67	20.88	✔
		(unten)	Feld	1	3.89	46.67	8.33	✔
1	3	(oben)	Feld	1	3.12	46.67	6.68	✔
		(unten)	Feld	1	0.49	46.67	1.05	✔
1	1	(oben)	Feld	1	0.39	46.67	0.84	✔
		(unten)	Feld	1	0.72	46.67	1.53	✔



- Design measures (cf. Section 10.5) effectively prevent the influence of vertical slab deformations from liveload (as well as further creeping). Therefore no vertical deformation from liveload is considered.
- The slab inter-story drift is neglectable. Therefore no horizontal deformation (induced by the concrete slabs) is considered.
- The material compatibility between the SSG silicones and the various adjacent materials has been successfully confirmed by the SSG manufacturer.

If one of the above mentioned assumptions does not apply, this static calculation is not valid.

8.4. Design Strength of the SSG joint

8.4.1. General

According to the European Technical Approvals [9, 10] and ETAG-002 [6] the following design values are used for dynamic loading:

Sikasil SG-550:

Design stress in tension $\sigma_{des} = 0.20$ N mm^{-2}

Design stress in shear $\tau_{des} = 0.13$ N mm^{-2}

Sikasil SG-20:

Design stress in tension $\sigma_{des} = 0.17$ N mm^{-2}

Design stress in shear $\tau_{des} = 0.12$ N mm^{-2}

In ETAG 002 [6] a simplified method to design the structural glazing silicone is presented. The stress in the joint is calculated by the approach force (distributed load on the glass panes) divided by the silicone surface. In contrast to the simplified approach (engineering stresses) according to ETAG-002 [6] the numerically estimated stress distributions shows local stress concentrations, since the true stresses are calculated. The local stress distributions depend significantly on the refinement of the finite element mesh: the finer the mesh, the higher the stress concentration. A general design concept of structural sealant glazing silicone for numerical calculations is currently not available.

Appropriate design values for the numerical approach are derived by numerical calculations of the tensile test and shear test according to ETAG 002 [6]. For this purpose, the test geometry was modelled with several mesh refinements (element size). The loading was defined according to the design values of the Sikasil SG-550 and Sikasil SG-20. Based on these results the equivalent tensile stresses (von Misses; σ_v) and max. principal tensile stresses (σ_1) were plotted against the element size. To estimate the design values the ratio σ_{true} / $\sigma_{engineering}$ is considered. This ratio is used as factor for increasing the design stresses according to the European Technical Approvals [9, 10]. The mesh refinement for the actual calculation of the stress distributions of the silicone joints at the façade elements was then chosen identically for relevant sections.

8.4.2. Finite Element Calculation of Tensile Tests According to ETAG-002

In Figure 1 the schematic geometry of the specimens of the tensile and shear test according to ETAG 002 [6] is shown. The following dimensions according to [6] were used in the numerical calculation:

b	=	12 mm
e	=	12 mm
l	=	50 mm
w	=	50 mm

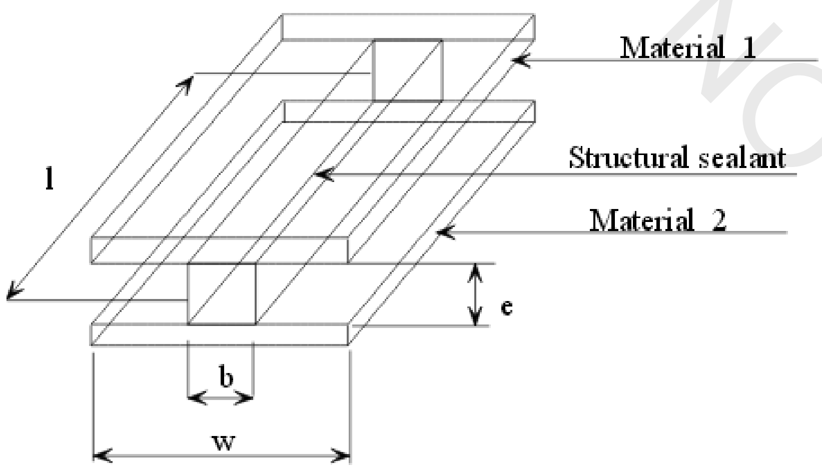


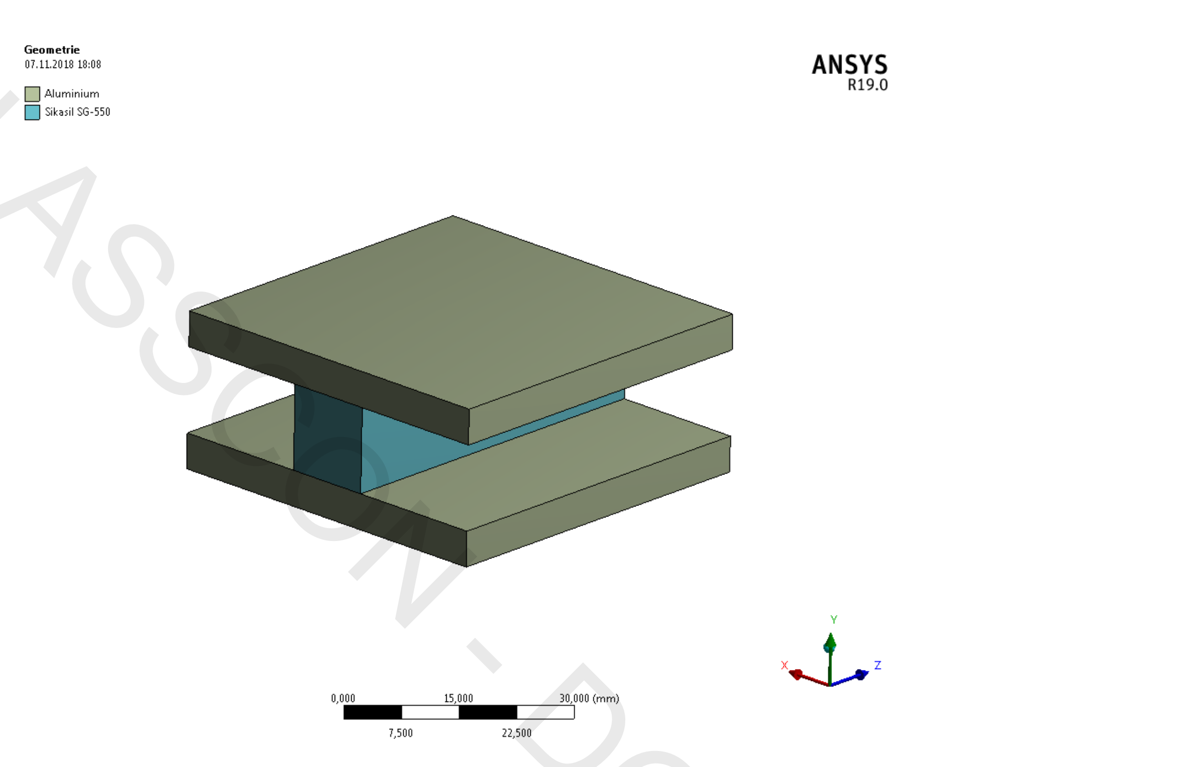
Figure 1 Specimen geometry of the tensile and shear test according to ETAG-002 **[6]**

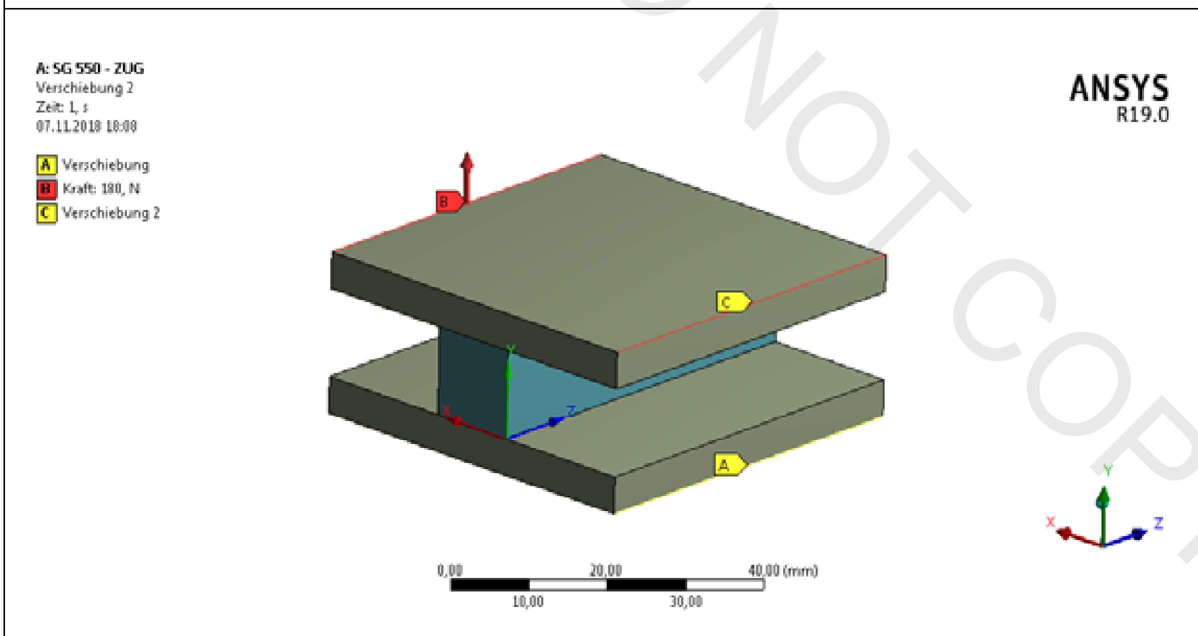
The finite element model used for the calculation, the support and an example of the meshing is shown in the figures in the following table. The following assumptions were made for the numerical calculation in Ansys [11]:

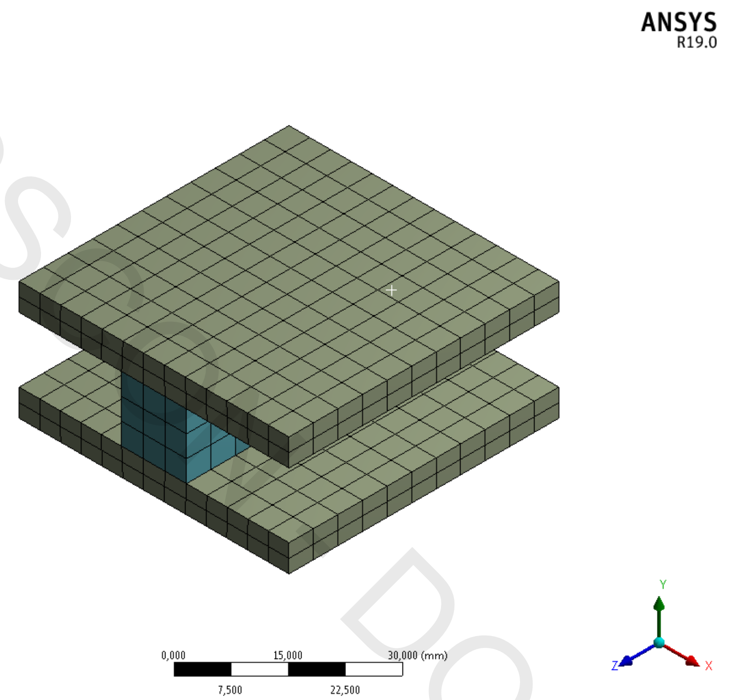
- Volume elements Solid 186 were used for all components, SOLID186 is a higher order 3-D 20-node solid element that exhibits quadratic displacement behavior
- For the relevant SSG joint only brick volume elements with an aspect ratio close to 1 were used
- Hyperelastic material parameters according to section 4
- Bonded contact between SSG joint and support plates
- Dimensions according to Figure 1
- The meshing size was varied between 1.0 mm and 12.0 mm
- For the tensile test the edges of the lower plate were fixed in vertical direction and a tensile load $F_{tension}$ was applied to the edges of the upper plate
- The tensile load $F_{tension}$ corresponds to the design strength values of the chosen materials. According to the specifications by Sika [5] the global safety factor of $g_G = 6$ given by ETAG 002 could be reduced to $g_G = 4$, if the stresses are derived by accurate Finite Element calculations.

$F_{tension,SG\text{-}550}$ = 0.20 N/mm^2 x 50 mm x 12 mm x 6 / 4 = 180.0 N

$F_{tension,SG\text{-}20}$ = 0.17 N/mm^2 x 50 mm x 12 mm x 6 / 4 = 153.0 N

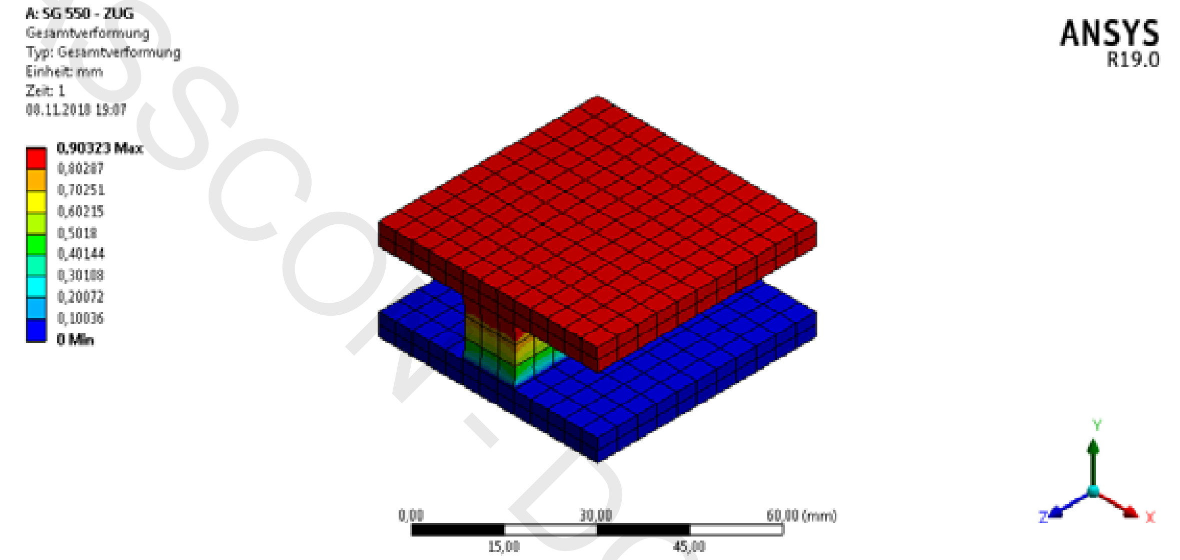
Isometry


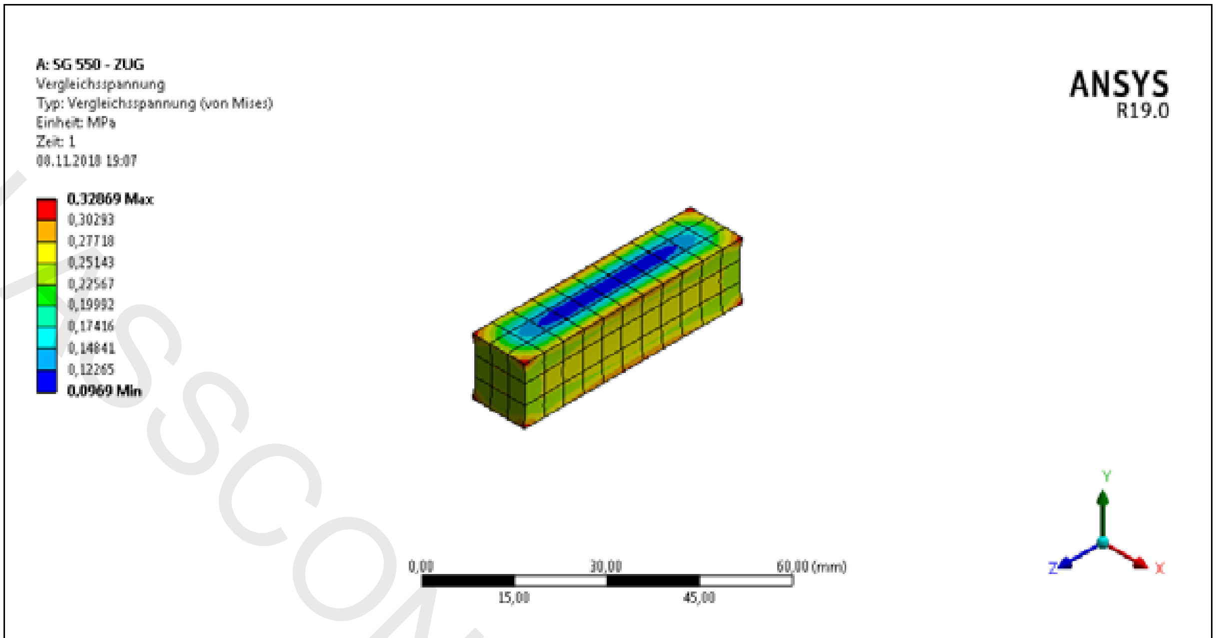
Support and Loading


Example of Meshing (element size of 4 mm)


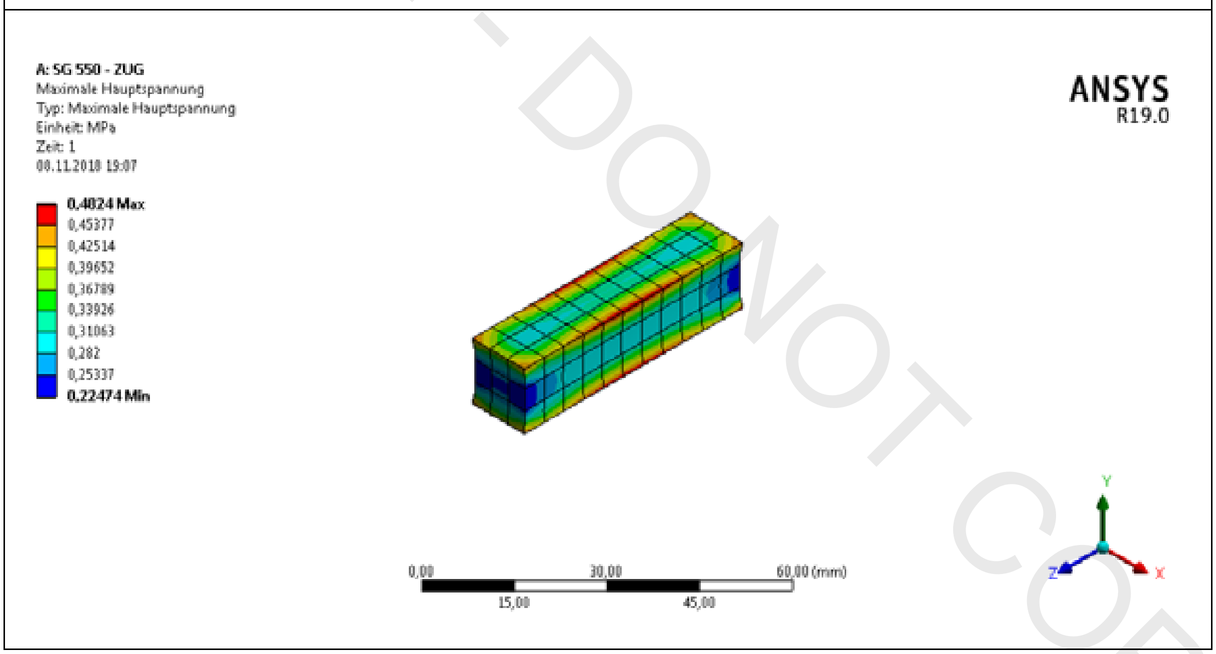
8.4.3. Resulting Design Values

The results of the numerical calculation (deformation, equivalent tensile stress (von Mises)) were shown exemplary for both materials Sikasil SG-550 and Sikasil SG-20 in the following figures.

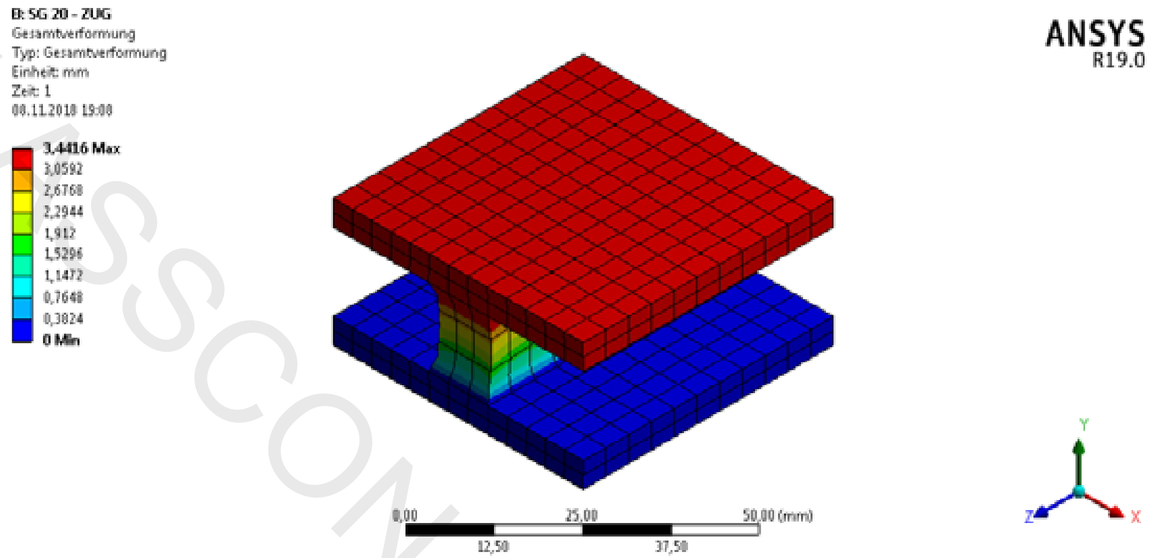
Sikasil SG-550 – Total deformation [mm]

Sikasil SG-550 – Equivalent tensile stress (von Misses) [MPa]



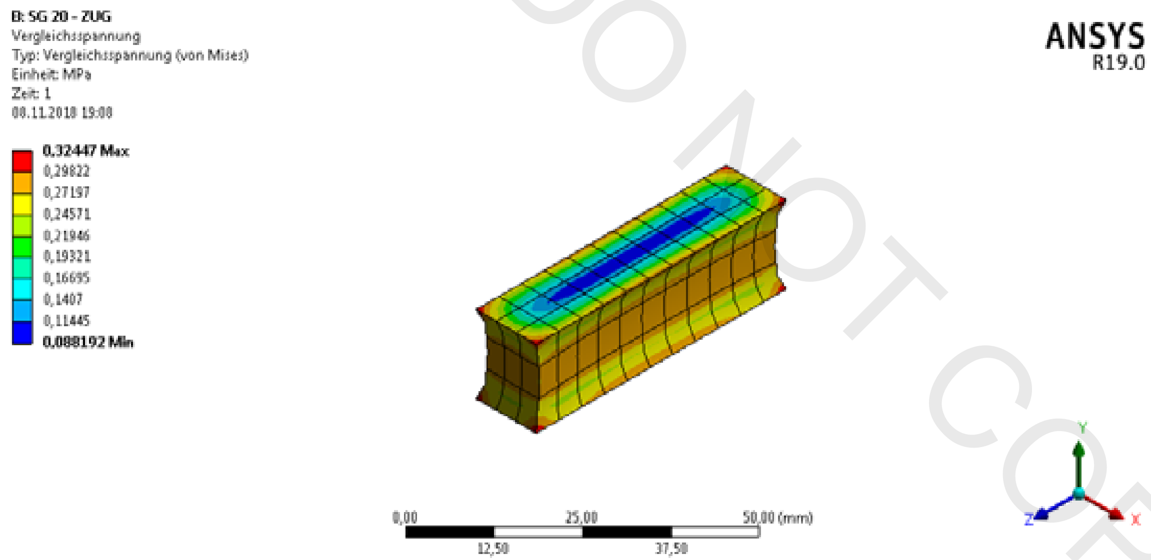
Sikasil SG-550 – max. principal tensile stress [MPa]



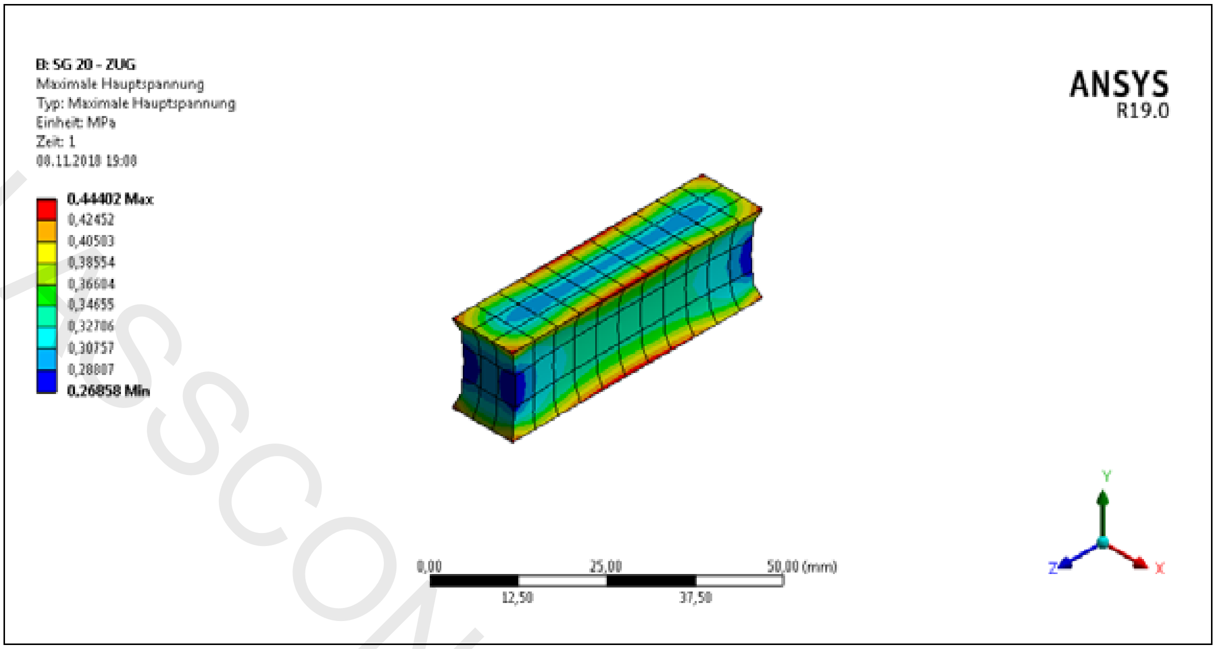
Sikasil SG-20 – Total deformation [mm]

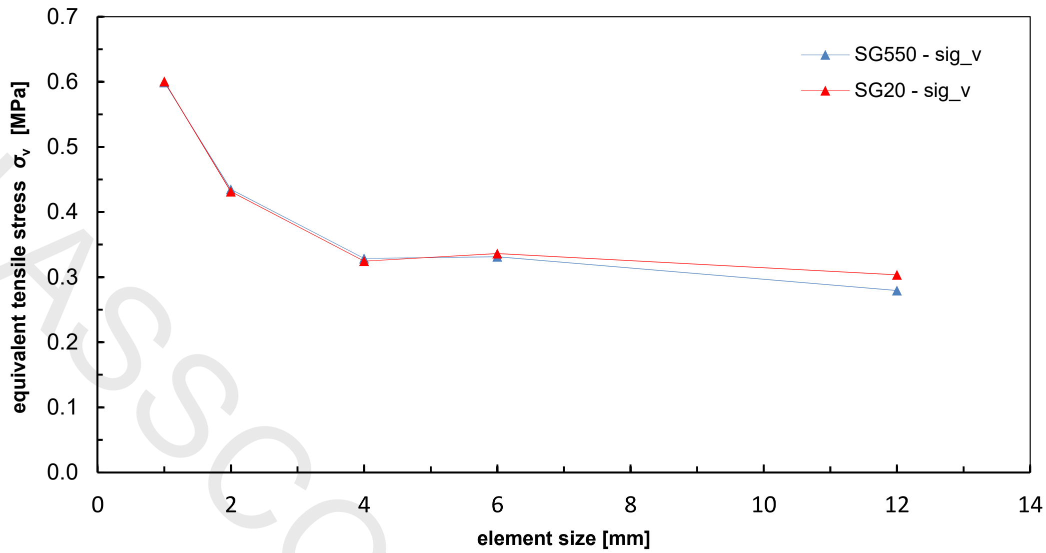


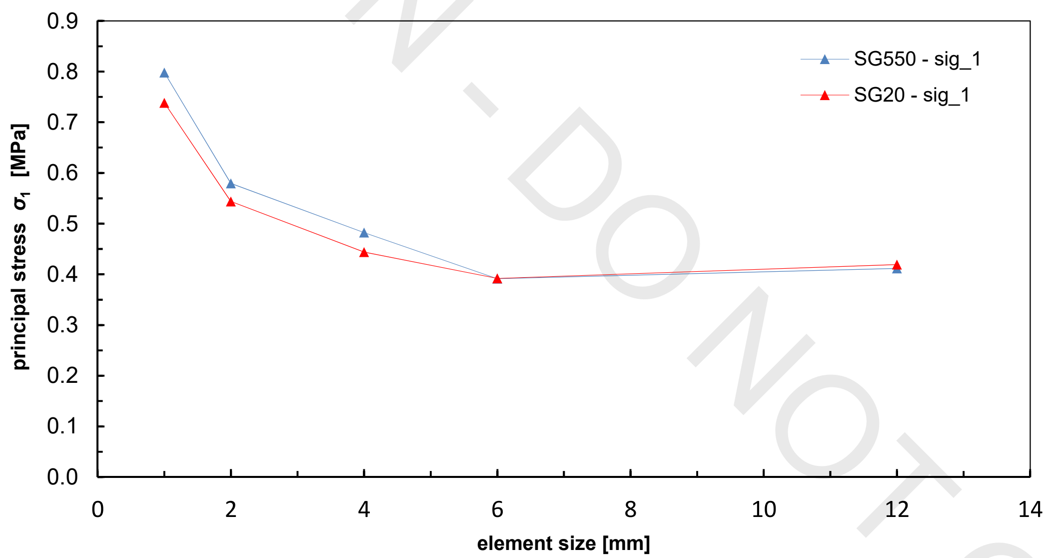
Sikasil SG-20 – Equivalent tensile stress (von Misses) [MPa]



Sikasil SG-20 – max. principal tensile stress [MPa]


B: SG 20 - ZUG
Maximale Hauptspannung
Typ: Maximale Hauptspannung
Einheit: MPa
Zeit: 1
08.11.2018 19:08
0,44402 Max
0,42452
0,40503
0,38554
0,36604
0,34655
0,32706
0,30757
0,28807
0,26858 Min
ANSYS
R19.0
0,00
25,00
50,00 (mm)
12,50
37,50
Y
Z
X





The equivalent tensile stresses and max. principal tensile stresses derived in the numerical calculations (true stresses) of the tests according to ETAG-002 [6] were plotted against the associated element size. It could be seen that for an element size less than 4 mm the resulting stress increases significantly. Accordingly a mesh size of 5 mm was chosen to be appropriate for the numerical calculations of the local stress distributions within the sealants of the façade elements. Therefore, the design values were adjusted to the correspondent equivalent tensile stress and principal tensile stress values.

As a conservative approach, the resulting silicone stresses within the complex façade simulation, calculated with a mesh size of 5 mm, were compared to design stresses estimated with a mesh size of 6 mm. If resulting stresses exceeds the allowable design stresses, a recalculation of the corresponding loadcase (LC) or loadcase combination (LCC) was performed with a local mesh refinement of 2 mm, where the resulting stresses were compared with the corresponding design stresses.

This results in the following design stress values for dynamic loading:

Sikasil SG-550:

	mesh size: 6 mm	mesh size: 2 mm
$\sigma_{v,des,SG\text{-}550}$	0,331	0,435
$\sigma_{1,des,SG\text{-}550}$	0,391	0,579

Sikasil SG-20:

	mesh size: 6 mm	mesh size: 2 mm
$\sigma_{v,des,SG\text{-}20}$	0,336	0,431
$\sigma_{1,des,SG\text{-}20}$	0,392	0,544

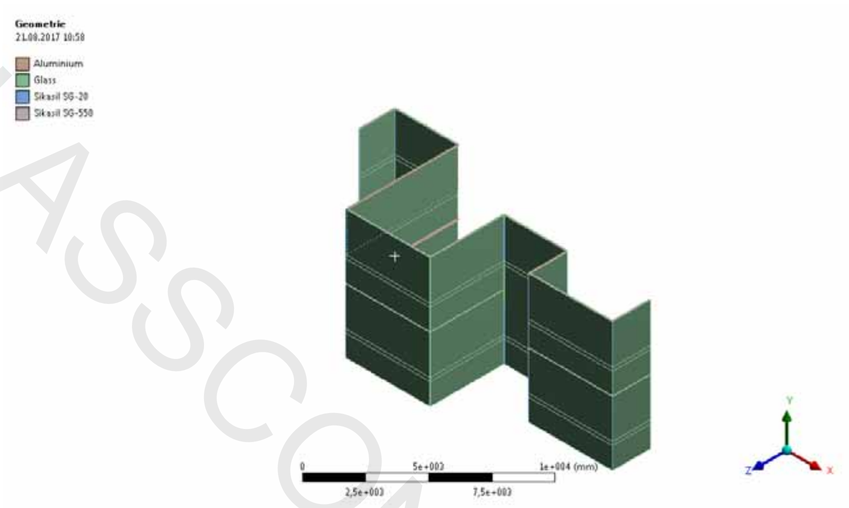
8.5. 3D Finite Element Calculation

8.5.1. Finite Element Model

The finite element model used for the calculation, the support and the meshing is given in the figures in the following table. The following assumptions were made for the numerical calculation in Ansys [11]:

- Two storey of the façade (glass, SSG joints, aluminium profiles) were modelled with dimensions according to [12]
- For the aluminium profiles a rectangular cross-section with equivalent bending stiffness was used
- Volume elements Solid 186 were used for all components, SOLID186 is a higher order 3-D 20-node solid element that exhibits quadratic displacement behaviour
- For the relevant SSG joints only brick volume elements with an aspect ratio close to 1 and a meshing size of 5 mm were used
- Hyperelastic material parameters for the SSG joints according to section 4
- Bonded contact between SSG joint and glass and between SSG joint and aluminium

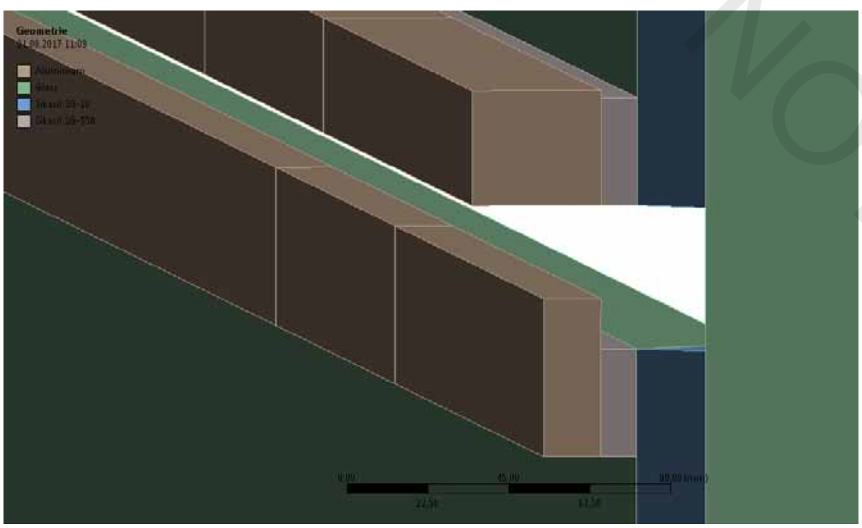
Isometry

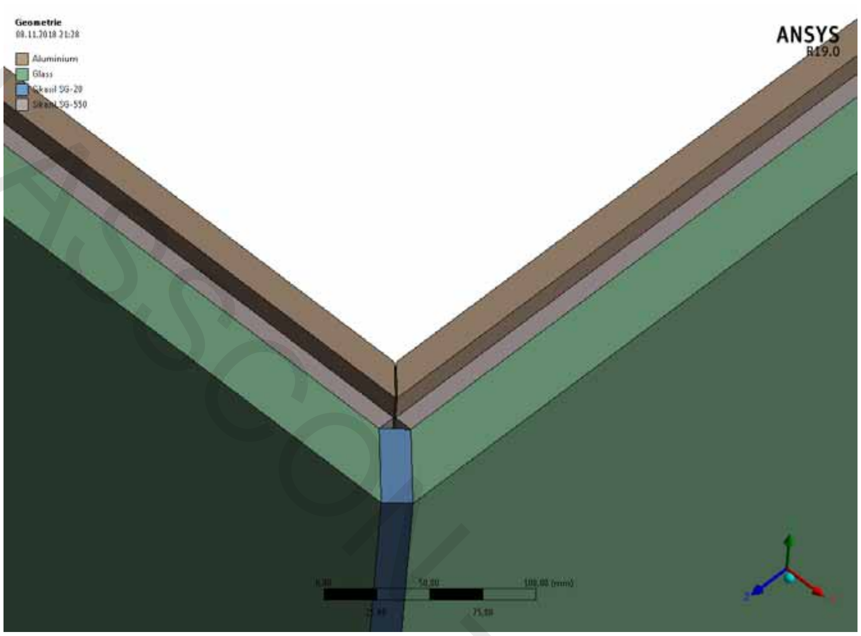
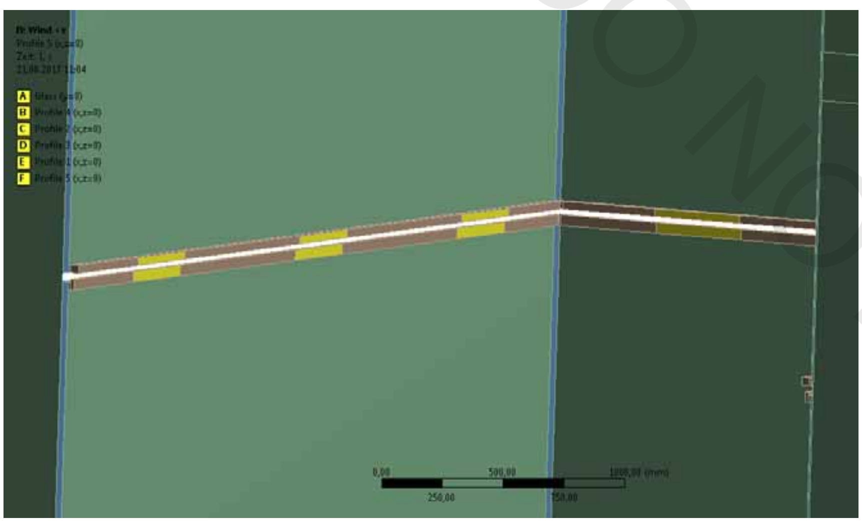


Detail horizontal SSG joints and idealized aluminium profiles

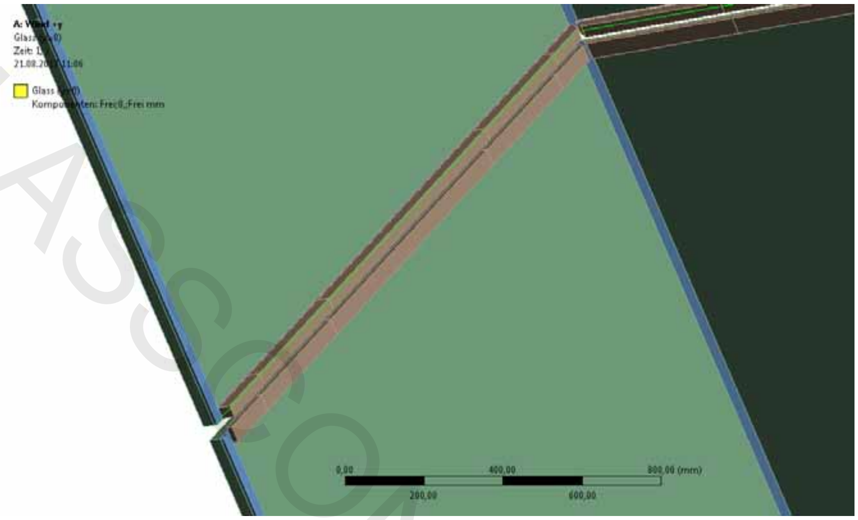
Upper aluminium profile:			Equivalent rectangular cross-section:		
I_1	=	111.94 cm^4	h	=	4.4 cm
I_2	=	14.08 cm^4	b	=	1.6 cm

Lower aluminium profile:			Equivalent rectangular cross-section:		
I_1	=	84.80 cm^4	h	=	3.2 cm
I_2	=	114.37 cm^4	b	=	3.6 cm

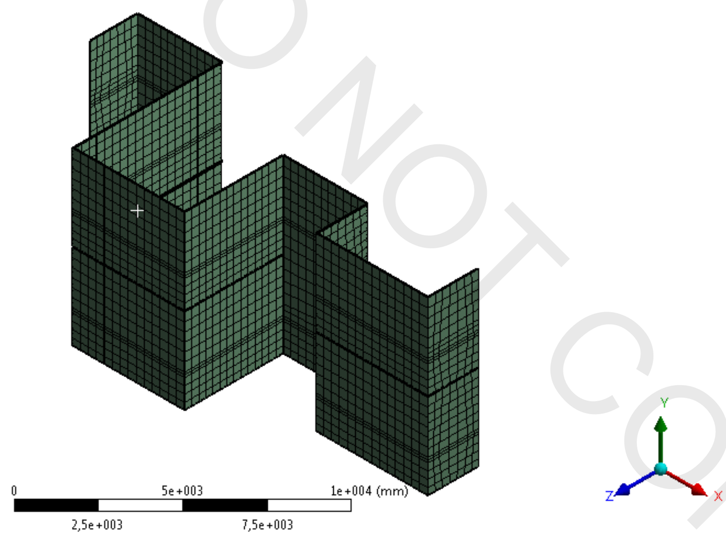


Detail vertical SSG joints

Support of the aluminium profiles (horizontal fixed in the area of the mounting brackets [x, z = 0])


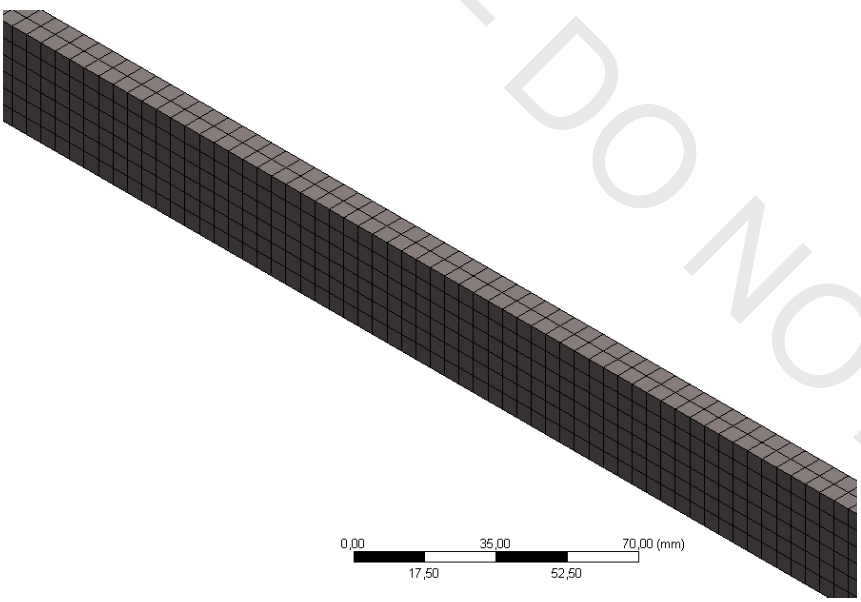
Support of the glass panes (vertical supported at the lower glass edge [y = 0])



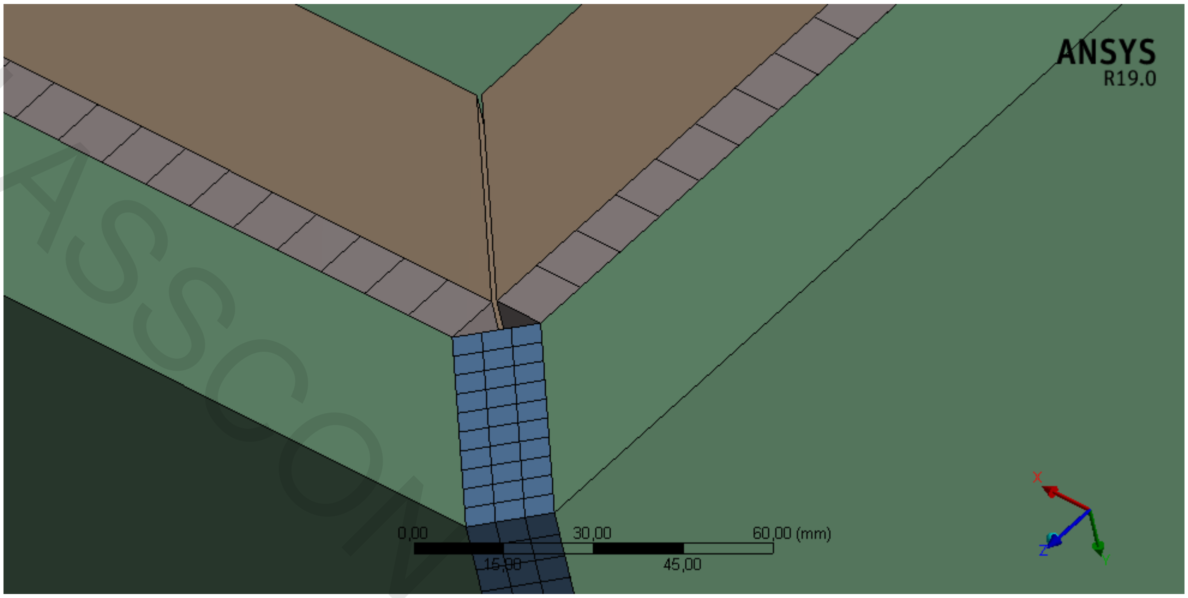
Meshing of the global model



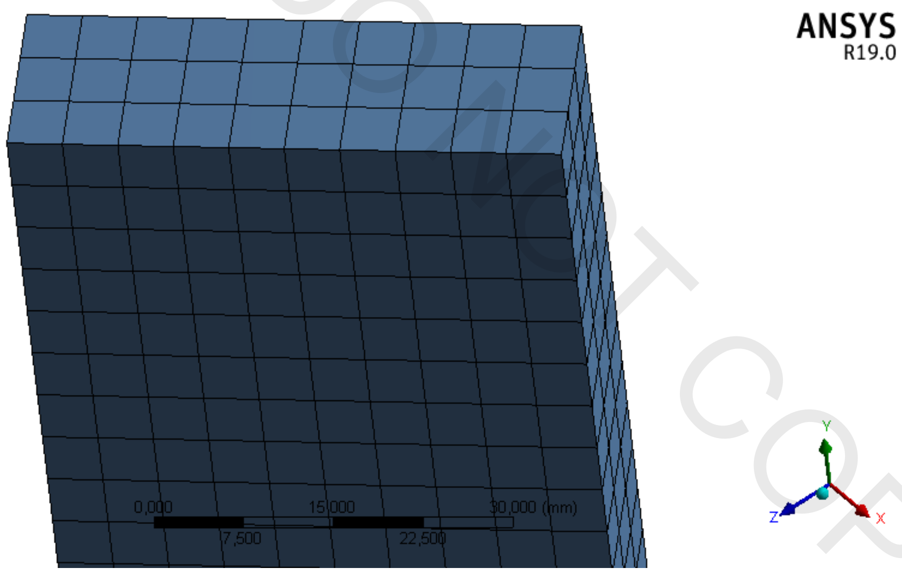
Local meshing of the horizontal SSG joint (element size of 5 mm)

Local meshing of the horizontal SSG joint (element size of 5 mm)


Local meshing of the vertical SSG joint (element size of 5 mm)

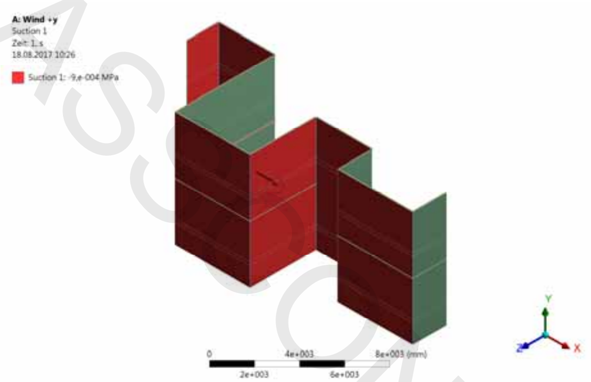
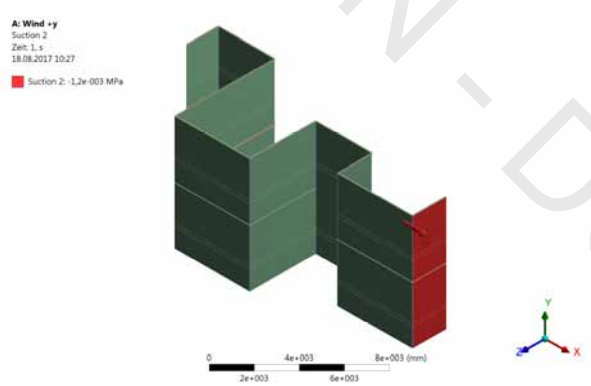


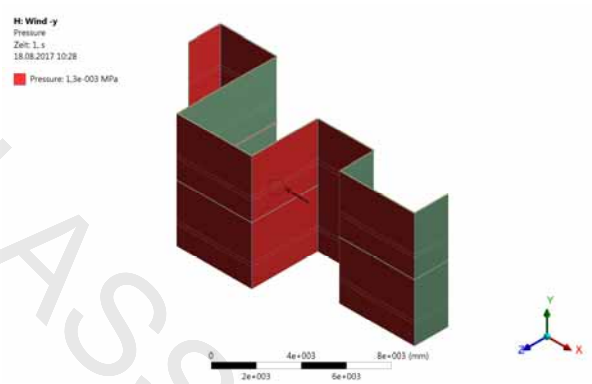
Local meshing of the vertical SSG joint (element size of 5 mm)

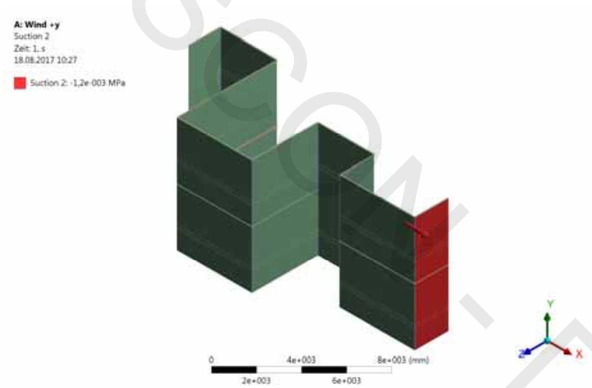


8.5.2. Load Cases (LC)

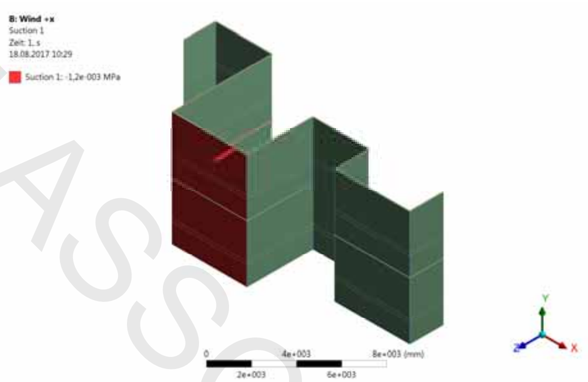
The loads according to section 6 were applied to the 3D Finite Element model:

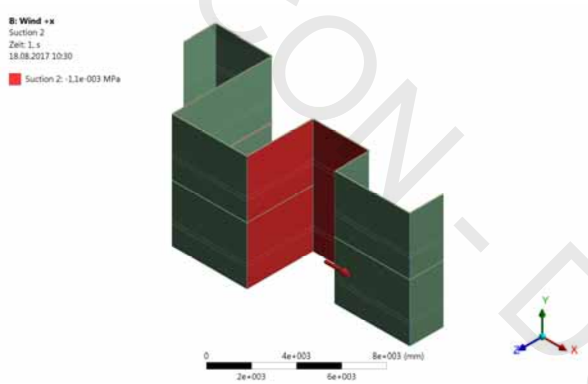
LC1: Wind +Y
 
LC2: Wind -Y

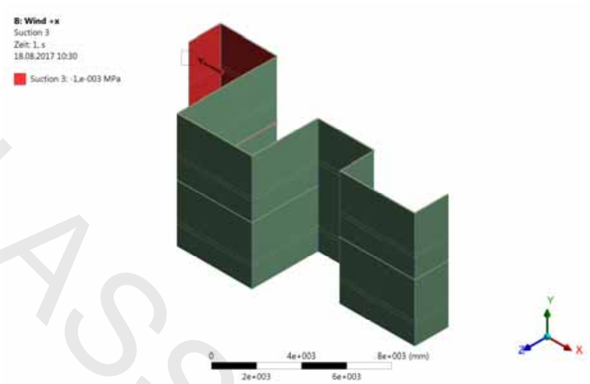

H: Wind -y
Pressure
Zeit: 1, s
18.08.2017 10:28
Pressure: 1,3e-003 MPa
0
4e+003
8e+003 (mm)
2e+003
6e+003
Y
Z
X

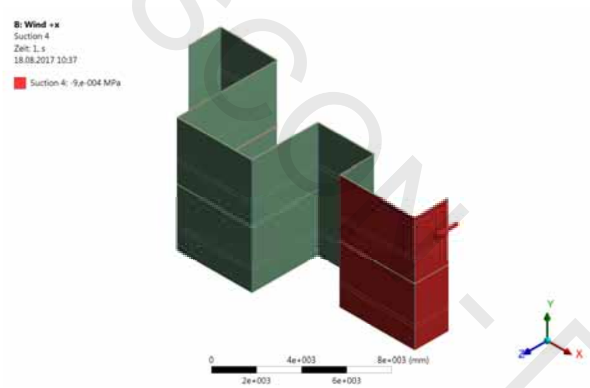

A: Wind +y
Suction 2
Zeit: 1, s
18.08.2017 10:27
Suction 2: -1,2e-003 MPa
0
4e+003
8e+003 (mm)
2e+003
6e+003
Y
Z
X

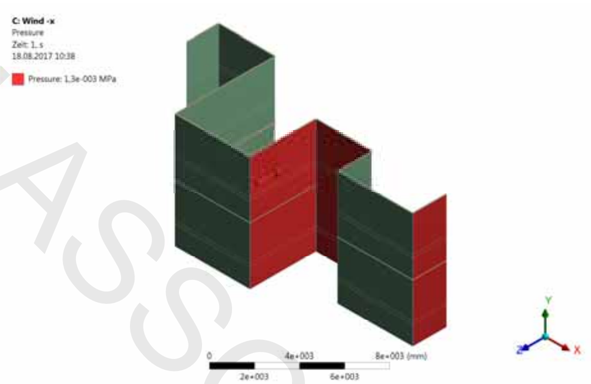
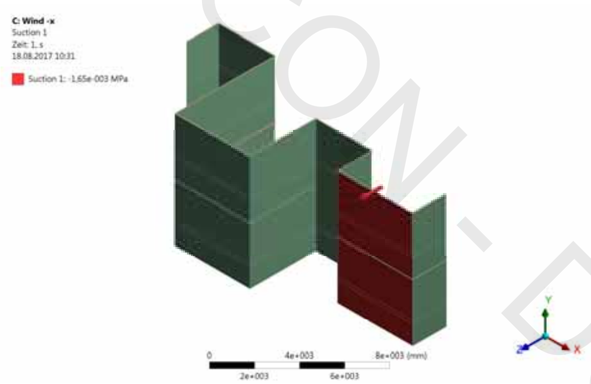
LC3: Wind +X

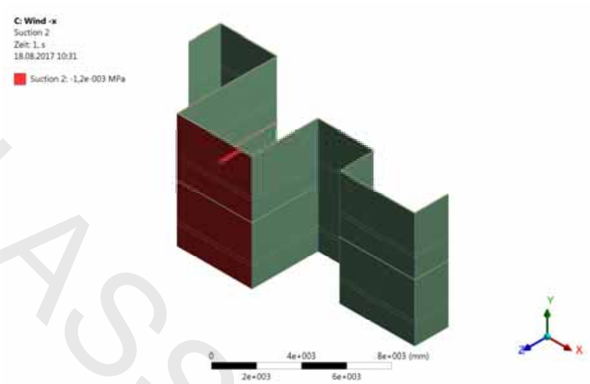

B: Wind +x
Suction 1
Zeit: 1, s
18.08.2017 10:29
Suction 1: -1,2e-003 MPa
0
4e+003
8e+003 (mm)
2e+003
6e+003
Y
Z
X

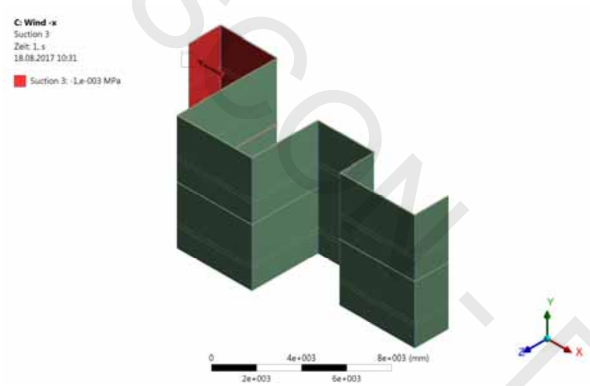

B: Wind +x
Suction 2
Zeit: 1, s
18.08.2017 10:30
Suction 2: -1,1e-003 MPa
0
4e+003
8e+003 (mm)
2e+003
6e+003
Y
Z
X

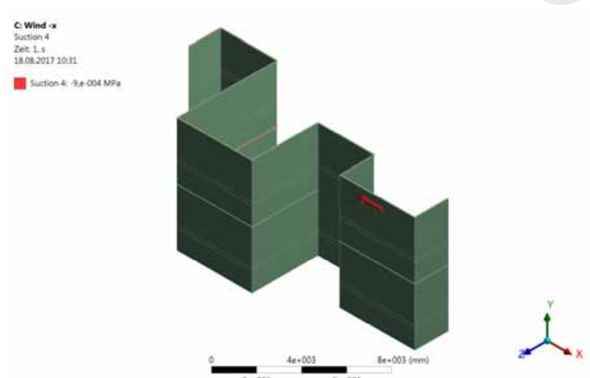

B: Wind +x
Suction 3
Zeit: 1, s
18.08.2017 10:30
Suction 3: -1,e-003 MPa
0
4e+003
8e+003 (mm)
2e+003
6e+003
Y
Z
X

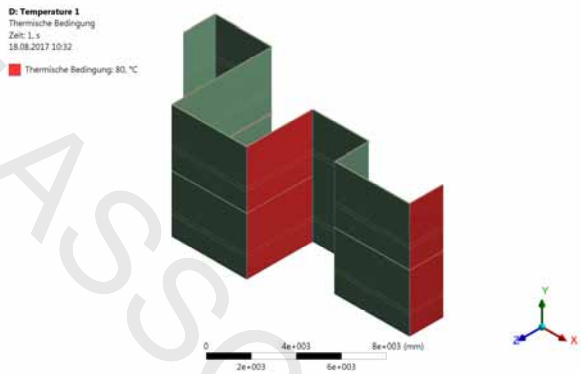
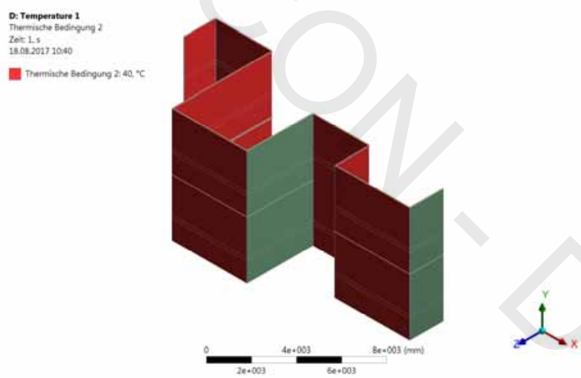

B: Wind +x
Suction 4
Zeit: 1, s
18.08.2017 10:37
Suction 4: -9,e-004 MPa
0
4e+003
8e+003 (mm)
2e+003
6e+003
Y
Z
X

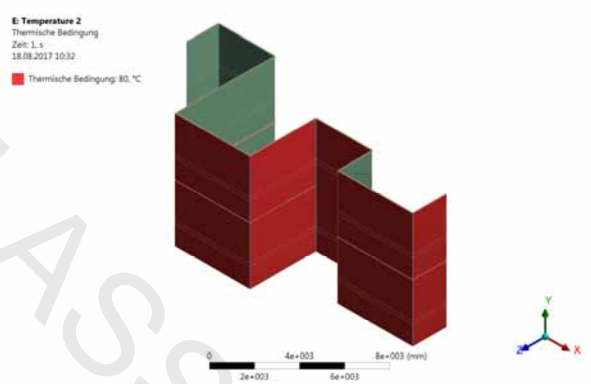
LC4: Wind –X
 C: Wind -x Pressure Zeit: 1, s 18.08.2017 10:38 Pressure: 1,3e-003 MPa 0 4e+003 8e+003 (mm) 2e+003 6e+003 Y Z X  C: Wind -x Suction 1 Zeit: 1, s 18.08.2017 10:31 Suction 1: -1,65e-003 MPa 0 4e+003 8e+003 (mm) 2e+003 6e+003 Y Z X

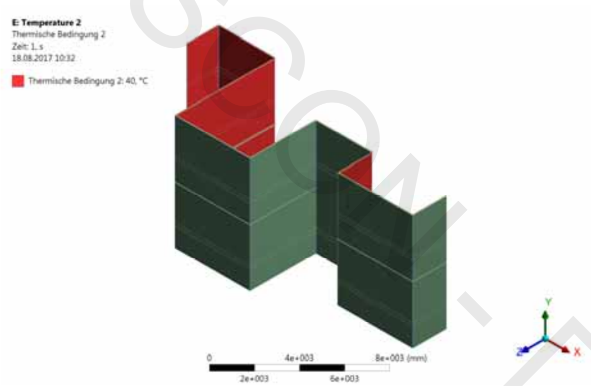

C: Wind -x
Suction 2
Zeit: 1, s
18.08.2017 10:31
Suction 2: -1,2e-003 MPa
0
4e+003
8e+003 (mm)
2e+003
6e+003
Y
Z
X


C: Wind -x
Suction 3
Zeit: 1, s
18.08.2017 10:31
Suction 3: -1,e-003 MPa
0
4e+003
8e+003 (mm)
2e+003
6e+003
Y
Z
X

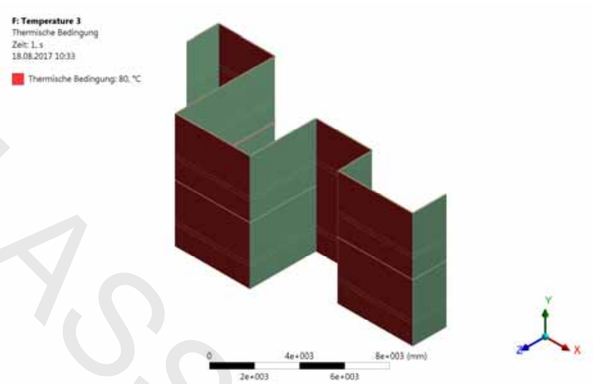

C: Wind -x
Suction 4
Zeit: 1, s
18.08.2017 10:31
Suction 4: -9,e-004 MPa
0
4e+003
8e+003 (mm)
2e+003
6e+003
Y
Z
X

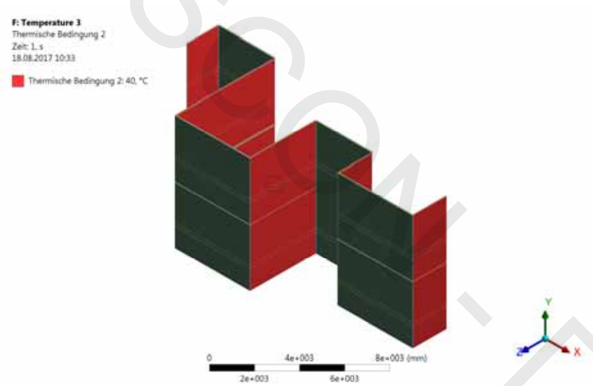
LC5: Temperature Scenario 1
 
LC6: Temperature Scenario 2

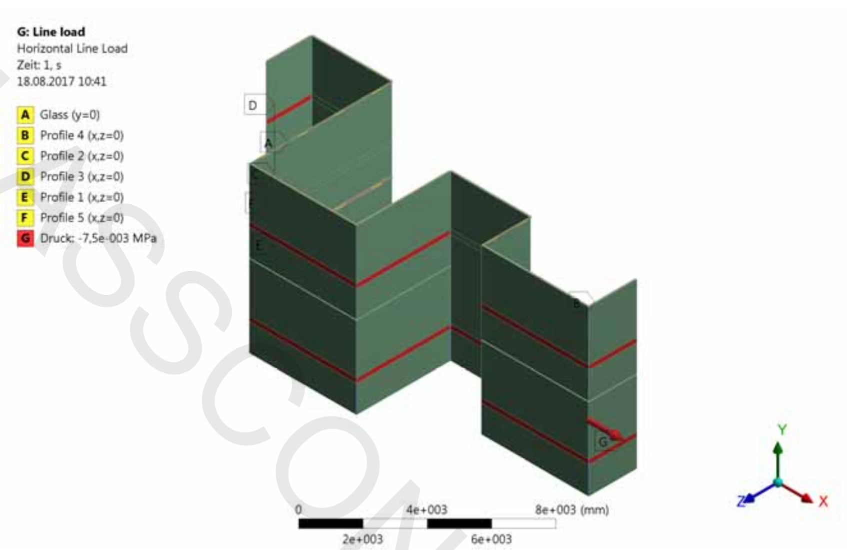




LC7: Temperature Scenario 3


F: Temperature 3
Thermische Bedingung
Zeit: 1. s
18.08.2017 10:33
Thermische Bedingung: 80. °C
0
4e+003
8e+003 (mm)
2e+003
6e+003
Y
Z
X


F: Temperature 3
Thermische Bedingung 2
Zeit: 1. s
18.08.2017 10:33
Thermische Bedingung 2: 40. °C
0
4e+003
8e+003 (mm)
2e+003
6e+003
Y
Z
X

LC8: Horizontal line load


8.5.3. Load Case Combinations (LCC)

In addition to the individual load cases, the following load case combinations (LCC) were analysed.

Load Case Combination (LCC)	Combination Factor							
	LC1	LC2	LC3	LC4	LC5	LC6	LC7	LC8
101	1.00	-	-	-	0.60	-	-	0.70
102	1.00	-	-	-	-	0.60	-	0.70
103	1.00	-	-	-	-	-	0.60	0.70
104	-	1.00	-	-	0.60	-	-	0.70
105	-	1.00	-	-	-	0.60	-	0.70
106	-	1.00	-	-	-	-	0.60	0.70
107	-	-	1.00	-	0.60	-	-	0.70
108	-	-	1.00	-	-	0.60	-	0.70
109	-	-	1.00	-	-	-	0.60	0.70
110	-	-	-	1.00	0.60	-	-	0.70
111	-	-	-	1.00	-	0.60	-	0.70
112	-	-	-	1.00	-	-	0.60	0.70

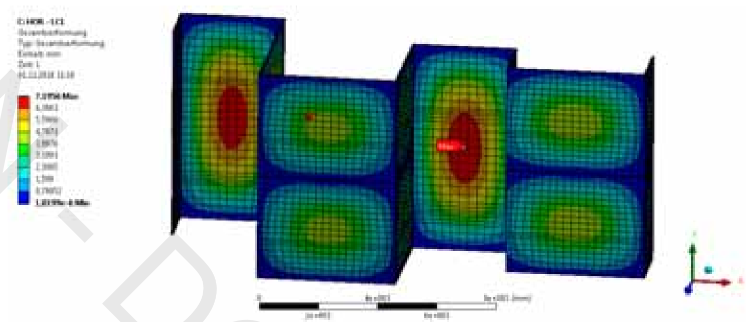
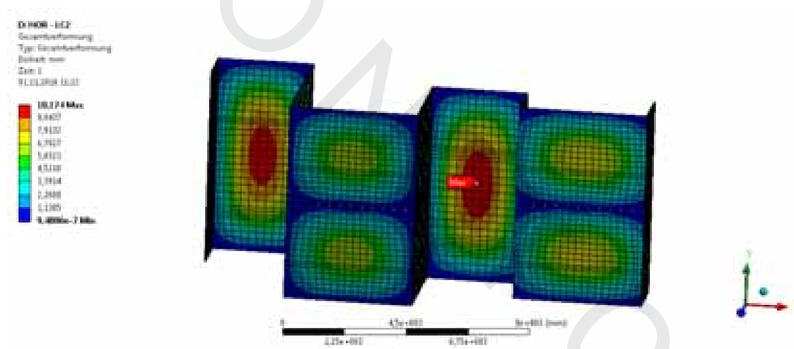
8.5.4. Results

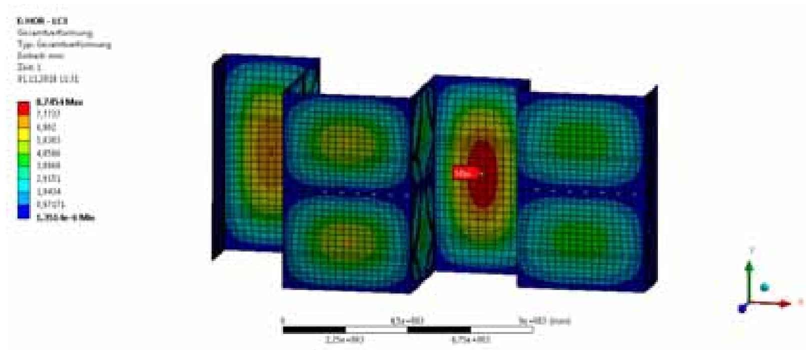
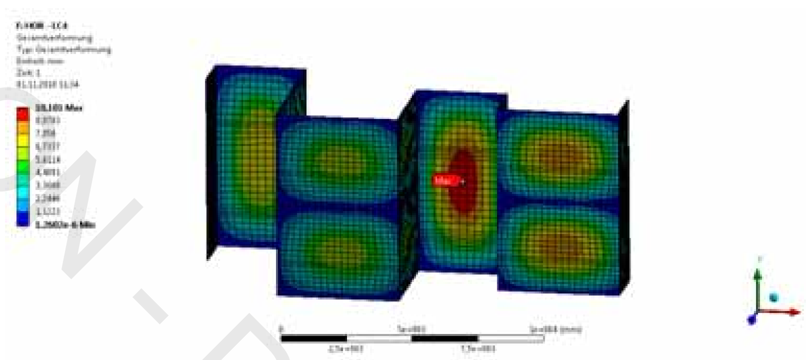
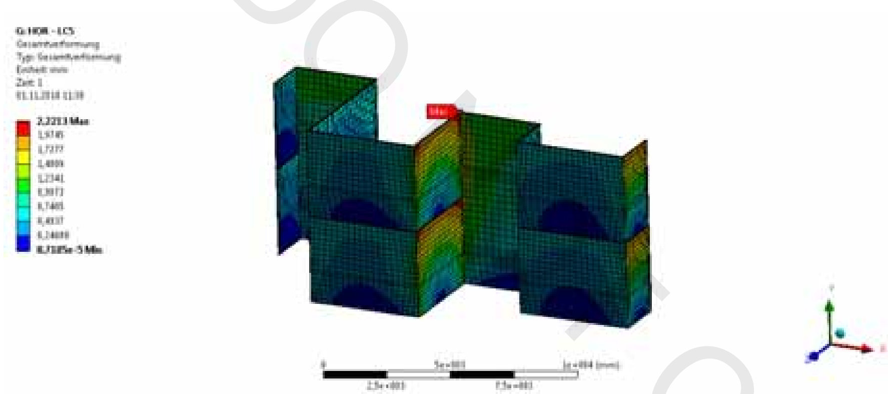
The following tables summarize the results of the individual load cases and the load case combinations.

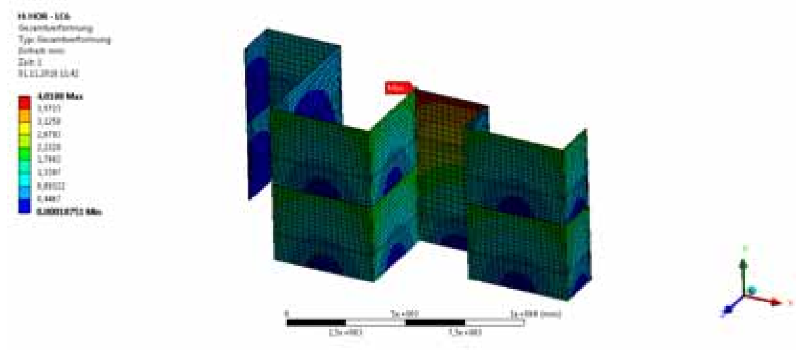
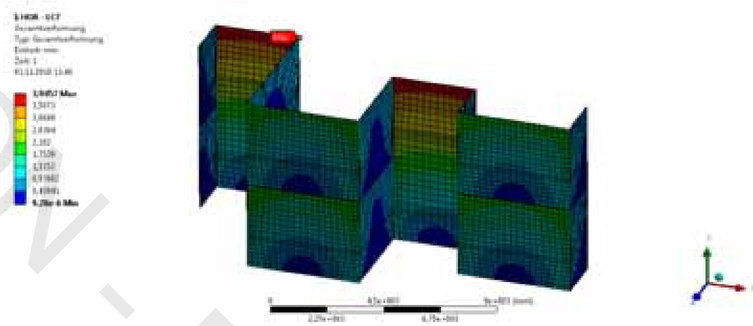
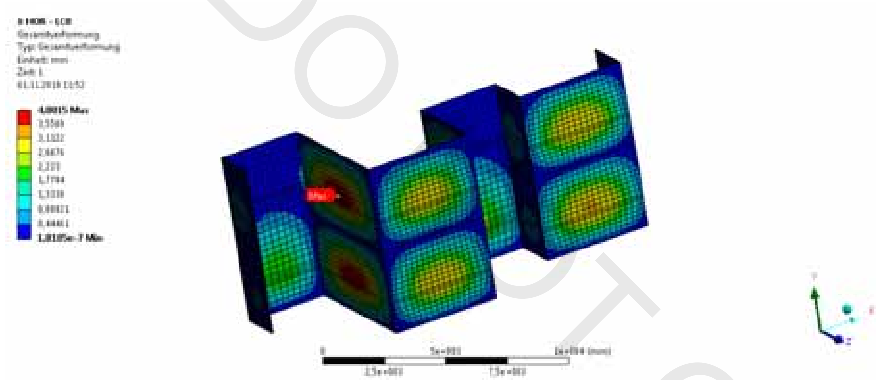
w maximum displacement

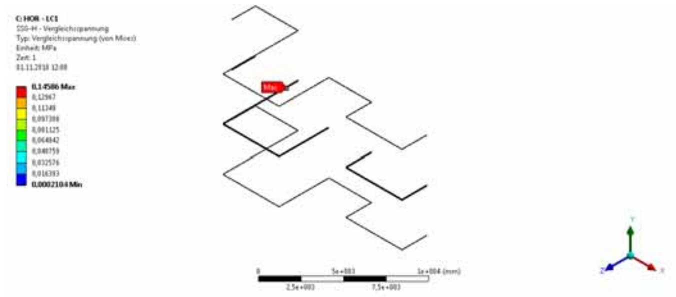
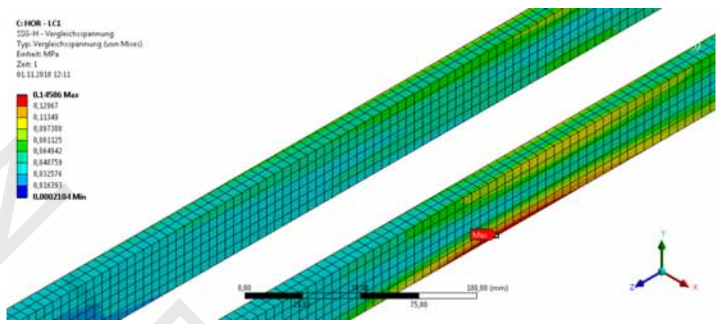
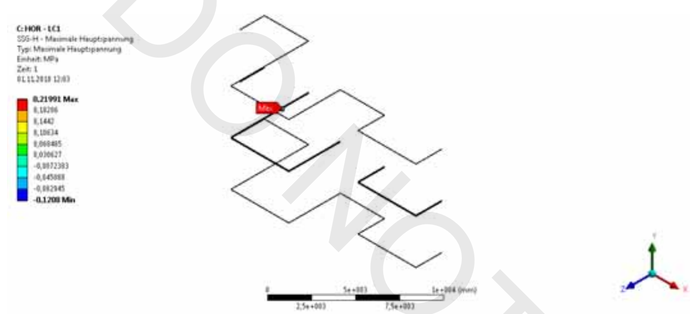
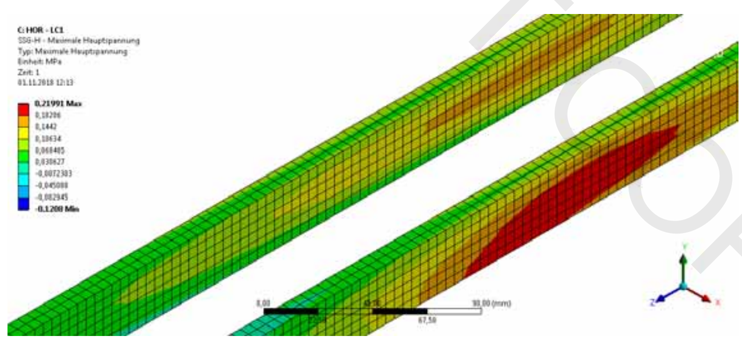
σ_V equivalent tensile stress (von Mises)

σ_1 max. principal tensile stress

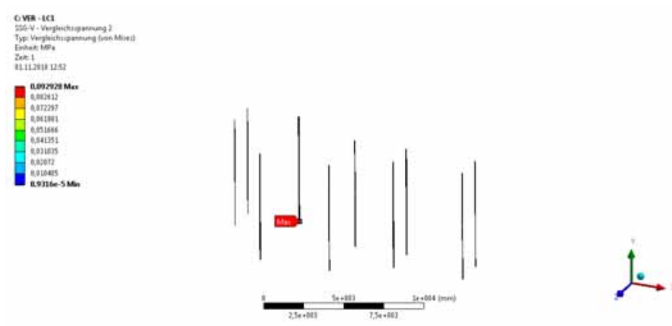
LC	Result		
1	w [mm]	7.2	
2	w [mm]	10.2	

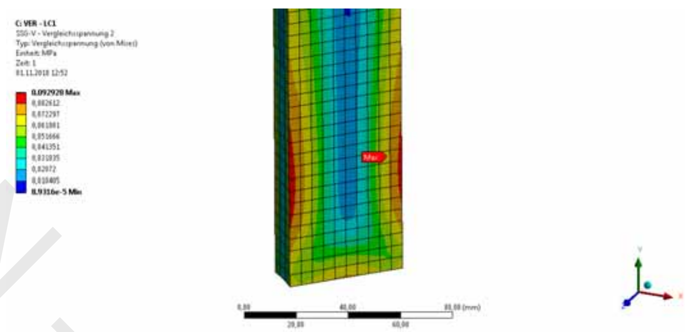
3	w [mm]	8.7	
4	w [mm]	10.1	
5	w [mm]	2.2	

6	w [mm]	4.0	
7	w [mm]	3.9	
8	w [mm]	4.0	

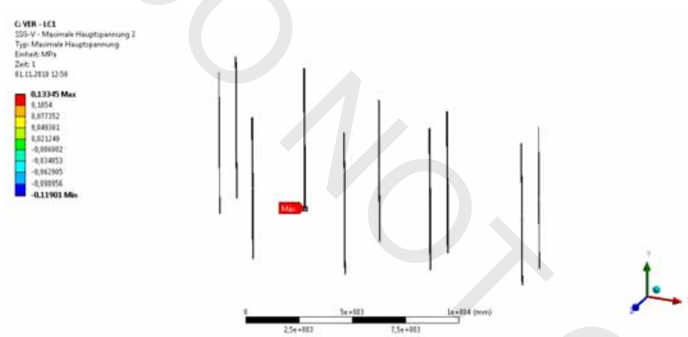
LC	Result		
1	$\sigma_{v,hor}$ [N/mm²]	0.146	 
	$\sigma_{1,hor}$ [N/mm²]	0.220	 

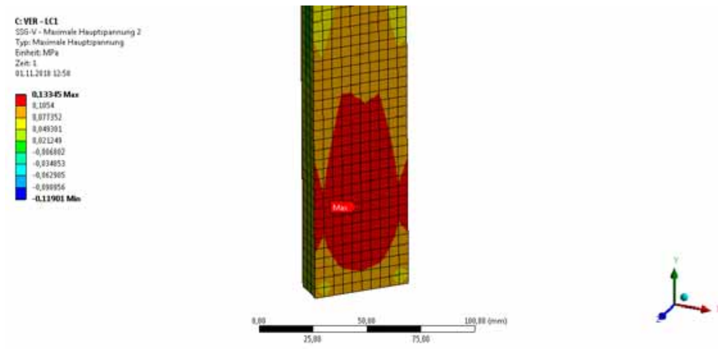
$\sigma_{v,ver}$ [N/mm²] 0,093

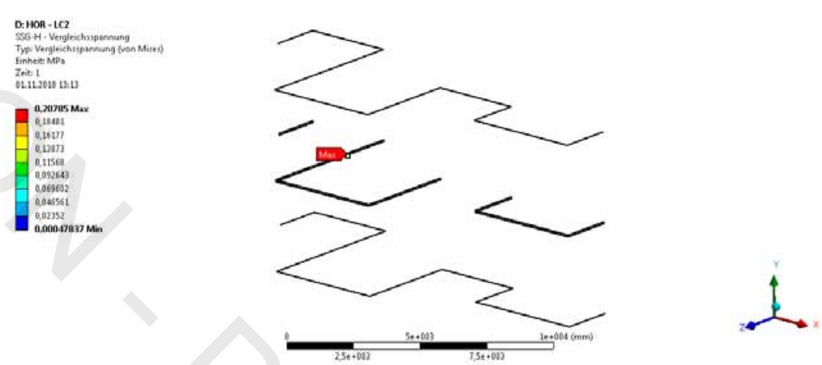
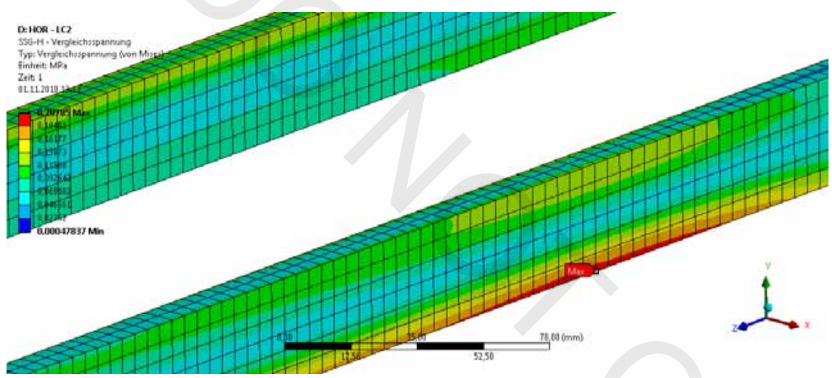




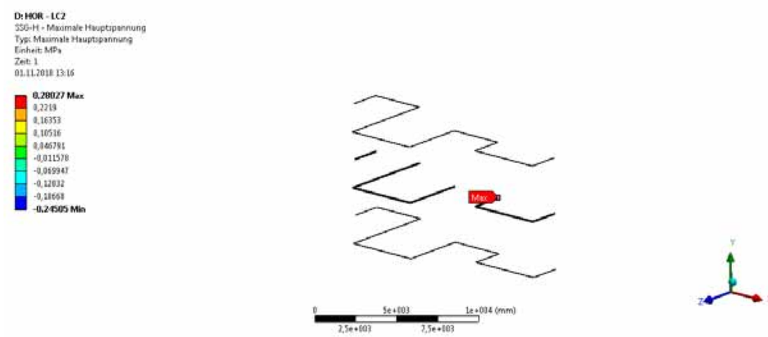
$\sigma_{1,ver}$ [N/mm²] 0.133

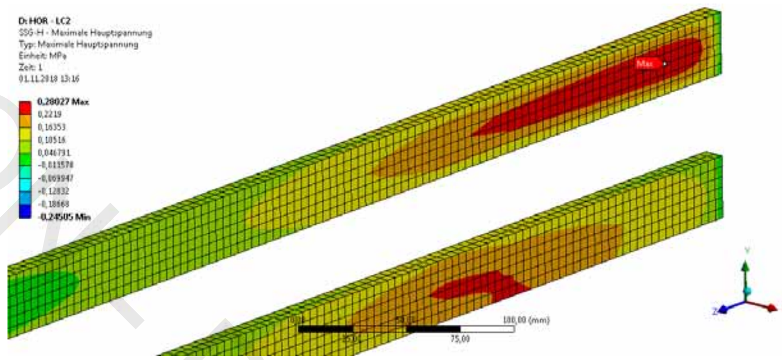




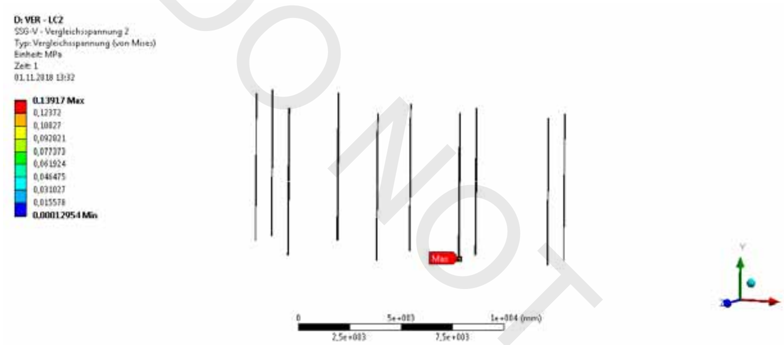
2	$\sigma_{v,hor}$ [N/mm²]	0.208	 

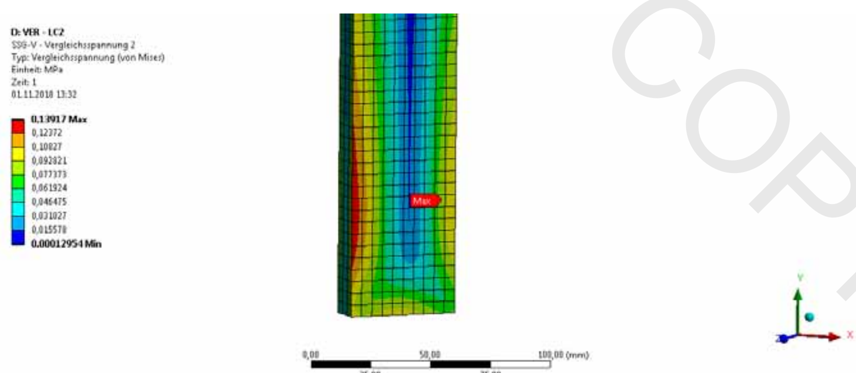
$\sigma_{1,hor}$ [N/mm²] 0.280

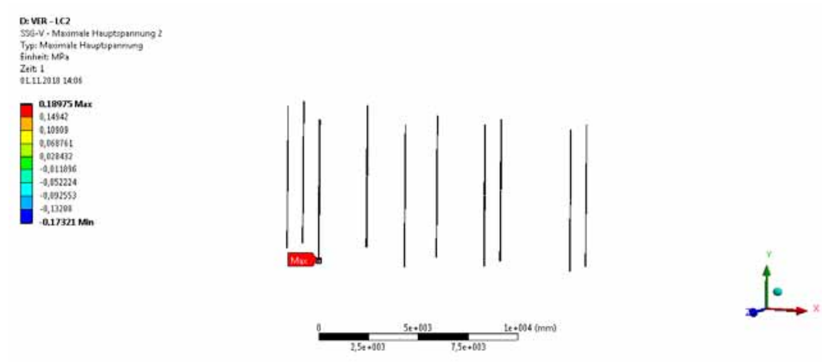
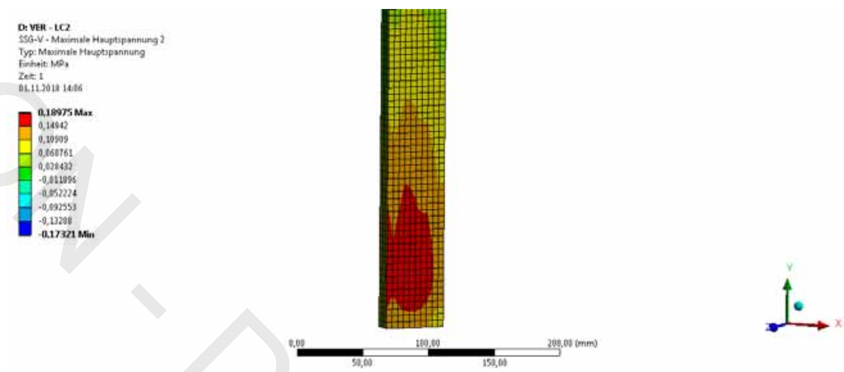
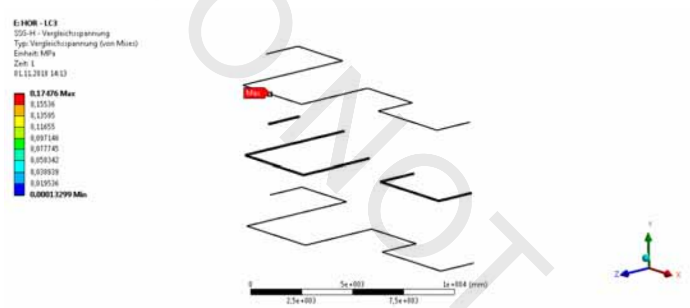
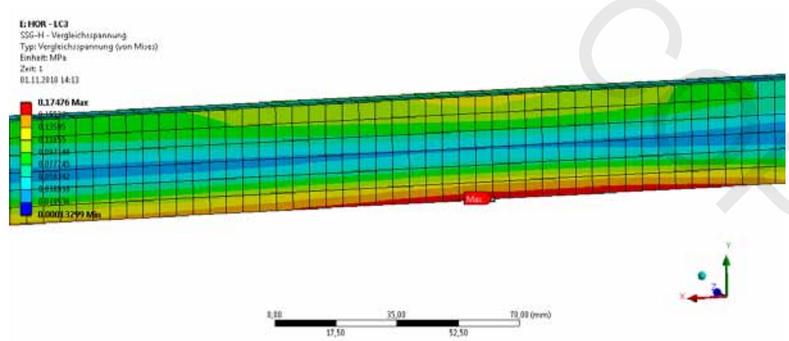


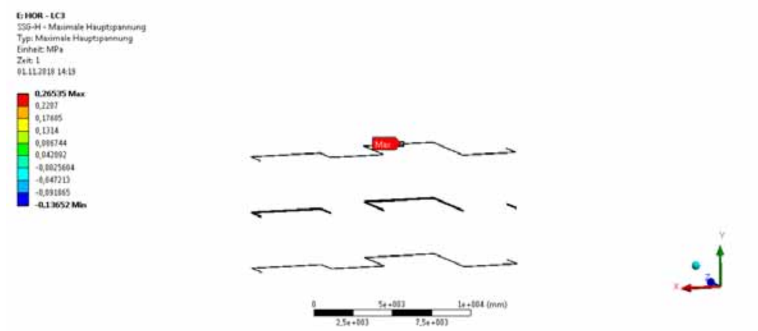
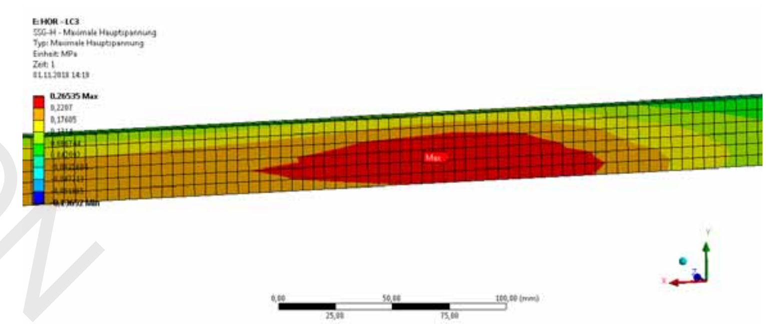
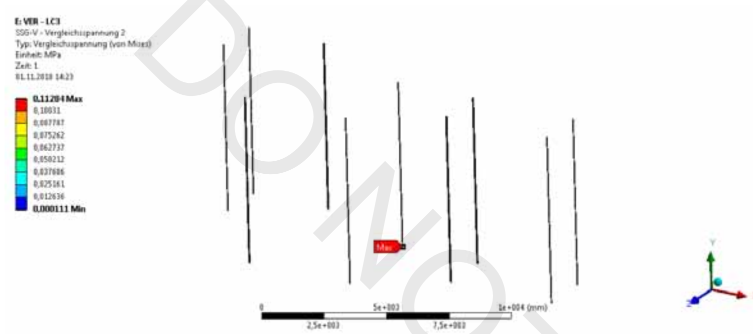
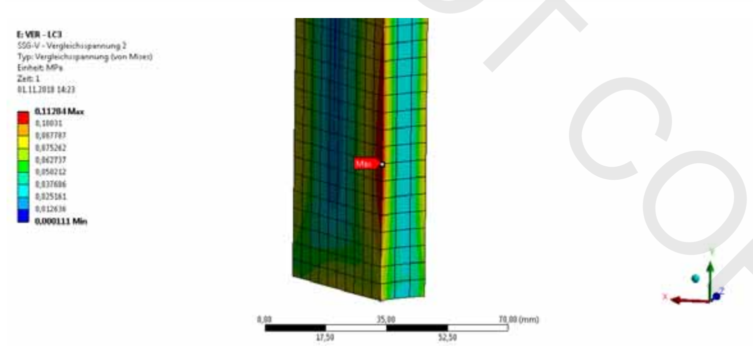


$\sigma_{v,ver}$ [N/mm²] 0.139

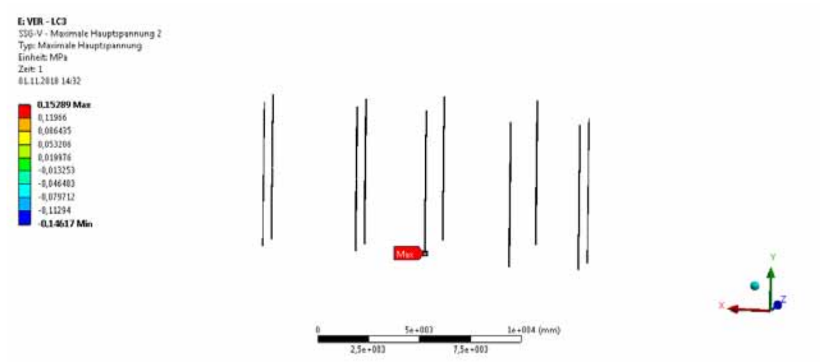


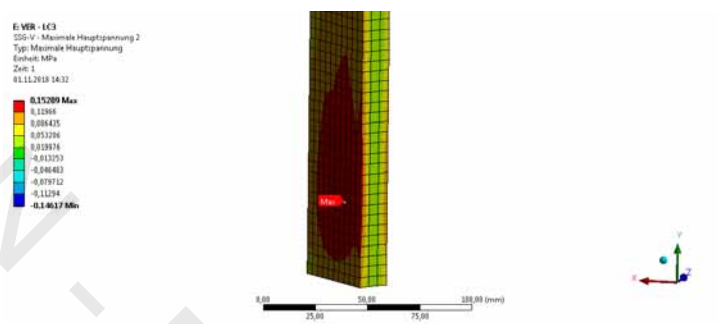


	$\sigma_{1,ver}$ [N/mm²]	0.190	 
3	$\sigma_{v,hor}$ [N/mm²]	0.175	 

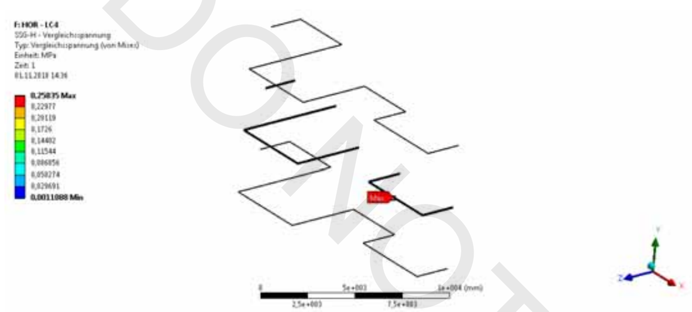
$\sigma_{1,hor}$ [N/mm²]	0.265	 
$\sigma_{v,ver}$ [N/mm²]	0.113	 

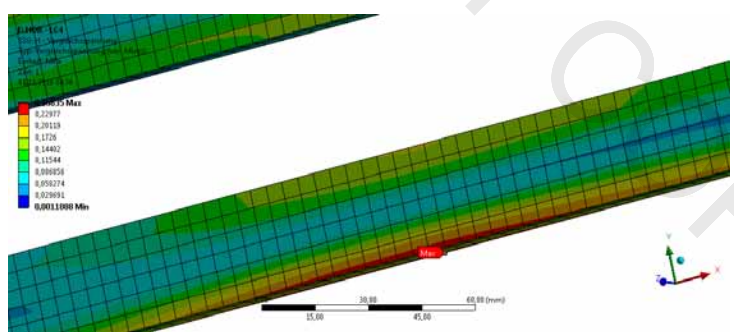
$\sigma_{1,ver}$ [N/mm²] 0.153



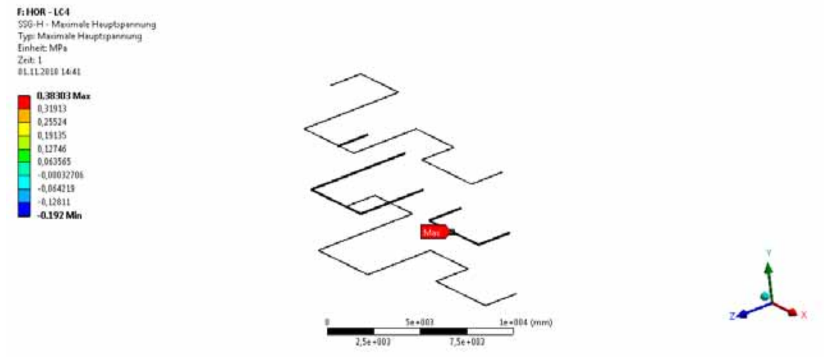


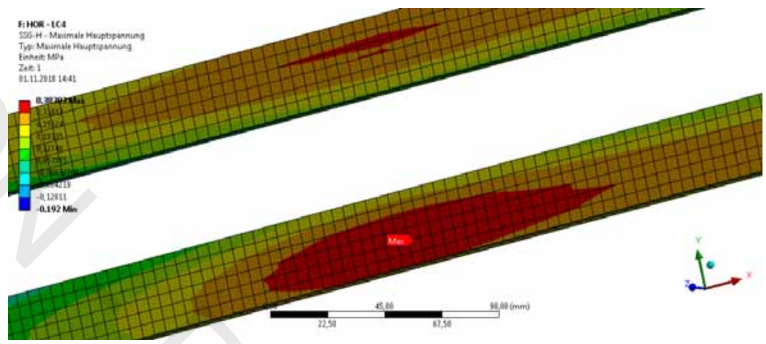
4 $\sigma_{v,hor}$ [N/mm²] 0.258



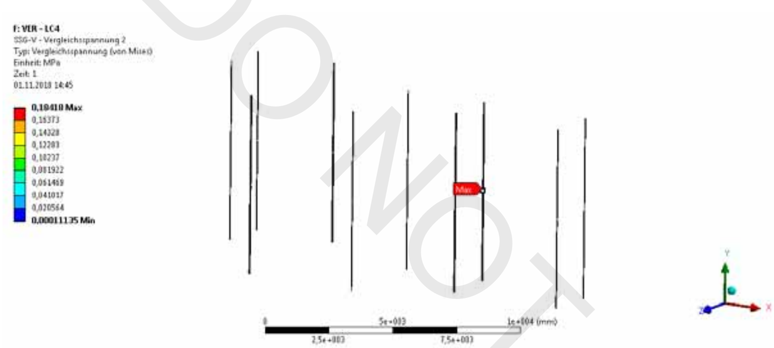


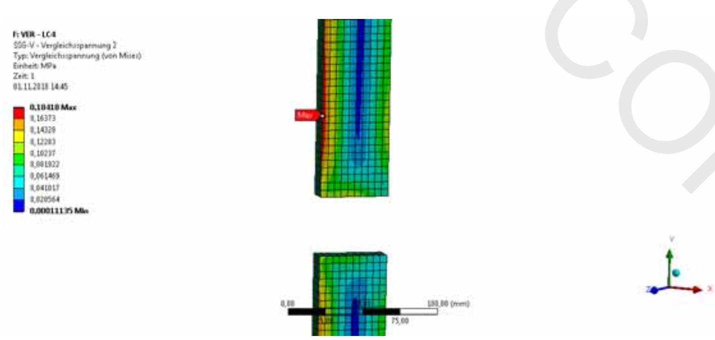
$\sigma_{1,hor}$ [N/mm²] 0.383



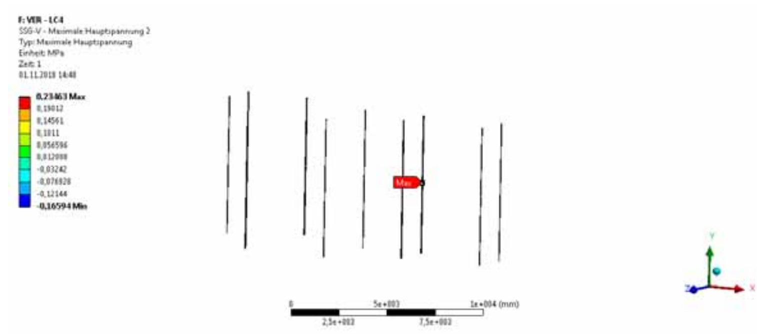


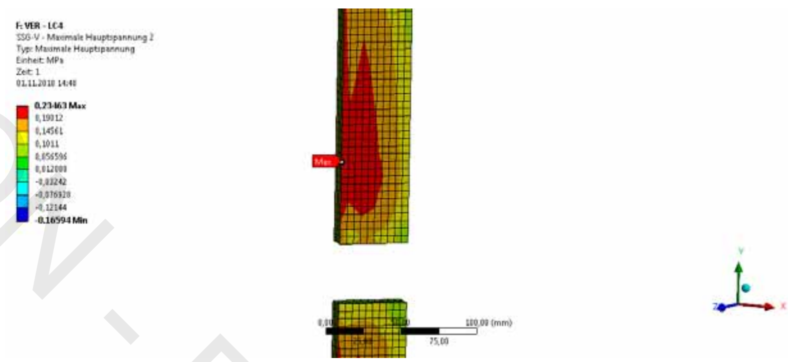
$\sigma_{v,ver}$ [N/mm²] 0.184



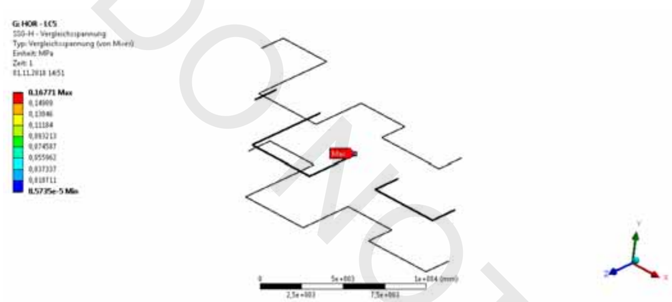


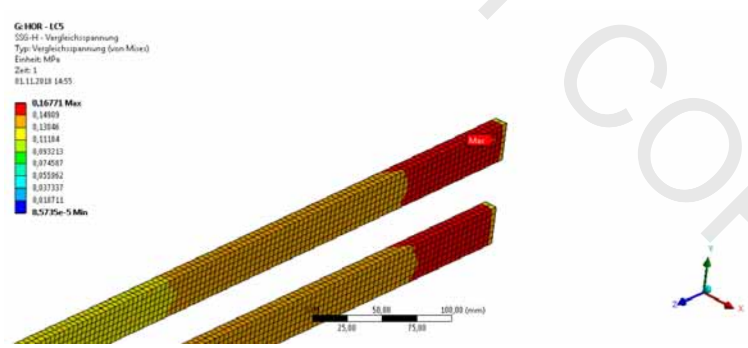
$\sigma_{1,ver}$ [N/mm²] 0.234

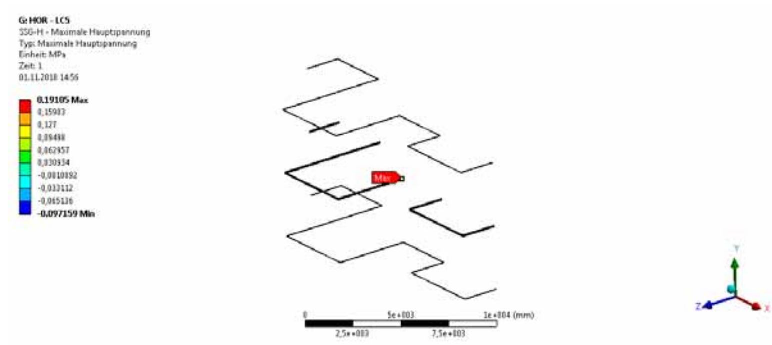
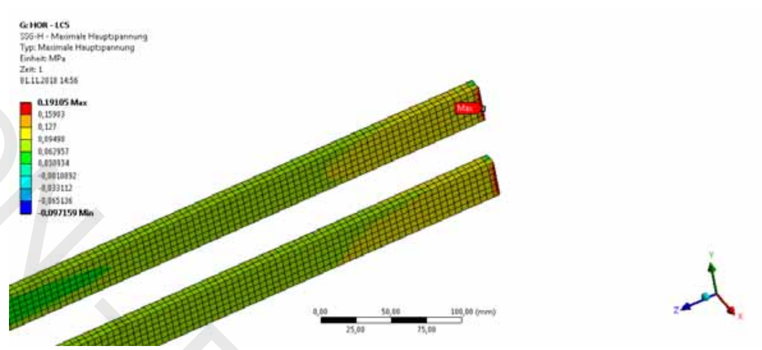
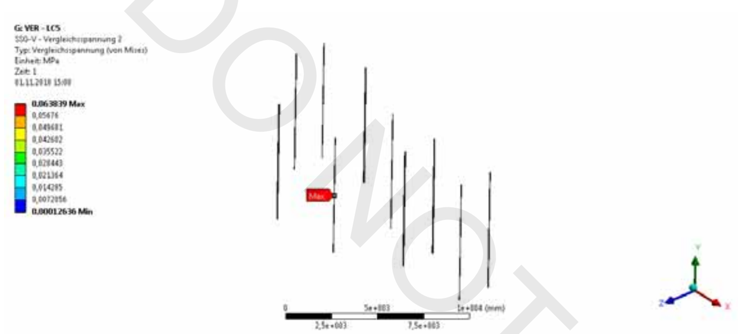
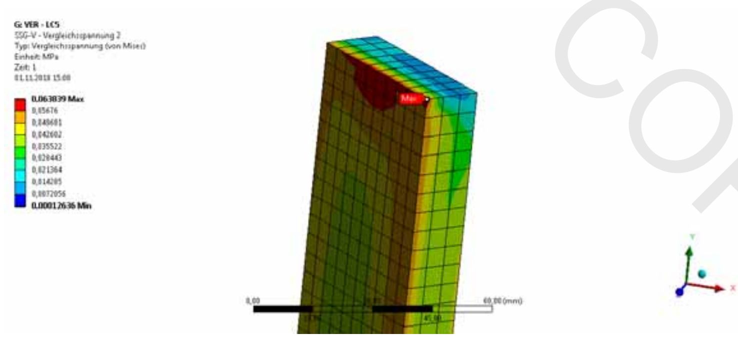


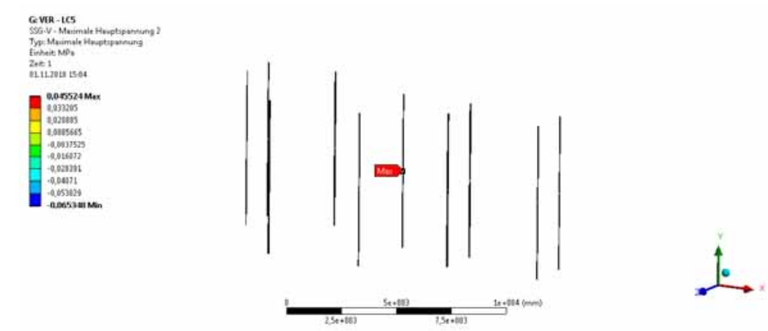
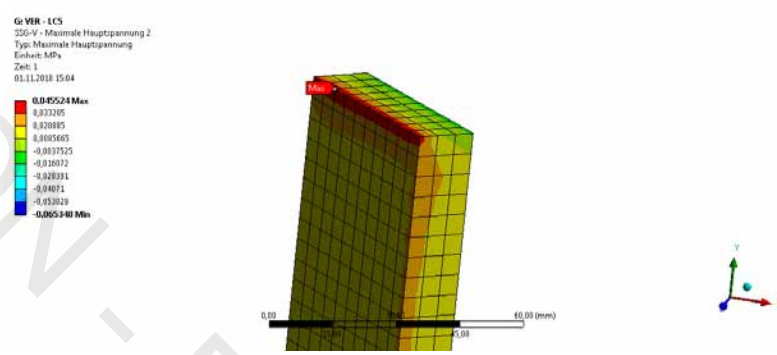
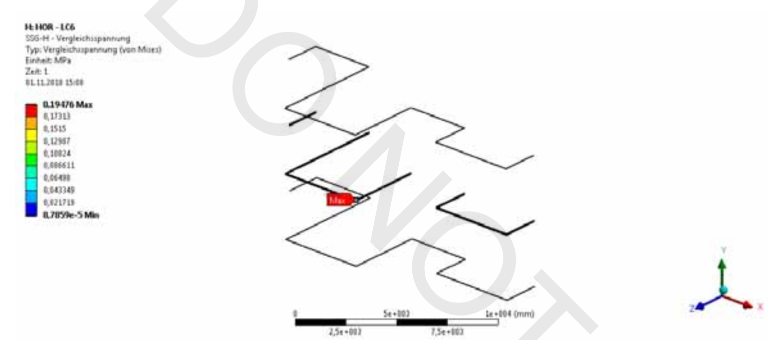
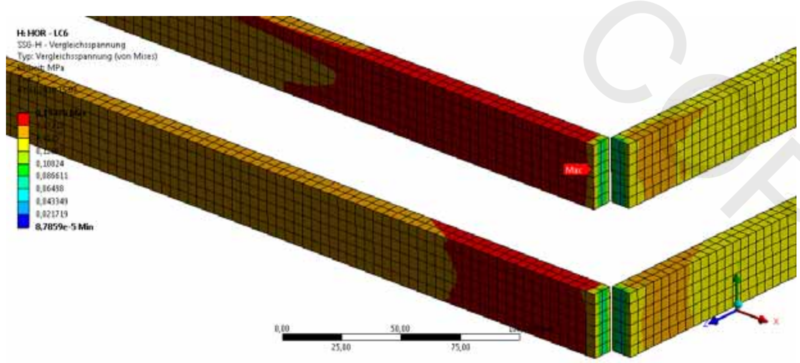


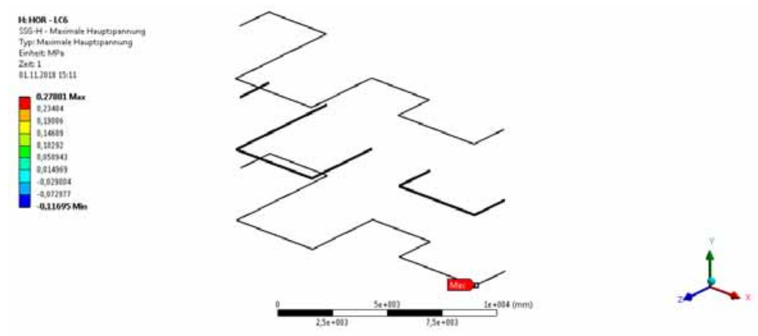
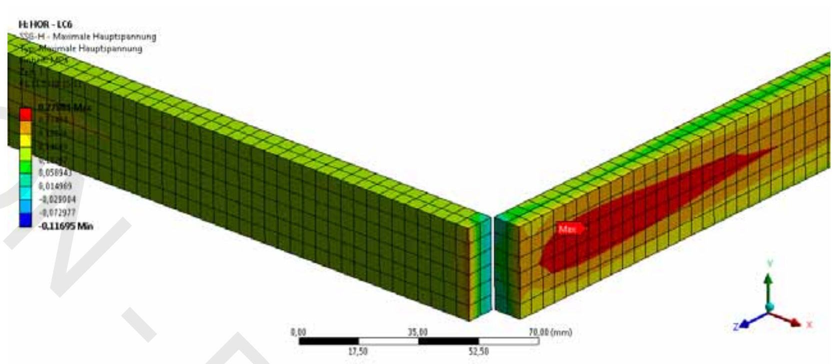
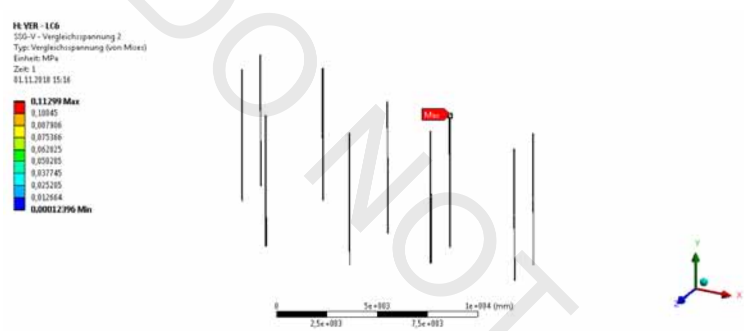
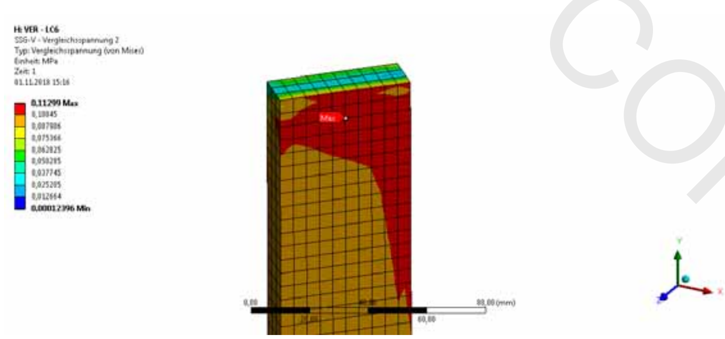
5 $\sigma_{v,hor}$ [N/mm²] 0.167



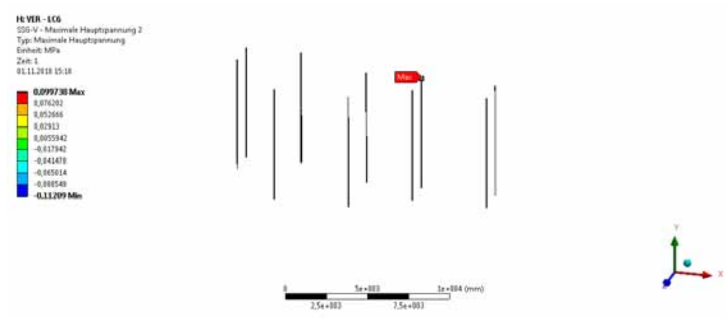


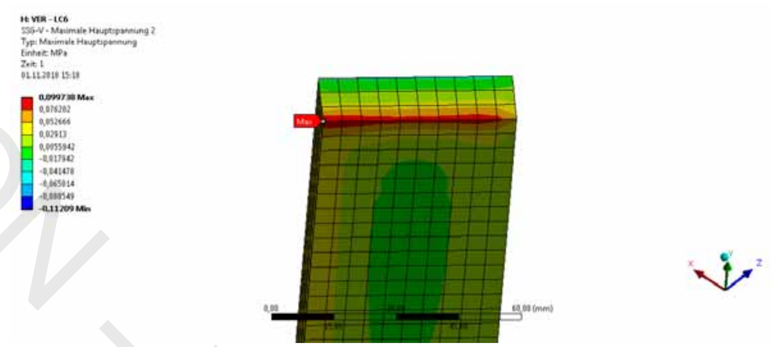
$\sigma_{1,hor}$ [N/mm²]	0.191	 
$\sigma_{v,ver}$ [N/mm²]	0.064	 

	$\sigma_{1,ver}$ [N/mm²]	0.046	 
6	$\sigma_{v,hor}$ [N/mm²]	0.195	 

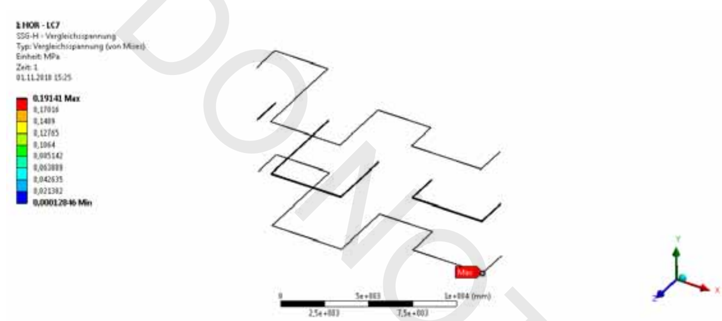
$\sigma_{1,hor}$ [N/mm²]	0.279	 
$\sigma_{v,ver}$ [N/mm²]	0.113	 

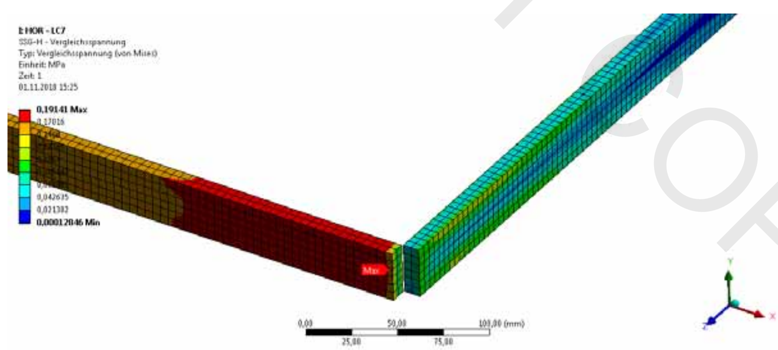
$\sigma_{1,ver}$ [N/mm²] 0.100

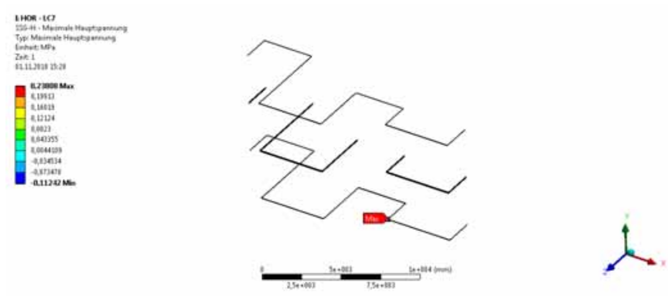
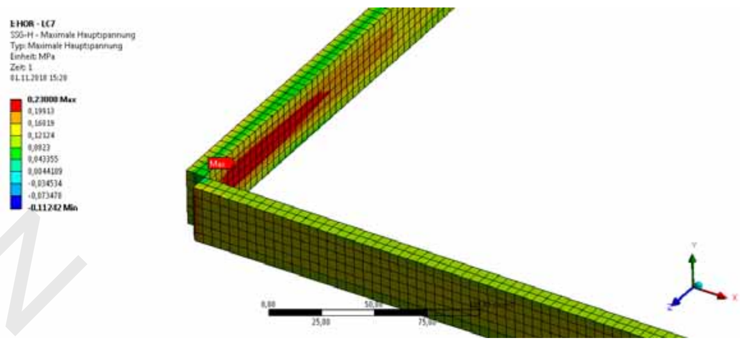
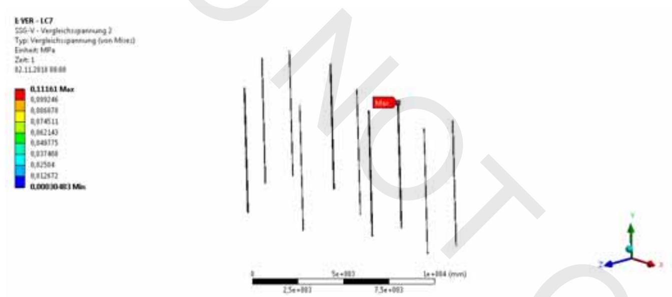
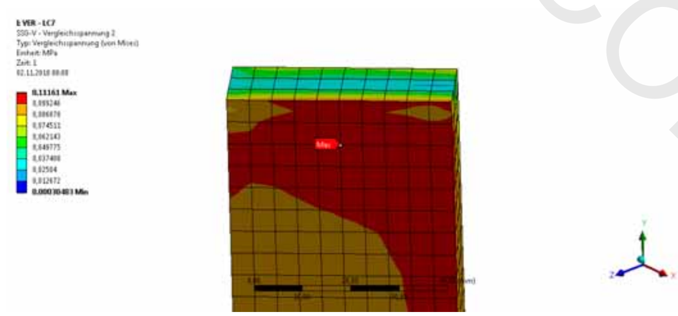


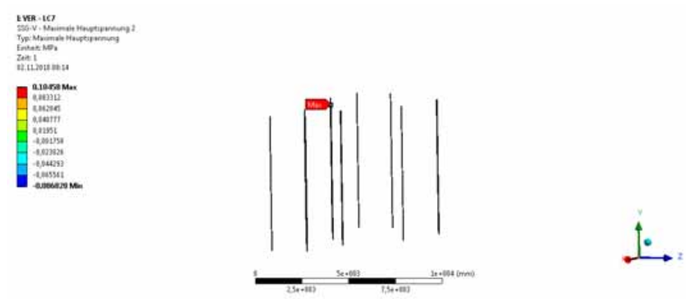
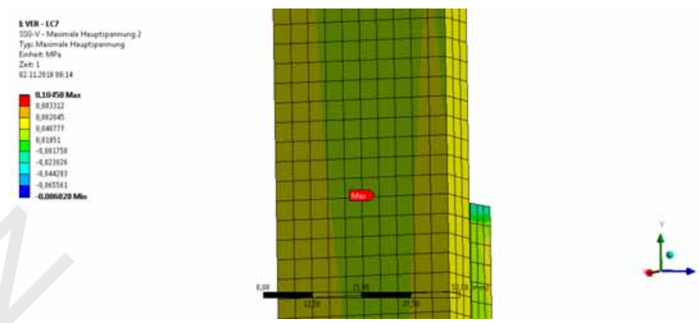
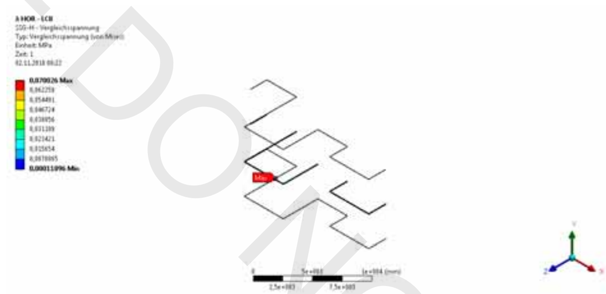
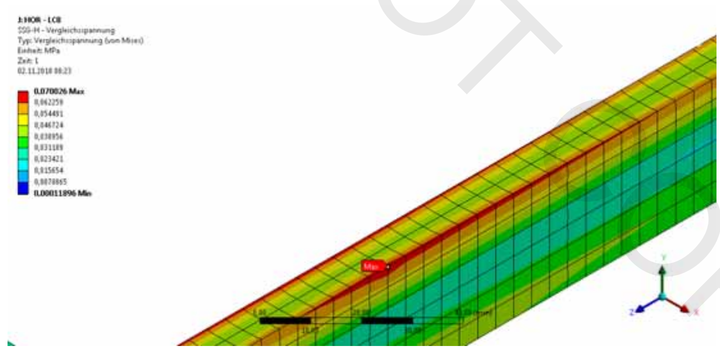


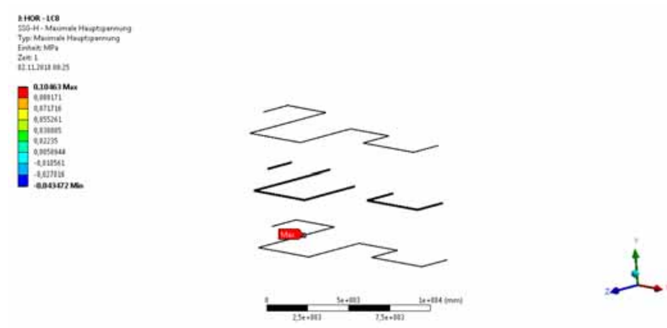
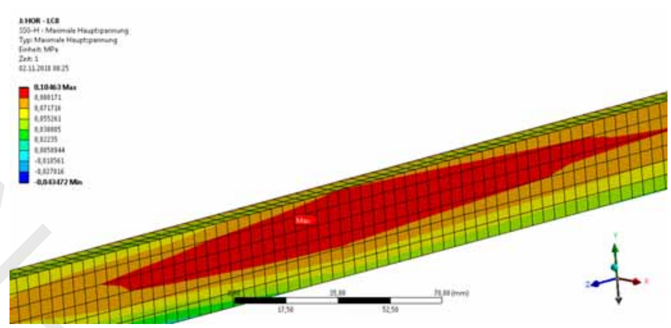
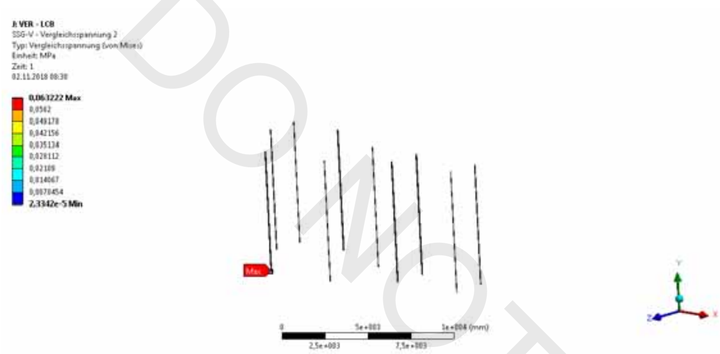
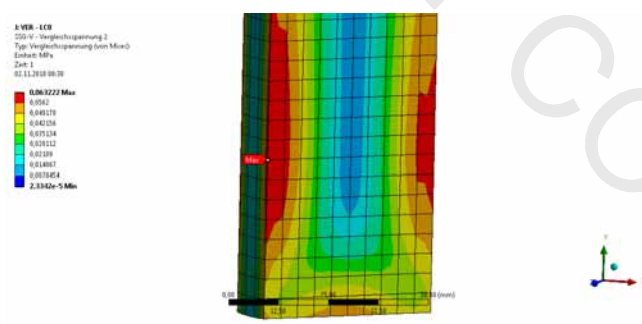
7 $\sigma_{v,hor}$ [N/mm²] 0.191

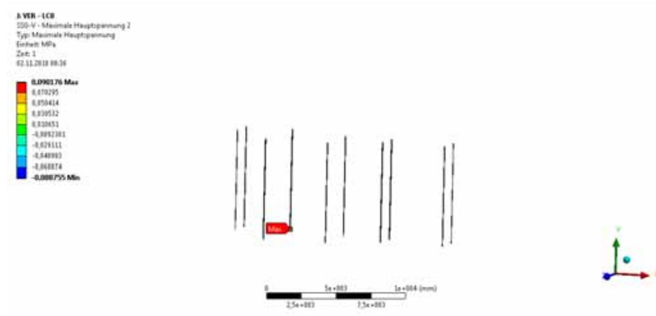
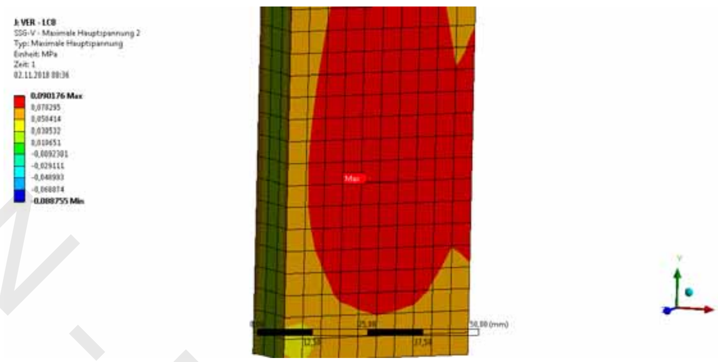




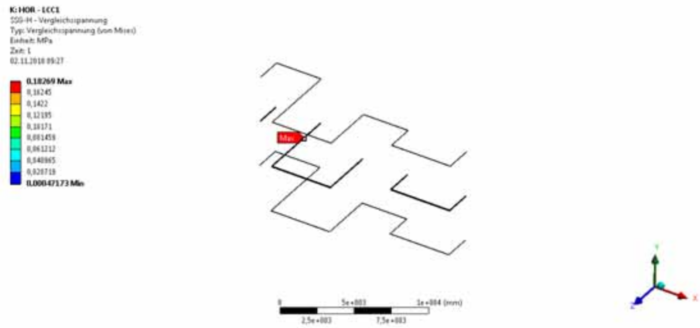
$\sigma_{1,hor}$ [N/mm²]	0.238	 
$\sigma_{v,ver}$ [N/mm²]	0.112	 

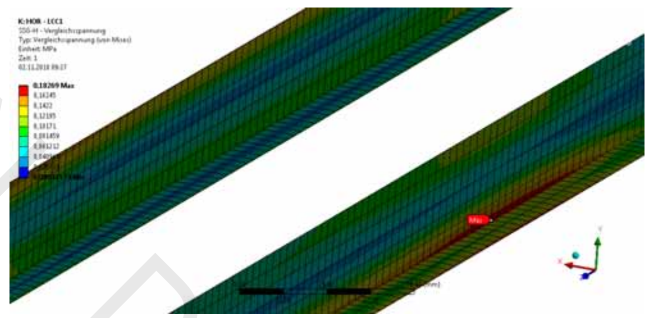
	$\sigma_{1,ver}$ [N/mm²]	0.105	 
8	$\sigma_{v,hor}$ [N/mm²]	0.070	 

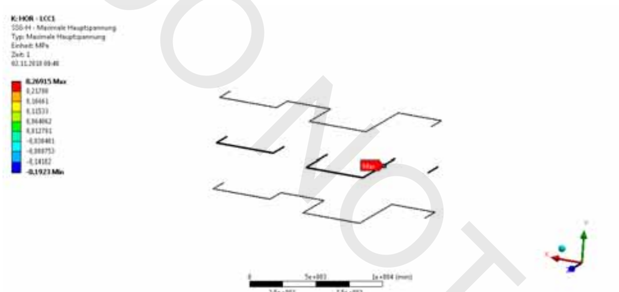
$\sigma_{1,hor}$ [N/mm²]	0.105	 
$\sigma_{v,ver}$ [N/mm²]	0.063	 

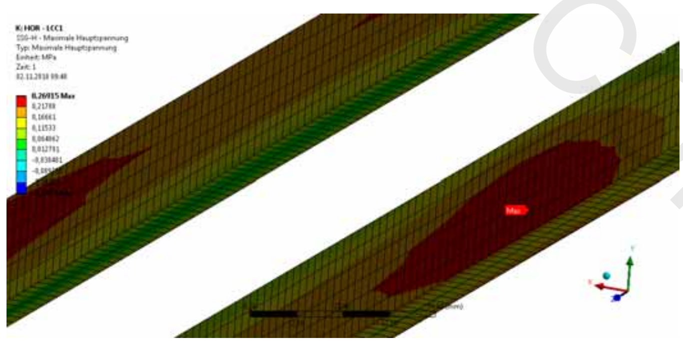
$\sigma_{1,ver}$ [N/mm²]	0.090	 

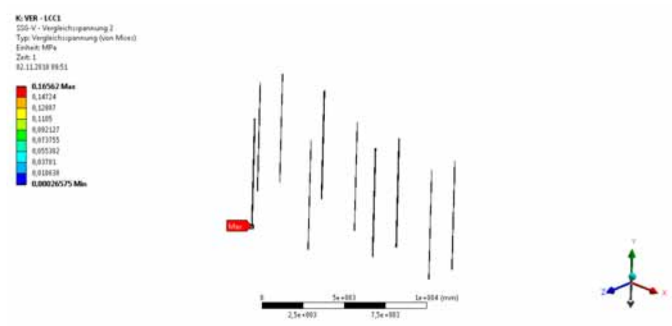
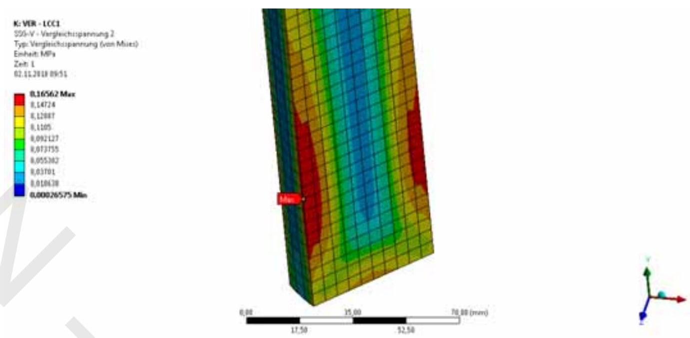
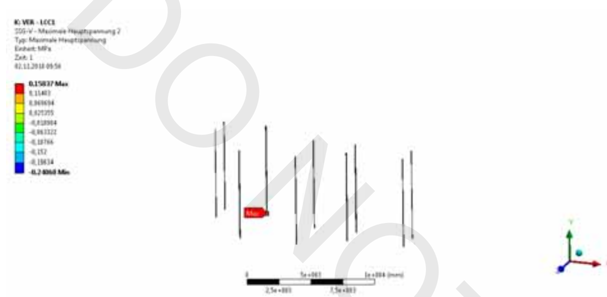
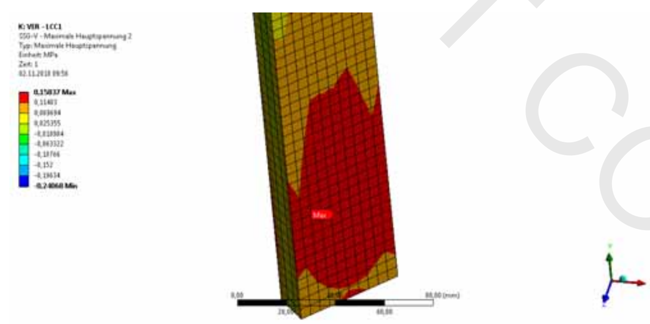
LCC	Result		
101	$\sigma_{v,hor}$ [N/mm²]	0.183	
	$\sigma_{1,hor}$ [N/mm²]	0.269	

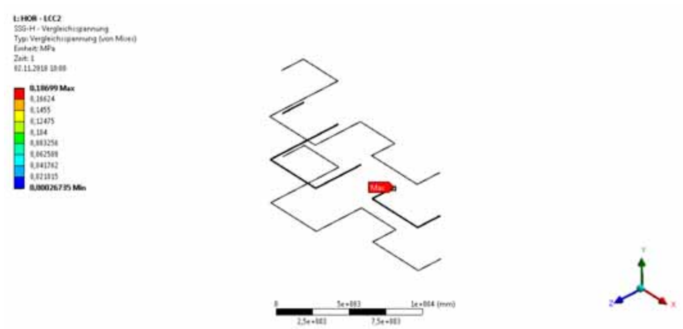
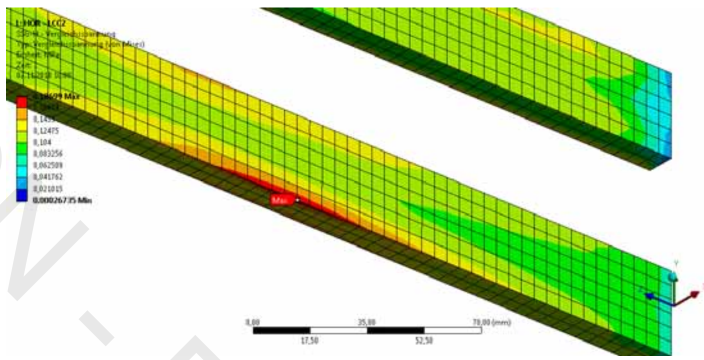
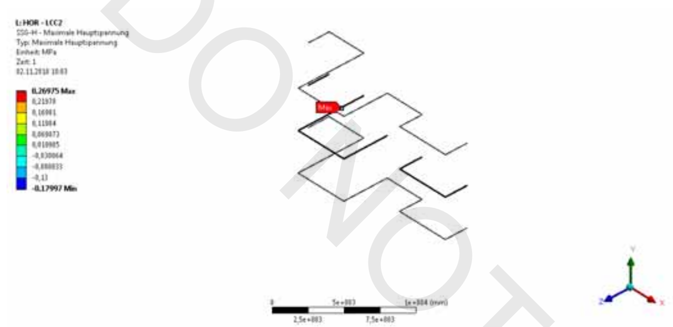
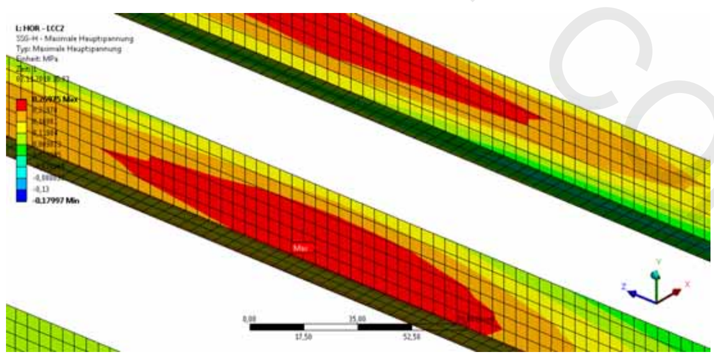


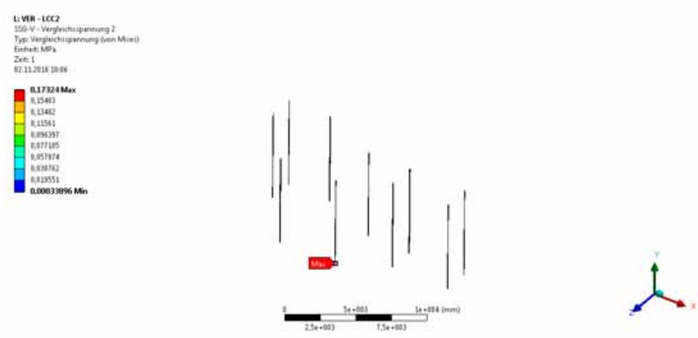
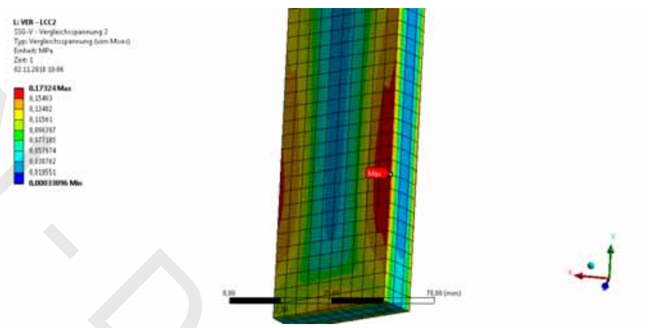
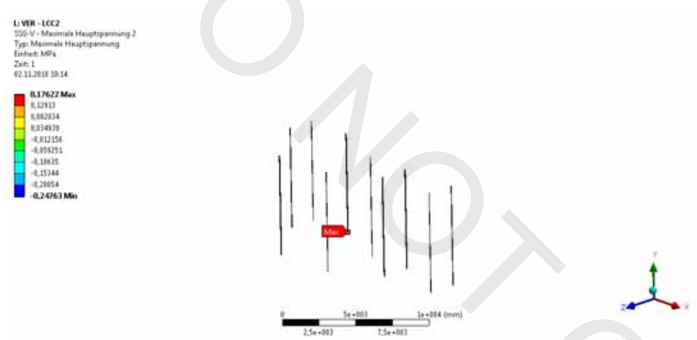


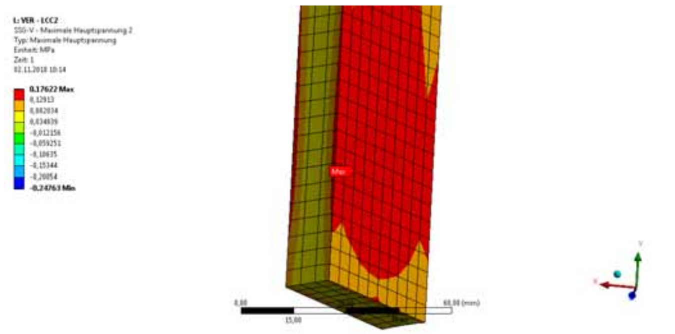
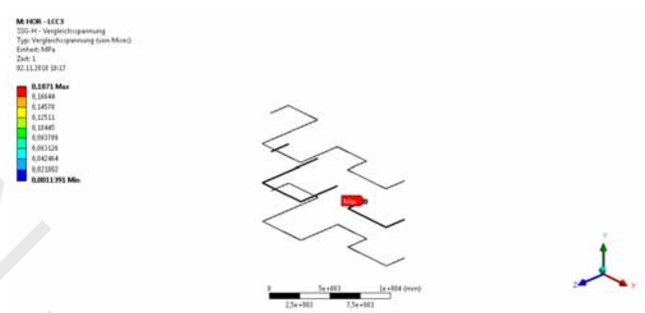
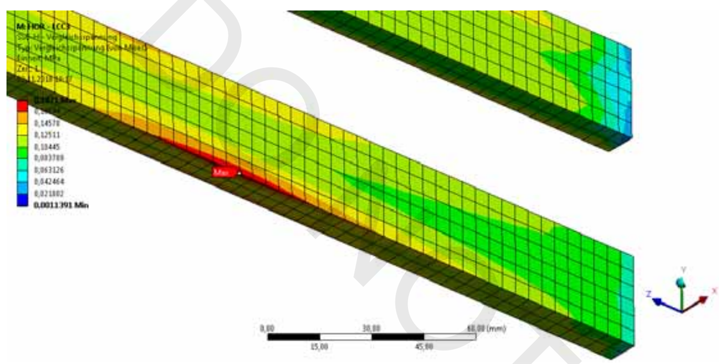
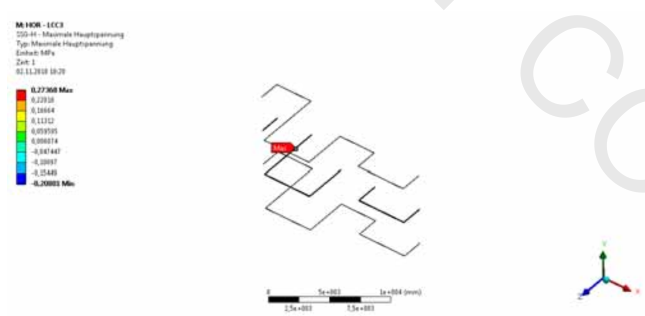


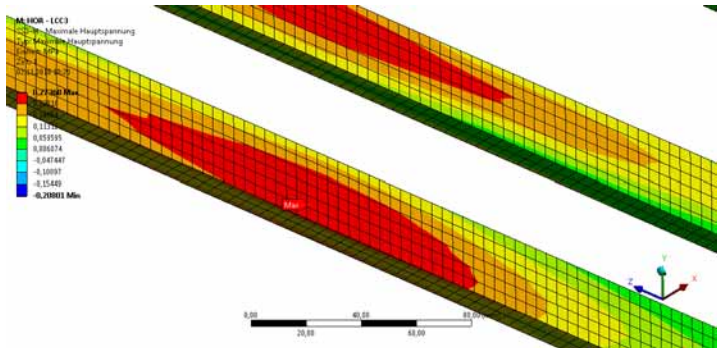


$\sigma_{v,ver}$ [N/mm²]	0.166	 
$\sigma_{1,ver}$ [N/mm²]	0.158	 

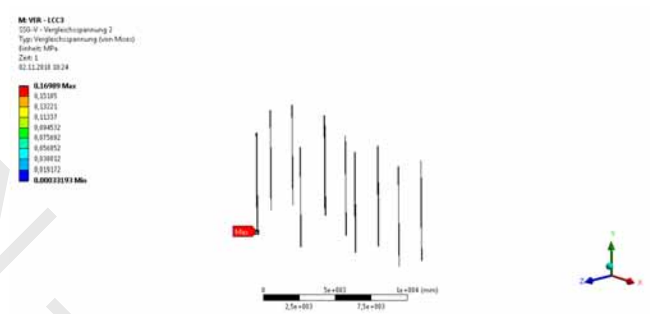
102	$\sigma_{v,hor}$ [N/mm²]	0.187	 
	$\sigma_{1,hor}$ [N/mm²]	0.270	 

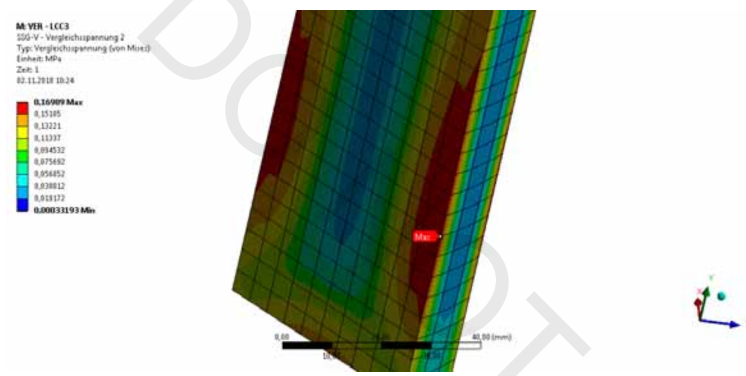
$\sigma_{v,ver}$ [N/mm²]	0.173	 
$\sigma_{1,ver}$ [N/mm²]	0.176	

			
103	$\sigma_{v,hor}$ [N/mm²]	0.187	 
	$\sigma_{1,hor}$ [N/mm²]	0.274	

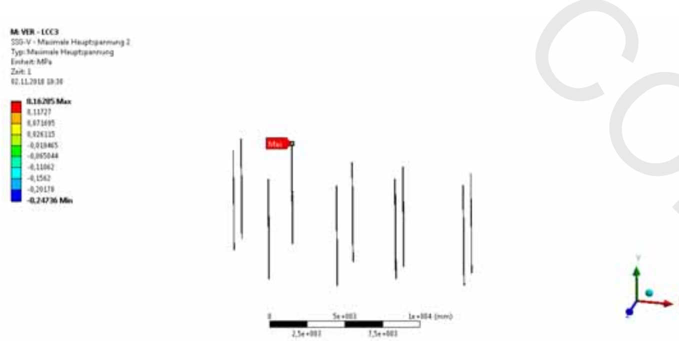


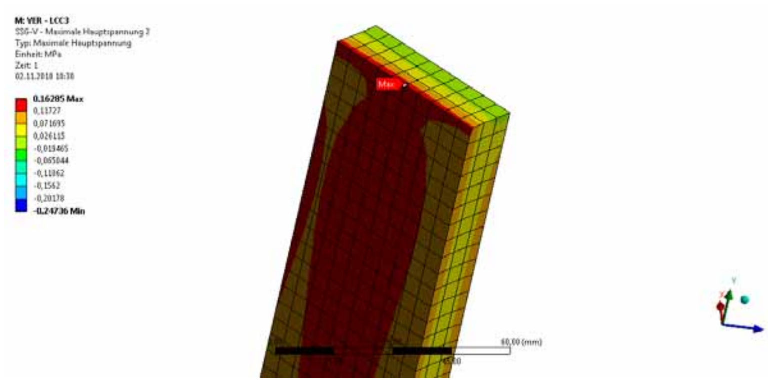
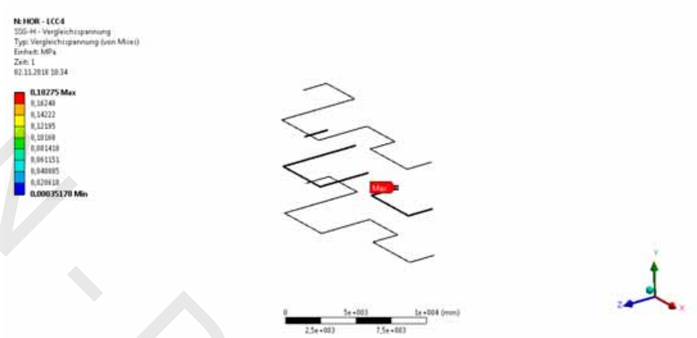
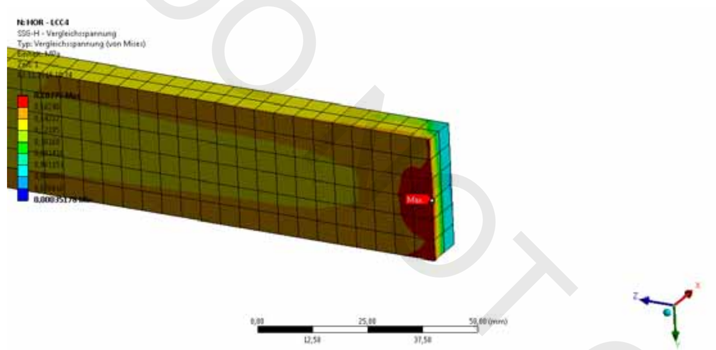
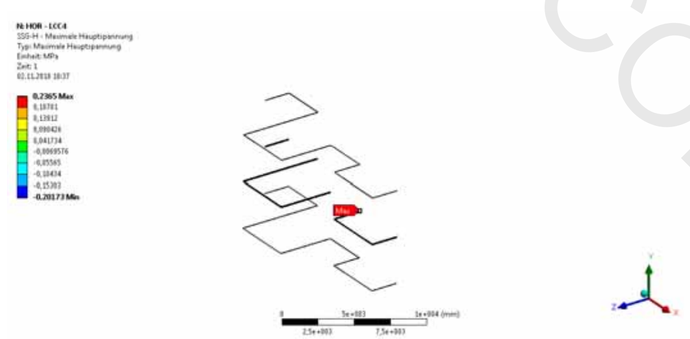
$\sigma_{v,ver}$ [N/mm²] 0.170

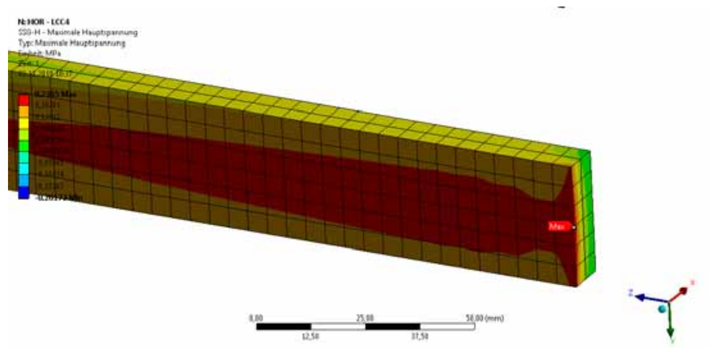
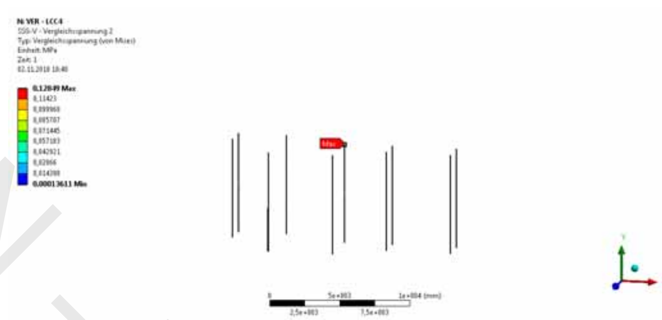
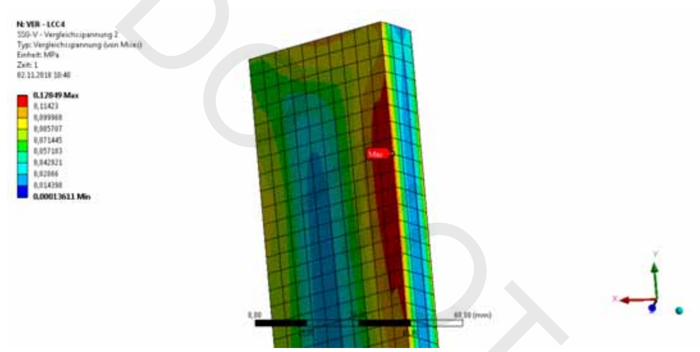
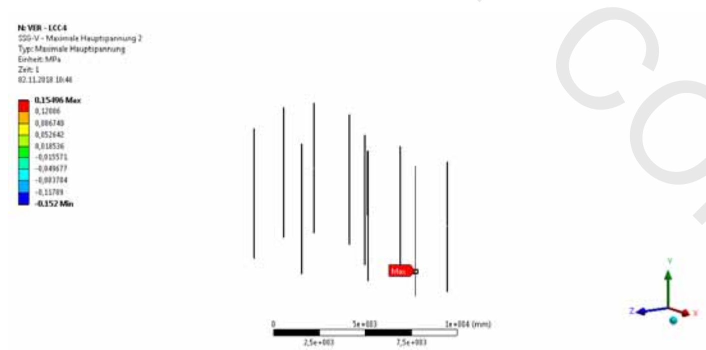


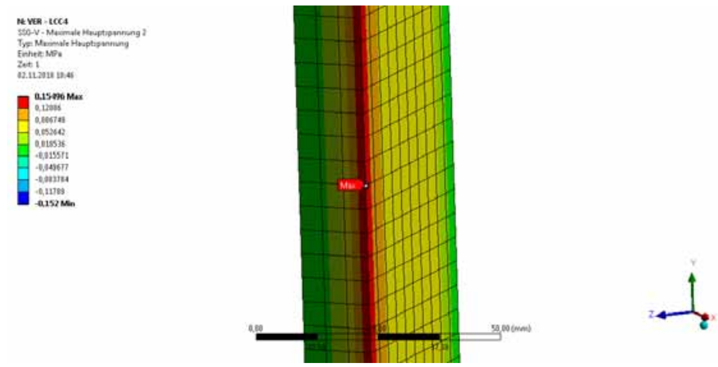
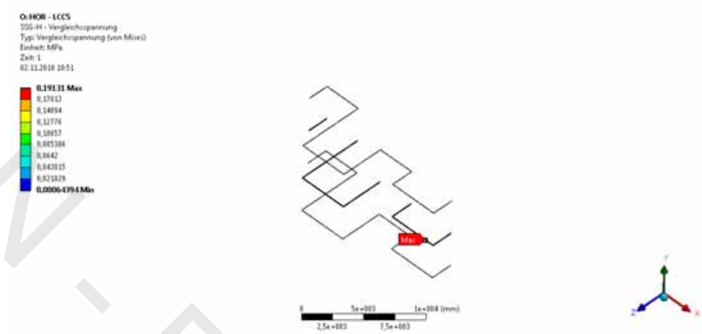
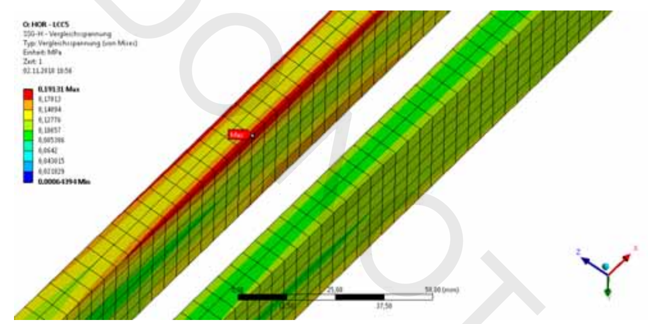
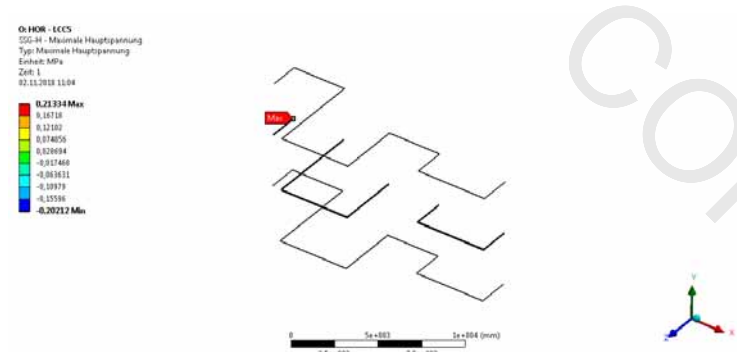


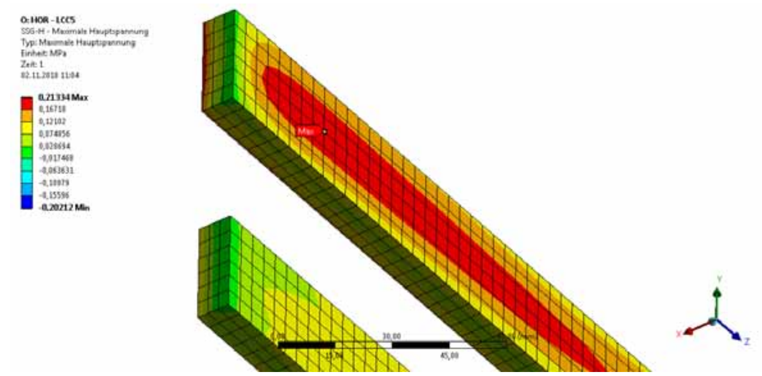
$\sigma_{1,ver}$ [N/mm²] 0.163



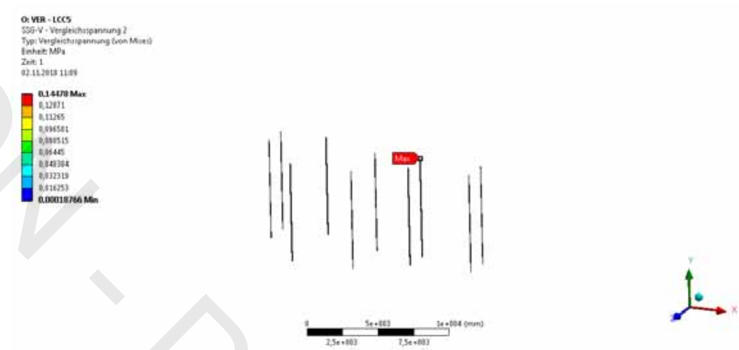
			
104	$\sigma_{v,hor}$ [N/mm²]	0.183	 
	$\sigma_{1,hor}$ [N/mm²]	0.237	

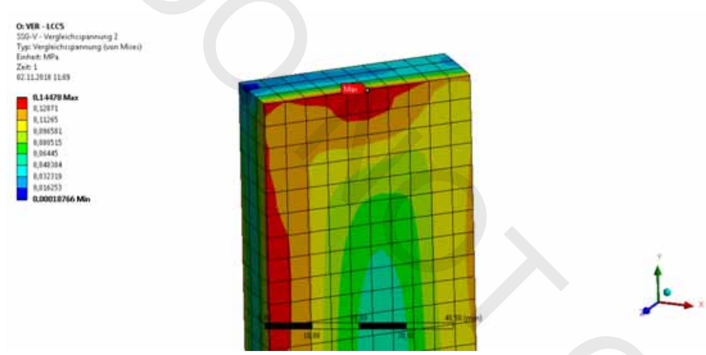
		
$\sigma_{v,ver}$ [N/mm²]	0.128	 
$\sigma_{1,ver}$ [N/mm²]	0.155	

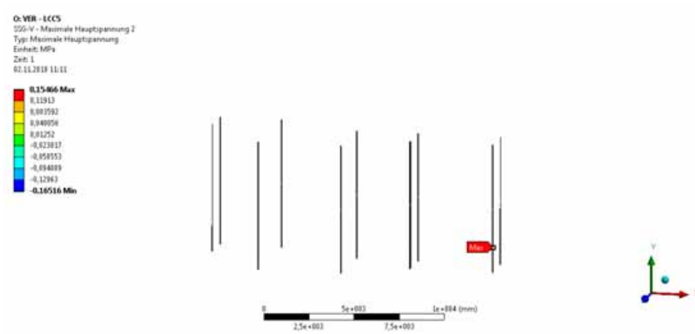
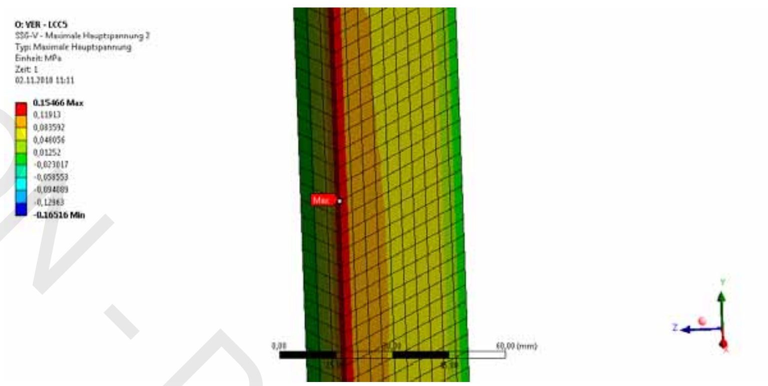
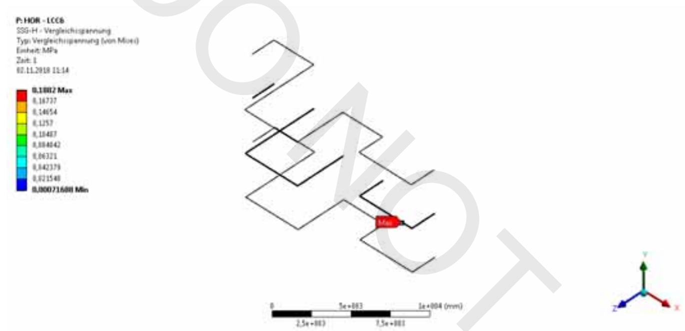
			
105	$\sigma_{v,hor}$ [N/mm²]	0.191	 
	$\sigma_{1,hor}$ [N/mm²]	0.213	

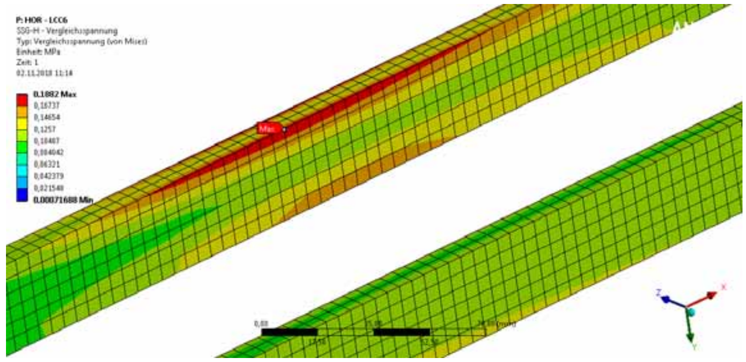


$\sigma_{v,ver}$ [N/mm²]	0.145



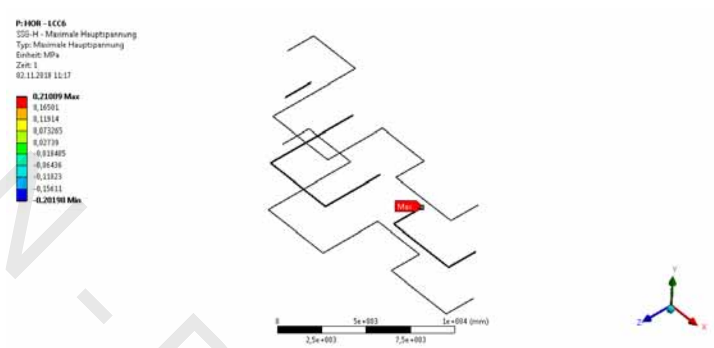


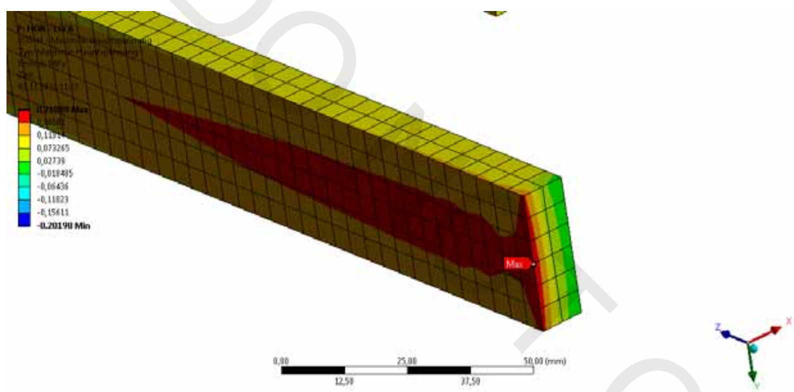
	$\sigma_{1,ver}$ [N/mm²]	0.155	
106	$\sigma_{v,hor}$ [N/mm²]	0.188	

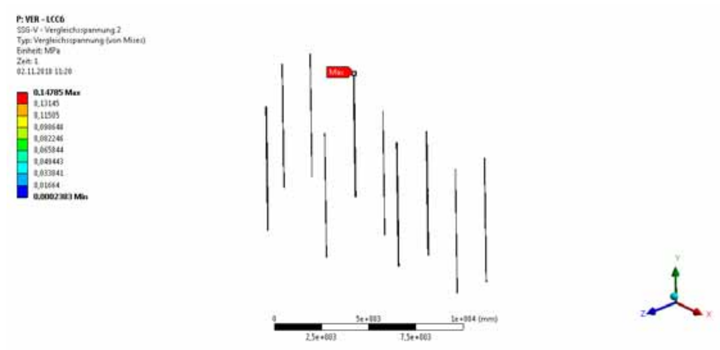
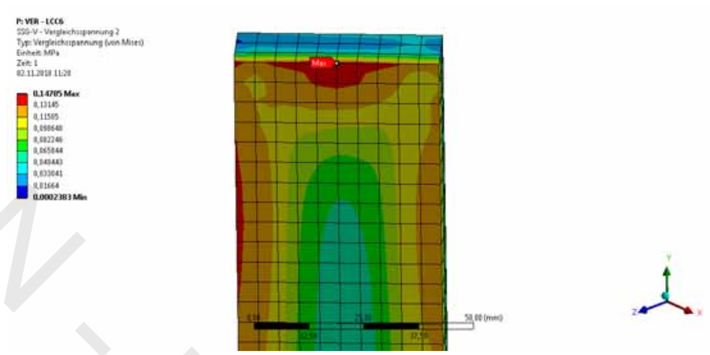
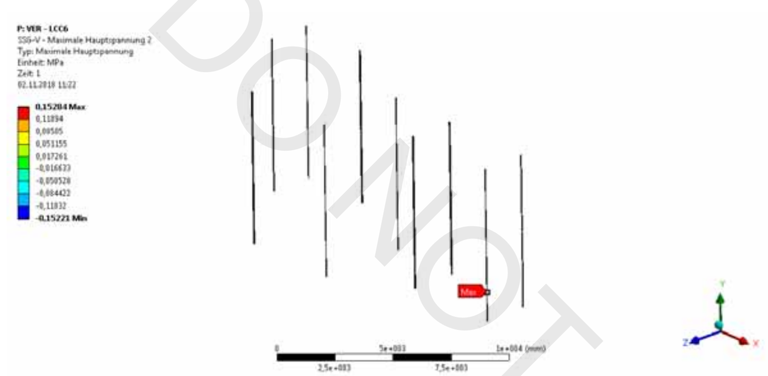


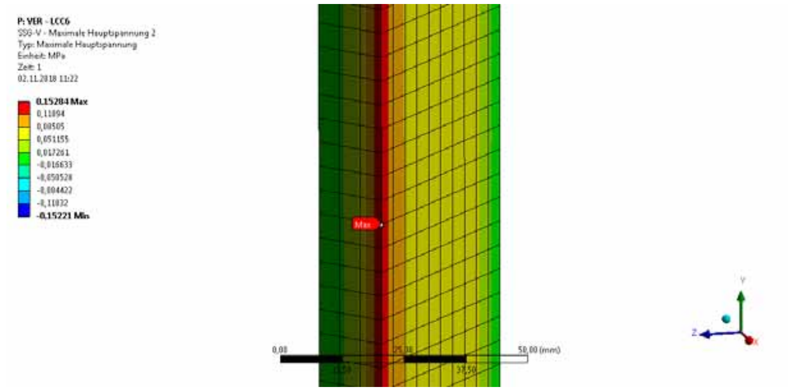
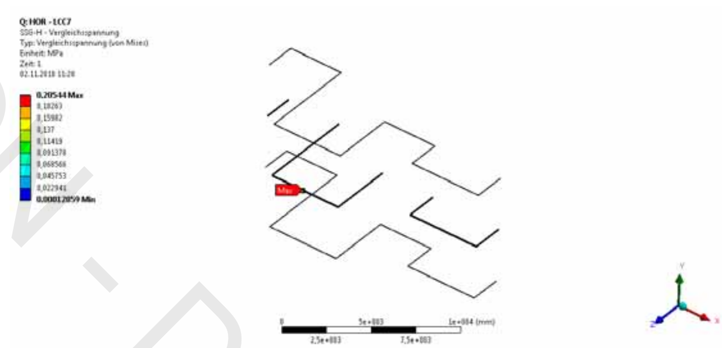
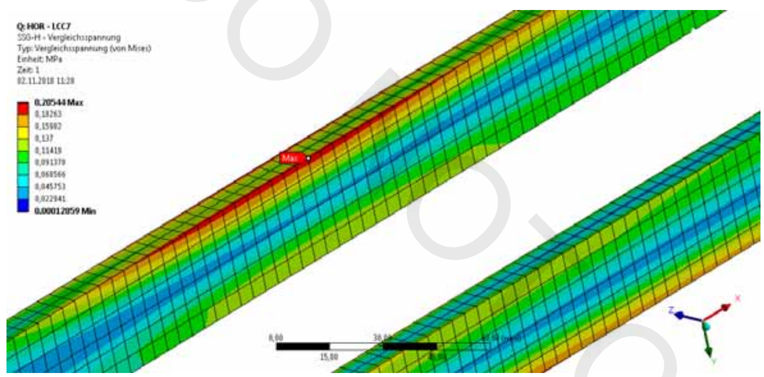
σ

$\sigma_{1,hor}$ [N/mm²] 0.211

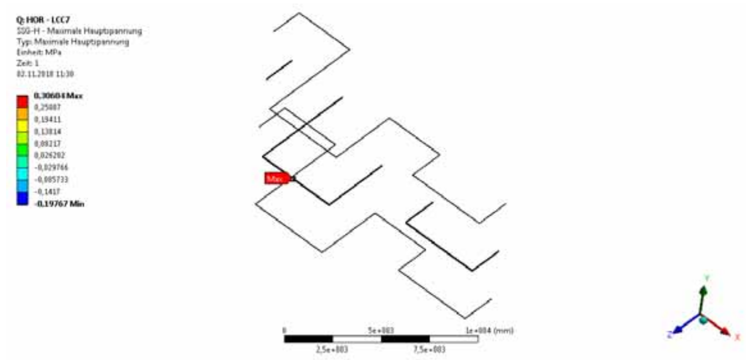


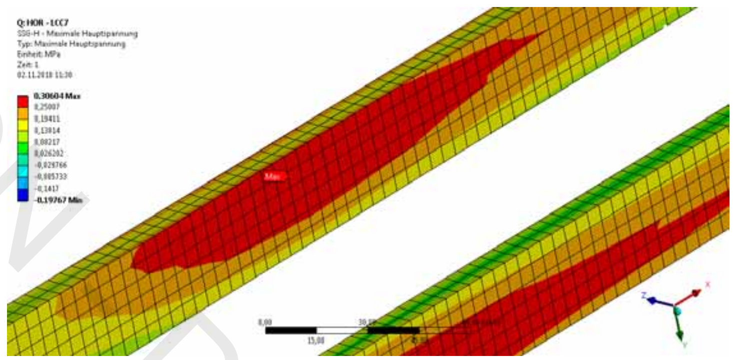


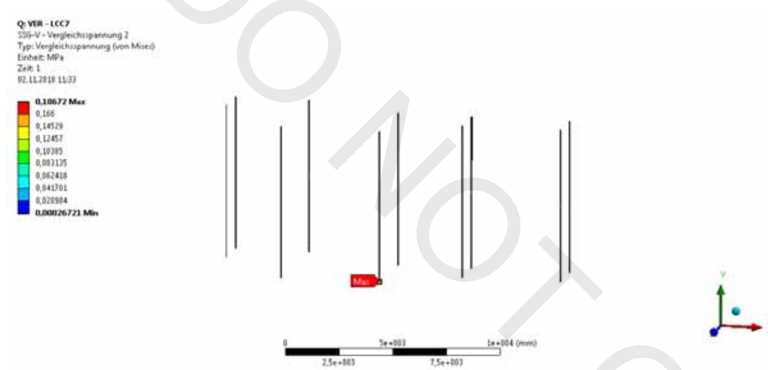
$\sigma_{v,ver}$ [N/mm²]	0.148	 
$\sigma_{1,ver}$ [N/mm²]	0.153	

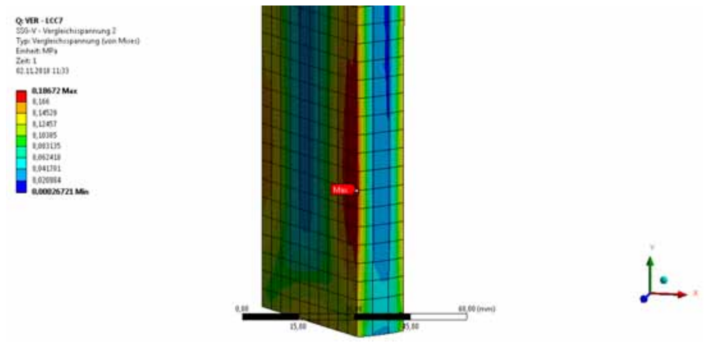
			
107	$\sigma_{v,hor}$ [N/mm²]	0.205	

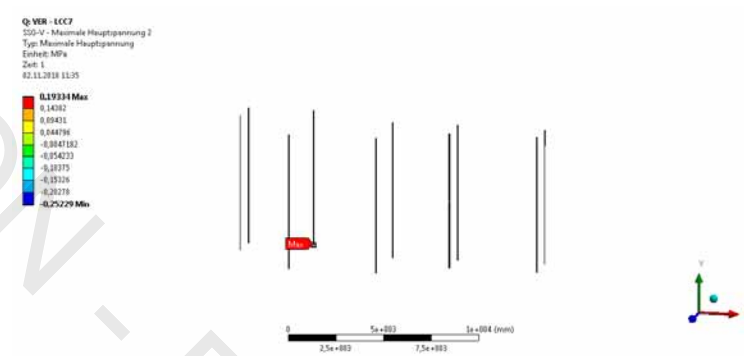
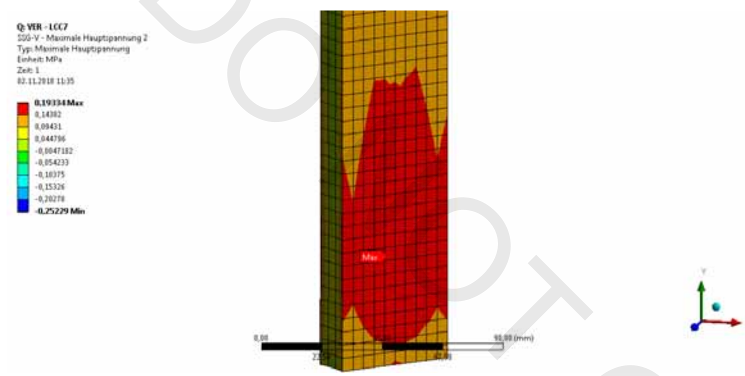
$\sigma_{1,hor}$ N/mm²]	0.306	
$\sigma_{v,ver}$ [N/mm²]	0.187	

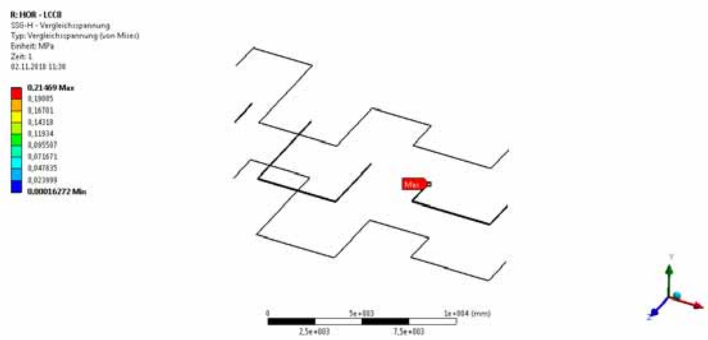
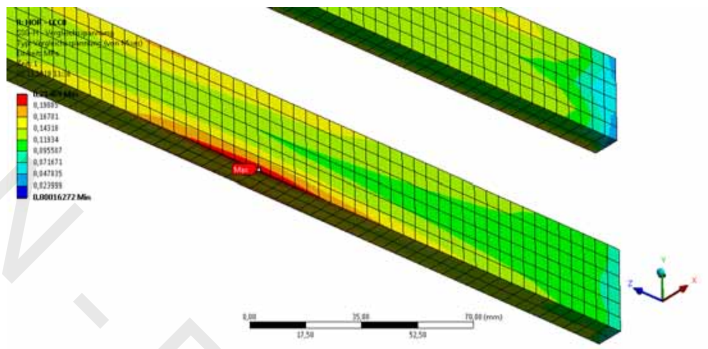
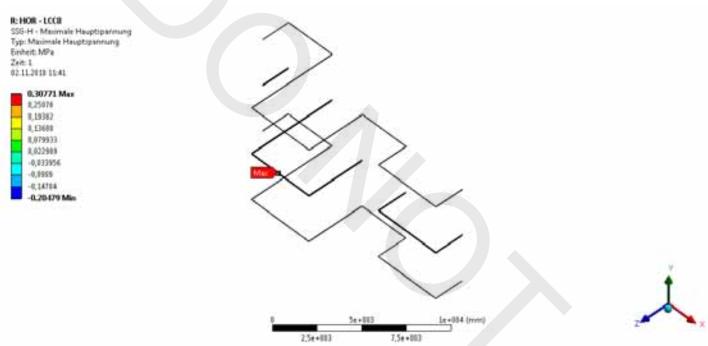


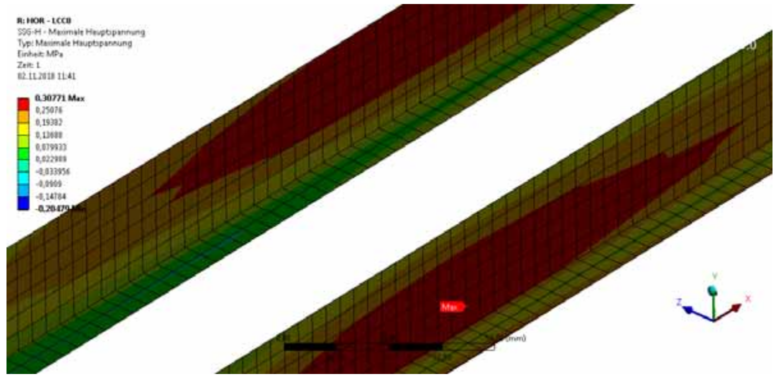


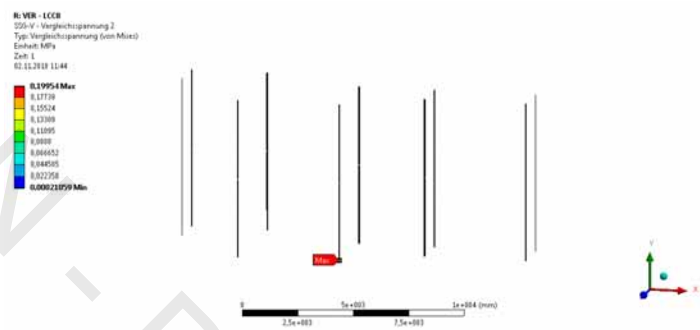
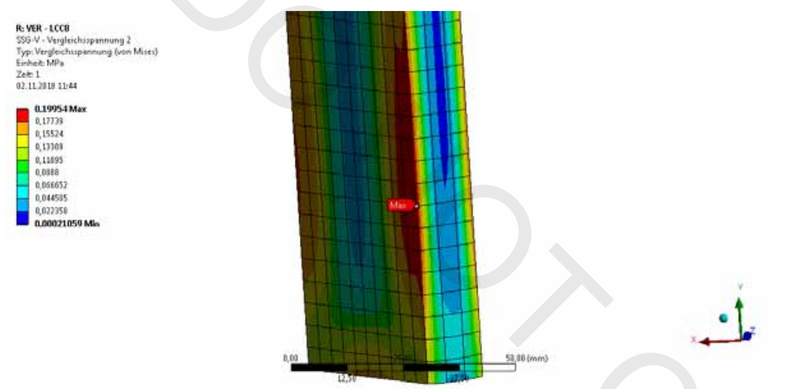


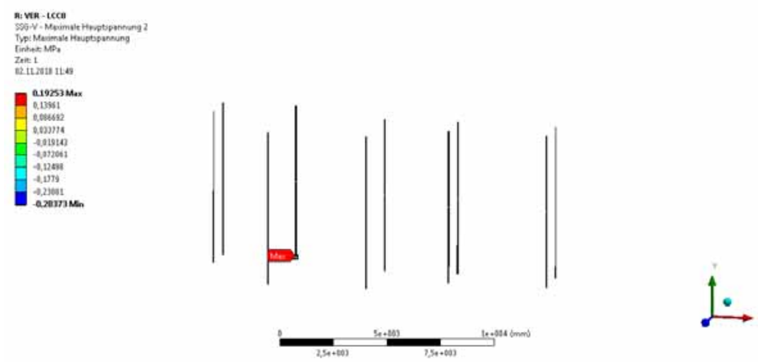
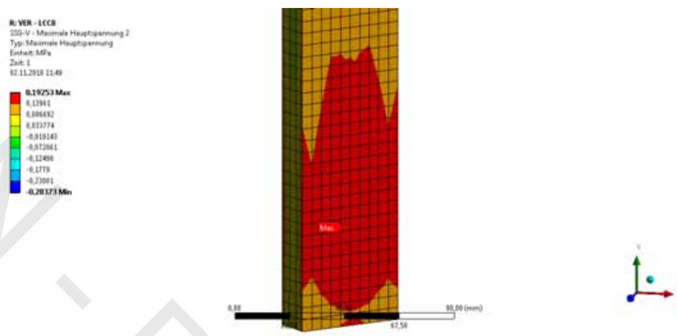
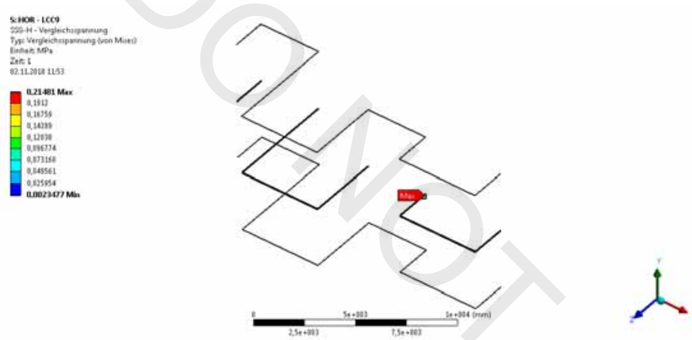
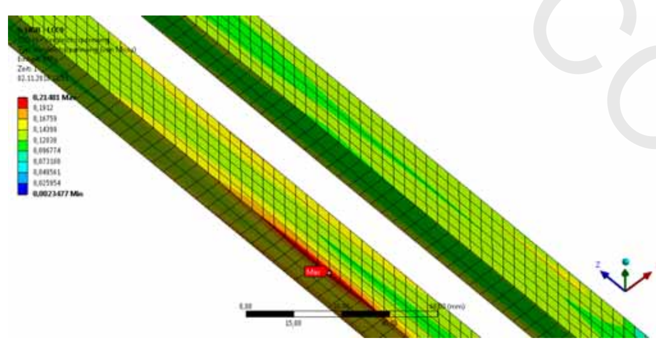


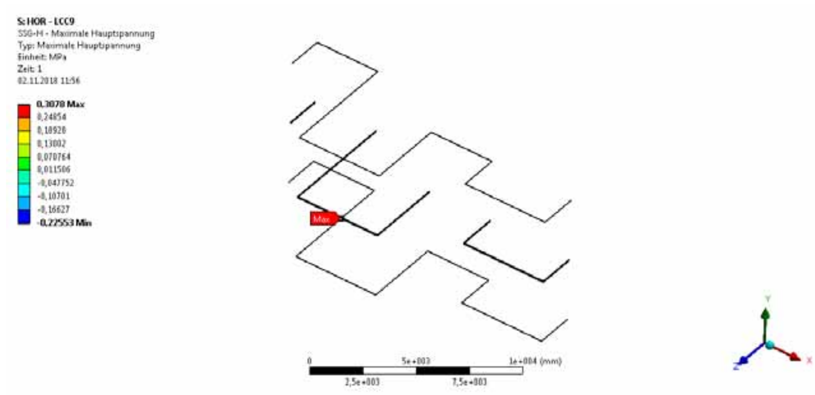
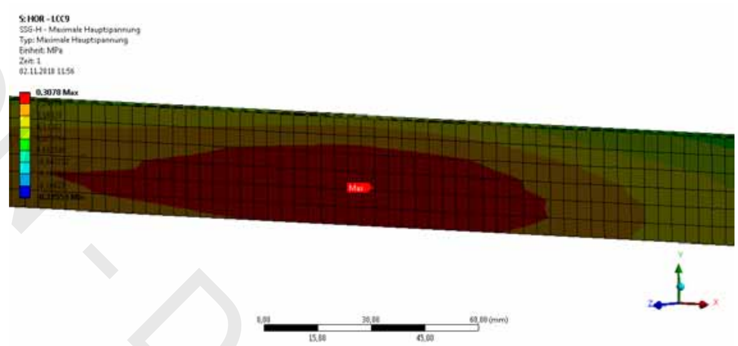
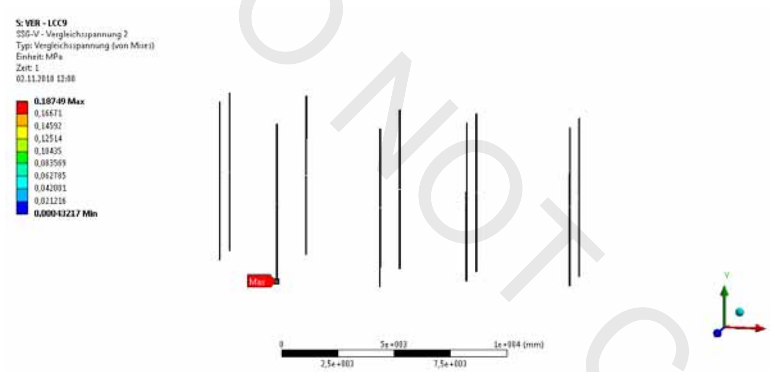
$\sigma_{1,ver}$ [N/mm²]	0.193	 

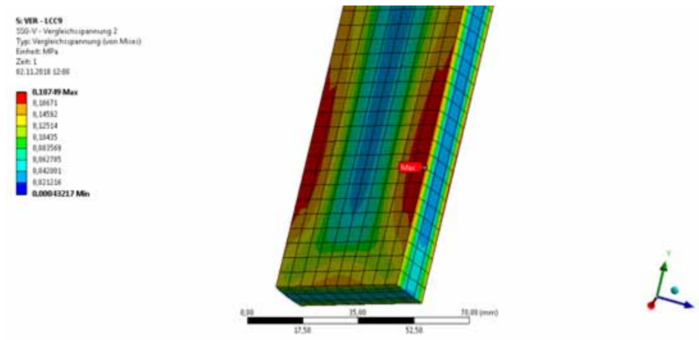
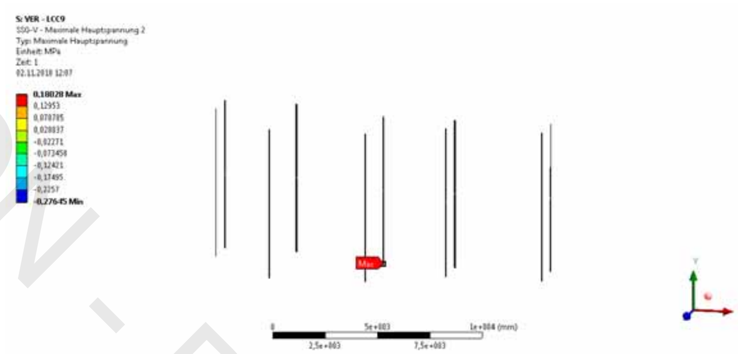
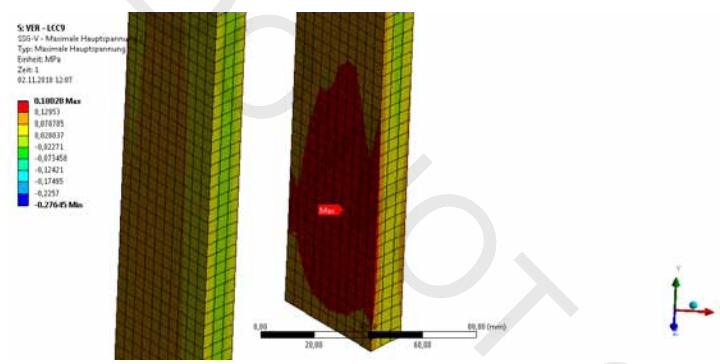
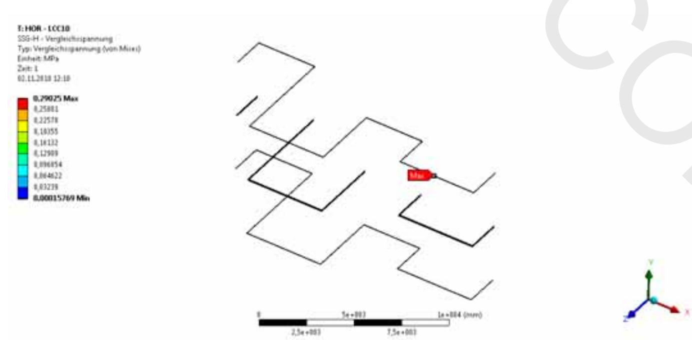
108	$\sigma_{v,hor}$ [N/mm²]	0.215	 
	$\sigma_{1,hor}$ [N/mm²]	0.308	

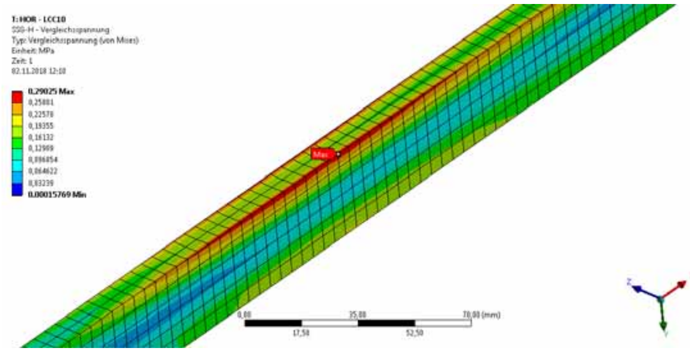


$\sigma_{v,ver}$ [N/mm²]	0.200	 

	$\sigma_{1,ver}$ N/mm²]	0.193	 
109	$\sigma_{v,hor}$ [N/mm²]	0.215	 

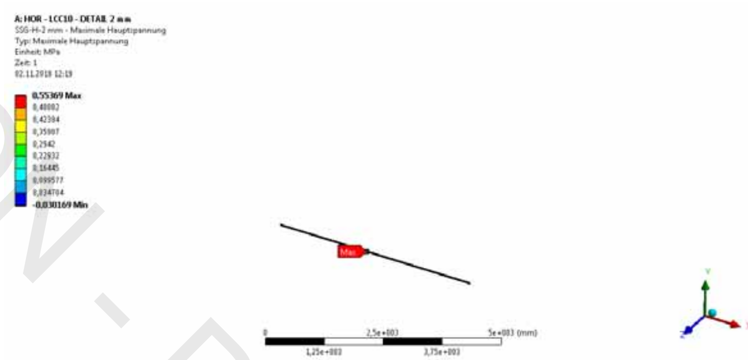
$\sigma_{1,hor}$ [N/mm²]	0.308	
$\sigma_{v,ver}$ [N/mm²]	0.187	

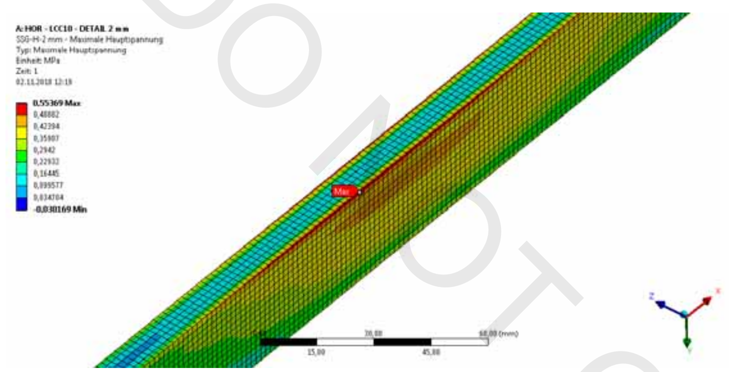
			
	$\sigma_{1,ver}$ N/mm²]	0.180	 
110	$\sigma_{v,hor}$ [N/mm²]	0.290	



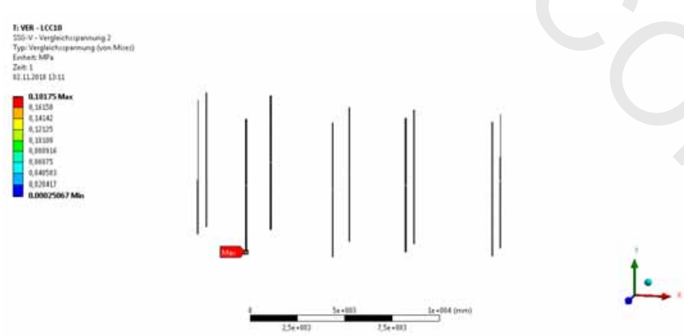
$\sigma_{1,hor}$ [N/mm²] 0.554

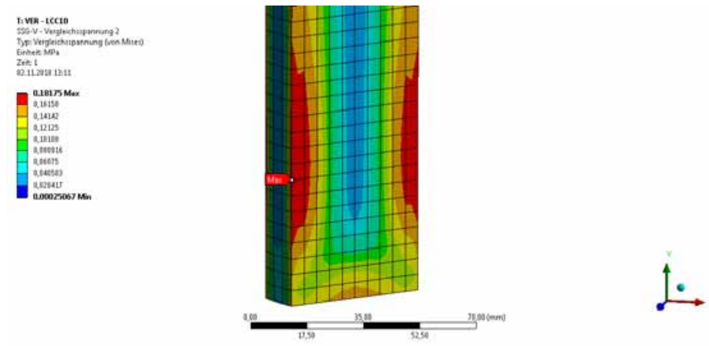
mesh size: 2 mm

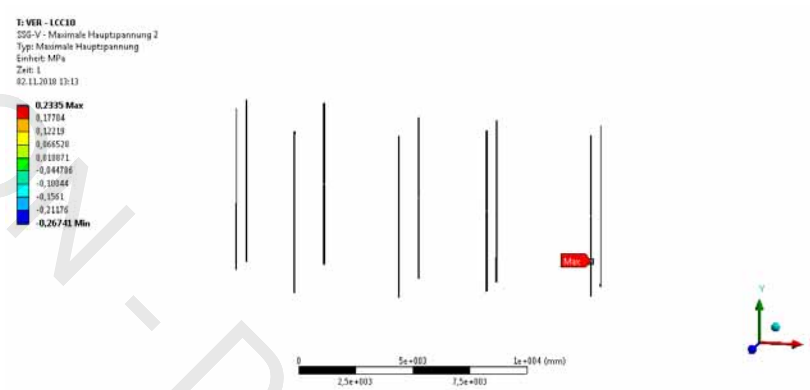
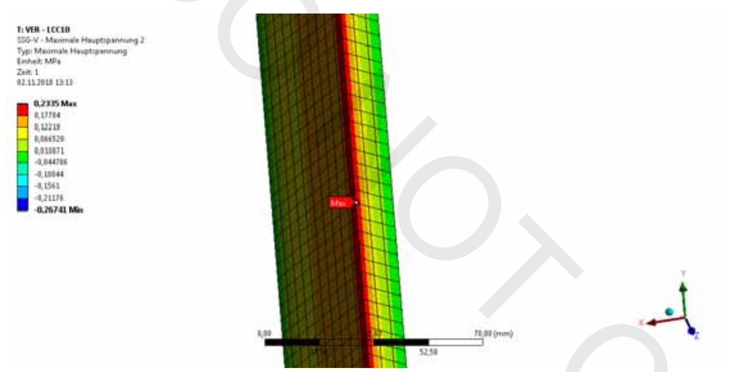




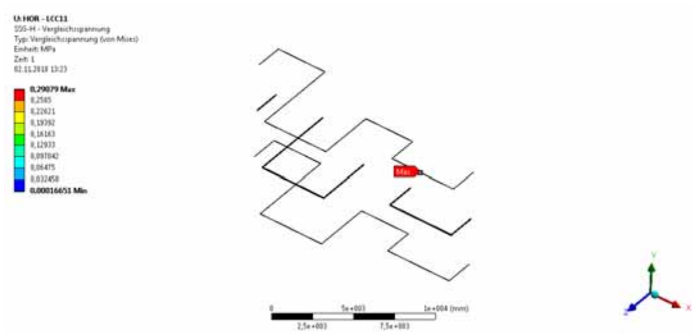
$\sigma_{v,ver}$ [N/mm²] 0.182

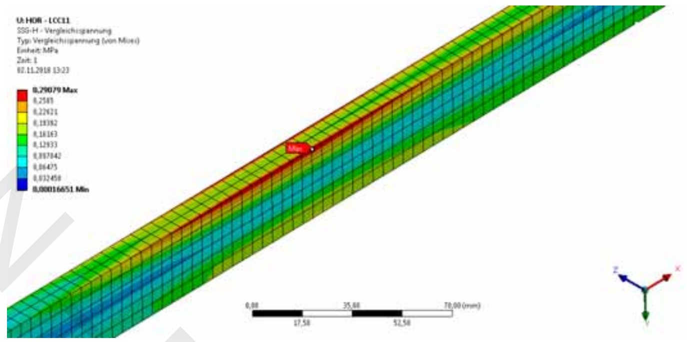




$\sigma_{1,ver}$ [N/mm²]	0.234	 

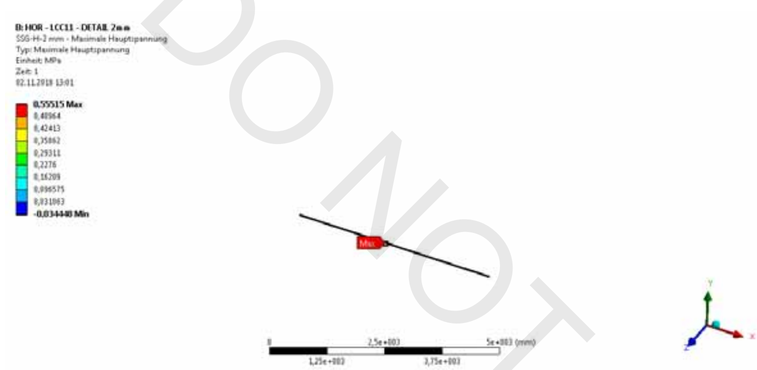
111 $\sigma_{v,hor}$ [N/mm²] 0.291

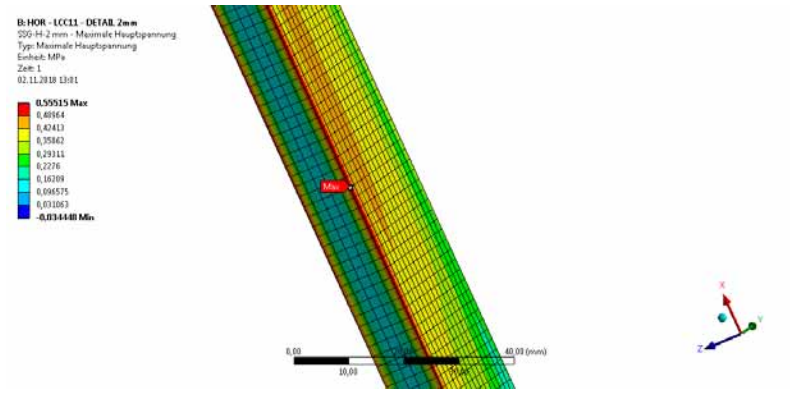


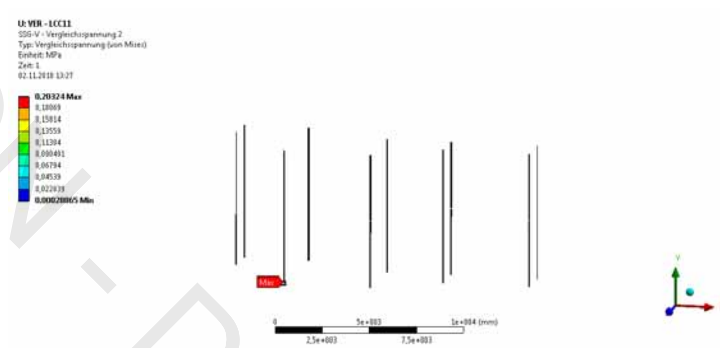
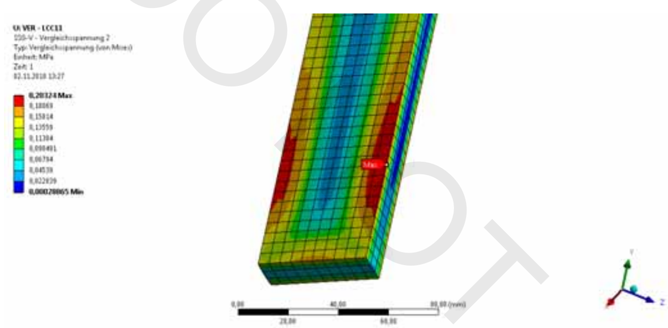


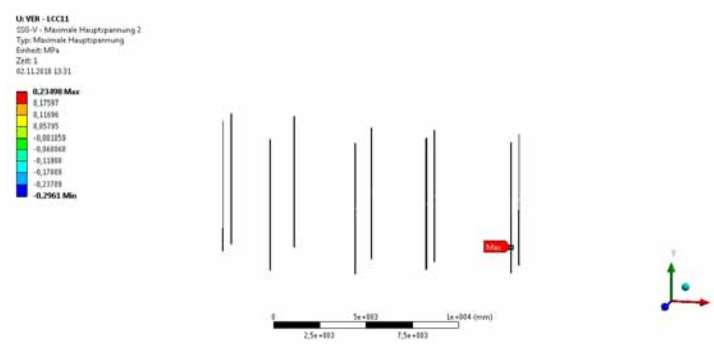
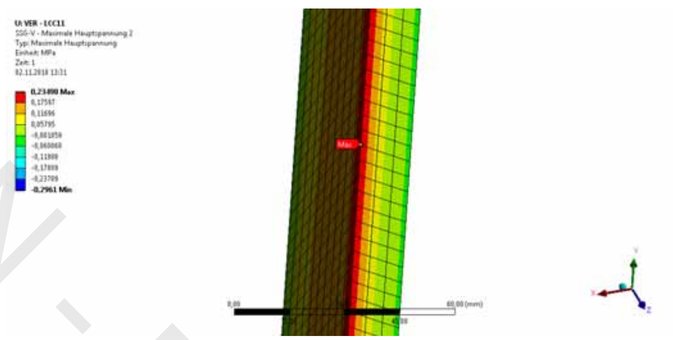
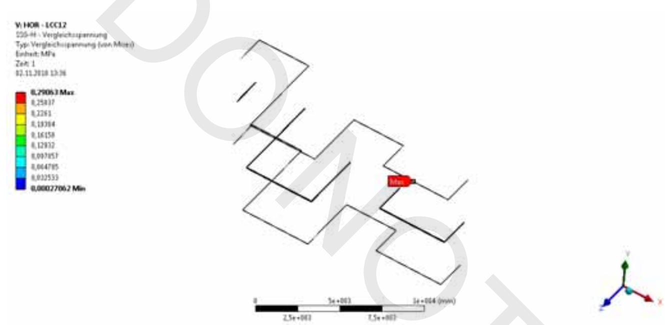
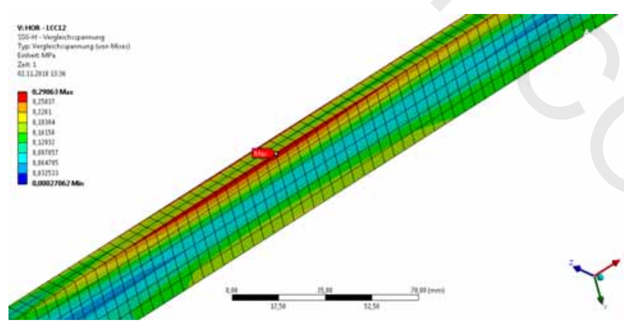
$\sigma_{1,hor}$ [N/mm²] 0.555

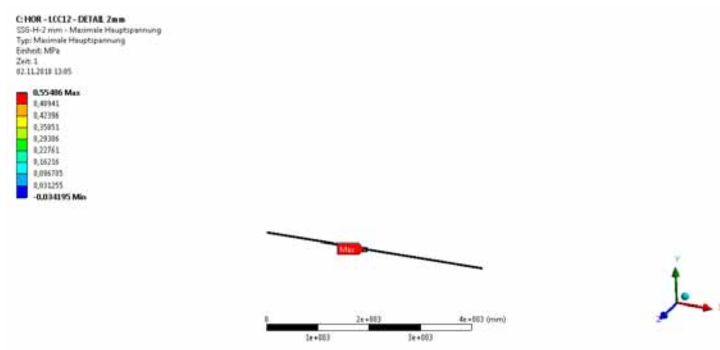
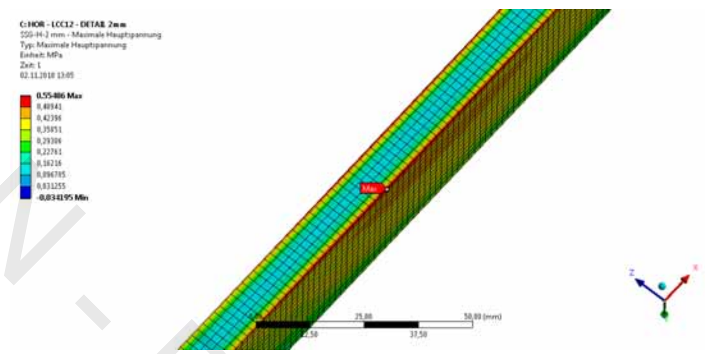
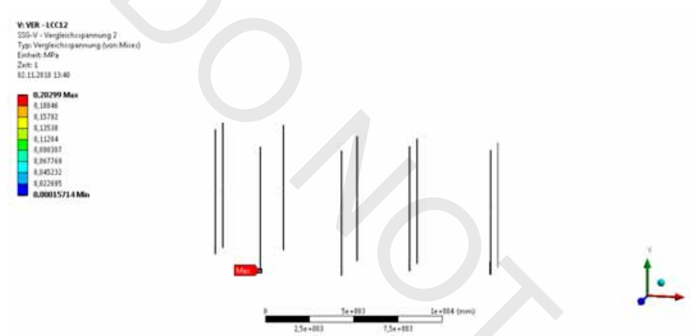
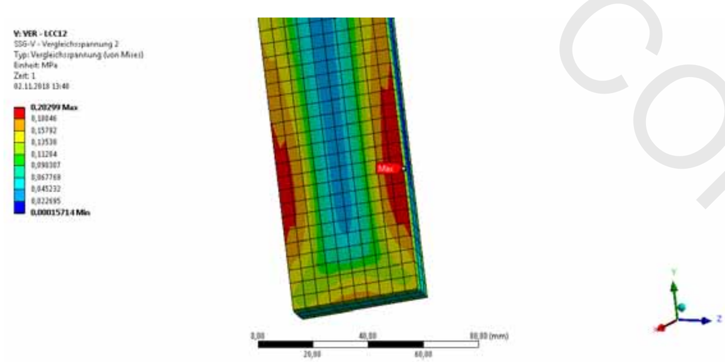
mesh size: 2 mm

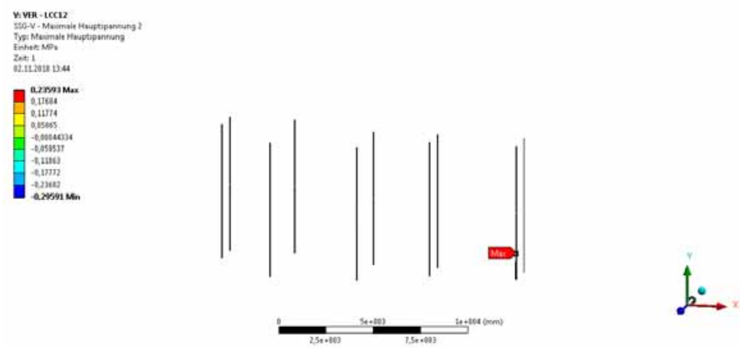
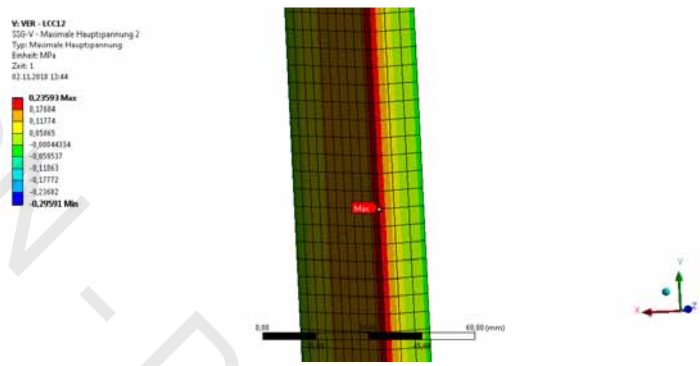




$\sigma_{v,ver}$ [N/mm²]	0.203	 

	$\sigma_{1,ver}$ [N/mm²]	0.235	 
112	$\sigma_{v,hor}$ [N/mm²]	0.291	 

$\sigma_{1,hor}$ [N/mm²]	0.555	 
$\sigma_{v,ver}$ [N/mm²]	0.203	 

$\sigma_{1,ver}$ [N/mm²]	0.236	

8.6. Verification

8.6.1. General

According to “Technical Information for Sikasil SG – Joint Calculation” by Sika [5] for the verification the equivalent tensile stress σ_v (von Mises stress) is used. In addition the max. principal tensile stresses are also considered. The design values were derived by Finite Element calculations in section 8.3. The calculations include an increase of the design values based on a lower safety factor for accurate numerical calculation of stresses [5].

8.6.2. Pos 2.1 – Horizontal SSG joint

Material: Sikasil SG-550

Thickness: 10 mm

Width: 30 mm

von Mises stress (mesh size: 6 mm):

$\sigma_{v,Rd}$ = 0.331 N/mm^2

$\sigma_{v,max}$ = 0.291 N/mm^2

$\sigma_{v,max} / \sigma_{v,Rd}$ = = 0.88 ≤ 1.00 (OK)

max. principal tensile stress (mesh size: 6 mm / 2 mm)

$\sigma_{1,Rd}$ = 0.391 N/mm^2 / 0.579 N/mm^2

$\sigma_{1,max}$ = 0.383 N/mm^2 / 0.555 N/mm^2

$\sigma_{1,max} / \sigma_{1,Rd}$ = = 0.98 / 0.96 ≤ 1.00 (OK)

8.6.3. Pos. 2.2 – Vertical SSG joint

Material: Sikasil SG-20

Thickness: 15 mm

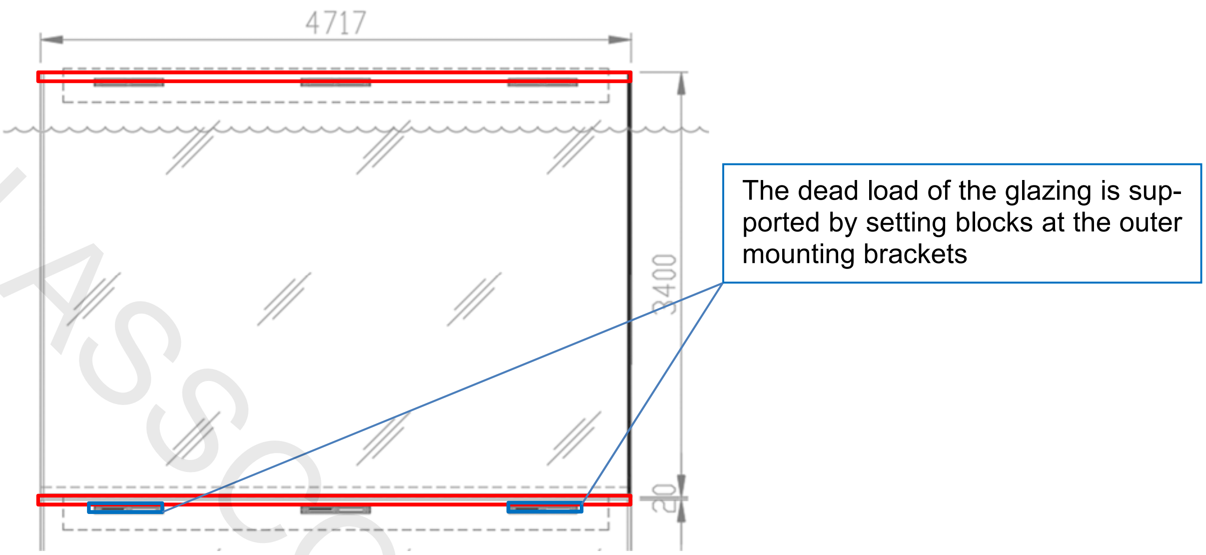
Width: 46.7 mm

von Mises stress (mesh size: 6 mm):

$\sigma_{v,Rd}$	=	0.336 N/mm^2
$\sigma_{v,max}$	=	0.203 N/mm^2
$\sigma_{v,max} / \sigma_{v,Rd}$	=	0.60 ≤ 1.00 (OK)

max. principal tensile stress (mesh size: 6 mm)

$\sigma_{1,Rd}$	=	0.392 N/mm^2
$\sigma_{1,max}$	=	0.235 N/mm^2
$\sigma_{1,max} / \sigma_{1,Rd}$	=	0.60 ≤ 1.00 (OK)



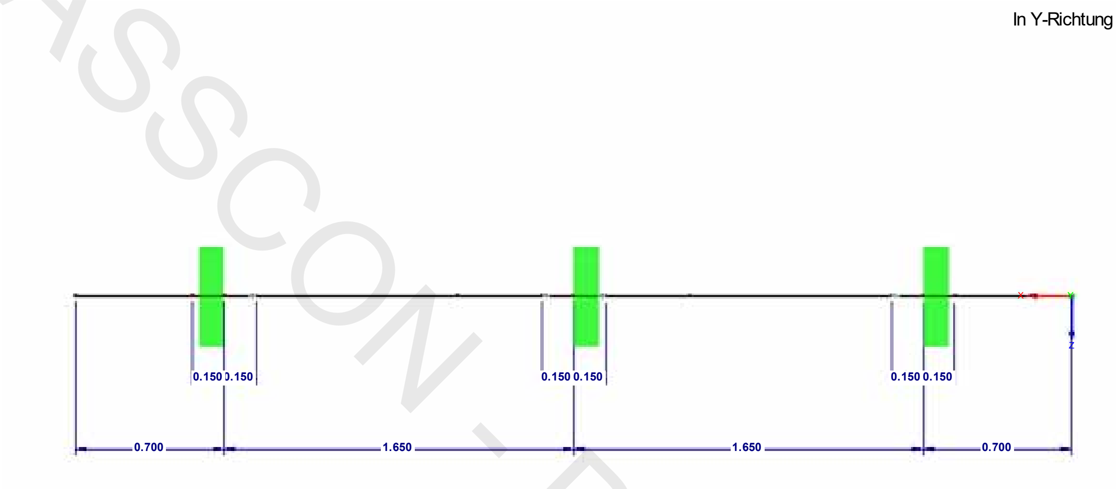
The glazing at the west façade is connected to horizontal aluminium profiles by SSG joints. These aluminium profiles at the upper edge of the glazing ("upper aluminium profile") and the lower edge of the glazing ("lower aluminium profile") are each fastened to the solid structure by two, three or four mounting brackets depending on the size of the glazing. Both profiles are screwed to a end plate of the mounting bracket. At the "lower aluminium profile", this end plate engages the profile. The end plate is 320 mm wide. To reduce the deformation, the "upper aluminium profile" is doubled by an additional profile between the brackets.

The maximum stress on the aluminium profiles occurs at the aluminium profiles with the maximum span width. Correspondingly, the aluminium profiles for the glazing with a width of 4.7 m and three brackets are verified (Pos. 3.1a). For the other glazing, smaller spans are planned.

Furthermore, the aluminium profile for the glazing with a maximum vertical span of 7.2 m is verified (Pos. 3.1b), since when failure of the vertical SSG joint occur, the maximum stress is to be expected here. For this reason, a different distance between glass edge and mounting bracket is chosen for these glasses.

The aluminium profile is doubled by an additional profile (app. 40 x 20 x 3, EN-AW 6063 (T6)) between the brackets.

9.1.2. Static System



9.1.3. Load Cases (LC)

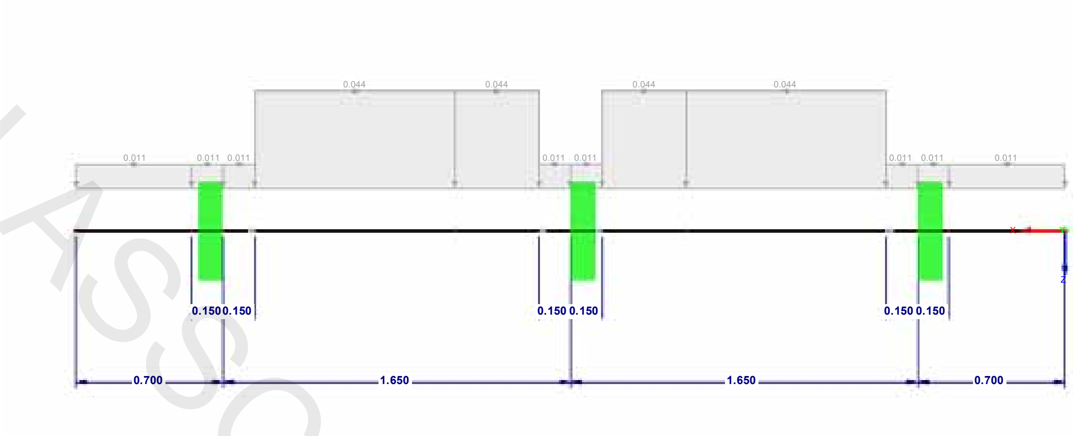
LC 1 – Dead Load

The dead load of the aluminium profile is taken into account by the software:

$\gamma = 27.0\ kN/m^3$

LF1: Eigengewicht
Belastung [kN/m]

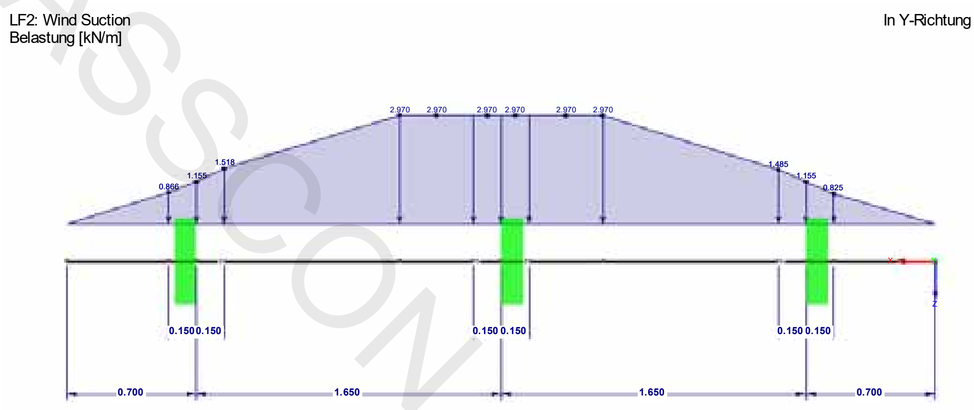
In Y-Richtung



LC 2 – Wind Suction

For the verification of the aluminium profiles, the loads according to section 6.2 are recognized. The surface load is converted into a linear line load according to the span:

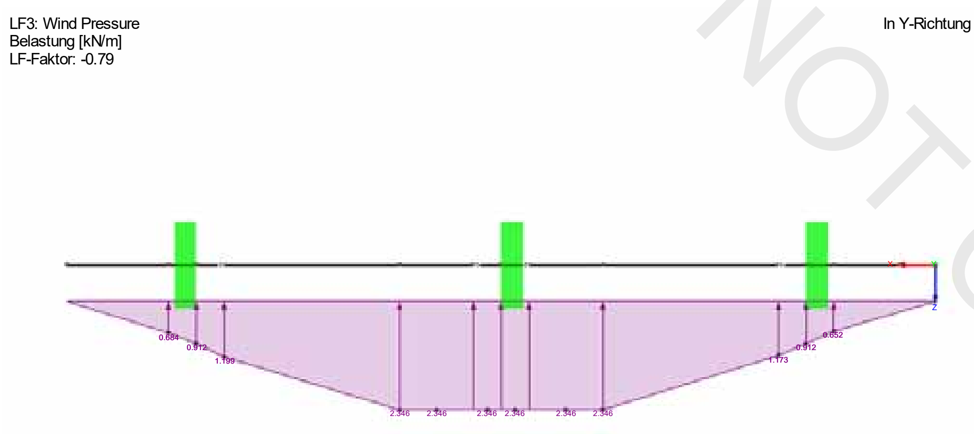
w_k = 1.8 m x 1.65 kN/m^2 = 2.97 kN/m



LC 3 – Wind Pressure

For the verification of the aluminium profiles, the loads according to section 6.2 are recognized. The surface load is converted into a linear line load according to the span:

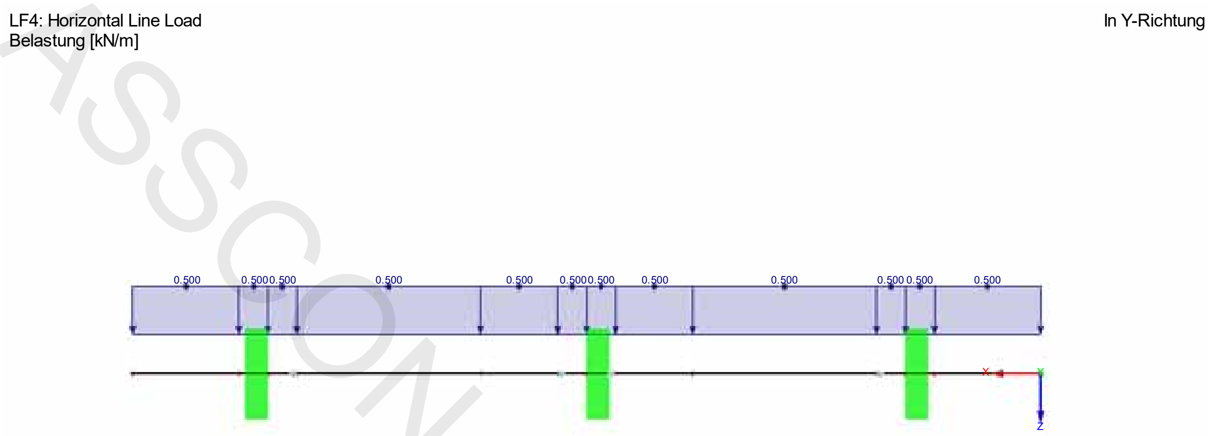
w_k = 1.8 m x 1.30 kN/m^2 = 2.34 kN/m



LC 4 – Horizontal Line Load

For the verification of the aluminium profiles, the horizontal line load on the glazing is divided conservatively:

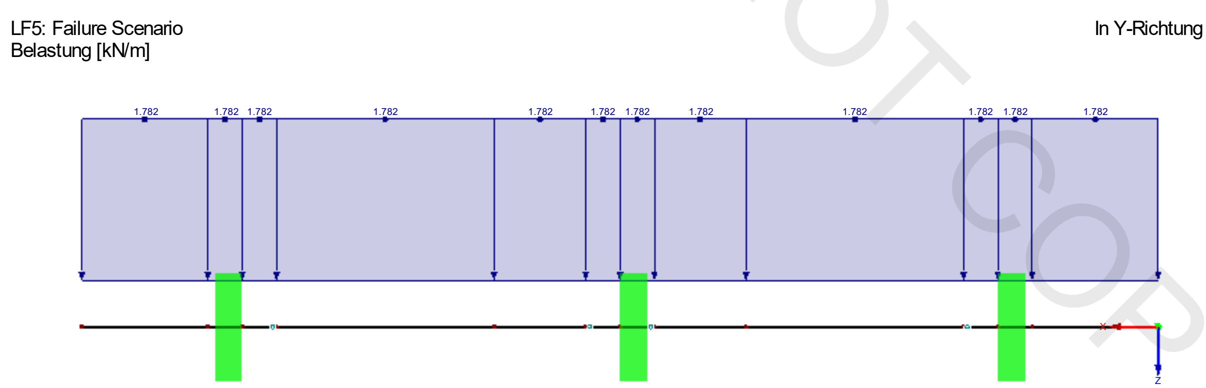
q_k = 1.2 m / 3.6 m x 1.50 kN/m = 0.50 kN/m



LC 5 – Failure Scenario

As decisive load, a characteristic wind load which is reduced by ψ_0 is taken into account for the scenario "failure of vertical SSG joints". The surface load is converted into a linear line load according to the span:

w_k = 0.6 x 1.8 m x 1.65 kN/m^2 = 1.782 kN/m



9.1.4. Load Case Combinations (LCC)

The loadings are combined under consideration of the combination and partial safety coefficients according to DIN EN 1990. The following tables provide an overview of the load cases and the calculated load case combinations. The following abbreviations are used:

ULS: Ultimate limit state (EN 1990, Abs. 6.4)

SLS: Serviceability limit state (EN 1990, Abs. 6.5)

Table 1 Load Cases

Load case	Description
LC1	Dead Load
LC2	Wind Suction
LC3	Wind Pressure
LC4	Horizontal Line Load
LC5	Failure Scenario

Table 2 Load Case Combinations

Load-comb.	LC.1		LC.2		LC.3	
	Factor	No.	Factor	No.	Factor	No.
LCC1	1,350	LC1				
LCC2	1,350	LC1	1,500	LC2		
LCC3	1,350	LC1	1,500	LC3		
LCC4	1,350	LC1	1,500	LC2	1,050	LC4
LCC5	1,350	LC1	1,500	LC3	1,050	LC4
LCC6	1,350	LC1	1,500	LC4		
LCC7	1,350	LC1	0,900	LC2	1,500	LC4
LCC8	1,350	LC1	0,900	LC3	1,500	LC4
LCC9	1,000	LC5				
LCC10	1,000	LC1				
LCC11	1,000	LC1	1,000	LC2		
LCC12	1,000	LC1	1,000	LC3		
LCC13	1,000	LC1	1,000	LC2	0,700	LC4
LCC14	1,000	LC1	1,000	LC3	0,700	LC4
LCC15	1,000	LC1	1,000	LC4		
LCC16	1,000	LC1	0,600	LC2	1,000	LC4
LCC17	1,000	LC1	0,600	LC3	1,000	LC4

LCC18	1,000	LC1				
LCC19	1,000	LC1	0,200	LC2		
LCC20	1,000	LC1	0,200	LC3		
LCC21	1,000	LC1	0,200	LC2	0,300	LC4
LCC22	1,000	LC1	0,200	LC3	0,300	LC4
LCC23	1,000	LC1	0,500	LC4		
LCC24	1,000	LC1	0,000	LC2	0,500	LC4
LCC25	1,000	LC1	0,000	LC3	0,500	LC4
LCC26	1,000	LC1				
LCC27	1,000	LC1	0,000	LC2		
LCC28	1,000	LC1	0,000	LC3		
LCC29	1,000	LC1	0,000	LC2	0,300	LC4
LCC30	1,000	LC1	0,000	LC3	0,300	LC4
LCC31	1,000	LC1	0,300	LC4		

9.1.5. Verification

Ultimate limit state

Aluminium profile QRO 35x40x3:

Aluminium EN-AW 6063 T6

σ_{Rd} = 16.0 kN/cm² / 1.1 = 14.5 kN/cm²

τ_{Rd} = 16.0 kN/cm² / 1.1 / (3)^{1/2} = 8.4 kN/cm²

Stress resultants (see figure below):

M_{Ed} = 53.0 kNcm

V_y = 3.91 kN

Cross-section values:

W_y = 4.22 cm³

A_s = 4.14 cm²

Normal stress:

σ_{Ed} = 53.0 kNcm / 4.22 cm³ = 12.6 kN/cm²

$\sigma_{Ed} / \sigma_{Rd}$ = 12.6 kN/cm² / 14.5 kN/cm² = <u>0.87 ≤ 1.00 (OK)</u>

Shear stress:

τ_{Ed} = 3.91 kN / 4.14 cm² = 0.95 kN/cm²

τ_{Ed} / τ_{Rd} = 0.95 kN/cm² / 8.4 kN/cm² = 0.11 ≤ 1.00 (OK)

Equivalent stress:

$(0.87^2 + 3 \times 0.11^2)^{1/2}$ = 0.89 ≤ 1.00 (OK)

<u>Aluminium profile QRO 35x40x3 doubled with QRO 20x40x3:</u>

Aluminium EN-AW 6063 T6

σ_{Rd} = 16.0 kN/cm^2 / 1.1 = 14.5 kN/cm^2

τ_{Rd} = 16.0 kN/cm^2 / 1.1 / (3)$^{1/2}$ = 8.4 kN/cm^2

Stress resultants (see figure below):

M_{Ed} = 99.0 kNcm

V_y = 3.91 kN

Cross-section values:

W_y = 9.13 cm³

A_s = 5.64 cm^2

Normal stress:

σ_{Ed} = 99.0 kNcm / 9.13 cm^3 = 10.9 kN/cm²

$\sigma_{Ed} / \sigma_{Rd}$ = 10.9 kN/cm^2 / 14.5 kN/cm^2 = <u>0.75 ≤ 1.00 (OK)</u>

Shear stress:

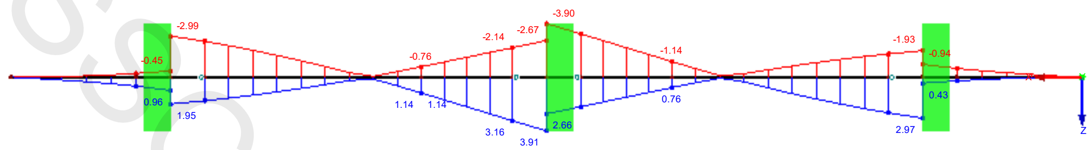
τ_{Ed} = 3.91 kN / 4.14 cm^2 = 0.95 kN/cm^2

τ_{Ed} / τ_{Rd} = 0.95 kN/cm^2 / 8.4 kN/cm^2 = <u>0.11 ≤ 1.00 (OK)</u>

Equivalent stress:

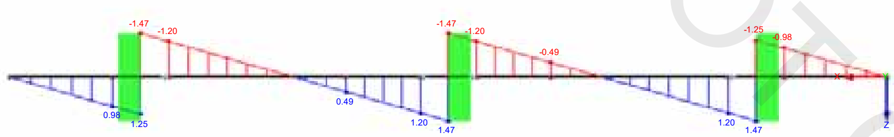
$(0.75^2 + 3 \times 0.11^2)^{1/2}$ = <u>0.78 ≤ 1.00 (OK)</u>

EK1: GZT (STR/GEO) - Ständig / vorübergehend - Gl. 6.10 In Y-Richtung
Ergebniskombinationen: Max- und Min-Werte



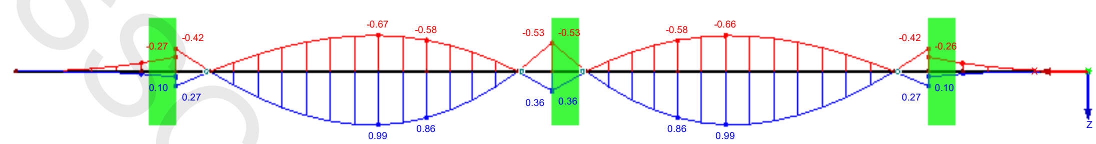
Max V-z: 3.91, Min V-z: -3.90 kN

LF5: Failure Scenario In Y-Richtung



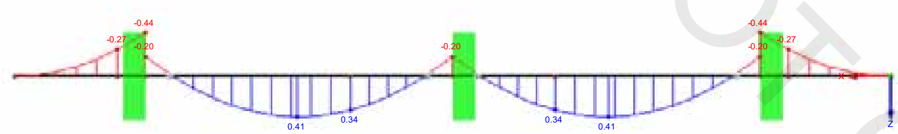
Max V-z: 1.47, Min V-z: -1.47 kN

EK1: GZT (STR/GEO) - Ständig / vorübergehend - Gl. 6.10 In Y-Richtung
Ergebniskombinationen: Max- und Min-Werte



Max M-y: 0.99, Min M-y: -0.67 kNm

LF5: Failure Scenario In Y-Richtung

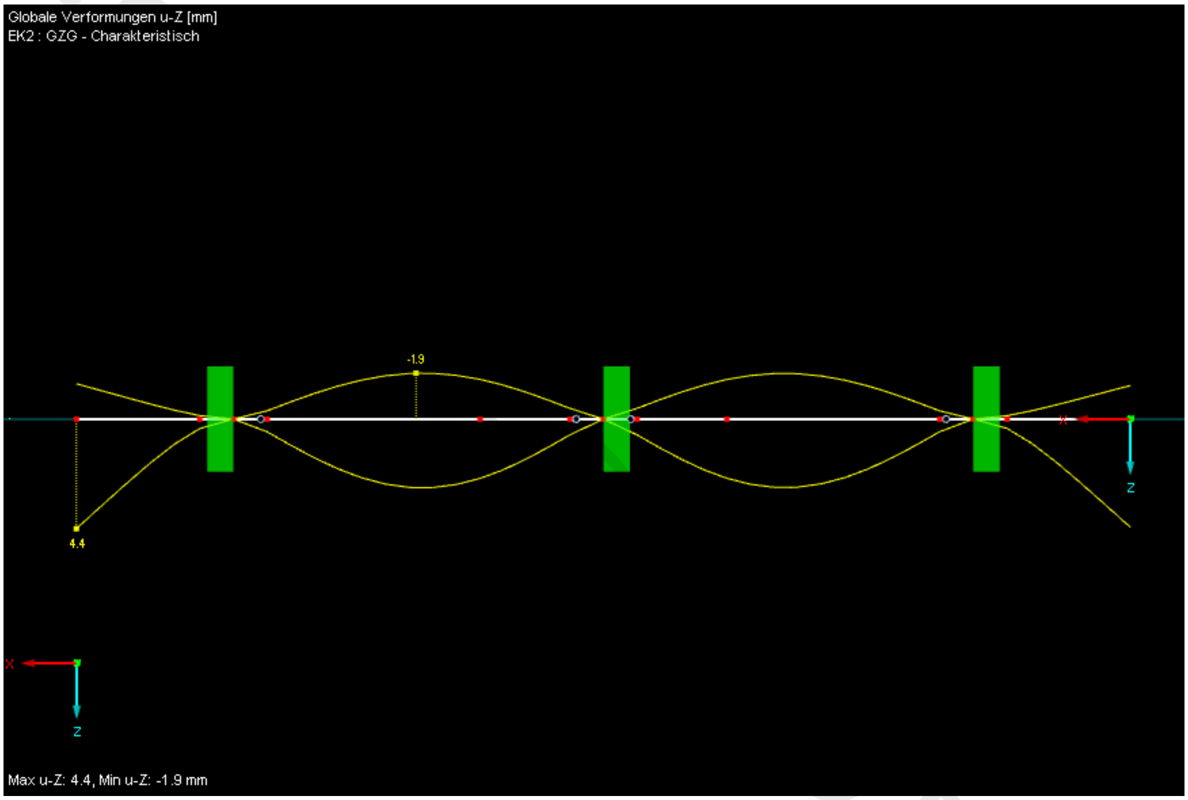


Max M-y: 0.41, Min M-y: -0.44 kNm

Serviceability limit state

According to ETAG 002 [6] the deflection of the substructure must be limited to $w_{allowed}$ = L/200:

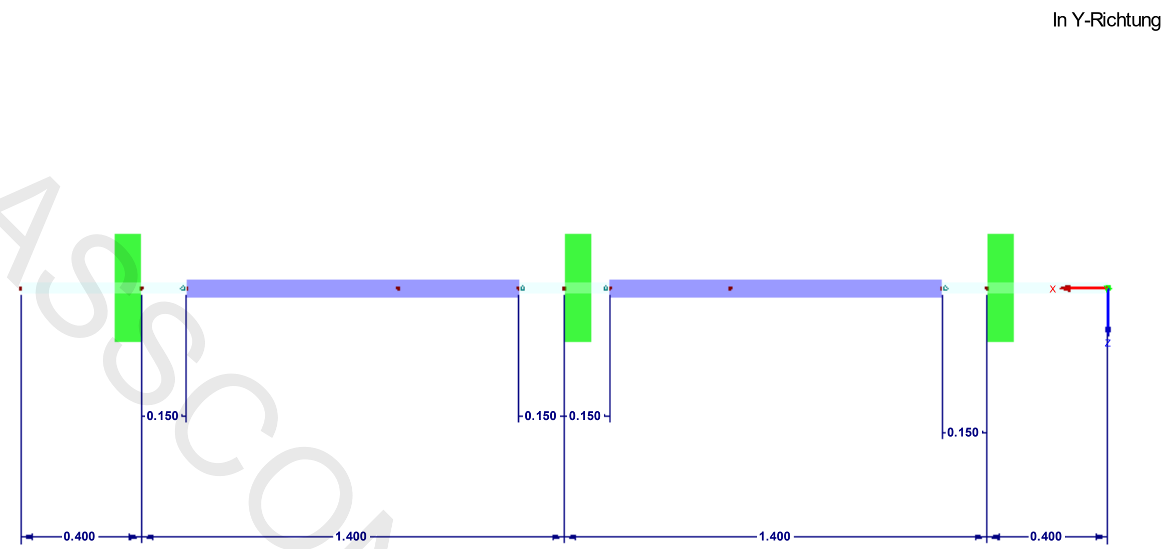
w			=	4.4 mm
$w_{allowed}$	=	700 mm x2 / 200	=	7.0 mm
w / $w_{allowed}$	=	4.4 mm / 7.0 mm	=	0.63 ≤ 1.00 (OK)



9.1.6. Reaction Forces

Node No.		Reaction Force $P_{Z'}$ [kN]	$M_{Y'}$ [kNm]	Load Case Combination
2	Max $P_{Z'}$	**3.91**	-0.16	LCC 4
	Min $P_{Z'}$	**-2.36**	0.17	LCC 3
3	Max $P_{Z'}$	**7.81**	0	LCC 4
	Min $P_{Z'}$	**-5.33**	0	LCC 3
4	Max $P_{Z'}$	**3.95**	0.15	LCC 4

9.2.2. Static System

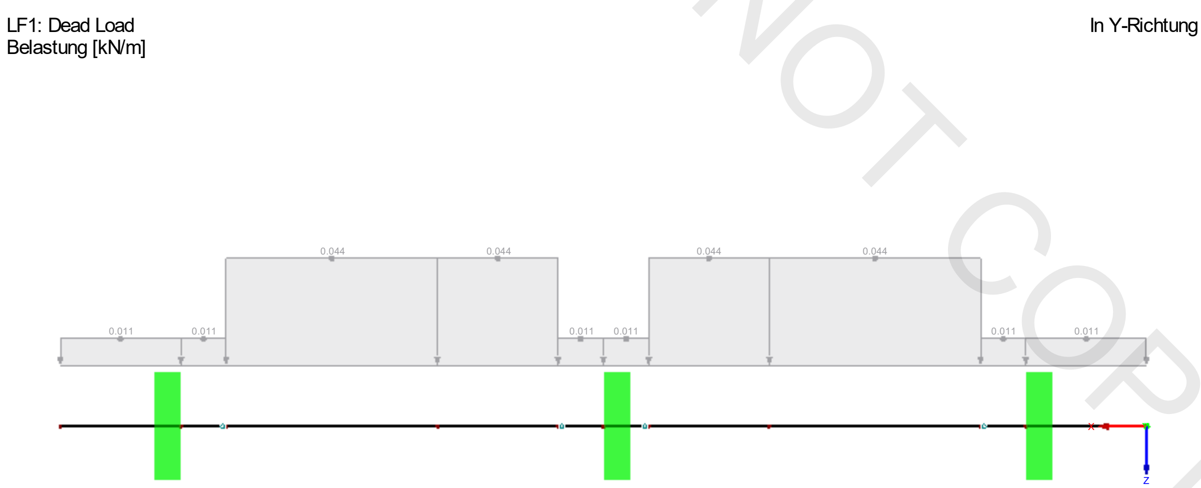


9.2.3. Load Cases (LC)

LC 1 – Dead Load

The dead load is taken into account by the software:

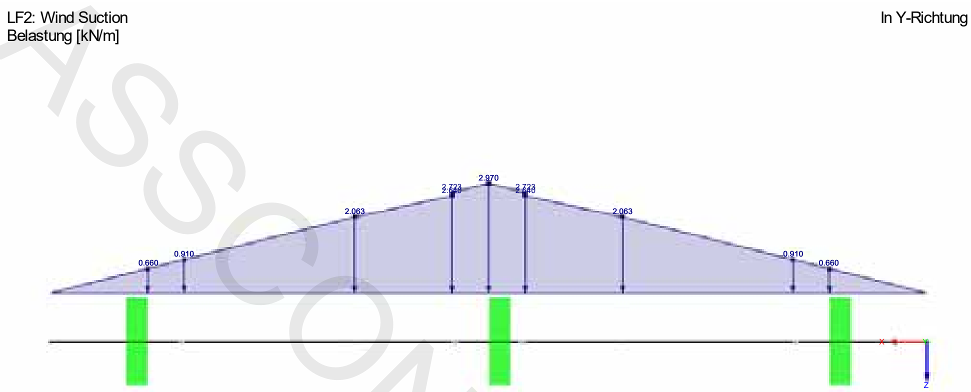
γ = 27.0 kN/m^3



LC 2 – Wind Suction

For the verification of the aluminium profiles, the loads according to section 6.2 are recognized. The surface load is converted into a linear line load according to the span:

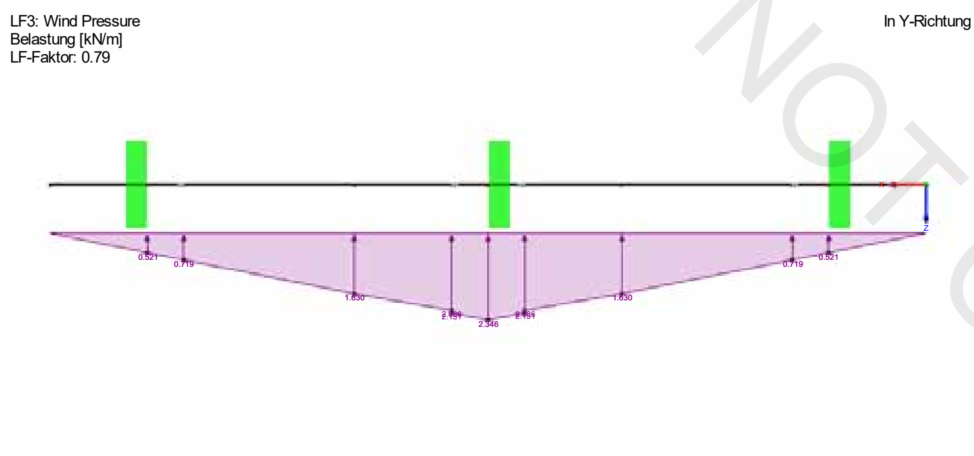
w_k = 1.8 m x 1.65 kN/m^2 = 2.97 kN/m



LC 3 – Wind Pressure

For the verification of the aluminium profiles, the loads according to section 6.2 are recognized. The surface load is converted into a linear line load according to the span:

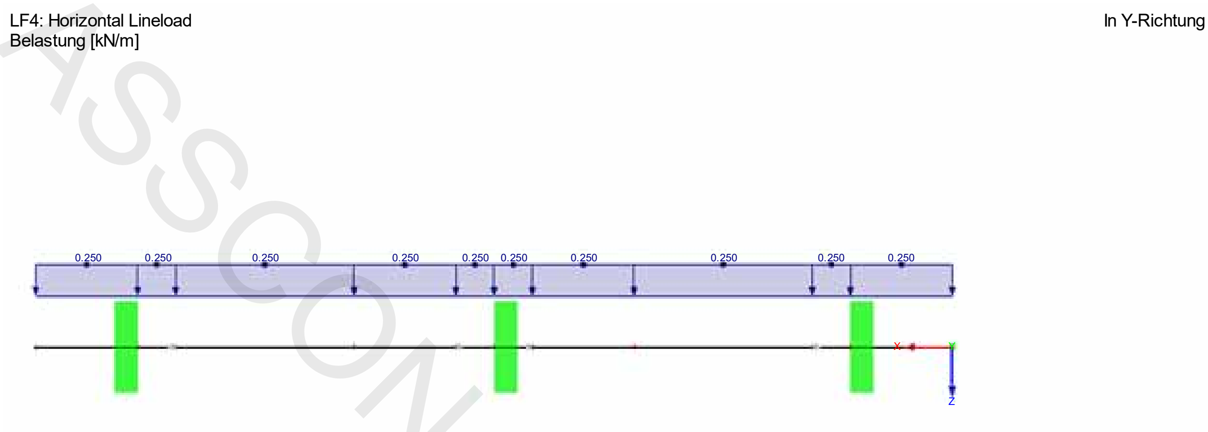
w_k = 1.8 m x 1.30 kN/m^2 = 2.34 kN/m



LC 4 – Horizontal Line Load

For the verification of the aluminium profiles, the horizontal line load on the glazing is divided as follows:

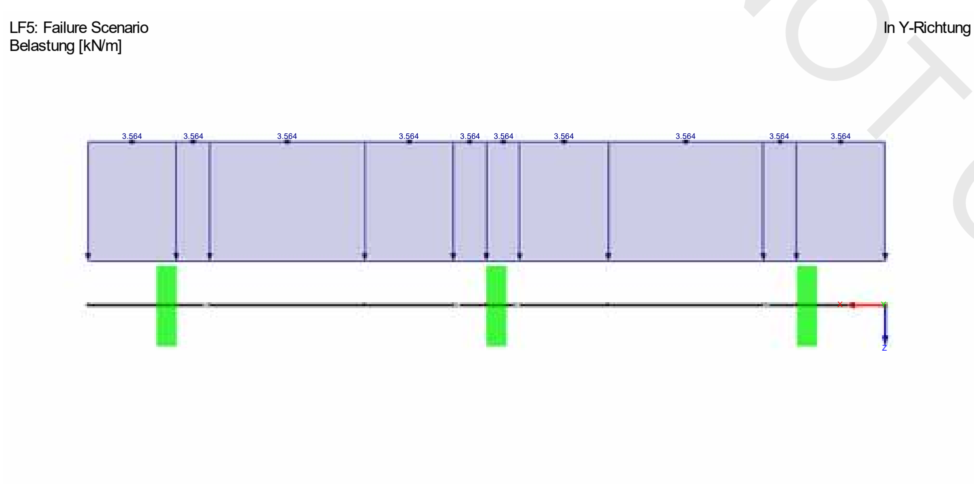
q_k = 1.2 m / 7.2 m x 1.50 kN/m = 0.25 kN/m^2



LC 5 – Failure Scenario

As decisive load, a characteristic wind load which is reduced by ψ_0 is taken into account for the scenario "failure of vertical SSG joints". The surface load is converted into a linear line load according to the span:

w_k = 0.6 x 3.6 m x 1.65 kN/m^2 = 3.564 kN/m



9.2.4. Load Case Combinations (LCC)

The loadings are combined under consideration of the combination and partial safety coefficients according to DIN EN 1990. The following tables provide an overview of the load cases and the calculated load case combinations. The following abbreviations are used:

ULS: Ultimate limit state (EN 1990, Abs. 6.4)

SLS: Serviceability limit state (EN 1990, Abs. 6.5)

Table 3 Load Cases

Load case	Description
LC1	Dead Load
LC2	Wind Suction
LC3	Wind Pressure
LC4	Horizontal Line Load
LC5	Failure Scenario

Table 4 Load Case Combination

Load-	LC.1		LC.2		LC.3	
comb.	Factor	No.	Factor	No.	Factor	No.
LCC1	1,350	LC1				
LCC2	1,350	LC1	1,500	LC2		
LCC3	1,350	LC1	1,500	LC3		
LCC4	1,350	LC1	1,500	LC2	1,050	LC4
LCC5	1,350	LC1	1,500	LC3	1,050	LC4
LCC6	1,350	LC1	1,500	LC4		
LCC7	1,350	LC1	0,900	LC2	1,500	LC4
LCC8	1,350	LC1	0,900	LC3	1,500	LC4
LCC9	1,000	LC5				
LCC10	1,000	LC1				
LCC11	1,000	LC1	1,000	LC2		
LCC12	1,000	LC1	1,000	LC3		
LCC13	1,000	LC1	1,000	LC2	0,700	LC4
LCC14	1,000	LC1	1,000	LC3	0,700	LC4
LCC15	1,000	LC1	1,000	LC4		
LCC16	1,000	LC1	0,600	LC2	1,000	LC4
LCC17	1,000	LC1	0,600	LC3	1,000	LC4

LCC18	1,000	LC1				
LCC19	1,000	LC1	0,200	LC2		
LCC20	1,000	LC1	0,200	LC3		
LCC21	1,000	LC1	0,200	LC2	0,300	LC4
LCC22	1,000	LC1	0,200	LC3	0,300	LC4
LCC23	1,000	LC1	0,500	LC4		
LCC24	1,000	LC1	0,000	LC2	0,500	LC4
LCC25	1,000	LC1	0,000	LC3	0,500	LC4
LCC26	1,000	LC1				
LCC27	1,000	LC1	0,000	LC2		
LCC28	1,000	LC1	0,000	LC3		
LCC29	1,000	LC1	0,000	LC2	0,300	LC4
LCC30	1,000	LC1	0,000	LC3	0,300	LC4
LCC31	1,000	LC1	0,300	LC4		

9.2.5. Verification

Ultimate load state (ULS)

Aluminium profile QRO 35x40x3:

Aluminium EN-AW 6063 (T6)

σ_{Rd} = $16.0\ kN/cm^2 / 1.1$ = $14.5\ kN/cm^2$

τ_{Rd} = $16.0\ kN/cm^2 / 1.1 / (3)^{1/2}$ = $8.4\ kN/cm^2$

Stress resultants (see figure below):

M_{Ed} = 33.0 kNcm

V_y = 2.49 kN

Cross-section values:

W_y = $4.22\ cm^3$

A_s = $4.14\ cm^2$

Normal stress:

σ_{Ed} = $33.0\ kNcm / 4.22\ cm^3$ = $7.82\ kN/cm^2$

$\sigma_{Ed} / \sigma_{Rd}$ = $7.82\ kN/cm^2 / 14.5\ kN/cm^2$ = <u>0.54 ≤ 1.00 (OK)</u>

Shear stress:

τ_{Ed} = $2.49\ kN / 4.14\ cm^2$ = $0.61\ kN/cm^2$

τ_{Ed} / τ_{Rd} = $0.61\ kN/cm^2 / 8.4\ kN/cm^2$ = <u>0.08 ≤ 1.00 (OK)</u>

Equivalent stress:

$(0.54^2 + 3 \times 0.08^2)^{1/2}$ = <u>0.56 ≤ 1.00 (OK)</u>

Aluminium profile QRO 35x40x3 doubled with QRO 20x40x3:

Aluminium EN-AW 6063 (T6)

σ_{Rd} = 16.0 kN/cm^2 / 1.1 = 14.5 kN/cm^2

τ_{Rd} = 16.0 kN/cm^2 / 1.1 / (3)$^{1/2}$ = 8.4 kN/cm^2

Stress resultants (see figure below):

M_{Ed} = 33.0 kNcm

V_y = 2.58 kN

Cross-section values:

W_y = 9.13 cm^3

A_s = 5.64 cm^2

Normal stress:

σ_{Ed} = 54.0 kNcm / 9.13 cm^3 = 5.92 kN/cm^2

σ_{Ed} / σ_{Rd} = 5.92 kN/cm^2 / 14.5 kN/cm^2 = 0.41 ≤ 1.00 (OK)

Shear stress:

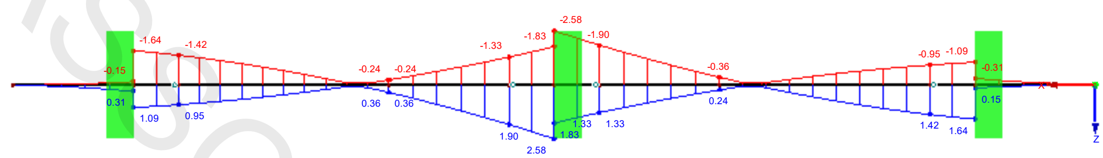
τ_{Ed} = 2.58 kN / 5.64 cm^2 = 0.46 kN/cm^2

τ_{Ed} / τ_{Rd} = 0.46 kN/cm^2 / 8.4 kN/cm^2 = 0.06 ≤ 1.00 (OK)

Equivalent stress:

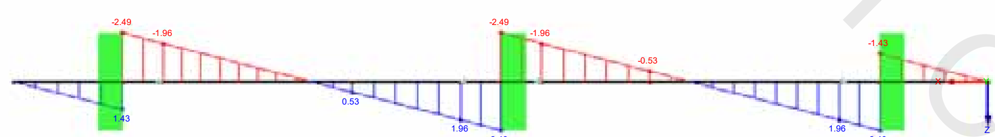
(0.41^2 + 3 x 0.06^2)$^{1/2}$ = 0.45 ≤ 1.00 (OK)

EK1: GZT (STR/GEO) - Ständig / vorübergehend - Gl. 6.10 In Y-Richtung
Ergebniskombinationen: Max- und Min-Werte



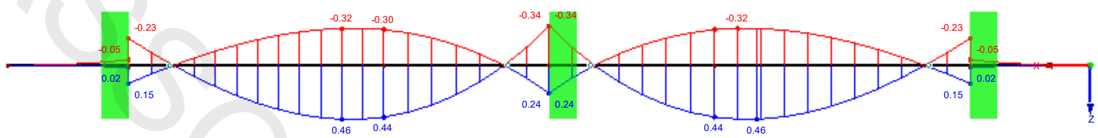
Max V-z: 2.58, Min V-z: -2.58 kN

LF5: Failure Scenario In Y-Richtung

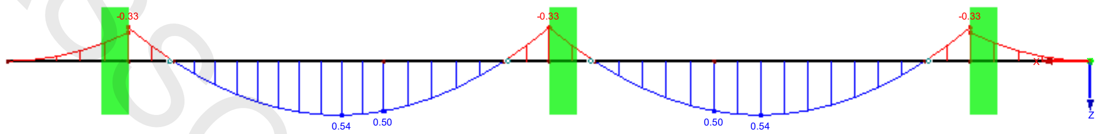


Max V-z: 2.49, Min V-z: -2.49 kN

EK1: GZT (STR/GEO) - Ständig / vorübergehend - Gl. 6.10 In Y-Richtung
Ergebniskombinationen: Max- und Min-Werte



Max M-y: 0.46, Min M-y: -0.34 kNm

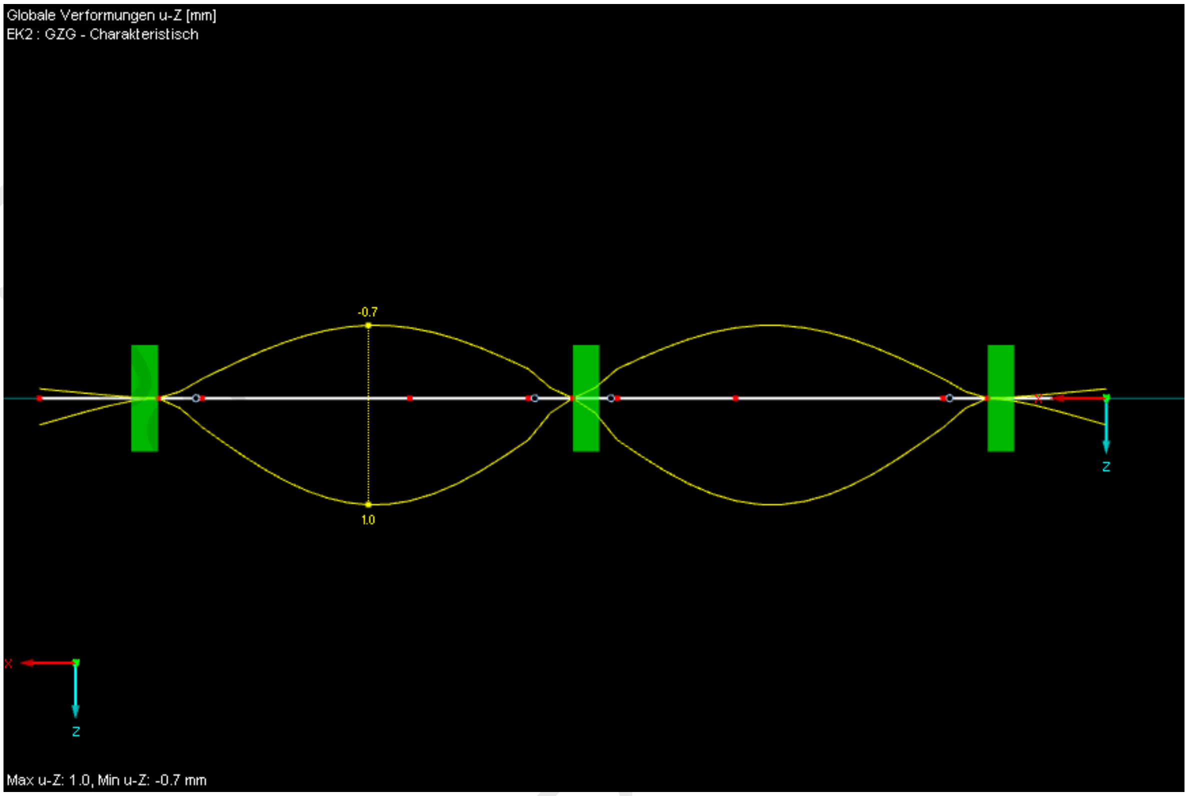


Max M-y: 0.54, Min M-y: -0.33 kNm

Serviceability limit state (SLS)

According to ETAG 002 [6] the deflection of the substructure must be limited to $w_{allowed}$ = L/200:

w			=	1.0 mm
$w_{allowed}$	=	400 mm / 200	=	2.0 mm
w / $w_{allowed}$	=	1.0 mm / 2.0 mm	=	0.50 ≤ 1.00 (OK)



9.2.6. Reaction Forces

Node No.		Reaction Force $P_{Z'}$ [kN]	$M_{Y'}$ [kNm]	Load Case Combination
2	Max $P_{Z'}$	**1.95**	-0.18	LCC 4
	Min $P_{Z'}$	**-1.24**	0.13	LCC 3
3	Max $P_{Z'}$	**5.17**	0.00	LCC 4
	Min $P_{Z'}$	**-3.67**	0.00	LCC 3
4	Max $P_{Z'}$	**1.95**	0.18	LCC 4
	Min $P_{Z'}$	**-1.24**	-0.13	LCC 3

9.2.7. Details – Upper Aluminium Profile

Screwed connection of aluminium profile QRO 35 x 40 x 3 to flat steel (t = 12 mm):

Stress resultants:

$F_{v,Ed}$ = 32 kN / 3 brackets / 4 screws = 2.7 kN

$F_{t,Ed}$ = 8.0 kN / 4 screws + 18 kNcm / (5 x 7.5 cm) = 2.5 kN

Verification:

Shear

$F_{v,ED}$ / $F_{v,Rd}$ = 2.7 kN / 22.3 kN = 0.13 < 1.0 (OK)

Bearing stress

$F_{v,Ed}$ / $F_{b,Rd}$ = 2.7 kN / 21.6 kN = 0.13 < 1.0 (OK)

Tension

$F_{t,Ed}$ / $F_{t,Rd}$ = 2.5 kN / 33.4 kN = 0.08 < 1.0 (OK)

Tension und Shear

$F_{v,ED}$ / $F_{v,Rd}$ + $F_{t,Ed}$ / (1,4 x $F_{t,Rd}$) = 0.13 + 0.08 / 1.4 = 0.19 < 1,0 (OK)

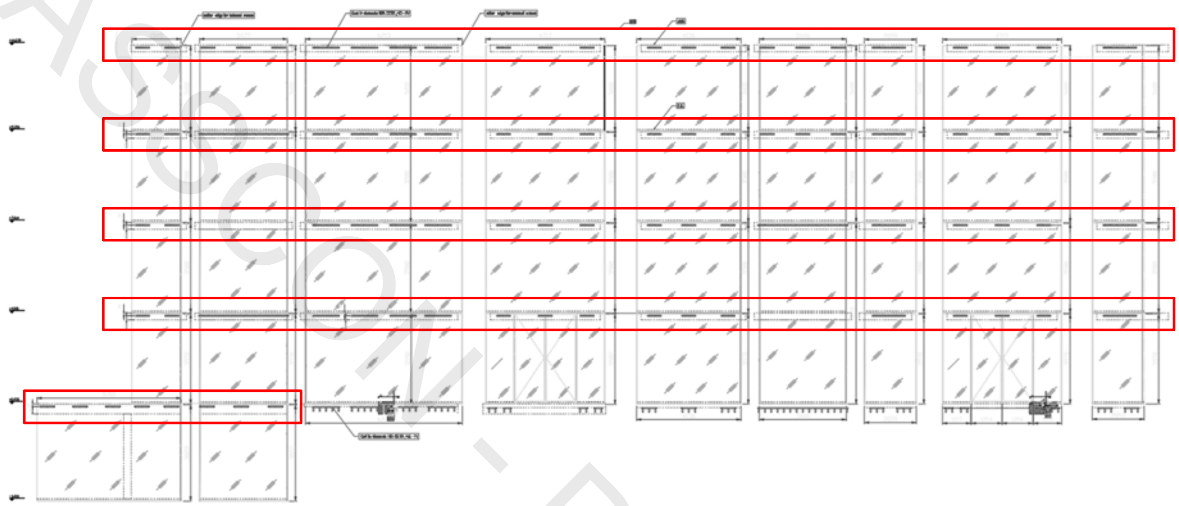
Thread stripping

$F_{t,Ed}$ / $F_{ts,Rd}$ = 2.5 kN / 14.6 kN = 0.18 < 1.0 (OK)

10. Pos. 4 – Mounting bracket

10.1. Pos. 4.1 – Mounting bracket (front)

10.1.1. General



Three different brackets (Pos. 4.1, Pos. 4.2, Pos. 4.3) are used at the west façade to connect the aluminium profiles to the solid structure. In the upper floors, the brackets are connected to the Halfen anchor channels (Pos. 5.1, Pos. 5.2), which are provided in the front faces of the solid building ceilings (Pos. 4.1, Pos. 4.2). On the ground floor, the brackets are fastened to Halfen anchor channels (Pos. 5.3, Pos. 5.4), which are installed on the top side of the concrete (Pos. 4.3, Pos. 4.4).

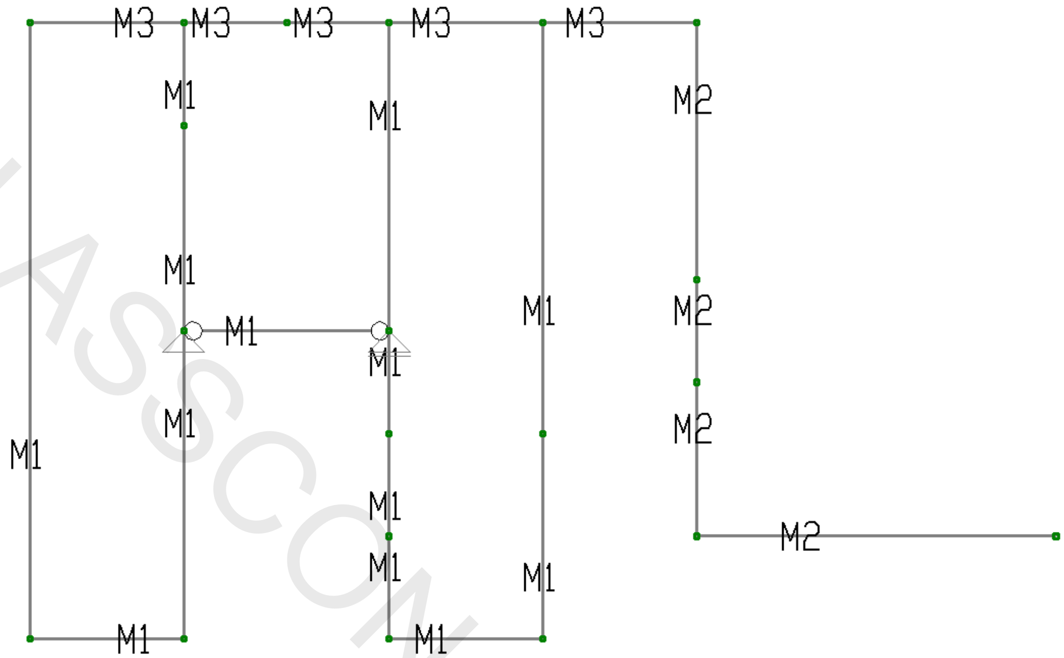
The mounting brackets are made of steel and can be adjusted in all directions to absorb tolerances of the solid construction. Perpendicular to the facade level, the tolerance is absorbed by slotted holes. In order to transfer the forces acting in this direction (e.g. wind), plates with toothing are used.

The brackets support the horizontal aluminium profiles of the glazing beneath and above. Because of the SSG joints in the vertical corners, the brackets are stressed both by shear (horizontal force in the façade level), as well as by their own weight and tension and pressure from wind. Since the brackets are mounted eccentric, these loads result in large moments which have to be absorbed. The most unfavourable loads from Pos. 3 are used for verification.

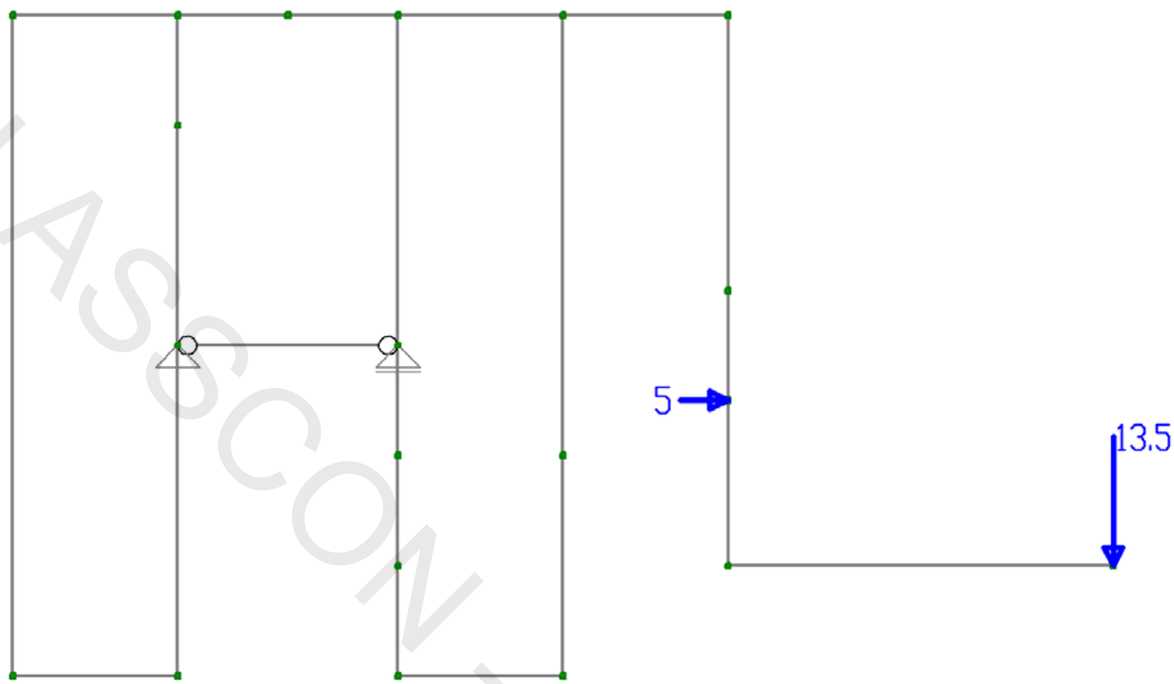
Framework analysis

Cross-section values:

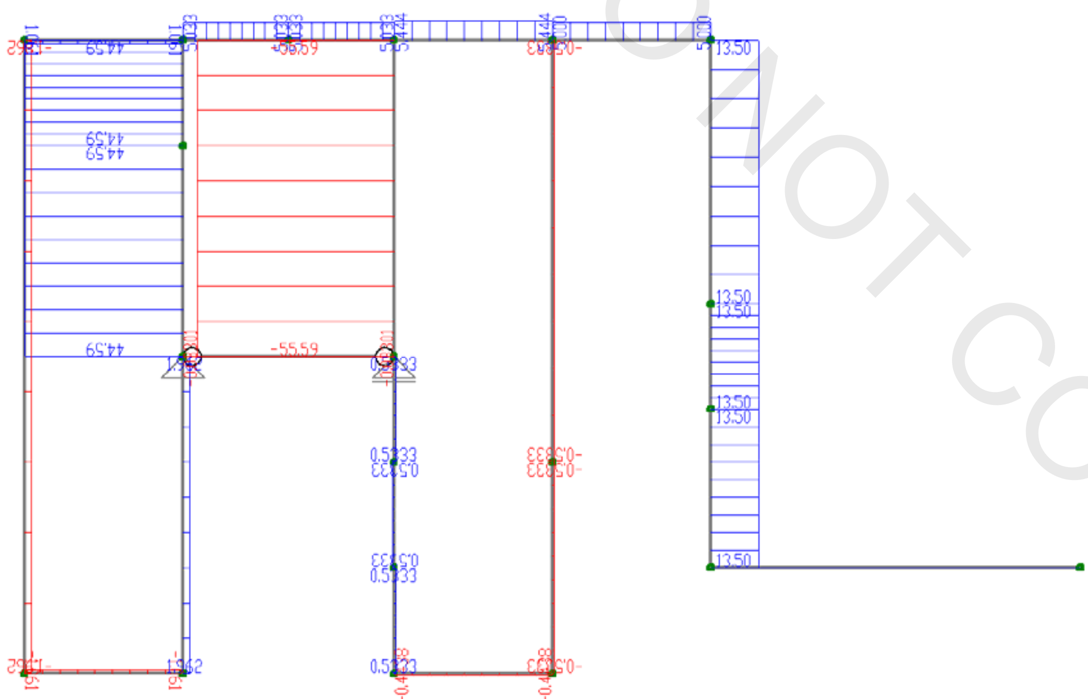
t_1	=	5 mm		
A_1	=	$0.5\ cm \times 32.0\ cm^2$	=	$16\ cm^2$
$W_{1,y}$	=	$(0.5\ cm)^2 \times 32.0\ cm^3 / 6$	=	$1.33\ cm^3$
$I_{1,y}$	=	$(0.5\ cm)^3 \times 32.0\ cm^3 / 12$	=	$0.33\ cm^3$
t_2	=	8 mm		
A_2	=	$0.8\ cm \times 32.0\ cm^2$	=	$28.8\ cm^2$
$W_{2,y}$	=	$(0.8\ cm)^2 \times 32.0\ cm^3 / 6$	=	$3.41\ cm^3$
$I_{2,y}$	=	$(0.8\ cm)^3 \times 32.0\ cm^3 / 12$	=	$1.37\ cm^3$
t_3	=	12 mm		
A_3	=	$1.2\ cm \times 32.0\ cm^2$	=	$43.2\ cm^2$
$W_{3,y}$	=	$(1.2\ cm)^2 \times 32.0\ cm^3 / 6$	=	$7.68\ cm^3$
$I_{3,y}$	=	$(1.2\ cm)^3 \times 32.0\ cm^3 / 12$	=	$4.61\ cm^3$


M3
M3
M3
M3
M3
M1
M1
M1
M1
M1
M1
M1
M1
M1
M1
M1
M1
M1
M2
M2
M2
M2

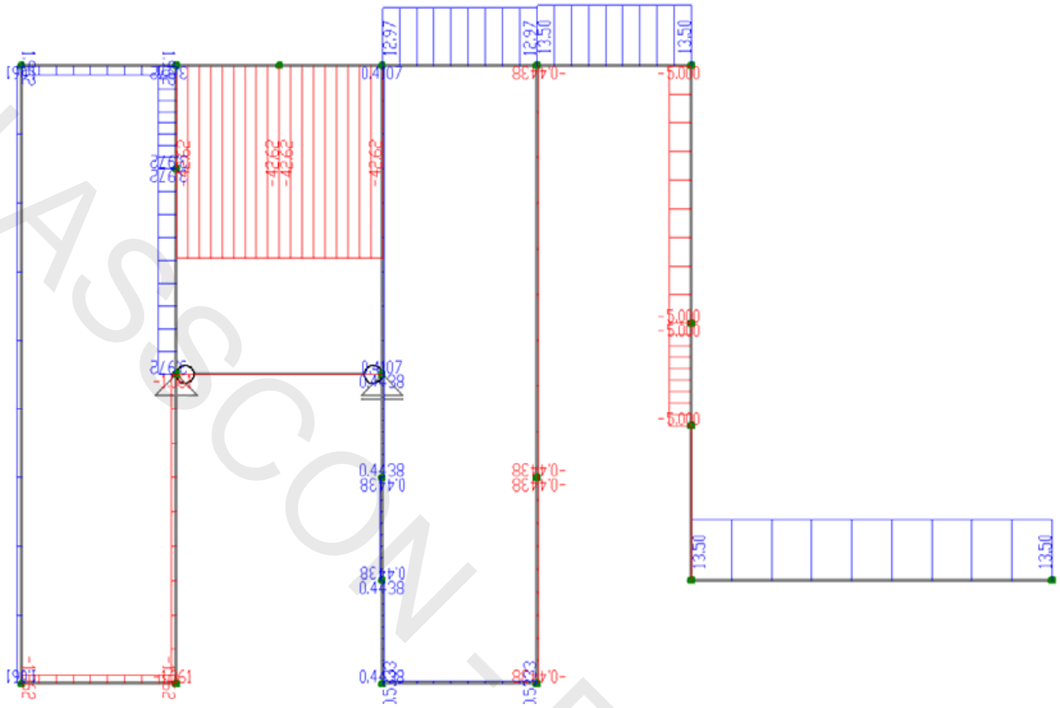
Static system and loading:



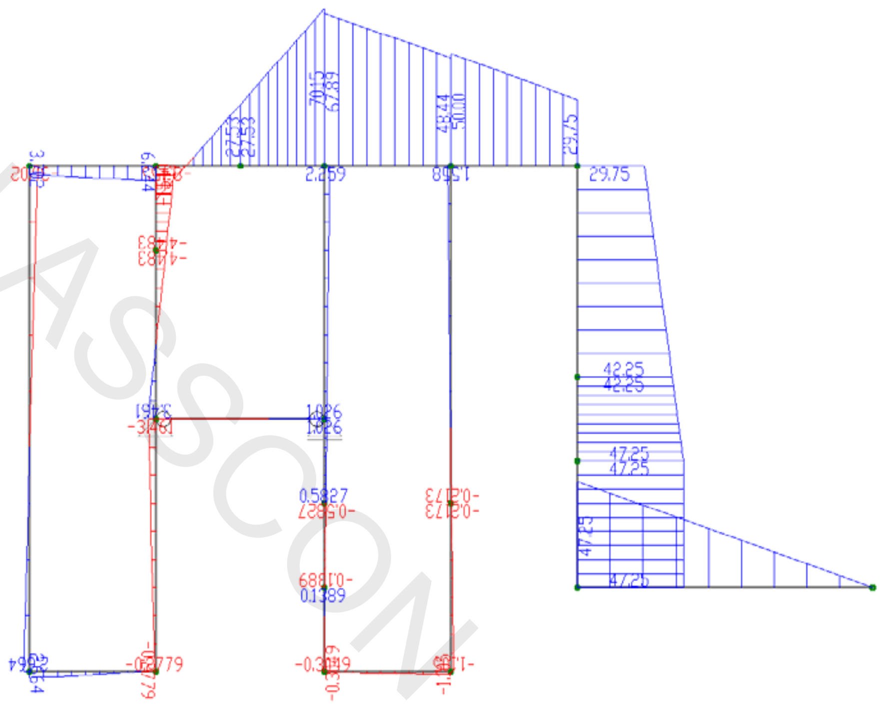
Normal force:



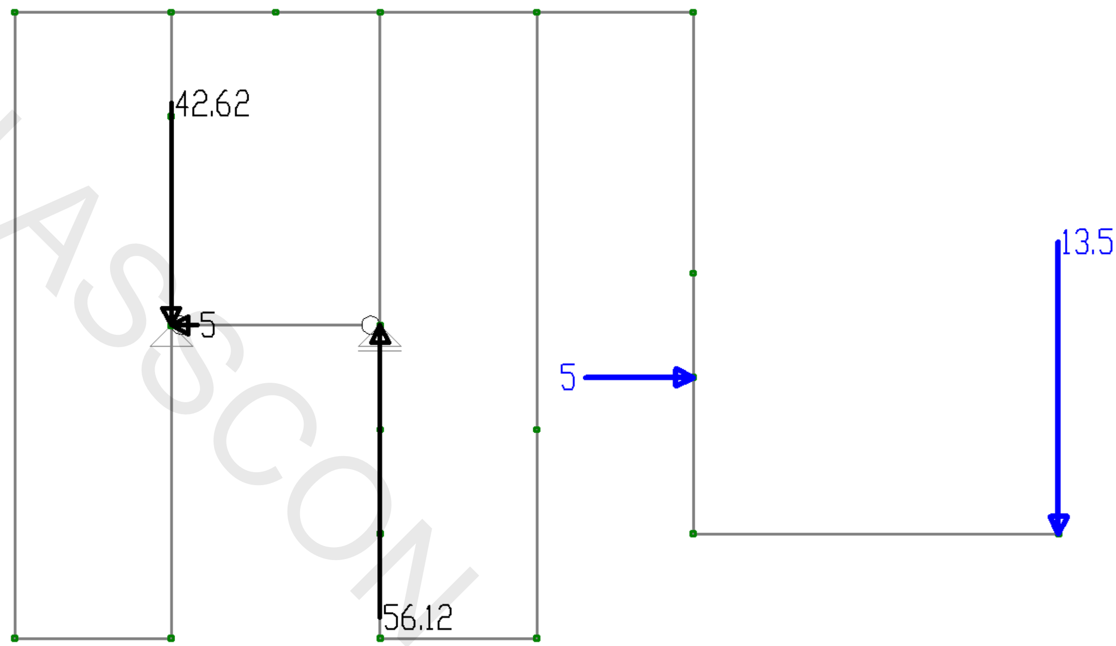
Shear force:



Bending moment:


27.53
27.53
70.15
67.87
48.44
50.00
29.75
29.75
2.269
1.568
42.25
42.25
47.25
47.25
47.25
47.25
1.026
1.026
0.5827
-0.5827
-0.2173
-0.2173
-0.1389
0.1389
-4.483
-4.483
-3.461
-0.2779
-0.3049

Reaction forces:



Deformation:

Verification

Cross section 1:

$M_{1,y,Ed}$		=	9.10 kNcm
$\sigma_{1,x,Ed}$ =	9.10 kNcm / 1.33 cm^3	=	7.0 kNcm
$\sigma_{1,x,Ed} / \sigma_{Rd}$ =	7.0 kN/cm^2 / 14.5 kN/cm^2	=	<u>0.49 ≤ 1.00 (OK)</u>

Cross section 2:

$M_{2,y,Ed}$		=	47.25 kNcm
$\sigma_{2,x,Ed}$ =	47.25 kNcm/3.41 cm^3 + 13.5 kN/28.8 cm^2	=	14.3 kNcm
$\sigma_{2,x,Ed} / \sigma_{Rd}$ =	14.3 kN/cm^2 / 14.5 kN/cm^2	=	<u>0.99 ≤ 1.00 (OK)</u>

Cross section 3:

$M_{3,y,Ed}$		=	70.15 kNcm
$\sigma_{3,x,Ed}$ =	70.15 kNcm / 7.68 cm^3	=	9.13 kNcm
$\sigma_{3,x,Ed} / \sigma_{Rd}$ =	9.13 kN/cm^2 / 14.5 kN/cm^2	=	<u>0.63 ≤ 1.00 (OK)</u>

$F_{b,Rd}$ = α_b x k_1 x f_u x d x t / γ_{M2}

= 1.0 x 2.5 x 19.5 kN/cm^2 x 1.2 cm x 0.35 cm / 1.25

= 14.0 kN

Stress resultants:

$F_{t,Ed}$ = 5.0 kN / 6 screws = 0.9 kN

$F_{v,Rd}$ = ((56.2 kN)^2 + (10.7 kN)^2)$^{1/2}$ / 6 screws = 9.6 kN

Verification:

Shear

$F_{v,Ed}$ / $F_{v,Rd}$ = 9.6 kN / 32.4 kN = <u>0.30 < 1.0</u> (OK)

Bearing stress

$F_{v,Ed}$ / $F_{b,Rd}$ = 9.6 kN / 14.0 kN = <u>0.69 < 1.0</u> (OK)

Tension

$F_{t,Ed}$ / $F_{t,Rd}$ = 0.9 kN / 48.6 kN = <u>0.02 < 1.0</u> (OK)

Tension und Shear

$F_{v,Ed}$ / $F_{v,Rd}$ + $F_{t,Ed}$ / (1,4 x $F_{t,Rd}$) = 0.30 + 0.02 / 1.4 = <u>0.32 < 1.0</u> (OK)

Finite Elemente Calculation

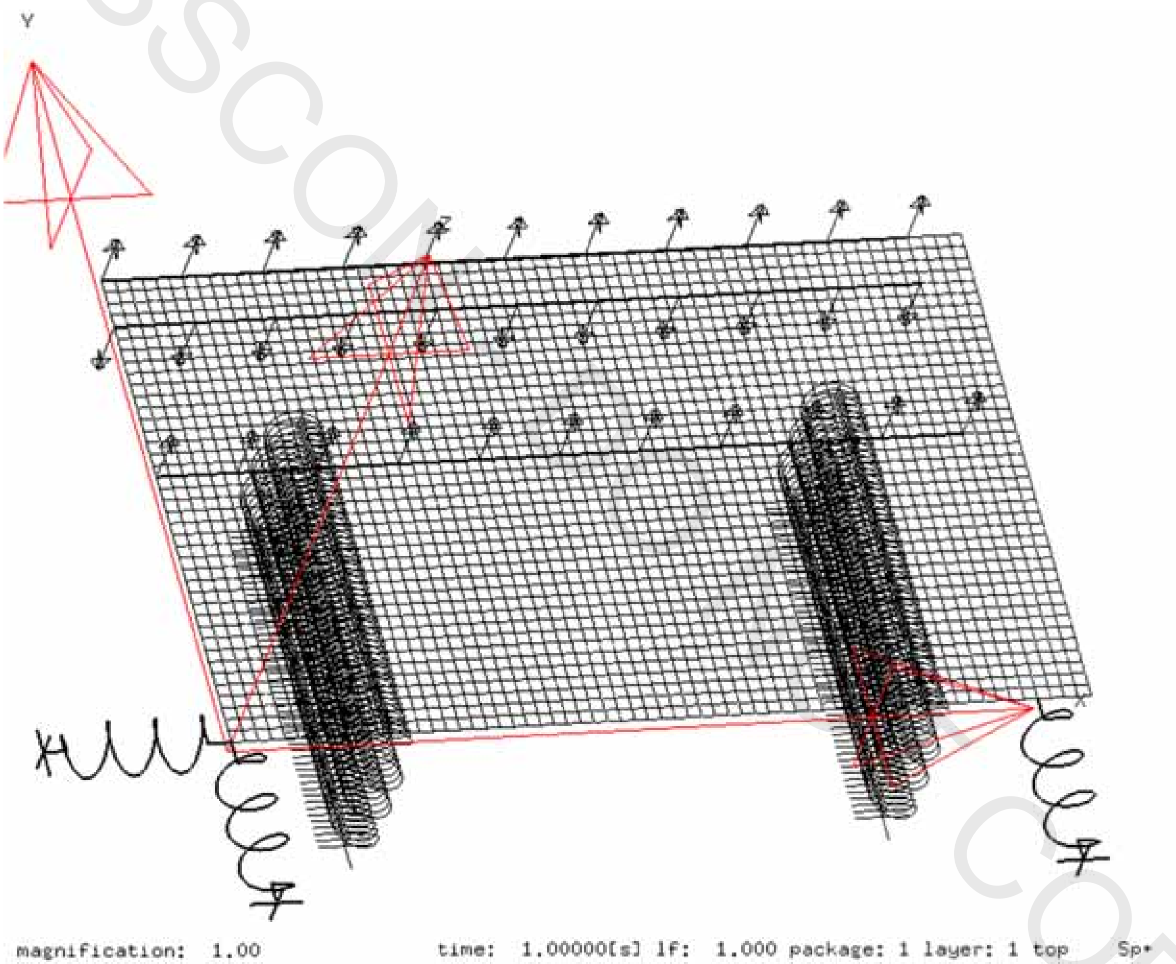
Material properties:

t = 12 mm

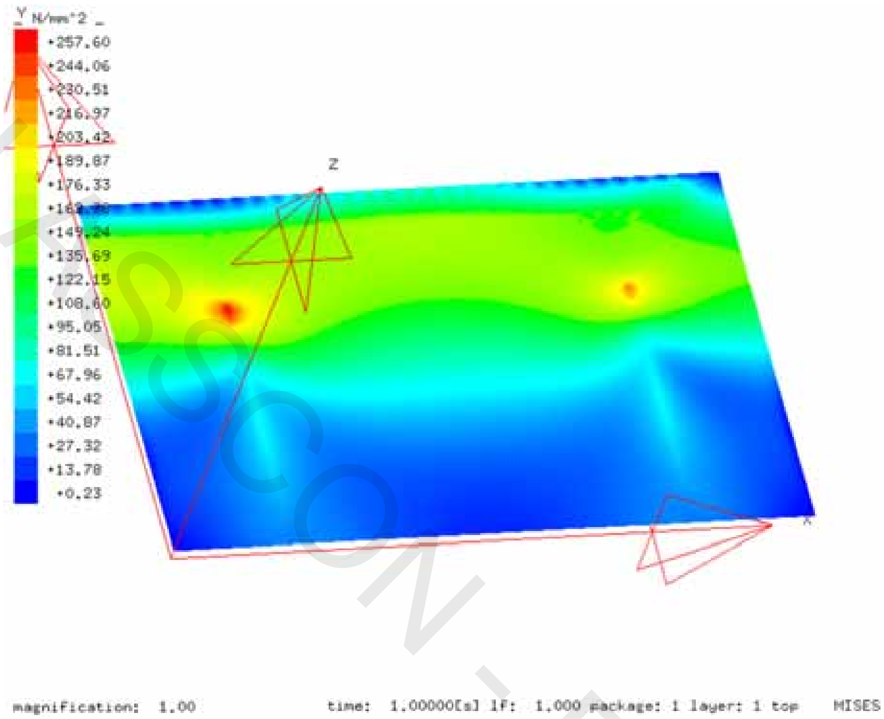
E = 210.000 N/mm^2

M 0.3

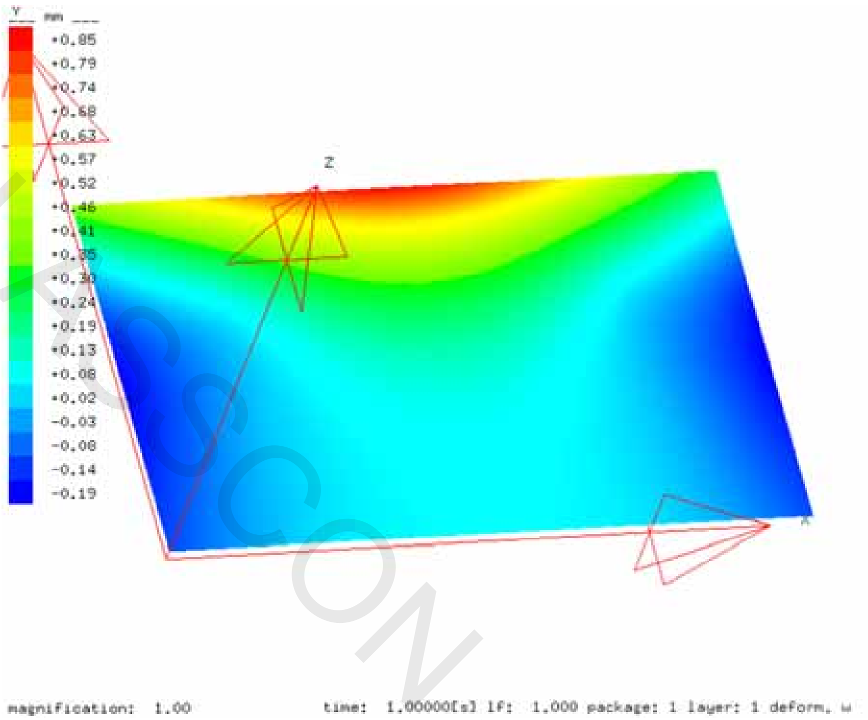
Finite element model:



Stress (von Mises):



Deformation:



Verification

As the calculated stress values are local stress peaks, for the verfication the plastic restitance value f_u is used:

$\sigma_{V,Ed}$			=	25.8 kNcm
$\sigma_{1,x,Ed} / f_u$	=	25.8 kN/cm^2 / 36.0 kN/cm^2	=	$\underline{0.72 \leq 1.00}$ <u>(OK)</u>

$F_{w,Ed} / F_{w,Rd}$ = 2.10 kN/cm / 6.24 kN/cm = $0.34 \leq 1.00$ (OK)

Normal stress:

$\sigma_{x,Ed}$ = 96.9 kNcm / 39.2 cm^3 + 58.9 kNcm / 3.36 cm^3 + 5 kN / 16.8 cm^2
= 20.3 kNcm

$\sigma_{x,Ed} / \sigma_{Rd}$ = 20.3 kN/cm^2 / 23.5 kN/cm^2 = <u>0.87 ≤ 1.00 (OK)</u>

Shear stress:

τ_{Ed} = (10.7 kN + 13.5 kN) / 16.8 cm^2 = 1.44 kN/cm^2

τ_{Ed} / τ_{Rd} = 1.44 kN/cm^2 / 13.5 kN/cm^2 = <u>0.11 ≤ 1.00 (OK)</u>

Equivalent stress:

$((\sigma_{x,Ed} / \sigma_{Rd})^2 + 3 \times (\tau_{Ed} / \tau_{Rd})^2)^{1/2}$ = $((0.87)^2 + 3 \times (0.11)^2)^{1/2}$ = <u>0.89 ≤ 1.00 (OK)</u>

Stress resultants:

- Horizontal loads perpendicular to the facade are transferred by the corrugation of the steel plates.
- Vertical loads are transferred by contact (pressure) on (6). On the safe side, however, they are taken into account in the verification.

$F_{t,Ed}$ = 10.7 kN / 2 Screws + 58.9 kNcm / 1.5 cm / 2 Screws = 25.0 kN

$F_{v,Ed}$ = 15.7 kN / 2 Screws = 7.9 kN

Verification:

Shear

$F_{v,Ed} / F_{v,Rd}$ = 7.9 kN / 32.4 kN = 0.25 < 1.0 (OK)

Bearing stress

$F_{v,Ed} / F_{b,Rd}$ = 7.9 kN / 66.4 kN = 0.12 < 1.0 (OK)

Tension

$F_{t,Ed} / F_{t,Rd}$ = 25.0 kN / 48.6 kN = 0.52 < 1.0 (OK)

Tension und Shear

$F_{v,Ed} / F_{v,Rd} + F_{t,Ed} / (1,4 \times F_{t,Rd})$ = 0.12 + 0.52 / 1.4 = 0.50 < 1.0 (OK)

Section 1:

F_V = 13.5 kN / 2 = 6.75 kN

$M_{y,Ed}$ = F x l / 2 = 6.75 kN x 3.5 cm / 1.5= 15.8 kNcm

W_y = (1.6 cm)^2 x (2 x 2.0 cm) / 6 = 1.71 cm^3

$\sigma_{x,Ed}$ = 15.8 kN / 1.71 cm^2 = 9.3 kNcm

$\sigma_{x,Ed}$ / σ_{Rd} = 9.3 kN/cm^2 / 23.5 kN/cm^2 = <u>0.40 ≤ 1.00 (OK)</u>

Section 2:

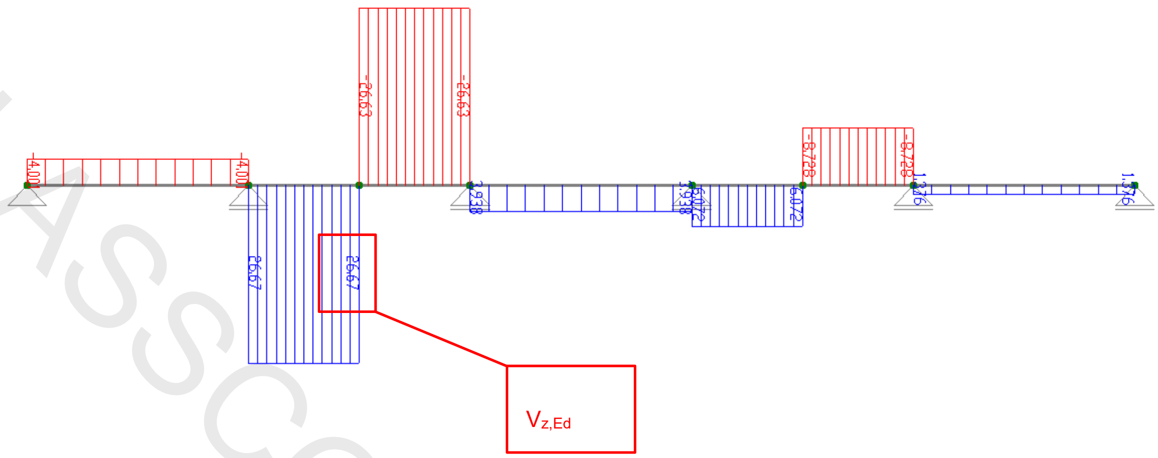
M_{Ed} = ($G_{1,d}$ kN x (7.5 cm + 15 cm – 2.0 cm – 2.5 cm) + $W_{1,d}$ x 17.75 cm + $W_{2,d}$ x 9.25 cm)
= (13.5 kN x 18.0 cm + 5.0 kN x 17.75 cm + 5.0 kN x 9.25 cm)
= (243.0 kNcm + 88.75 kNcm + 46.25 kNcm) = 378.0 kNcm

$F_{H,left}$ = 378.0 kNcm / 6.0 cm / 2 + 2 x 5 kN / 2 / 2 + 2 x 10.7 kN x 18.0 cm / 20.0 cm
= <u>53.3 kN</u>

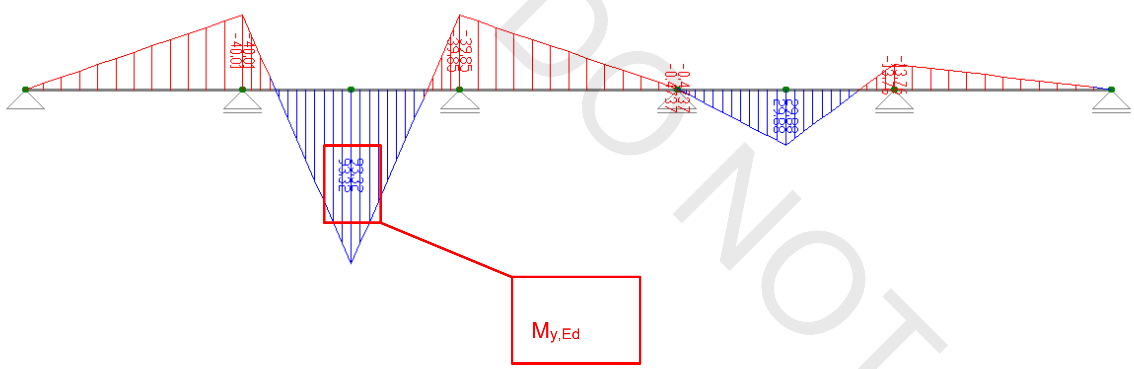
$F_{H,right}$ = 378.0 kNcm / 6.0 cm / 2 + 2 x 5 kN / 2 / 2 - 2 x 10.7 kN x 18.0 cm / 20.0 cm
= <u>14.8 kN</u>

Static system:

Shear force V [kN]:



Bending moment M [kNm]:



Verification:

$V_{z,Ed}$ = 26.7 kN

$M_{y,Ed}$ = 93.4 kNcm

A = 1.6 cm x 10 cm = 16 cm^2

W_y = $(1.6\ cm)^2$ x 10 cm / 6 = 4.27 cm^3

Normal stress:

$\sigma_{x,Ed}$ = 93.4 kN / 4.27 cm^2 = 21.9 kNcm

$\sigma_{x,Ed} / \sigma_{Rd}$ = 21.9 kN/cm^2 / 23.5 kN/cm^2 = $\underline{0.93 \leq 1.00}$ (OK)

Shear stress:

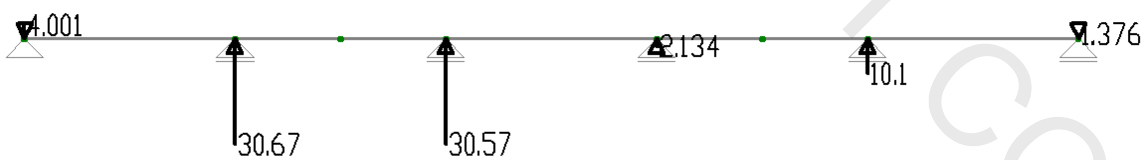
τ_{Ed} = 26.7 kN / 16.0 cm^2 = 1.67 kN/cm^2

τ_{Ed} / τ_{Rd} = 1.67 kN/cm^2 / 13.5 kN/cm^2 = $\underline{0.13 \leq 1.00}$ (OK)

Equivalent stress:

$((\sigma_{x,Ed} / \sigma_{Rd})^2 + 3 \times (\tau_{Ed} / \tau_{Rd})^2)^{1/2}$ = $((0.93)^2 + 3 \times (0.13)^2)^{1/2}$ = $\underline{0.96 \leq 1.00}$ (OK)

Reaction forces (for the design of Halfen Anchor Channel, Pos. 5):



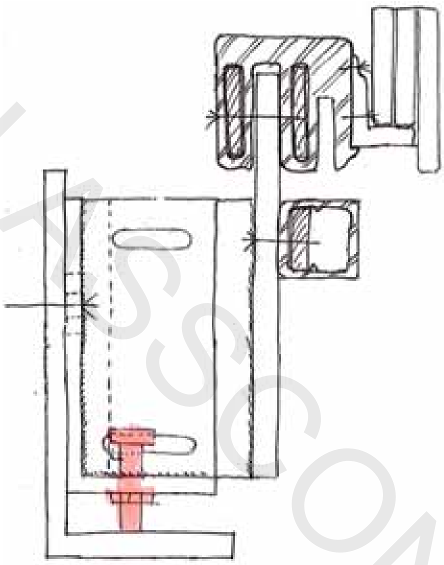
B = 30.7 kN

C = 30.6 kN

D = 2.4 kN

E = 10.1 kN

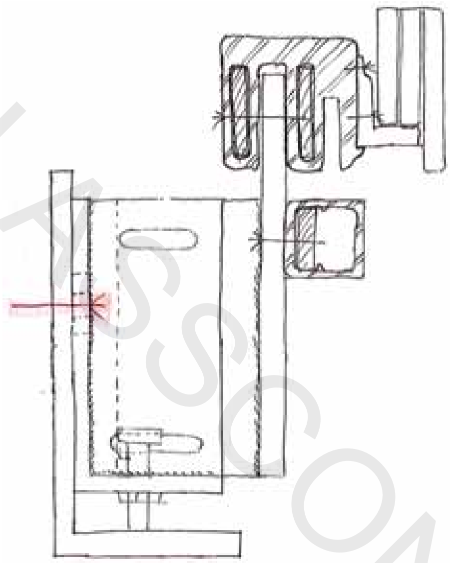
(S4) Screwed joint (6) to (7):



Bolt: 2 x M12 8.8

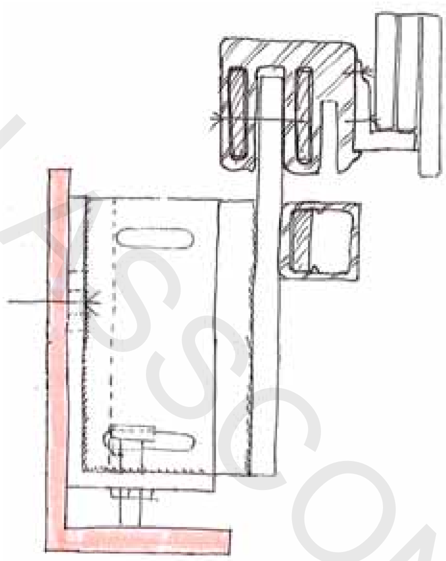
The screw is only subjected to pressure (dead weight of the glazing) and is not endangered by stability. No verification is given.

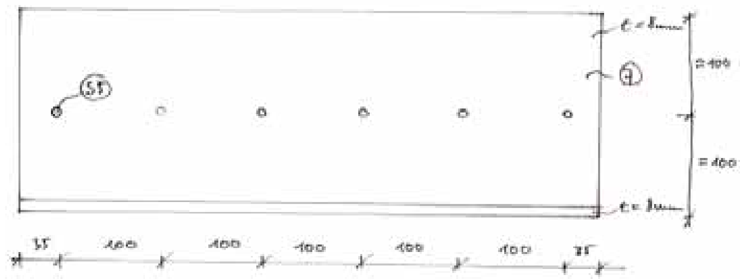
(S5) screwed joint (6) and (7) to Halfen anchor channel:



The verification of the screw is given in Pos. 5 - Halfen anchor channel.

<u>(7) L-Profile 200 x 100 x 8:</u>





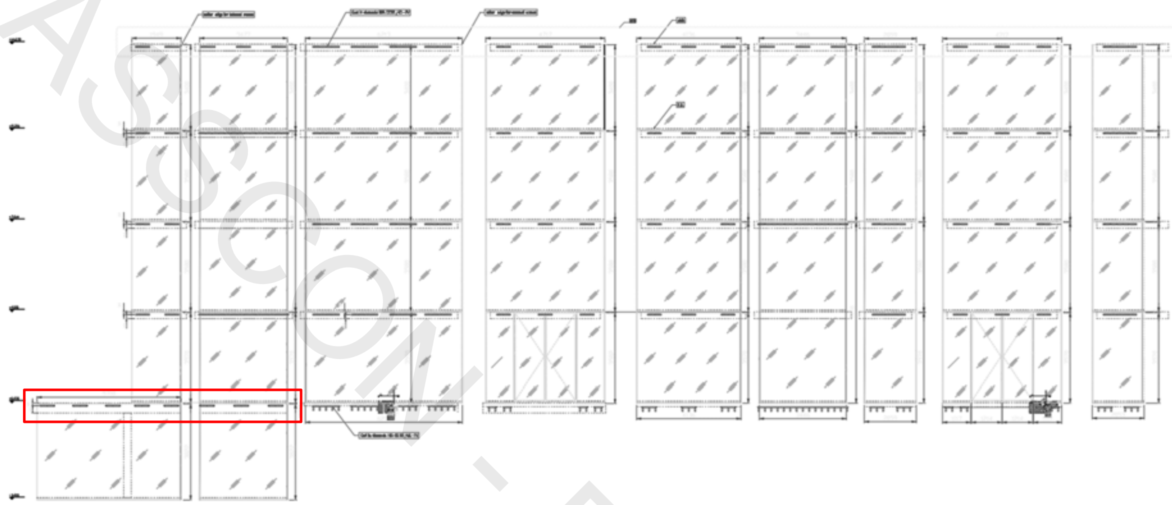
Steel S235

σ_{Rd}	=	23.5 kN/cm^2 / 1.0	=	23.5 kN/cm^2
τ_{Rd}	=	23.5 kN/cm^2 / 1.0 / (3)$^{1/2}$	=	13.5 kN/cm^2
t	=	8 mm		
F_V	=	13.5 kN / 2	=	6.75 kN
$M_{y,Ed}$	=	F x l = 6.75 kN x 3.5 cm	=	23.7 kNcm
W_y	=	(1.0 cm)^2 x 10 cm / 6	=	1.67 cm^3
$\sigma_{x,Ed}$	=	23.7 kN / 1.67 cm^2	=	14.2 kNcm
$\sigma_{x,Ed}$ / σ_{Rd}	=	14.2 kN/cm^2 / 23.5 kN/cm^2	=	<u>0.61 ≤ 1.00 (OK)</u>

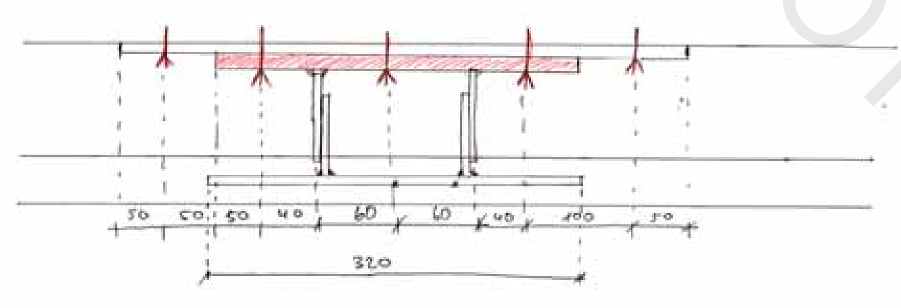
10.2. Pos. 4.2 – Mounting bracket (front, ground floor)

10.2.1. General

Due to lower loads smaller mounting brackets are used for the ground floor.

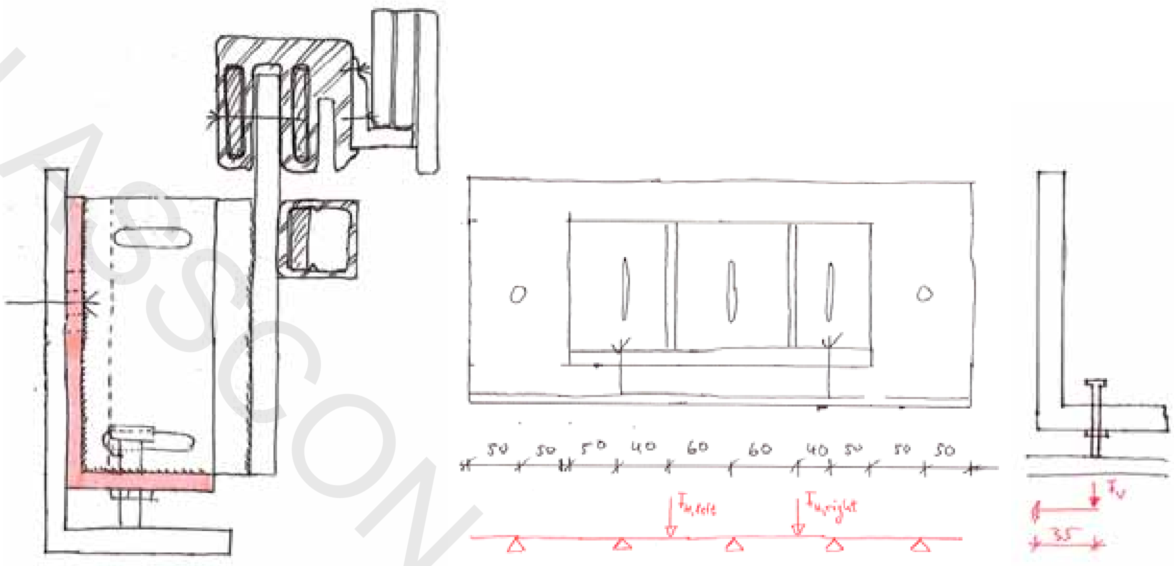


Due to lower loads smaller Halfen anchor channels and smaller mounting brackets are used for the ground floor. The only difference is in the width of the L-profile t = 16 mm (6) and the amount of Halfen screws (S5) which were used. Accordingly, in the following only the verification of these elements is given.



10.2.3. Verification

L-Profile 156 x 88.5 x 16:



Steel S235

σ_{Rd}	=	23.5 kN/cm^2 / 1.0	=	23.5 kN/cm^2
τ_{Rd}	=	23.5 kN/cm^2 / 1.0 / (3)$^{1/2}$	=	13.5 kN/cm^2

t = 16 mm

Section 1:

F_V = 3.2 kN / 2 = 3.2 kN

$M_{y,Ed}$ = F x l / 2 = 3.2 kN x 3.5 cm / 1.5 = 7.5 kNcm

W_y = $(1.6\ cm)^2$ x (2 x 2.0 cm) / 6 = 1.71 cm^3

$\sigma_{x,Ed}$ = 7.5 kN / 1.71 cm^2 = 4.4 kNcm

$\sigma_{x,Ed}$ / σ_{Rd} = 4.4 kN/cm^2 / 23.5 kN/cm^2 = <u>0.19 ≤ 1.00 (OK)</u>

Section 2:

M_{Ed} = ($G_{1,d}$ kN x (7.5 cm + 15 cm – 2.0 cm – 2.5 cm) + $W_{1,d}$ x 17.75 cm + $W_{2,d}$ x 9.25 cm)

= (6.8 kN x 18.0 cm + 5.0 kN x 17.75 cm + 5.0 kN x 9.25 cm)

= (115.5 kNcm + 88.75 kNcm + 46.25 kNcm) = 378.0 kNcm

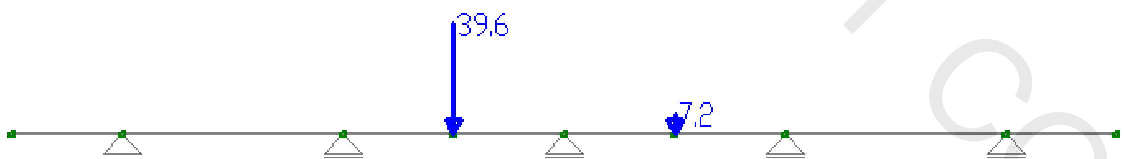
$F_{H,left}$ = <u>250.5 kNcm</u> / 6.0 cm / 2 + 2 x 5 kN / 2 / 2 + 2 x <u>5.4 kN</u> x 18.0 cm / <u>12.0 cm</u>

= <u>39.6 kN</u>

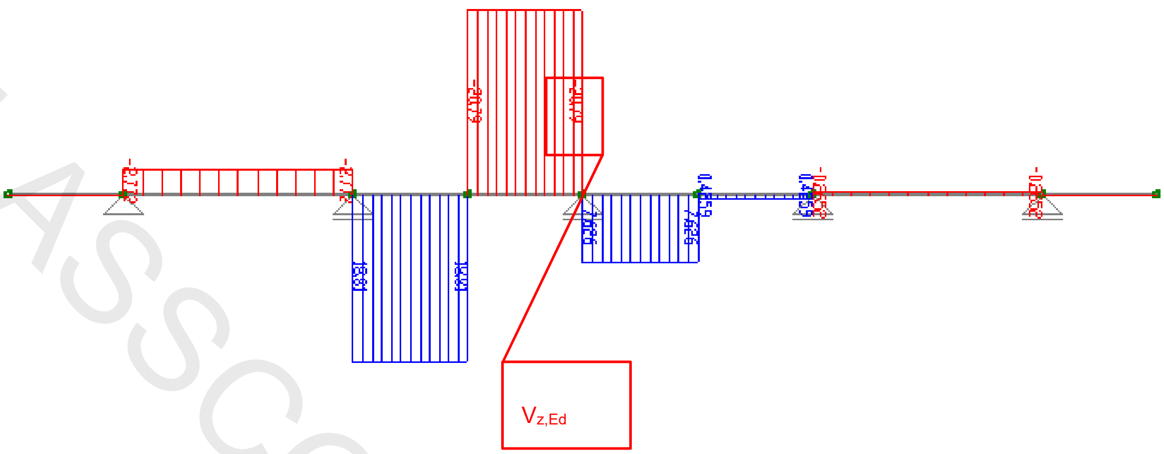
$F_{H,right}$ = <u>250.5 kNcm</u> / 6.0 cm / 2 + 2 x 5 kN / 2 / 2 - 2 x <u>5.4 kN</u> x 18.0 cm / <u>12.0 cm</u>

= <u>7.2 kN</u>

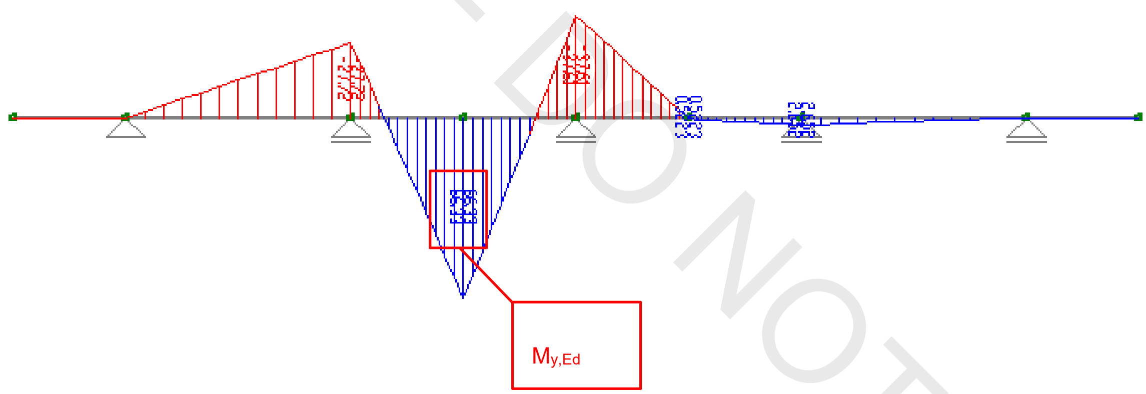
Static system:



Shear force V [kN]:



Bending moment M [kNm]:



Verification:

$V_{z,Ed}$ = 20.8 kN

$M_{y,Ed}$ = 66.4 kNcm

A = 1.6 cm x 10 cm = 16 cm^2

W_y = $(1.6\ cm)^2$ x 10 cm / 6 = 4.27 cm^3

Normal stress:

$\sigma_{x,Ed}$ = 66.4 kN / 4.27 cm^2 = 15.6 kNcm

$\sigma_{x,Ed} / \sigma_{Rd}$ = 15.6 kN/cm^2 / 23.5 kN/cm^2 = <u>0.67 ≤ 1.00 (OK)</u>

Shear stress:

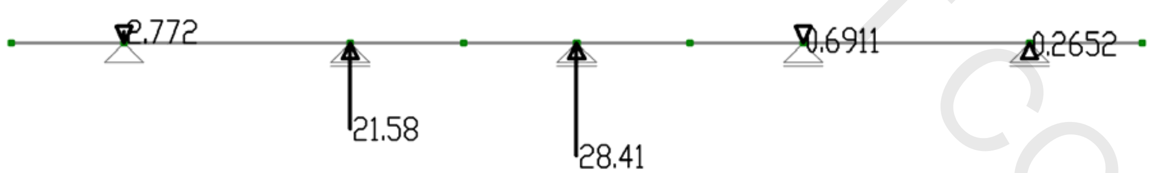
τ_{Ed} = 20.8 kN / 16.0 cm^2 = 1.30 kN/cm^2

τ_{Ed} / τ_{Rd} = 1.30 kN/cm^2 / 13.5 kN/cm^2 = <u>0.10 ≤ 1.00 (OK)</u>

Equivalent stress:

$((\sigma_{x,Ed} / \sigma_{Rd})^2 + 3 \times (\tau_{Ed} / \tau_{Rd})^2)^{1/2}$ = $((0.67)^2 + 3 \times (0.10)^2)^{1/2}$ = <u>0.70 ≤ 1.00 (OK)</u>

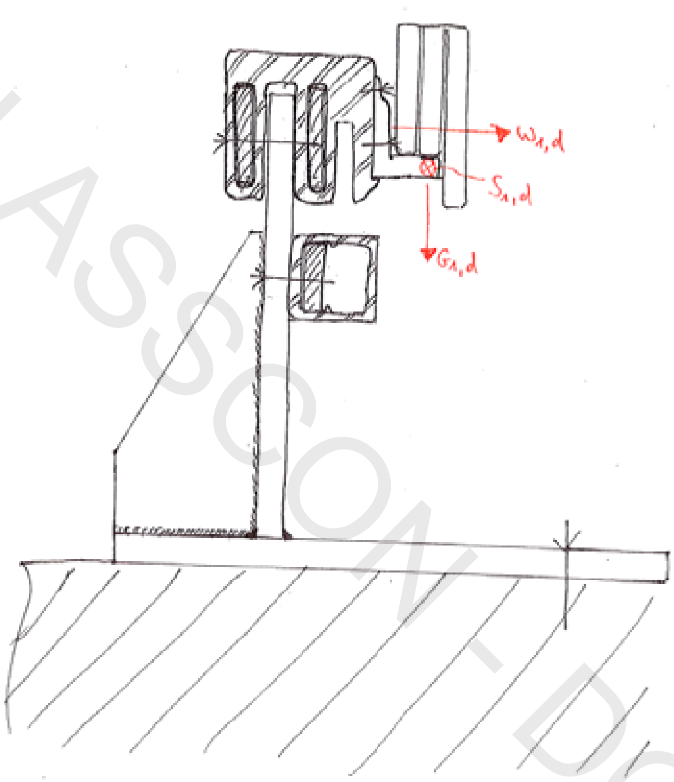
Reaction forces (for the design of Halfen Anchor Channel, Pos. 5):



C = <u>21.6 kN</u>

D = <u>28.4 kN</u>

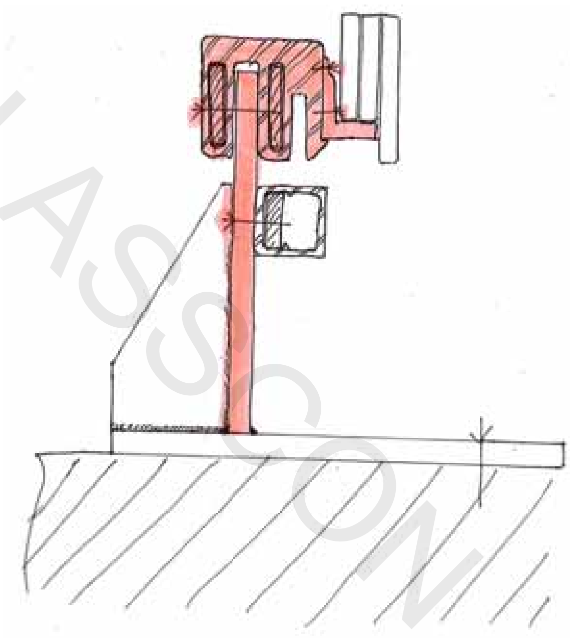
10.3.2. Loads



The most unfavourable loads from Pos. 3 are used for verification:

$W_{1,d}$			=	5.0 kN
$S_{1,d}$			=	10.7 kN
$G_{1,d}$	=	7.2 m x 3.6 m x 3 x 0.01 m x 25 kN/m^3 / 2	=	13.5 kN

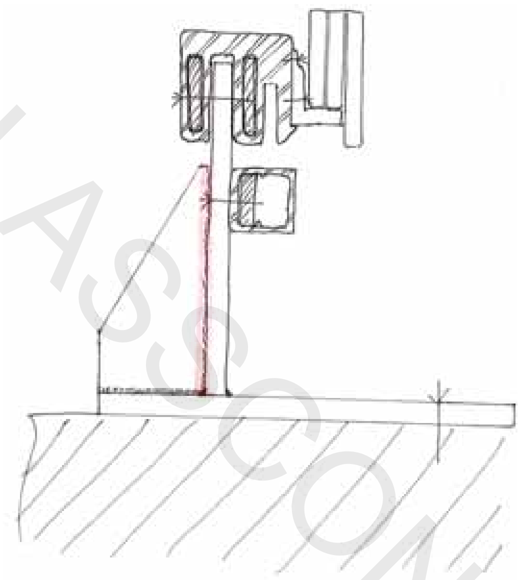
10.3.3. Verification



The geometry dimensions and materials of the components listed below are equal to Pos. 4.1 and are not subjected to bigger loads. Accordingly, the verification of these components can be found in Pos. 4.1.

- Screwed joint S1 (1) to (2)
- Aluminium Profile (2)
- Screwed joint S2 (2) to (3)
- End plate (3)

(S1) Welded connection end plate t = 12 mm (3) to 2 x flat steel t = 12 mm (4):



Welded seam: Fillet weld/Butt weld circumferential

a_w = 3 mm

l_w = 4 x 14.0 cm

$F_{w,Rd}$ = 6.24 kN/cm

M_{Ed} = ($G_{1,d}$ x 7.5 cm + $W_{1,d}$ x 10.5 cm) / 2 = (13.5 kN x 7.5 cm + 5.0 kN x 10.5 cm) / 2

= (101.3 kNcm + 52.5 kNcm) / 2 = 76.9 kNcm

V_{Ed} = $S_{1,d}$ / 2 = 10.7 kN / 2 = 5.4 kN

$V_{II,Ed}$ = $G_{1,d}$ / 2 + $S_{1,d}$ x 10.5 cm / 20 cm

= 13.5 kN / 2+ 10.7 kN x 10.5 cm / 20 cm

= 12.4 kN

N_{Ed} = $W_{1,d}$ / 2 = 5 kN / 2= 2.5 kN

$F_{w,Ed}$ = $((2.5 \text{ kN} / (2 \text{ x } 10 \text{ cm}) + 76.9 \text{ kNcm} / (2 \text{ x } (10 \text{ cm})^2 / 6))^2$

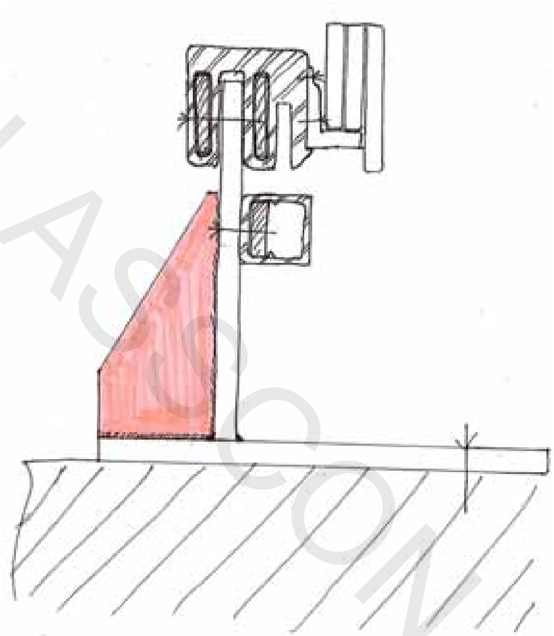
$+ (5.4 \text{ kN} / (2 \text{ x } 10 \text{ cm}))^2 + (12.4 \text{ kN} / (2 \text{ x } 10 \text{ cm}))^2)^{1/2}$

= $((0.13 \text{ kN/cm} + 2.31 \text{ kN/cm})^2 + (0.27 \text{ kN/cm})^2 + (0.62 \text{ kN/cm})^2)^{1/2}$

= 3.33 kN/cm

$F_{w,Ed}$ / $F_{w,Rd}$ = 3.33 kN/cm / 6.24 kN/cm = 0.54 ≤ 1.00 (OK)

(4) Flat steel (t = 12 mm):



Steel S235

σ_{Rd}	=	23.5 kN/cm^2 / 1.0	=	23.5 kN/cm^2
τ_{Rd}	=	23.5 kN/cm^2 / 1.0 / (3)$^{1/2}$	=	13.5 kN/cm^2

t	=	12 mm		
A	=	1.2 cm x 5.5 cm	=	6.6 cm^2
W_y	=	(5.5 cm)^2 x 1.2 cm^3 / 6	=	6.05 cm^3

$V_{z,Ed}$ = 2.5 kN

$M_{y,Ed}$ = ($G_{1,d}$ x 9.0 cm + $W_{1,d}$ x 15.5 cm) / 2 = (13.5 kN x 9.0 cm + 5.0 kN x 15.5 cm) / 2

= (121.5 kNcm + 77.5 kNcm) / 2 = 99.5 kNcm

N_{Ed} = $S_{1,d}$ x 15.5 cm / 20 cm = 10.7 kN x 15.5 cm / 20 cm

= 8.3 kN

Normal stress:

$\sigma_{x,Ed}$ = 99.5 kNcm / 6.05 cm^3 + 8.3 kNcm / 6.6 cm^2 = 17.7 kNcm

$\sigma_{x,Ed} / \sigma_{Rd}$ = 17.7 kN/cm^2 / 23.5 kN/cm^2 = <u>0.76 ≤ 1.00 (OK)</u>

Shear stress:

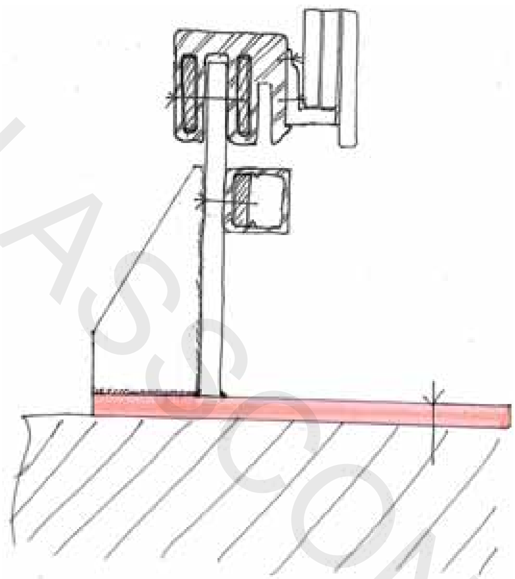
τ_{Ed} = 2.5 kN / 6.6 cm^2 = 0.38 kN/cm^2

τ_{Ed} / τ_{Rd} = 0.38 kN/cm^2 / 13.5 kN/cm^2 = <u>0.03 ≤ 1.00 (OK)</u>

Equivalent stress:

$((\sigma_{x,Ed} / \sigma_{Rd})^2 + 3 \times (\tau_{Ed} / \tau_{Rd})^2)^{1/2}$ = $((0.76)^2 + 3 \times (0.03)^2)^{1/2}$ = <u>0.76 ≤ 1.00 (OK)</u>

(5) End plate:



Steel S235

Thickness	t	=	16 mm
Length	l	=	400 mm
Width	w	=	270 mm

σ_{Rd} = 23.5 kN/cm^2 / 1.0 = 23.5 kN/cm^2

τ_{Rd} = 23.5 kN/cm^2 / 1.0 / (3)$^{1/2}$ = 13.5 kN/cm^2

f_u = = 36.0 kN/cm^2

For the calculation of the stresses occurring in the steel plate a finite element model is used. For this, the most unfavourable loads (maximum dead load, maximum horizontal wind and horizontal line load) are considered. The resulting moments are applied as line loads:

F_{left} = $W_{1,d}$ x 16 cm / 17.25 cm / 2 + $S_{1,d}$ x 16 cm / 20.0 cm

= 5 kN x 16 cm / 17.25 cm / 2 + 10.7 kN x 16 cm / 20.0 cm

= 10.9 kN

F_{left} = $W_{1,d}$ x 16 cm / 17.25 cm / 2 - $S_{1,d}$ x 16 cm / 20.0 cm

= 5 kN x 16 cm / 17.25 cm / 2 - 10.7 kN x 16 cm / 20.0 cm

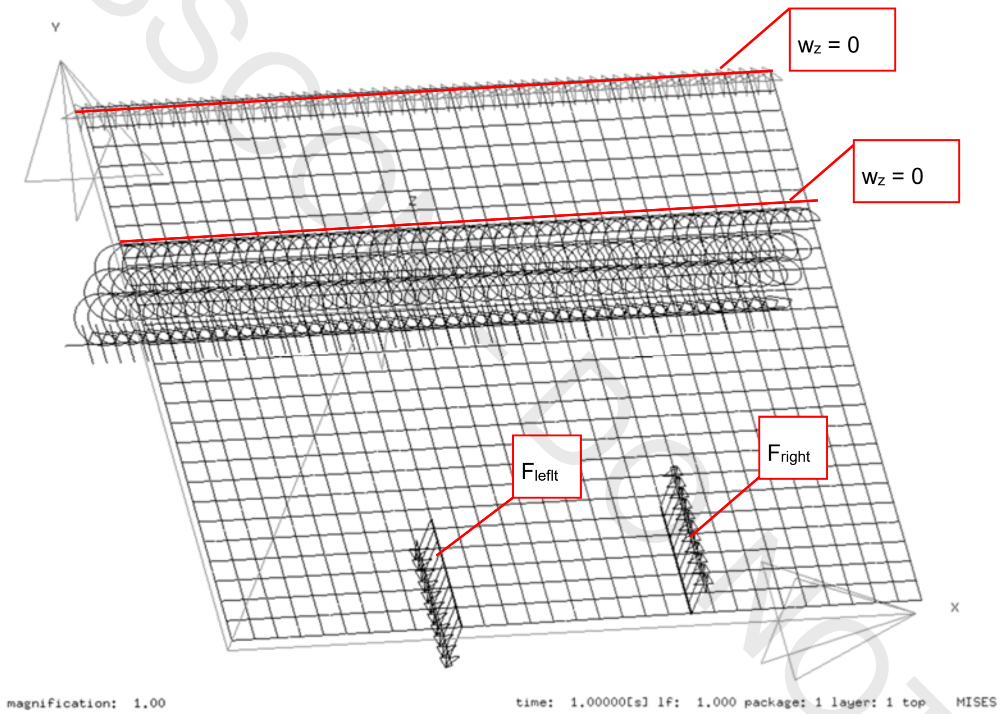
= -6.2 kN

Finite elemente calculation

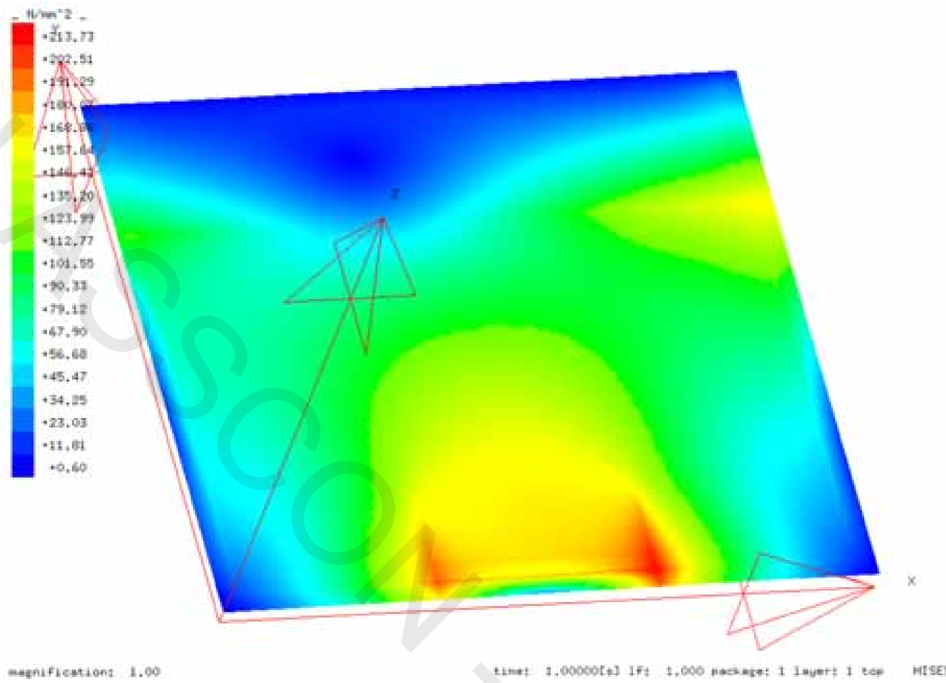
Material properties:

t	=	16 mm
E	=	210.000 N/mm^2
M		0.3

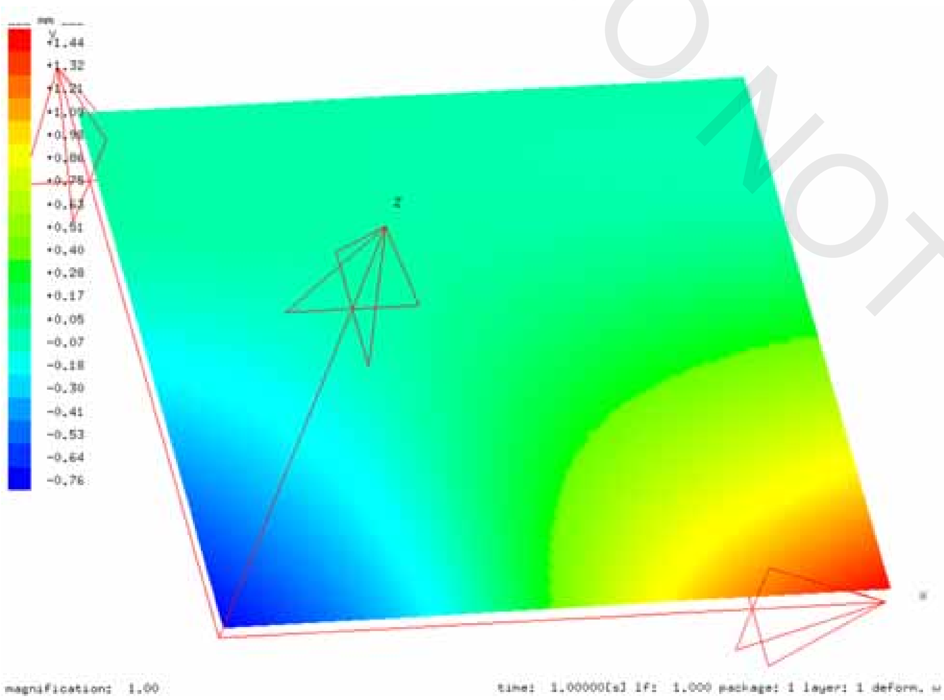
Finite element model:



Stress (von Mises):



Deformation:

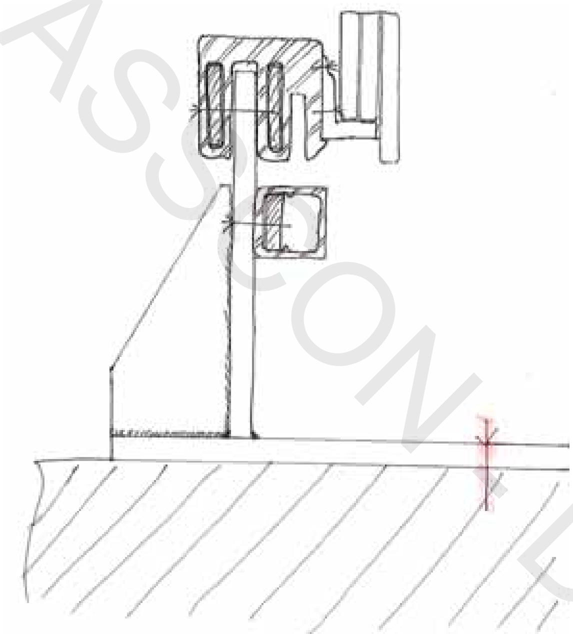


Verification

$\sigma_{V,Ed}$ = 21.2 kNcm

$\sigma_{V,Ed} / \sigma_{Rd}$ = 21.2 kN/cm^2 / 23.5 kN/cm^2 = <u>0.90 ≤ 1.00 (OK)</u>

<u>(S3) Screwed joint (5) to Halfen anchor channel:</u>



The verification of the screw is given in Pos. 5 - Halfen anchor channel.

Bolt forces:

B_Z = F_{left} / 2 x 27.0 cm / 7.0 cm = 10.9 kN / 2 x 27.0 cm / 7.0 cm

= <u>21.1 kN</u>

C_Z = B_z = <u>21.1 kN</u>

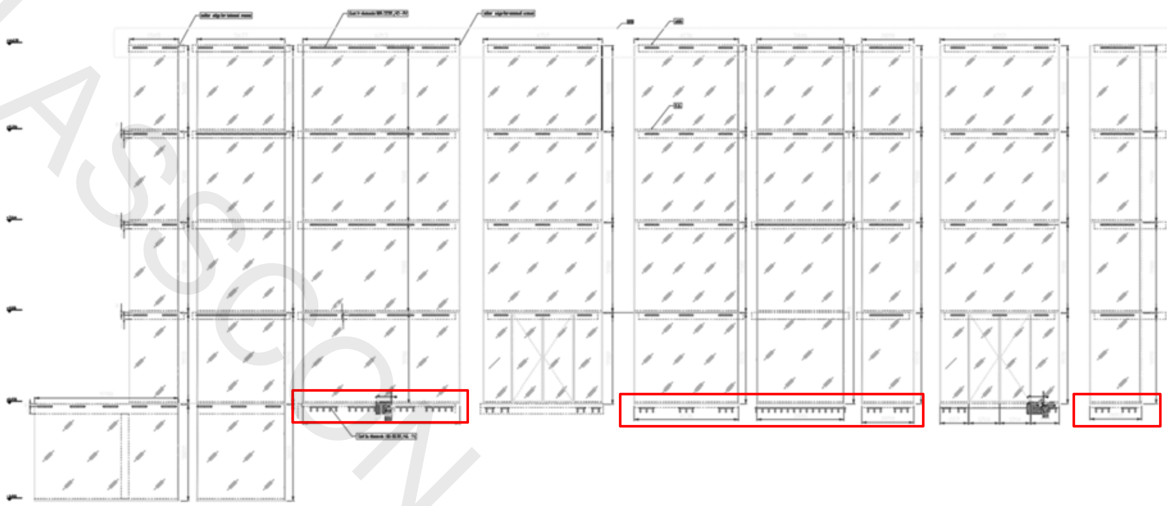
H = $W_{1,d}$ / 4 Screws + $S_{1,d}$ x 7.7 cm / 20 cm / 2 Screws

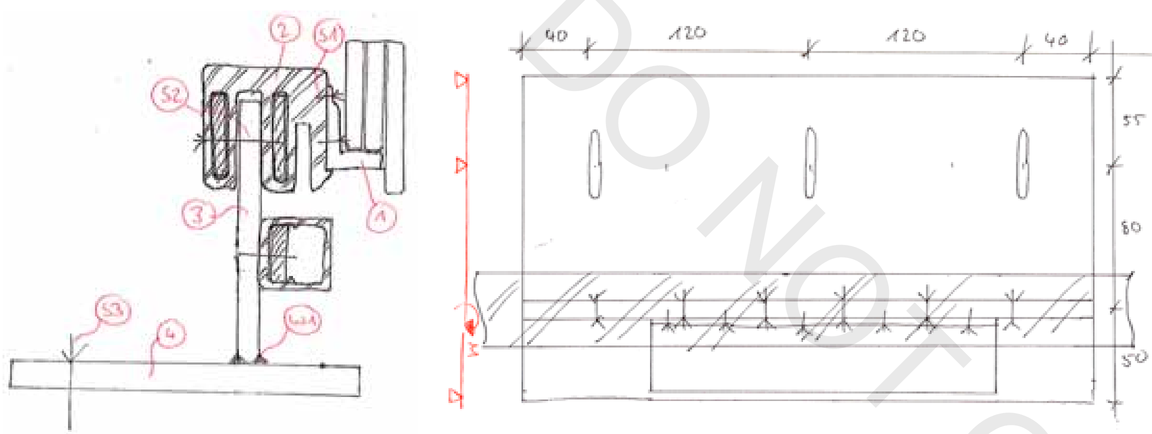
= 5 kN / 4 + 10.7 kN x 7.7 cm / 20 cm / 2

= <u>3.4 kN</u>

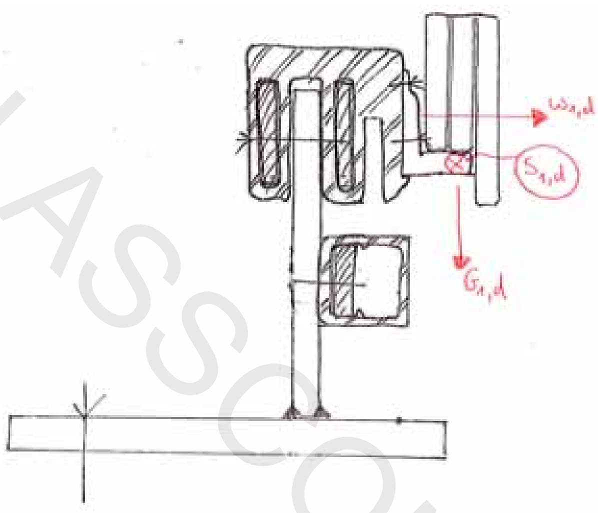
10.4. Pos. 4.4 – Mounting bracket (floor, door)

10.4.1. General





10.4.2. Loads



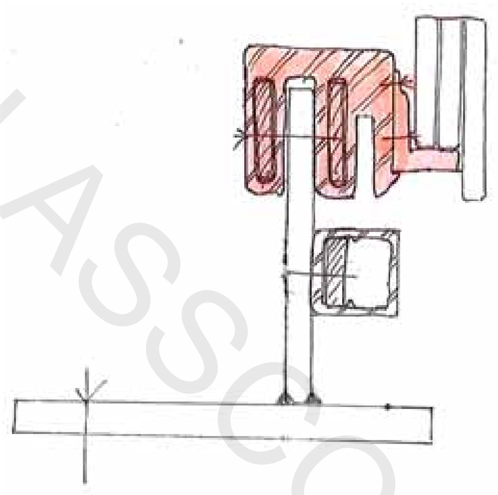
The most unfavourable loads from Pos. 3 are used for verification:

$W_{1,d}$ = 1.8 m x 1.65 kN/m² x1.1 m x 1.5 / 2 = 2.5 kN

$S_{1,d}$ = 3.6 m x 3.6 m / 2 x 1.65 kN/m² x 1.5 / 2 = 8.0 kN

$G_{1,d}$ = 3.6 m x 1.1 m x 3 x 0.01 m x 25 kN/m³ / 2 x 1.35 = 2.0 kN

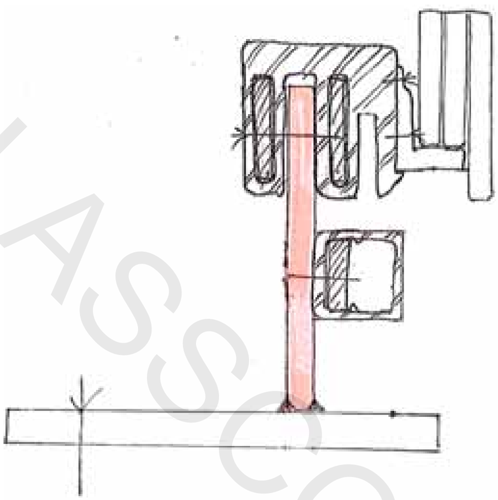
10.4.3. Verification



The geometry dimensions and materials of the components listed below are equal to Pos. 4.1 and are not subjected to bigger loads. Accordingly, the verification of these components can be found in Pos. 4.1.

- Bracket (1)
- Screwed joint S1 (1) to (2)
- Aluminium Profile (2)
- Screwed joint S2 (2) to (3)

(3) Flat steel (t = 12 mm):



Steel S235

σ_{Rd}	=	23.5 kN/cm^2 / 1.0	=	23.5 kN/cm^2
τ_{Rd}	=	23.5 kN/cm^2 / 1.0 / (3)$^{1/2}$	=	13.5 kN/cm^2
t	=	12 mm		
A	=	1.2 cm x 32 cm	=	38.4 cm^2
W_y	=	(1.2 cm)^2 x 32.0 cm^3 / 6	=	7.68 cm^3
$V_{z,Ed}$	=	$W_{1,d}$	=	2.5 kN
$M_{y,Ed}$	=	$G_{1,d}$ x 7.5 cm + $W_{1,d}$ x 12.5 cm		
	=	2.0 kN x 7.5 cm + 2.5 kN x 12.5 cm	=	46.3 kNcm

Normal stress:

$\sigma_{x,Ed}$	=	46.3 kNcm / 7.68 cm^3	=	6.0 kNcm
$\sigma_{x,Ed}$ / σ_{Rd}	=	6.0 kN/cm^2 / 23.5 kN/cm^2	=	0.26 ≤ 1.00 (OK)

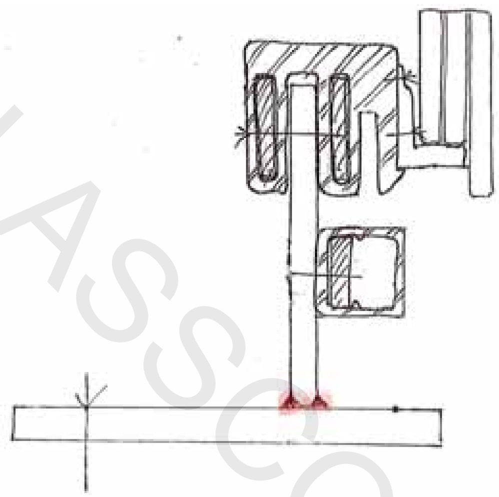
Shear stress:

τ_{Ed}	=	2.5 kN / 38.4 cm^2	=	0.07 kN/cm^2
τ_{Ed} / τ_{Rd}	=	0.07 kN/cm^2 / 13.5 kN/cm^2	=	0.01 ≤ 1.00 (OK)

Equivalent stress:

$((\sigma_{x,Ed} / \sigma_{Rd})^2 + 3 \times (\tau_{Ed} / \tau_{Rd})^2)^{1/2}$ = $((0.26)^2 + 3 \times (0.01)^2)^{1/2}$ = 0.26 ≤ 1.00 (OK)

(S1) Welded connection end plate (3) [t = 12 mm] to 2 x flat steel (4) [t = 12]:



Welded seam: Fillet weld/Butt weld circumferential

a_w = 5 mm

l_w = 2 x 30.0 cm

$F_{w,Rd}$ = 10.39 kN/cm

M_{Ed} = $S_{1,d}$ x 12.5 cm / 2 = 50.0 kNcm

V_{Ed} = $W_{1,d}$ / 2 = 2.5 kN / 2 = 1.25 kN

$V_{II,Ed}$ = $S_{1,d}$ / 2 = 8.0 kN / 2 = 4.0 kN

N_{Ed} = 46.3 kNcm / 1.2 cm = 38.6 kN

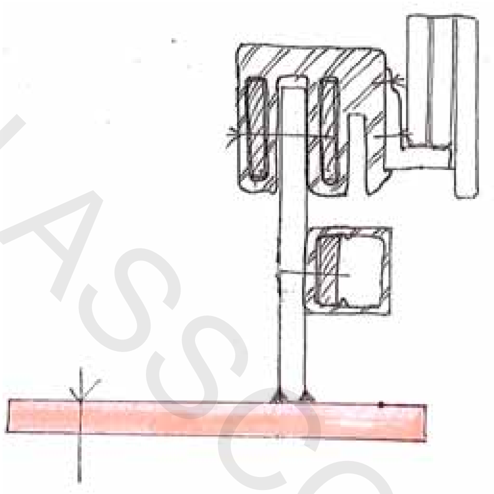
$F_{w,Ed}$ = $((38.6\ kN / (30\ cm) + 50.0\ kNcm / ((30\ cm)^2 / 6))^2 + (1.25\ kN / (30\ cm))^2 + (4.0\ kN / (30\ cm))^2)^{1/2}$

= $((1.3\ kN/cm + 0.3\ kN/cm)^2 + (0.1\ kN/cm)^2 + (0.2\ kN/cm)^2)^{1/2}$

= 1.7 kN/cm

$F_{w,Ed} / F_{w,Rd}$ = 1.7 kN/cm / 10.39 kN/cm = 0.17 ≤ 1.00 (OK)

(4) Flat steel (t = 12 mm):



Steel S235

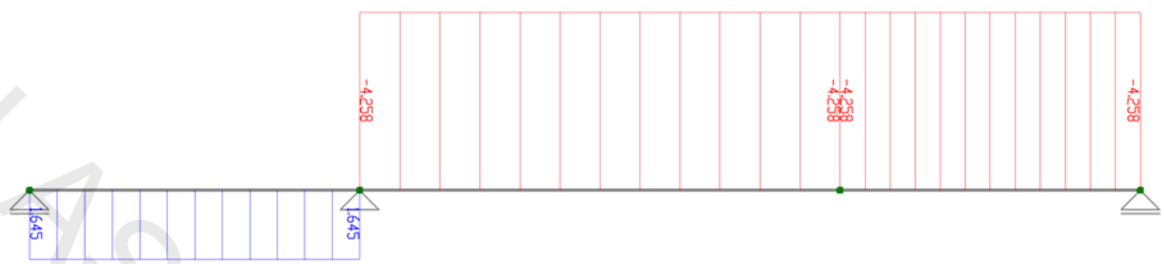
σ_{Rd}	=	23.5 kN/cm^2 / 1.0	=	23.5 kN/cm^2
τ_{Rd}	=	23.5 kN/cm^2 / 1.0 / (3)$^{1/2}$	=	13.5 kN/cm^2

t	=	14 mm		
A	=	1.4 cm x 32 cm	=	44.8 cm^2
W_y	=	(1.4 cm)^2 x 32.0 cm^3 / 6	=	10.45 cm^3

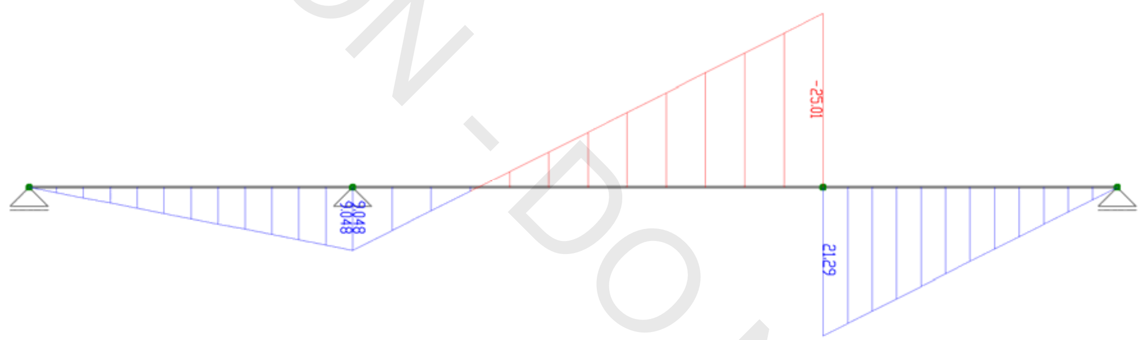
$V_{z,Ed}$	=	$W_{1,d}$	=	2.5 kN
M	=	$G_{1,d}$ x 7.5 cm + $W_{1,d}$ x 12.5 cm		
	=	2.0 kN x 7.5 cm + 2.5 kN x 12.5 cm	=	46.3 kNcm

Static system:

Shear force V [kN]:



Bending moment M [kNm]:



Reaction forces [kN]:

Normal stress:

$\sigma_{x,Ed}$ = 25.1 kNcm / 10.45 cm^3 = 2.4 kNcm

$\sigma_{x,Ed} / \sigma_{Rd}$ = 2.4 kN/cm^2 / 23.5 kN/cm^2 = <u>0.11 ≤ 1.00 (OK)</u>

Shear stress:

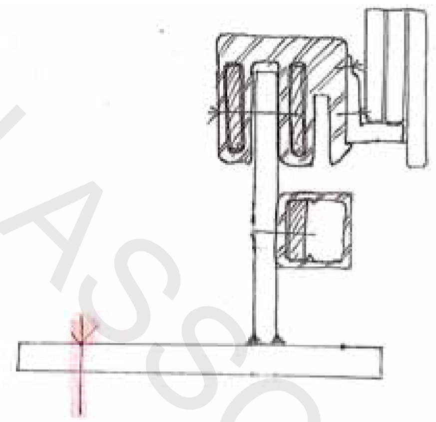
τ_{Ed} = 4.3 kN / 44.8 cm^2 = 0.10 kN/cm^2

τ_{Ed} / τ_{Rd} = 0.10 kN/cm^2 / 13.5 kN/cm^2 = <u>0.01 ≤ 1.00 (OK)</u>

Equivalent stress:

$((\sigma_{x,Ed} / \sigma_{Rd})^2 + 3 \times (\tau_{Ed} / \tau_{Rd})^2)^{1/2}$ = $((0.11)^2 + 3 \times (0.01)^2)^{1/2}$ = <u>0.11 ≤ 1.00 (OK)</u>

(S3) Screwed joint (5) to Halfen Anchor Channel:



The verification of the screw is given in Pos. 5 - Halfen anchor channel.

Bolt forces:

A = 5.9 kN / 2 Screws + $S_{1,d}$ x 12.5 cm / 16.0 cm x 2 / 3

5.9 kN / 4 + 8.0 kN x 12.5 cm / 16.0 cm x 2

= 7.2 kN

B = 5.9 kN / 2 Screws + $S_{1,d}$ x 12.5 cm / 16.0 cm / 3

5.9 kN / 4 + 8.0 kN x 12.5 cm / 16.0 cm x 3

= 5.1 kN

C = 5.9 kN / 2 Screws - $S_{1,d}$ x 12.5 cm / 16.0 cm / 2

5.9 kN / 4 - 8.0 kN x 12.5 cm / 16.0 cm x 2

= -0.2 kN

H = $W_{1,d}$ / 3 Screws + $S_{1,d}$ x 8.0 cm / 24 cm

= 2.5 kN / 3 + 8.0 kN x 8.0 cm / 24 cm

= 3.5 kN

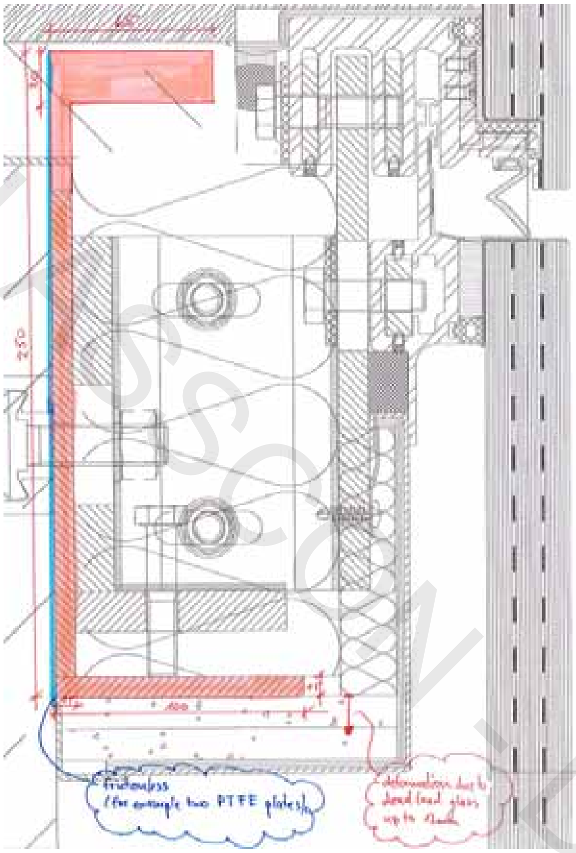
10.5. Pos. 4.5 – Steel frame (cantilever)

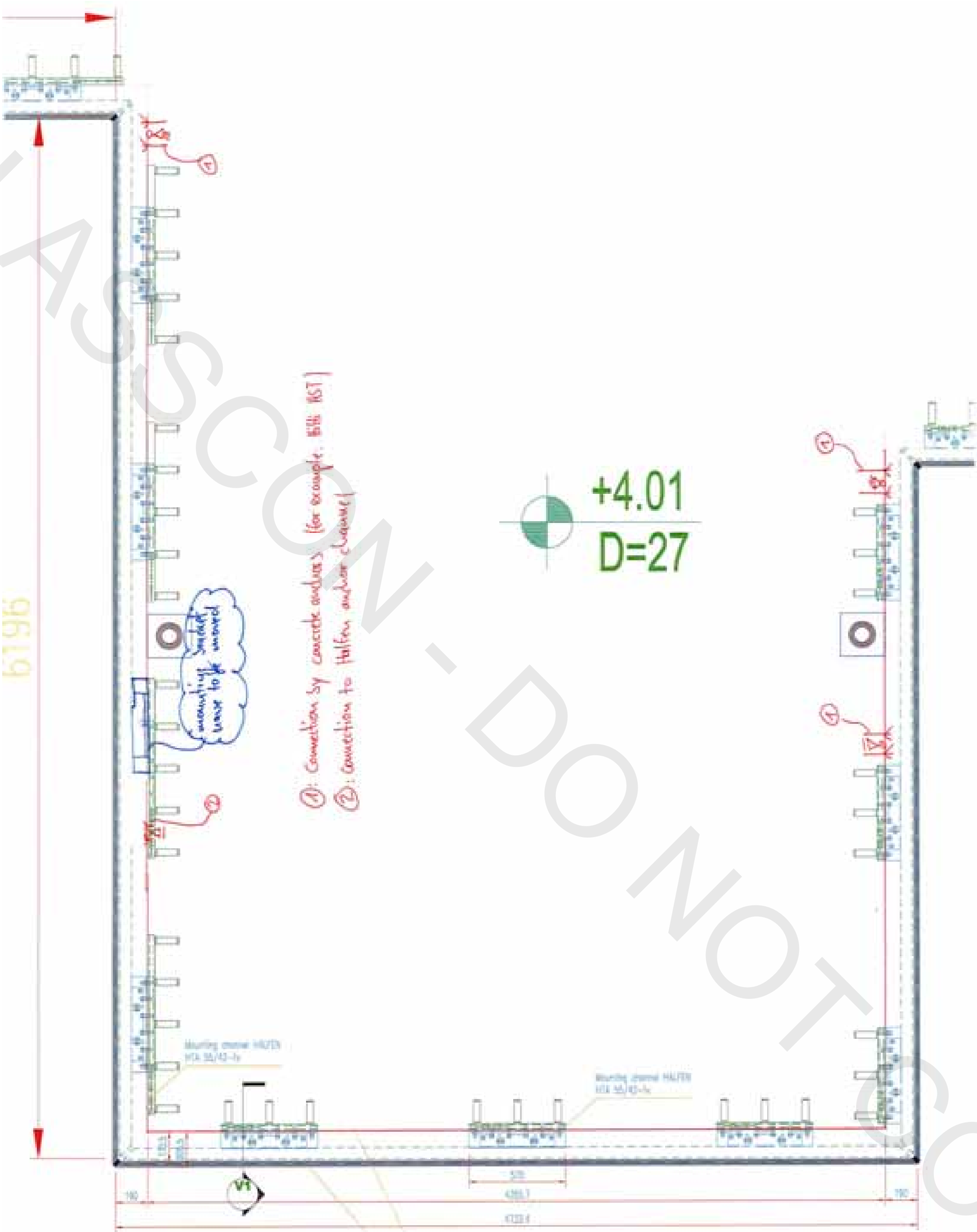
10.5.1. General

At the cantilever occur big vertical deflections due to live load. These vertical deflections cause strains in the vertical as well as in the horizontal SSG joints, which could not be absorbed by the silicone. To minimize the strains induced by the live load on the concrete cantilever a steel frame is arranged at the cantilever. The steel frame is intended as cantilever arm, which is fixed by concrete anchors (1) and Halfen anchor channel (2) at two points on both sides of the concrete cantilever. At the front face of the concrete cantilever the steel frame is connected by hinged connections to the steel cantilever arms on both sides.

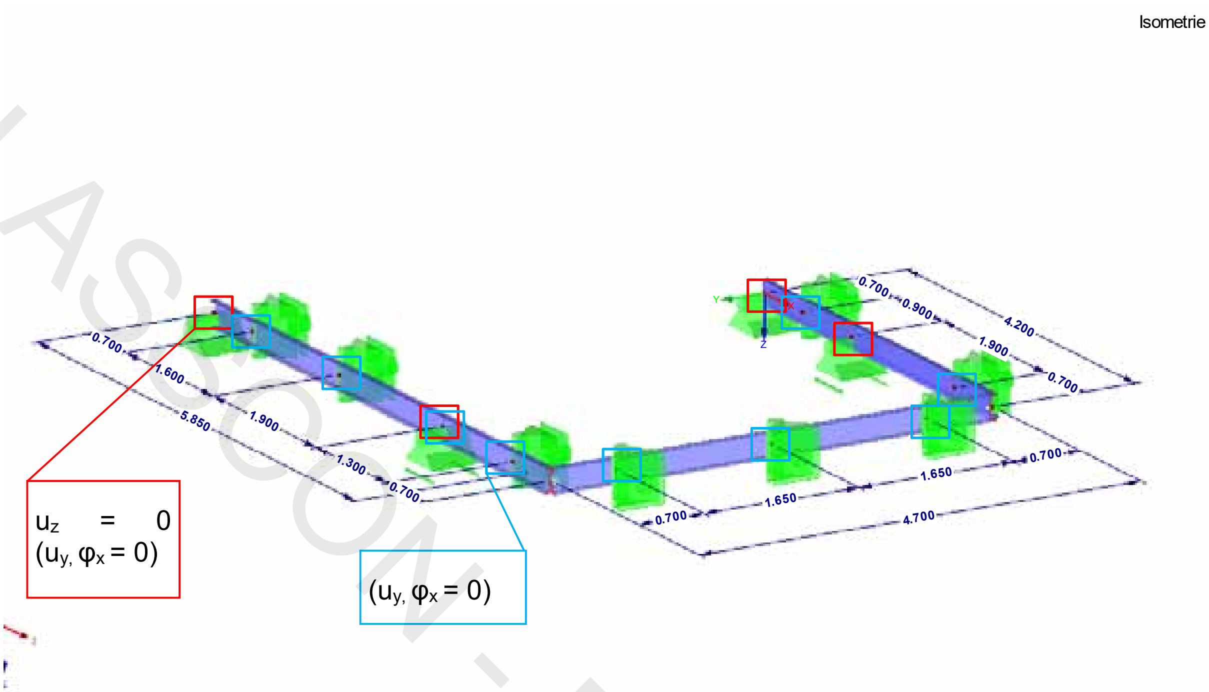
The steel frame should only carry the dead load of the glazing. When the ceiling (cantilever) is loaded by live load, the ceiling should deform independently of the steel frame.For this purpose the contact area between the concrete an the steel frame has to be executed frictonless and slotted wholes has to be provided at the mounting brackets.

The steel frame replaces the L-Profile 200 x 100 x 8 of the mounting brackets.


frictionless
(for example two PTFE plates)
deformation due to
dead load glass


+4.01
D=27
6196
①: Connection by concrete anchors (for example: BSW BST)
②: Connection to Halfen anchor channel
mounting bracket have to be moved
Mounting channel HALFEN
HTA 38/17-A
V1

10.5.2. Static System

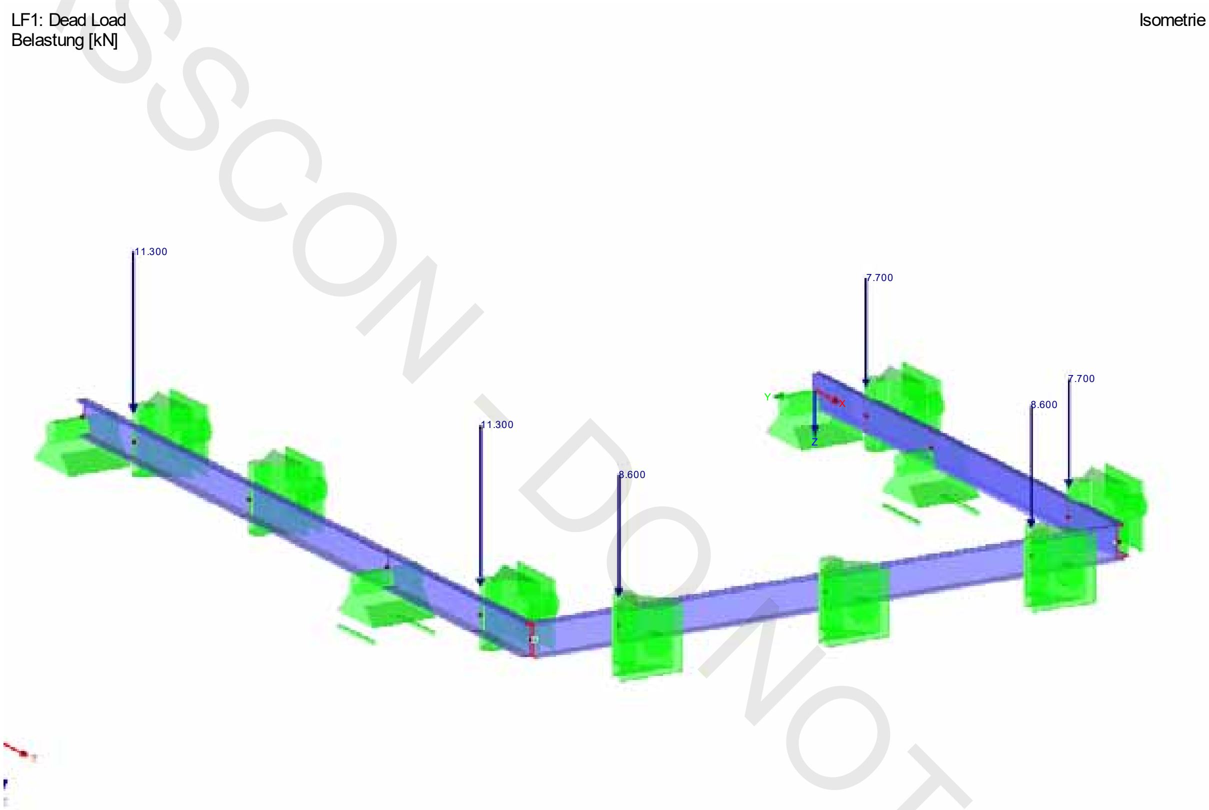


10.5.3. Loads

$G_{1,Ed}$ = 6.2 m x 3.6 m x 0.03 m x 25 kN m^3 / 2 x 1.35 = 11.3 kN

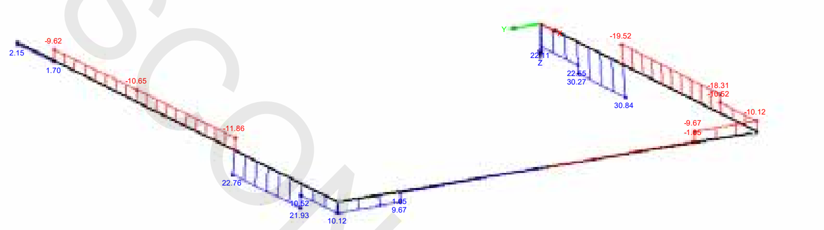
$G_{2,Ed}$ = 4.7 m x 3.6 m x 0.03 m x 25 kN m^3 / 2 x 1.35 = 8.6 kN

$G_{3,Ed}$ = 4.2 m x 3.6 m x 0.03 m x 25 kN m^3/ 2 x 1.35 = 7.7 kN



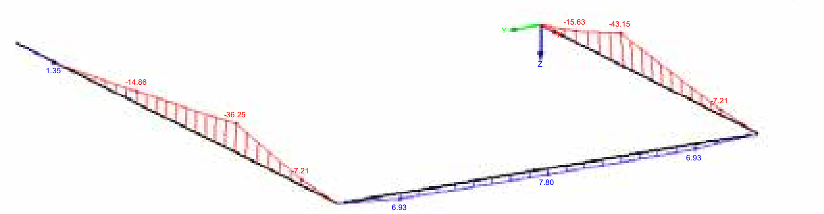
10.5.4. Stress resultants

LF1: Dead Load Isometrie



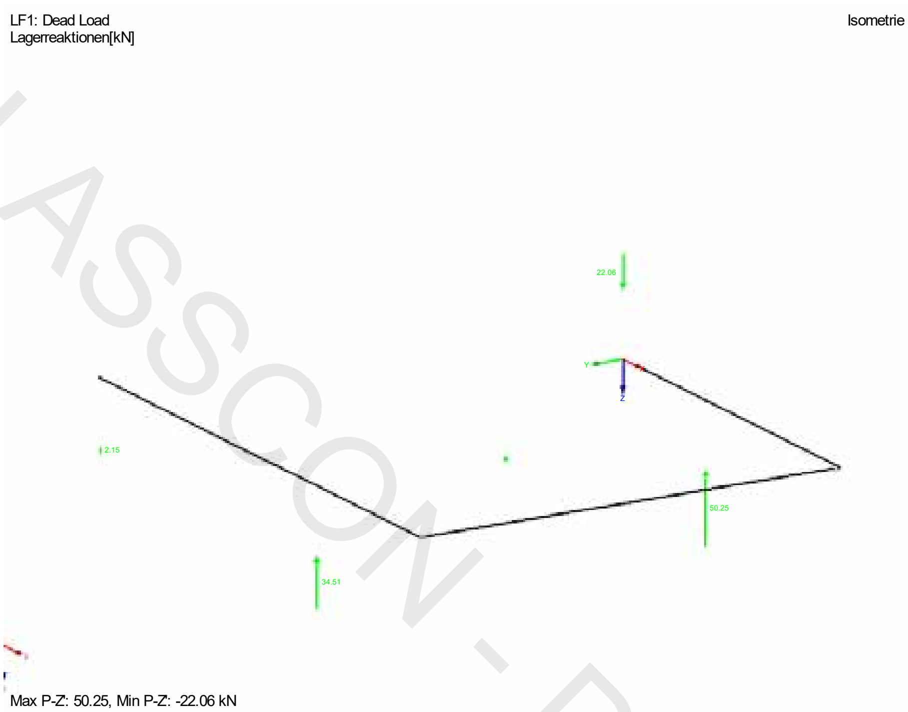
Max V-v: 30.84, Min V-v: -19.52 kN

LF1: Dead Load Isometrie



Max M-u: 7.80, Min M-u: -43.15 kNm

10.5.5. Reaction forces

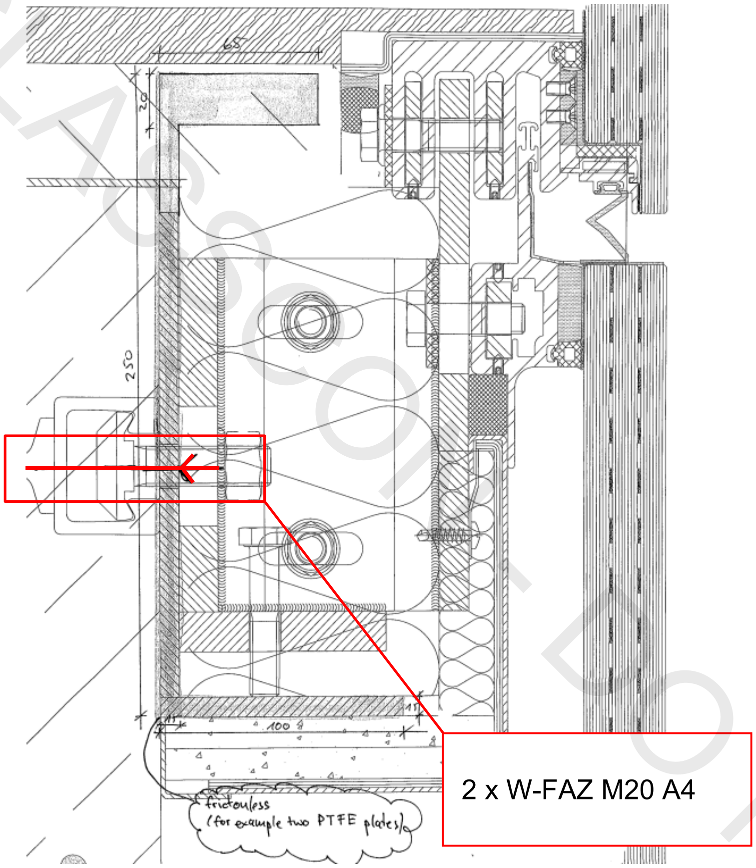


10.5.6. Verification

Cross-section No.	Beam No.	Location x [m]	Load	Verification Utilization		Formular
2	UU 65/100/15/20/15/250/4					
	3	1.900	LC1	0.48	□ 1	112) Cross-section proof - Bending around u-axis according to 6.2.5 - Class 3
	2	0.000	LC1	0.07	□ 1	122) Cross - section proof - lateral force in axis v according to 6.2.6 (4) - Class 3 or 4
	3	1.900	LC1	0.48	□ 1	143) Cross section proof - bending and lateral force according to 6.2.9.2 and 6.2.10 - Class 3 - General cross section
	3	1.900	LC1	0.48	□ 1	332) Stability verification - bending buckling according to 6.3.2.1 and 6.3.2.2 (4) - General case

10.5.7. Details

Support by concrete anchors:

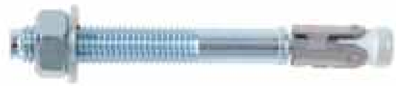


Input data

Base material:	Concrete: Cracked
	C40/50, f_{ck} = 40,00 N/mm², $f_{ck,cube}$ = 50,00 N/mm²
Service temperature:	selected by user: Short-term: 40 °C / long-term: 24 °C
Reinforcement:	Concrete reinforcement: Normal
	Edge reinforcement: Stirrups
	Reinforcement to control splitting according to ETAG 001, Annex C and TR 029 clause 5.2.2.6 present
Base material- / component thickness:	h = 1000,00 mm
Anchor plate:	
Dimensions:	l_x x l_y x t = 320 mm x 250 mm x 15 mm
Thickness of anchor plate:	User-defined anchor plate thickness: t = 15 mm
Clearance hole:	With annular gap acc. to ETAG 001, Annex C; Table 4.1
Material:	S235JR
	Modulus of elasticity: E = 210000 N/mm²
	Yield strength: f_{yk} = 235 N/mm²
	Poisson's ratio: μ = 0,30
	Partial safety factor: γ = 1,10
Structural steel section:	FI Customized
Height:	30 mm
Width:	5 mm
Installation conditions:	
Drill the hole:	Hammer drilling
Condition of drill hole:	Dry
Anchor bending:	Levelling layer
	Thickness of levelling layer: 10,00 mm
	Compressive strength: 30,00 N/mm²
	Degree of restraint: 2,00
Selected type and size of anchor:	W-FAZ/A4 M20
Material:	./A4: Stainless steel A4
Diameter:	M20
Effective anchorage depth:	100 mm
Tightening torque:	200,00 Nm

The input data shall be in compliance with the given data and be checked for plausibility! Würth disclaims liability for wrong input data by user.

Approval number / Validity: ETA-99/0011 (W-FAZ New); valid from 08.04.2016

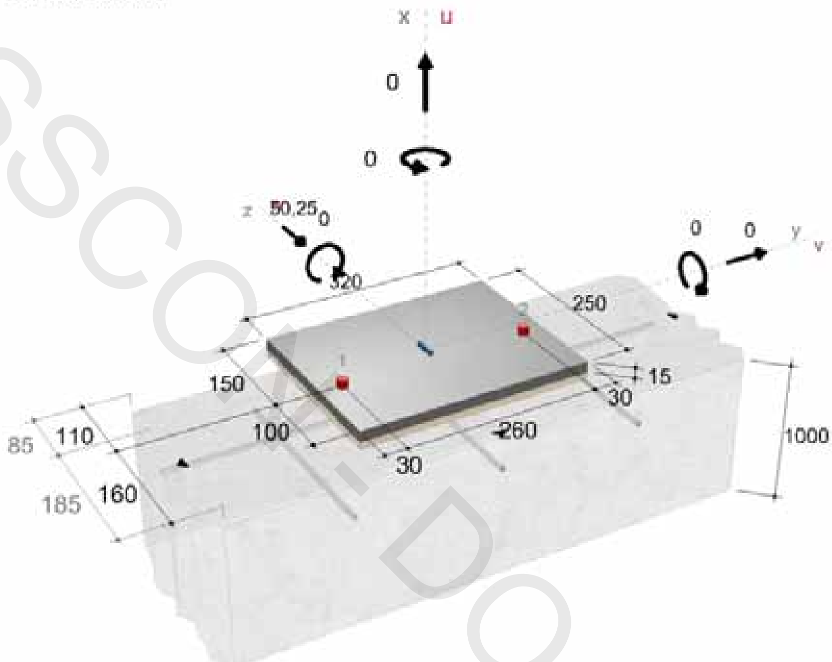


The input data shall be in compliance with the given data and be checked for plausibility! Würth disclaims liability for wrong input data by user.

User:
Company:
Position:
Würth Anchor Design 8.0.7.11

Mobile phone:
e-mail:
Internet:

Geometry and loads:



Load cases:

Number of load case	$N_{Sd,u}$ [kN]	$V_{Sd,v}$ [kN]	$V_{Sd,w}$ [kN]	$M_{Sd,u}$ [kNm]	$M_{Sd,v}$ [kNm]	$M_{Sd,w}$ [kNm]	Type of Action
1	0,00	0,00	-50,25	0,00	0,00	0,00	Normal

Remark: Design actions are given by user.

The input data shall be in compliance with the given data and be checked for plausibility! Würth disclaims liability for wrong input data by user.

User:
Company:
Position:
Würth Anchor Design 8.0.7.11

Mobile phone:
e-mail:
Internet:

Verifications

Overview

Verification method:

ETAG 001, Annex C: 2010-08
ETAG 001, Annex E: 2013-04
TR 020: 2004-05
TR 029: 2010-09
TR 045: 2013-02
fib (CEB - FIP) Bulletin 58: Design of anchorages in concrete, 2010-11

For those cases, which are not explicitly regulated by ETAG 001 and by TR 029, the instructions and recommendations of the fib Bulletin 58 are considered for engineering judgement. The distribution of shear loads in case of anchorages without hole clearance is particularly benefiting from the relevant clauses. The results may be taken for agreements on an individual basis.

Summary

Number of load case	Utilization			Type of load combination
	Tension	Shear	Tension/Shear combination	
1	0,00 %	83,60 %	0,00 %	Normal

Structural verification successfully completed!

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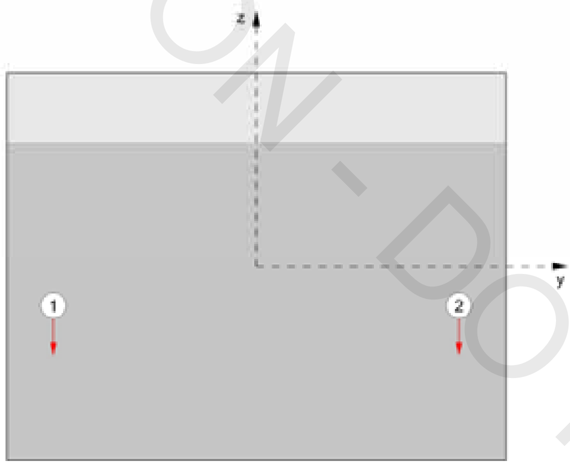
Verification: Quasi static loads

Resulting anchor forces

Anchor number	$N^{i}_{Sd,x}$ [kN]	$(V^{Mx,i})_{Sd,y}$ [kN]	$(V^{Mx,i})_{Sd,z}$ [kN]	$(V^{Vy,i})_{Sd,y}$ [kN]	$(V^{Vz,i})_{Sd,z}$ [kN]	$V^{i}_{Sd,y}$ [kN]	$V^{i}_{Sd,z}$ [kN]	V^{i}_{Sd} [kN]
1	0,000	0,000	0,000	0,000	-25,125	0,000	-25,125	25,125
2	0,000	0,000	0,000	0,000	-25,125	0,000	-25,125	25,125
	$\Sigma N^{i}_{Sd,x}$ [kN]	$\Sigma (V^{Mx,i})_{Sd,y}$ [kN]	$\Sigma (V^{Mx,i})_{Sd,z}$ [kN]	$\Sigma (V^{Vy,i})_{Sd,y}$ [kN]	$\Sigma (V^{Vz,i})_{Sd,z}$ [kN]	$\Sigma V^{i}_{Sd,y}$ [kN]	$\Sigma V^{i}_{Sd,z}$ [kN]	$\lvert\Sigma V^{i}_{Sd}\rvert$ [kN]
Sum	0,000	0,000	0,000	0,000	-50,250	0,000	-50,250	50,250



Maximum concrete compressive strength : 0 N/mm²

Safe transmission of the fastener loads by the concrete member to its supports shall be demonstrated for the ultimate limit state and the serviceability limit state according to EN 1992-1-1. The respective verifications have to be provided by the responsible structural engineer.

Ultimate limit state

Required verification of post-installed anchor in shear

1. Steel failure, shear load without lever arm

$\beta_{V,s}$	=	$V^h_{Sd} / V_{Rd,s}$		Use of total capacity
V^h_{Sd}	=		25,13 kN	Design value of the actions
$V_{Rd,s}$	=	$V_{Rk,s} / \gamma_{Ms,V}$		ETAG 001, Annex C: 5.2.3.1
$V_{Rk,s}$	=	$k_2 \cdot 86{,}00$ kN		ETA + ETAG 001, Annex C: 5.2.3.2a)
k_2	=	1,00		ETA + ETAG 001, Annex C: 5.2.3.2a)
$\gamma_{Ms,V}$	=	1,40		ETA
$V_{Rd,s}$	=		61,43 kN	
$\beta_{V,s}$	=		0,41	

2. Concrete pry-out (Anchor group)

		1, 2		Governing number of anchors
$\beta_{V,cp}$	=	$V^g_{Sd} / V_{Rd,cp}$		Use of total capacity
V^g_{Sd}	=		50,25 kN	Design value of the actions
$V_{Rd,cp}$	=	$V_{Rk,cp} / \gamma_{Mcp,V}$		ETAG 001, Annex C: 5.2.3.1
$V_{Rk,cp}$	=	$k \cdot N_{Rk,c}$		ETAG 001, Annex C: 5.2.3.3 (5.6)
k	=	2,00		ETA
$N_{Rk,c}$	=	$N^0_{Rk,c} \cdot A_{c,V} / A^0_{c,V} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,V}$		ETAG 001, Annex C: 5.2.2.4 (5.2)
$N^0_{Rk,c}$	=	$k_1 \cdot f_{ck,cube}^{0,5} \cdot h_{ef}^{1,5}$		ETAG 001, Annex C: 5.2.2.4a) (5.2a)
k_1	=	7,20		ETAG 001, Annex C: 5.2.2.4a)
h_{ef}	=	100 mm		ETA
$N^0_{Rk,c}$	=	50,91 kN		
$A_{c,V}$	=	145600 mm²		ETAG 001, Annex C: 5.2.2.4b)
$A^0_{c,V}$	=	$s_{cr,N}^2$ = (300 mm)² = 90000 mm²		ETAG 001, Annex C: 5.2.2.4b) (5.2b)
$\psi_{s,N}$	=	$0{,}7 + 0{,}3 \cdot c / c_{cr,N} \le 1{,}0$		ETAG 001, Annex C: 5.2.2.4c) (5.2c)
c	=	110 mm		
$c_{cr,N}$	=	150 mm		
$\psi_{s,N}$	=	0,9200		
$\psi_{re,N}$	=	$0{,}5 + h_{ef} / 200 \text{ mm} \le 1{,}0$		ETAG 001, Annex C: 5.2.2.4d) (5.2d)
	=	1,0000		ETAG 001, Annex C: 5.2.2.4d) (5.2d)
$\psi_{ec,V}$	=	$1 / (1 + 2 \cdot e_V / s_{cr,N})$		ETAG 001, Annex C: 5.2.2.4e) (5.2e)
$e_{V,y}$	=	0 mm		
$e_{V,z}$	=	0 mm		
e_V	=	0 mm		
$\psi_{ec,V}$	=	1,0000		
$N_{Rk,c}$	=	75,77 kN		
$V_{Rk,cp}$	=	212,17 kN		
$\gamma_{Mcp,V}$	=	1,50		ETA
$V_{Rd,cp}$	=		141,45 kN	
$\beta_{V,cp}$	=		0,36	

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3. Concrete edge breakout

3.1 Overview of all conducted verifications

Edge failure in negative z-Direction

Due to existing annular gaps the following anchors take shear load perpendicular to edge: 1, 2

The calculation of the total sum of all acting V_{Sd} all vertical forces perpendicular to the edge including those resulting from the torsional moments are considered.

The respective total sum V_{Sd} is presented with the related verification in form of a summary below to keep the print-out reader-friendly.

Summary of verifications

Anchor	V_{Sd} [kN]	$\psi_{A,V}$ [-]	$\psi_{s,V}$ [-]	$\psi_{h,V}$ [-]	$\psi_{\alpha,V}$ [-]	$\psi_{ec,V}$ [-]	$\psi_{re,V}$ [-]	$V_{Rk,c}$ [kN]	$V_{Rd,c}$ [kN]	β_c [-]
1, 2	50,25	1,54	1,00	1,00	1,00	1,00	1,40	90,17	60,11	0,84

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Project name:	28. August 2017
Client:	jhilcken
Address of project:	Page 9 of 12

3.2 Governing verification

Resulting anchor forces: Edge failure in negative z-Direction

Governing number of anchors: 1, 2

		1, 2		Governing number of anchors
$\beta_{V,c}$	=	$V_{Sd} / V_{Rd,c}$		Use of total capacity
V_{Sd}	=		50,25 kN	Design value of the actions
$V_{Rd,c}$	=	$V_{Rk,c} / \gamma_{Mcp,V}$		ETAG 001, Annex C: 5.2.3.1
$V_{Rk,c}$	=	$V^0_{Rk,c} \cdot A_{c,V} / A^0_{c,V} \cdot \psi_{s,V} \cdot \psi_{h,V} \cdot \psi_{\alpha,V} \cdot \psi_{ec,V} \cdot \psi_{re,V}$		ETAG 001, Annex C: 5.2.3.4 (5.7)
$V^0_{Rk,c}$	=	$k_1 \cdot d_{nom}^{\alpha} \cdot h_{ef}^{\beta} \cdot f_{ck,cube}^{0,5} \cdot c_1^{1,5}$		ETAG 001, Annex C: 5.2.3.4a) (5.7a)
k_1	=	1,70		ETAG 001, Annex C: 5.2.3.4a)
d_{nom}	=	20 mm		ETA
h_{ef}	=	100 mm		ETA
α	=	$0,1 \cdot (l_f / c_1)^{0,5}$		ETAG 001, Annex C: 5.2.3.4a) (5.7b)
l_f	=	100,00 mm		ETA
c_1	=	160 mm		
α	=	0,08		
β	=	$0,1 \cdot (d_{nom} / c_1)^{0,2} = 0,07$		ETAG 001, Annex C: 5.2.3.4a) (5.7c)
$V^0_{Rk,c}$	=	41,78 kN		
$A_{c,V}$	=	177600 mm²		ETAG 001, Annex C: 5.2.3.4b)
$A^0_{c,V}$	=	$4,5 \cdot c_1^2 = 115200$ mm²		ETAG 001, Annex C: 5.2.3.4b) (5.7d)
$\psi_{s,V}$	=	$0,7 + 0,3 \cdot c_2 / (1,5 \cdot c_1) \leq 1,0$		ETAG 001, Annex C: 5.2.3.4c) (5.7e)
	=	1,0000		
$\psi_{h,V}$	=	$(1,5 \cdot c_1 / h)^{0,5} \geq 1,0$		ETAG 001, Annex C: 5.2.3.4d) (5.7f)
h	=	1000 mm		
$\psi_{h,V}$	=	1,0000		
$\psi_{\alpha,V}$	=	$(1 / [(\cos\alpha_V)^2 + (\sin\alpha_V / 2,5)^2])^{0,5} \geq 1,0$		ETAG 001, Annex C: 5.2.3.4e) (5.7g)
α_V	=	0,00°		ETAG 001, Annex C: 5.2.3.4e)
$\psi_{\alpha,V}$	=	1,0000		
$\psi_{ec,V}$	=	$1 / (1 + 2 \cdot e_V / (3 \cdot c_1)) \leq 1,0$		ETAG 001, Annex C: 5.2.3.4f) (5.7h)
e_V	=	0 mm		
$\psi_{ec,V}$	=	1,0000		
$\psi_{re,V}$	=	1,4000		ETAG 001, Annex C: 5.2.3.4g)
$V_{Rk,c}$	=	90,17 kN		
$\gamma_{Mc,V}$	=	1,50		ETA
$V_{Rd,c}$	=		60,11 kN	
$\beta_{V,c}$	=		0,84	

The input data shall be in compliance with the given data and be checked for plausibility! Würth disclaims liability for wrong input data by user.

User:	Mobile phone:
Company:	e-mail:
Position:	Internet:
Würth Anchor Design 8.0.7.11	

Maximum shear load

$\beta_{V,max}$ = 0,84

Remarks

- Verification
- The item numbers of the anchors are given in the respective product data sheets.
- The item numbers of the accessories are given in the respective product data sheets. The installation instructions in the respective approvals..
- The detailed verifications of the serviceability limit states are not shown. Please check with your certified structural engineer.
- This design is only valid if the diameter of the clearance hole is not larger than given in ETAG 001, Annex C, Table 4.1! Check for further requirements chapter 1.1 of ETAG 001, Annex C in case the diameter of the clearance hole is larger.
- The design is based on numerous anchor-specific values. If the selected anchor will be changed or when the given load values or geometrical data are being changed, the verification is no longer valid and must be conducted for the new situation. The requirements and provisions of the European Technical Approval must be considered.
- In an anchor group only anchors of the same type, size and length shall be used.
- Bond strength depends on the short- and long-term service temperature of base material.
- Verify selected base material strength.
- The assumption of a linear distribution of strains is valid only if the fixture is sufficient rigid. The base plate shall remain elastic under design actions and its deformation shall remain negligible in comparison with the axial displacement of the fasteners. The determination of the loads acting on the individual anchors and the calculation of the fixture thickness was conducted with these assumptions. The user has to structurally verify according to related national standards.
- Checking the transfer of loads into the base material is required in accordance with ETAG 001, Annex C: 2010-08, Section 7. The software considers that the grout is installed under the baseplate without creating air voids and before application of the loads.
- The proof of the local transmission of the anchor loads into the concrete member is required in accordance with ETAG 001, Annex C: 2010-08, Section 7. The software considers that the levelling layer is installed under the baseplate without any air voids and loads apply.
- The list of accessories in this report, is an information only. For a correct installation the setting instructions have to be taken from the instruction leaflet delivered with each product.

WÜRTH

Project name: 28. August 2017
Client: jhilcken
Address of project: Page 11 of 12

Setting instructions

Base material

Selected type and size of anchor: W-FAZ/A4 M20

Effective anchorage depth: h_{ef} = 100 mm

Drill hole depth: h_1 = 125 mm

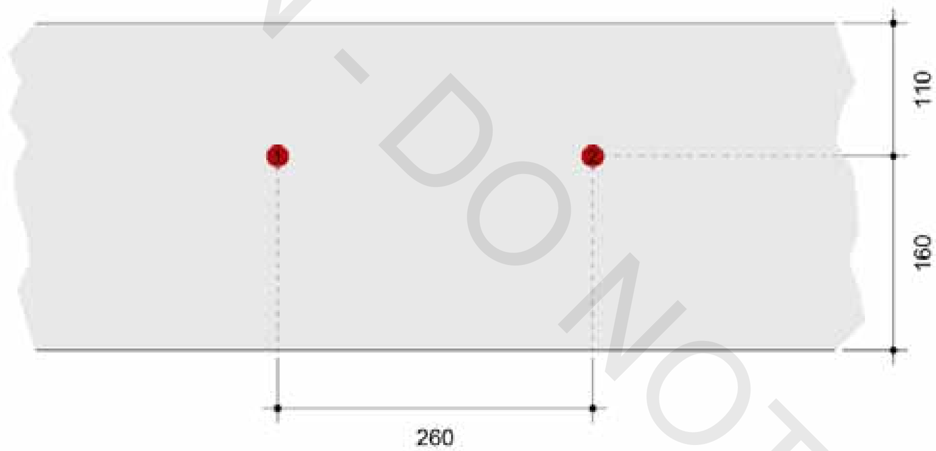
Drill hole diameter: d_0 = 20 mm

Minimum component thickness: h_{min} = 200 mm

Drill:

Nominal drill bit diameter: 20 mm

Working length of the drill bit: ≥ 140 mm



Cleaning required

Instructions referring to the approvals or to the instruction leaflet must be considered.

Cleaning tools according to the list of accessories and Würth Catalogues

Anchor installation

Tightening torque: 200,00 Nm

The input data shall be in compliance with the given data and be checked for plausibility! Würth disclaims liability for wrong input data by user.

User: Mobile phone:
Company: e-mail:
Position: Internet:
Würth Anchor Design 8.0.7.11

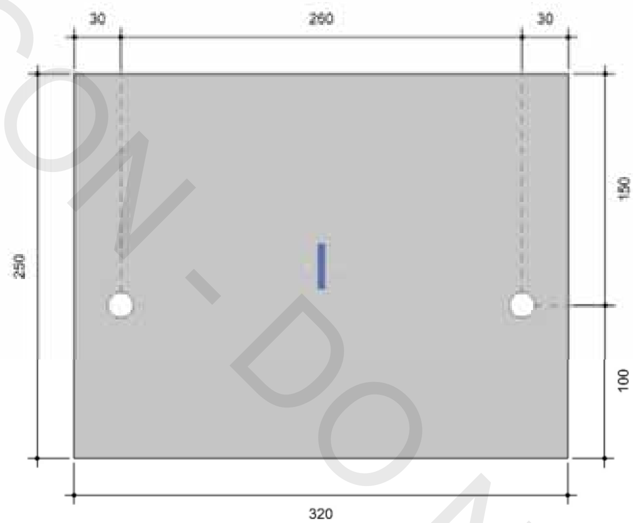
Anchor plate

Material: S235JR

Yield strength: f_{yk} = 235 N/mm²

Diameter of clearance hole in the fixture: Push-through installation: $d_f \le 22$ mm

Thickness of anchor plate: t = 15 mm (User input)



Structural steel section

Material: S 235 (St 37)

Structural steel section: Fl Customized

Height: 30 mm

Width: 5 mm

(2) Support by Halfen anchor channels:

see Pos. 5.5

11. Pos. 5 – Halfen Anchor Channels (horizontal) HTA-CE 55/42

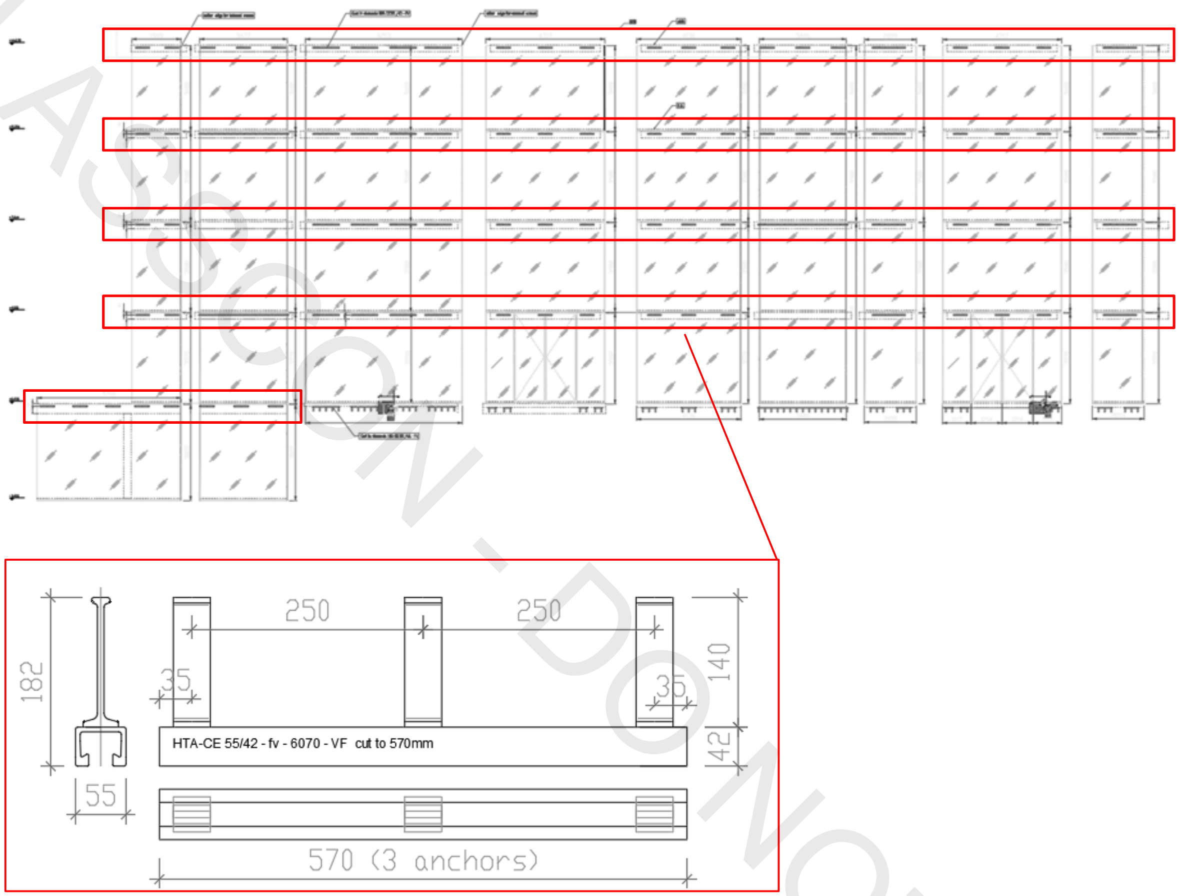
At the building, Halfen anchor channels with different dimensions are used (see illustration above) to fix the glazing construction to the solid construction. According to the size of the glazing two, three or four mounting brackets are used. In the upper floors, the brackets are connected to the Halfen anchor channels (Pos. 5.1, Pos. 5.2), which are provided in the front faces of the solid building ceilings. In the ground floor, the brackets are fastened to Halfen anchor channels (Pos. 5.3, Pos. 5.4), which are installed on the top side (Pos. 4.3, Pos. 4.4).

Structural analysis of the Halfen anchor channels:

- For verification, only the shortest rails with the maximum loads are verified on the safe side. Results can principally be transferred to longer anchor channels.
- The design is carried out according to ETA 09/0339.
- The assessment of the longitudinal forces for screws HS M20 8.8 is not included in this approval. For verification, the values given by the supplier (see table below) are used.
- For the installation of the mounting brackets, the torques specified by the supplier (M16: 200 Nm) must be observed in order to absorb the rail longitudinal forces.
- Shear forces from SSG joints, are splitted equally to all consoles.
- The self weight of the glazing is only divided to the outer Halfen screws with round holes and not to inner screws with slotted holes (for adjustment).
- The bending moment, resulting from wind, shear and dead load, is diveded by detailed calculations to the inner Halfen screws.

11.1. Pos. 5.1 – Halfen Anchor Channel (front)

11.1.1. General



Anchor channel HTA-CE 55/42 – FV 6070 (hot rolled)

Length of channel 570 mm*

Number of anchors 3

Bolt HSR M16 8.8

*The Halfen channel is going to be cut from a standard channel with a length of 6070 mm and anchor distance of 250 mm to a channel with a length of 570 mm and three symmetric arranged anchors. For the verification on the safe side both a channel with a length of 6700 mm (variable position of screws) and a channel with a length of 550 mm (tolerance +/-15 mm) were calculated.

The calculation of the screw forces can be found in Pos. 4.1

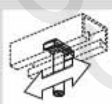
11.1.2. Verification

Longitudinal load in channel direction (HSR M16 8.8):

V_{Ed} = 2 x 10.7 kN / 6 screws = 3.6 kN

F_{Rd} = 7.0 kN

V_{Ed} / F_{Rd} = 3.6 kN / 7.0 kN = <u>0.52 ≤ 1.00 (OK)</u>

Load capacity	
 Bolt HSR	Grade 8.8 F_{Rd} in channel longitudinal direction according to expert report F_{Rd} [kN]
40/22 - M16	7.0
50/30 - M16	7.0
50/30 - M20	10.5
72/48 - M20	10.5

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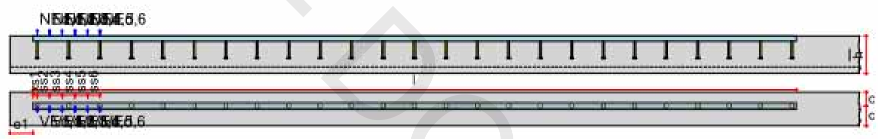
Halfen HTA-CE anchor channel - CEN/TS 1992-4, ETA-09/0339
Halfen Design Software HTA, Version 2.50

The design - including the static values - does only apply to the designated HALFEN product. The load bearing capacity of third party products, appearing to be identical in construction, might differ. For this reason, the software provider does not extend warranty if external products are used.

Input data

Anchor channel	HTA-CE 55/42 - FV - 6070 / 25, 25 anchors
Channel bolt	HS 50/30 M 16 FV 4.6
Approval / Design method	CEN/TS 1992-4, ETA-09/0339
Shear force	without lever arm
Concrete	C40/50, cracked
Reinforcement	no dense reinforcement
edge reinforcement	Straight edge reinforcement ds ≥ 12mm



h = 9999 mm l = 6070 mm c_{11} = 160 mm c_{12} = 110 mm e_1 = 180 mm
c_{nom} = 30 mm

Adjusting zone ±: full variability

Bolt	x_{s1}/s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]	Bolt	s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]
1	35	0.00	8.00	2	100	30.70	0.00
3	100	30.70	0.00	4	100	2.20	0.00
5	100	10.10	0.00	6	100	0.00	8.00

Utilisation: 98% - Proof successful

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Calculation Summary

Verifications for T-bolt

Tension	$N_{Rd,s,s}$	98% ⇦
Shear	$V_{Rd,s,s}$	35%
Combined load	$N_{Rd,s,s}$ - $V_{Rd,s,s}$	0%

Verifications for cast-in channels

Channel lips - Tension	$N_{Rd,s,l}$	75%
Channel lips - Shear	$V_{Rd,s,l}$	14%
Combined load	$N_{Rd,s,l}$ - $V_{Rd,s,l}$	0%
Local flexure of channel	$M_{Rd,s,flex}$	44%
Connection between anchor and channel (Tension)	$N_{Rd,s,c}$	87%
Connection between anchor and channel (Shear)	$V_{Rd,s,c}$	13%
Combined load	$N_{Rd,s,c}$ - $V_{Rd,s,c}$	76%

Verifications for concrete

Tension - Pull-out failure	$N_{Rd,cp}$	47%
Tension - Concrete cone failure	$N_{Rd,c}$	87%
Shear - Concrete edge failure	$V_{Rd,c}$	26%
Shear - Pry-out failure	$V_{Rd,cp}$	7%
Shear - Concrete edge failure, load parallel to edge	$V_{Rd,c90}$	13%
Combined load	$N_{Rd,c}$ - $V_{Rd,c}$	91%
Combined load	$N_{Rd,c}$ - $V_{Rd,cp}$	78%
Combined load	$N_{Rd,c}$ - $V_{Rd,c90}$	72%

Verifications:

Steel

Channel bolt

Maximum tension load (bolt): Bolt 2

$N_{Rk,s,s}$ [kN]	γ_{Ms}	$N_{Rd,s,s}$ [kN]	N_{Ed} [kN]	β_N
62.8	2.00	31.4	30.7	0.98

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,s}$ [kN]	γ_{Ms}	$V_{Rd,s,s}$ [kN]	V_{Ed} [kN]	β_V
37.7	1.67	22.57	8	0.35

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
0	0.00	8	0.35	0

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Anchor channel, channel lips
Maximum tension load (bolt): Bolt 2

$N_{Rk,s,l}$ [kN]	γ_{Ms}	$N_{Rd,s,l}$ [kN]	N_{Ed} [kN]	β_N
73.39	1.8	40.77	30.7	0.75

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,l}$ [kN]	γ_{Ms}	$V_{Rd,s,l}$ [kN]	V_{Ed} [kN]	β_V
104	1.8	57.78	8	0.14

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N{}^2+\beta_V{}^2$
0	0	8	0.14	0

Flexure of channel
Decisive span between anchors 17 and anchors 18

$N_{Ed,2}$ [kN]	load position [mm]
30.7	4085

$N_{Ed,3}$ [kN]	load position [mm]
30.7	4185

$N_{Ed,4}$ [kN]	load position [mm]
2.2	4285

M_{Ed} [Nm]	$M_{Rk,s,flex}$ [Nm]	$\gamma_{Ms,flex}$	$M_{Rd,s,flex}$ [Nm]	β_{flex}
2,456.00	6,447.00	1.15	5,606.09	0.44

Connection between anchor and channel
most unfavourable anchor: 2, load position xş = 85 mm

$N_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$N_{Rd,s,c}$ [kN]	N_{Ed} [kN]	β_N
80	1.8	44.44	38.57	0.87

most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$V_{Rd,s,c}$ [kN]	V_{Ed} [kN]	β_V
80	1.8	44.44	5.98	0.13

most unfavourable anchor: 2, load position xş = 85 mm

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N{}^2+\beta_V{}^2$
38.57	0.87	3.87	0.09	0.76

Concrete

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Tensile load - Pull-out failure
most unfavourable anchor: 2, load position xş = 85 mm

$N_{Rk,cp}$ [kN]	$\gamma_{M,cp}$	$N_{Rd,cp}$ [kN]	N_{Ed} [kN]	β_N
124	1.5	82.67	38.57	0.47

$N_{Rk,p(C12/15)}$ [kN]	$\psi_{ucr,N}$
37.2	1

Tensile load - Concrete cone failure
most unfavourable anchor: 2, load position xş = 85 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N
66.25	1.5	44.17	38.57	0.87

$N0_{Rk,c}$ [kN]	$s_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.74	269	0.64	1.00	1	1

Shear load - Pry-out failure
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,cp}$ [kN]	γ_{Mc}	$V_{Rd,cp}$ [kN]	V_{Ed} [kN]	β_V
127.14	1.5	84.76	5.98	0.07

$\alpha_{s,N(cp)}$	k_5
0.67	2

Shear load - Concrete edge failure
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
34.37	1.5	22.91	5.98	0.26

α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.67	375	0.76	1

Shear load - Concrete edge failure (V_c_90)
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
71.72	1.5	47.81	5.98	0.13

α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	215	104.77	0	1	485	0.27	1

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Combined loading

most unfavourable anchor: 2, load position xş = 85 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N			
66.25	1.5	44.17	38.57	0.87			

$N0_{Rk,c}$ [kN]	$S_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\Psi_{re,N}$	$\Psi_{ucr,N}$
139.14	538	0.74	269	0.64	1.00	1.00	1.0

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]
24.93	1.5	16.62	3.63

α_p*$\Psi_{re,V}$	$c_{1,1}$ [mm]	$\Psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.37	375	1	1

β_N	β_V	$\beta_N + \beta_V$
0.87	0.22	1.09

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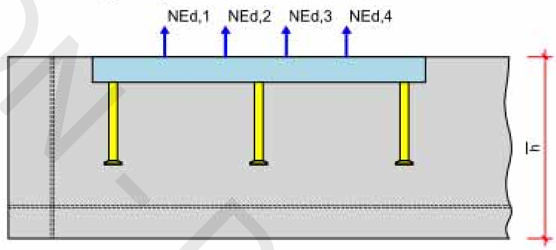
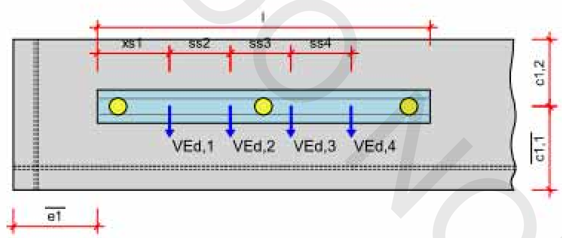
Halfen HTA-CE anchor channel - CEN/TS 1992-4, ETA-09/0339
Halfen Design Software HTA, Version 2.50

The design - including the static values - does only apply to the designated HALFEN product. The load bearing capacity of third party products, appearing to be identical in construction, might differ. For this reason, the software provider does not extend warranty if external products are used.

Input data

Anchor channel	HTA-CE 55/42 - FV - 550 / 3, 3 anchors
Channel bolt	HS 50/30 M 16 FV 8.8
Approval / Design method	CEN/TS 1992-4, ETA-09/0339
Shear force	without lever arm
Concrete	C40/50, cracked
Reinforcement	no dense reinforcement
edge reinforcement	Straight edge reinforcement ds ≥ 12mm





h = 9999 mm l = 550 mm c_{11} = 160 mm c_{12} = 110 mm e_1 = 180 mm
c_{nom} = 30 mm

Adjusting zone ±: Defined adjustment 15 mm, Shift interval 5 mm

Bolt	x_{s1}/s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]	Bolt	s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]
1	120	30.70	8.00	2	100	30.70	0.00
3	100	2.20	0.00	4	100	10.10	8.00

Utilisation: 95% - Proof successful

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Calculation Summary

Verifications for T-bolt

Tension	$N_{Rd,s,s}$	37%
Shear	$V_{Rd,s,s}$	16%
Combined load	$N_{Rd,s,s}$ - $V_{Rd,s,s}$	16%

Verifications for cast-in channels

Channel lips - Tension	$N_{Rd,s,l}$	75%
Channel lips - Shear	$V_{Rd,s,l}$	14%
Combined load	$N_{Rd,s,l}$ - $V_{Rd,s,l}$	54%
Local flexure of channel	$M_{Rd,s,flex}$	41%
Connection between anchor and channel (Tension)	$N_{Rd,s,c}$	83%
Connection between anchor and channel (Shear)	$V_{Rd,s,c}$	16%
Combined load	$N_{Rd,s,c}$ - $V_{Rd,s,c}$	71%

Verifications for concrete

Tension - Pull-out failure	$N_{Rd,cp}$	44%
Tension - Concrete cone failure	$N_{Rd,c}$	88%
Shear - Concrete edge failure	$V_{Rd,c}$	28%
Shear - Pry-out failure	$V_{Rd,cp}$	9%
Shear - Concrete edge failure, load parallel to edge	$V_{Rd,c90}$	10%
Combined load	$N_{Rd,c}$ - $V_{Rd,c}$	95% ⇦
Combined load	$N_{Rd,c}$ - $V_{Rd,cp}$	81%
Combined load	$N_{Rd,c}$ - $V_{Rd,c90}$	80%

Verifications:

Steel

Channel bolt

Maximum tension load (bolt): Bolt 1

$N_{Rk,s,s}$ [kN]	γ_{Ms}	$N_{Rd,s,s}$ [kN]	N_{Ed} [kN]	β_N
125.6	1.50	83.73	30.7	0.37

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,s}$ [kN]	γ_{Ms}	$V_{Rd,s,s}$ [kN]	V_{Ed} [kN]	β_V
62.8	1.25	50.24	8	0.16

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N{}^2+\beta_V{}^2$
30.7	0.37	8	0.16	0.16

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HALFEN	Project	ProNo.	Page 3
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Anchor channel, channel lips

Maximum tension load (bolt): Bolt 2

$N_{Rk,s,l}$ [kN]	γ_{Ms}	$N_{Rd,s,l}$ [kN]	N_{Ed} [kN]	β_N
73.39	1.8	40.77	30.7	0.75

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,l}$ [kN]	γ_{Ms}	$V_{Rd,s,l}$ [kN]	V_{Ed} [kN]	β_V
104	1.8	57.78	8	0.14

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
30.7	0.72	8	0.14	0.54

Flexure of channel

Decisive span between anchors 1 and anchors 2

$N_{Ed,1}$ [kN]	load position [mm]
30.7	130

$N_{Ed,2}$ [kN]	load position [mm]
30.7	230

M_{Ed} [Nm]	$M_{Rk,s,flex}$ [Nm]	$\gamma_{Ms,flex}$	$M_{Rd,s,flex}$ [Nm]	β_{flex}
2,308.90	6,447.00	1.15	5,606.09	0.41

Connection between anchor and channel

most unfavourable anchor: 2, load position x_S = 135 mm

$N_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$N_{Rd,s,c}$ [kN]	N_{Ed} [kN]	β_N
80	1.8	44.44	36.74	0.83

most unfavourable anchor: 2, load position x_S = 105 mm

$V_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$V_{Rd,s,c}$ [kN]	V_{Ed} [kN]	β_V
80	1.8	44.44	7.04	0.16

most unfavourable anchor: 2, load position x_S = 135 mm

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
36.74	0.83	7.04	0.16	0.71

Concrete

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Tensile load - Pull-out failure
most unfavourable anchor: 2, load position xş = 135 mm

$N_{Rk,cp}$ [kN]	$\gamma_{M,cp}$	$N_{Rd,cp}$ [kN]	N_{Ed} [kN]	β_N
124	1.5	82.67	36.74	0.44

$N_{Rk,p(C12/15)}$ [kN]	$\psi_{ucr,N}$
37.2	1

Tensile load - Concrete cone failure
most unfavourable anchor: 2, load position xş = 135 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N
62.94	1.5	41.96	36.74	0.88

$N0_{Rk,c}$ [kN]	$s_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.71	269	0.64	1.00	1	1

Shear load - Pry-out failure
most unfavourable anchor: 2, load position xş = 110 mm

$V_{Rk,cp}$ [kN]	γ_{Mc}	$V_{Rd,cp}$ [kN]	V_{Ed} [kN]	β_V
116.77	1.5	77.85	7.04	0.09

$\alpha_{s,N(cp)}$	k_5
0.58	2

Shear load - Concrete edge failure
most unfavourable anchor: 1, load position xş = 105 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
25.38	1.5	16.92	4.8	0.28

α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.5	375	0.76	1

Shear load - Concrete edge failure (V_c_90)
most unfavourable anchor: 1, load position xş = 105 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
71.72	1.5	47.81	4.8	0.1

α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	215	104.77	0	1	485	0.27	1

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Combined loading
most unfavourable anchor: 2, load position xş = 135 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N			
62.94	1.5	41.96	36.74	0.88			
$N0_{Rk,c}$ [kN]	$S_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.71	269	0.64	1.00	1.00	1.0
$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]				
39.26	1.5	26.17	7.04				
α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.58	375	1	1
β_N	β_V	$\beta_N + \beta_V$					
0.88	0.27	1.14					

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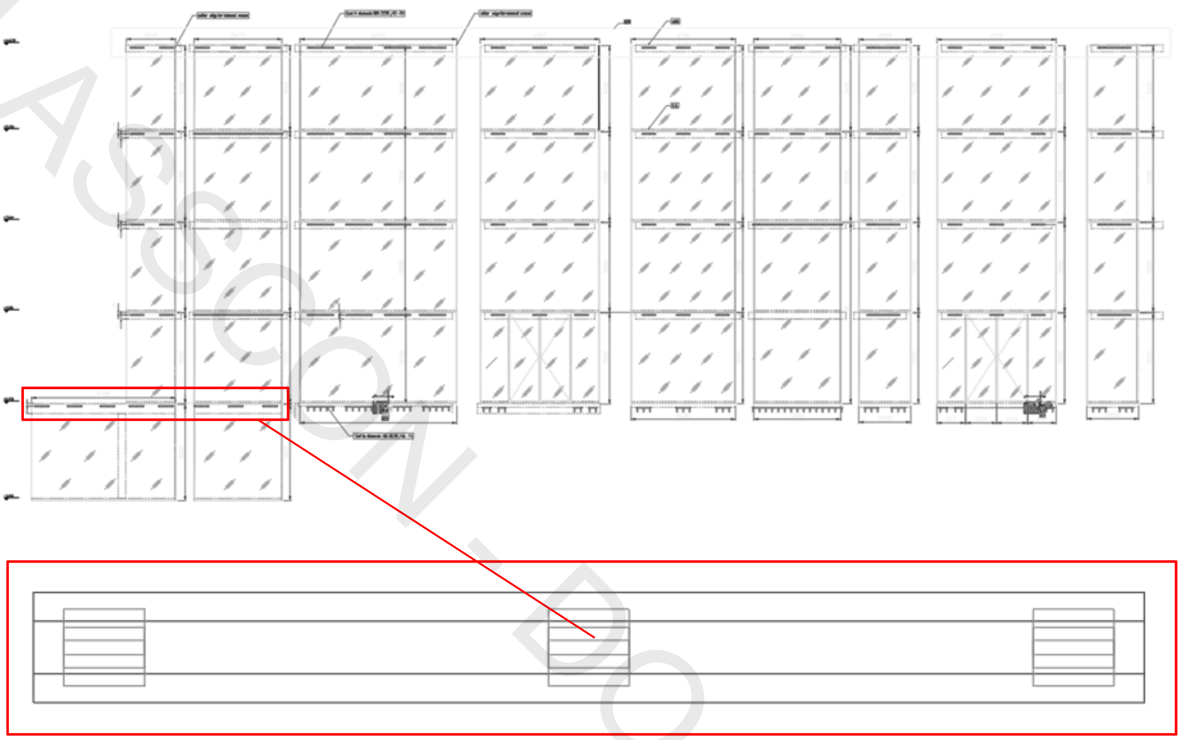
11.2. Pos. 5.2 – Halfen Anchor Channel (floor)

11.2.1. General



Anchor channel HTA-CE 55/42 – FV 6070 (hot rolled)

Length of channel 570 mm*

Number of anchors 3

Bolt HSR M16 8.8

*The Halfen channel is going to be cut from a standard channel with a length of 6070 mm and anchor distance of 250 mm to a channel with a length of 570 mm and three symmetric arranged anchors. For the verification on the safe side both a channel with a length of 6700 mm (variable position of screws) and a channel with a length of 550 mm (tolerance +/-15 mm) were calculated.

The calculation of the screw forces can be found in Pos. 4.2

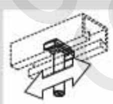
11.2.2. Verification

Longitudinal load in channel direction (HSR M16 8.8):

V_{Ed} = 5.4 kN / 3 screws = 1.8 kN

F_{Rd} = 7.0 kN

V_{Ed} / F_{Rd} = 1.8 kN / 7.0 kN = 0.26 ≤ 1.00 (OK)

Load capacity	
 Bolt HSR	Grade 8.8 F_{Rd} in channel longitudinal direction according to expert report F_{Rd} [kN]
40/22 - M16	7.0
50/30 - M16	7.0
50/30 - M20	10.5
72/48 - M20	10.5

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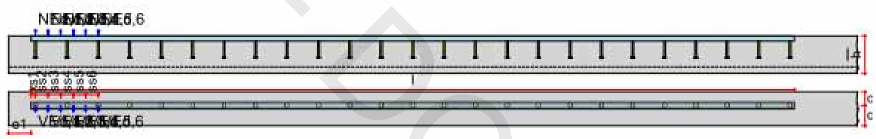
Halfen HTA-CE anchor channel - CEN/TS 1992-4, ETA-09/0339
Halfen Design Software HTA, Version 2.50

The design - including the static values - does only apply to the designated HALFEN product. The load bearing capacity of third party products, appearing to be identical in construction, might differ. For this reason, the software provider does not extend warranty if external products are used.

Input data

Anchor channel	HTA-CE 55/42 - FV - 6070 / 25, 25 anchors
Channel bolt	HS 50/30 M 16 FV 4.6
Approval / Design method	CEN/TS 1992-4, ETA-09/0339
Shear force	without lever arm
Concrete	C40/50, cracked
Reinforcement	no dense reinforcement
edge reinforcement	Straight edge reinforcement ds ≥ 12mm



h = 9999 mm l = 6070 mm c_{11} = 160 mm c_{12} = 110 mm e_1 = 180 mm
c_{nom} = 30 mm

Adjusting zone ±: full variability

Bolt	x_{s1}/s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]	Bolt	s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]
1	35	0.00	8.00	2	100	30.70	0.00
3	100	30.70	0.00	4	100	2.20	0.00
5	100	10.10	0.00	6	100	0.00	8.00

Utilisation: 98% - Proof successful

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Calculation Summary

Verifications for T-bolt

Tension	$N_{Rd,s,s}$	98% ⇦
Shear	$V_{Rd,s,s}$	35%
Combined load	$N_{Rd,s,s}$ - $V_{Rd,s,s}$	0%

Verifications for cast-in channels

Channel lips - Tension	$N_{Rd,s,l}$	75%
Channel lips - Shear	$V_{Rd,s,l}$	14%
Combined load	$N_{Rd,s,l}$ - $V_{Rd,s,l}$	0%
Local flexure of channel	$M_{Rd,s,flex}$	44%
Connection between anchor and channel (Tension)	$N_{Rd,s,c}$	87%
Connection between anchor and channel (Shear)	$V_{Rd,s,c}$	13%
Combined load	$N_{Rd,s,c}$ - $V_{Rd,s,c}$	76%

Verifications for concrete

Tension - Pull-out failure	$N_{Rd,cp}$	47%
Tension - Concrete cone failure	$N_{Rd,c}$	87%
Shear - Concrete edge failure	$V_{Rd,c}$	26%
Shear - Pry-out failure	$V_{Rd,cp}$	7%
Shear - Concrete edge failure, load parallel to edge	$V_{Rd,c90}$	13%
Combined load	$N_{Rd,c}$ - $V_{Rd,c}$	91%
Combined load	$N_{Rd,c}$ - $V_{Rd,cp}$	78%
Combined load	$N_{Rd,c}$ - $V_{Rd,c90}$	72%

Verifications:

Steel

Channel bolt

Maximum tension load (bolt): Bolt 2

$N_{Rk,s,s}$ [kN]	γ_{Ms}	$N_{Rd,s,s}$ [kN]	N_{Ed} [kN]	β_N
62.8	2.00	31.4	30.7	0.98

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,s}$ [kN]	γ_{Ms}	$V_{Rd,s,s}$ [kN]	V_{Ed} [kN]	β_V
37.7	1.67	22.57	8	0.35

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
0	0.00	8	0.35	0

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Anchor channel, channel lips

Maximum tension load (bolt): Bolt 2

$N_{Rk,s,l}$ [kN]	γ_{Ms}	$N_{Rd,s,l}$ [kN]	N_{Ed} [kN]	β_N
73.39	1.8	40.77	30.7	0.75

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,l}$ [kN]	γ_{Ms}	$V_{Rd,s,l}$ [kN]	V_{Ed} [kN]	β_V
104	1.8	57.78	8	0.14

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N{}^2+\beta_V{}^2$
0	0	8	0.14	0

Flexure of channel

Decisive span between anchors 17 and anchors 18

$N_{Ed,2}$ [kN]	load position [mm]
30.7	4085

$N_{Ed,3}$ [kN]	load position [mm]
30.7	4185

$N_{Ed,4}$ [kN]	load position [mm]
2.2	4285

M_{Ed} [Nm]	$M_{Rk,s,flex}$ [Nm]	$\gamma_{Ms,flex}$	$M_{Rd,s,flex}$ [Nm]	β_{flex}
2,456.00	6,447.00	1.15	5,606.09	0.44

Connection between anchor and channel

most unfavourable anchor: 2, load position xş = 85 mm

$N_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$N_{Rd,s,c}$ [kN]	N_{Ed} [kN]	β_N
80	1.8	44.44	38.57	0.87

most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$V_{Rd,s,c}$ [kN]	V_{Ed} [kN]	β_V
80	1.8	44.44	5.98	0.13

most unfavourable anchor: 2, load position xş = 85 mm

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N{}^2+\beta_V{}^2$
38.57	0.87	3.87	0.09	0.76

Concrete

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Tensile load - Pull-out failure
most unfavourable anchor: 2, load position xş = 85 mm

$N_{Rk,cp}$ [kN]	$\gamma_{M,cp}$	$N_{Rd,cp}$ [kN]	N_{Ed} [kN]	β_N
124	1.5	82.67	38.57	0.47

$N_{Rk,p(C12/15)}$ [kN]	$\Psi_{ucr,N}$
37.2	1

Tensile load - Concrete cone failure
most unfavourable anchor: 2, load position xş = 85 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N
66.25	1.5	44.17	38.57	0.87

$N0_{Rk,c}$ [kN]	$s_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\Psi_{re,N}$	$\Psi_{ucr,N}$
139.14	538	0.74	269	0.64	1.00	1	1

Shear load - Pry-out failure
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,cp}$ [kN]	γ_{Mc}	$V_{Rd,cp}$ [kN]	V_{Ed} [kN]	β_V
127.14	1.5	84.76	5.98	0.07

$\alpha_{s,N(cp)}$	k_5
0.67	2

Shear load - Concrete edge failure
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
34.37	1.5	22.91	5.98	0.26

α_p*$\Psi_{re,V}$	$c_{1,1}$ [mm]	$\Psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.67	375	0.76	1

Shear load - Concrete edge failure (V_c_90)
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
71.72	1.5	47.81	5.98	0.13

α_p*$\Psi_{re,V}$	$c_{1,1}$ [mm]	$\Psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	215	104.77	0	1	485	0.27	1

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Combined loading
most unfavourable anchor: 2, load position xş = 85 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N			
66.25	1.5	44.17	38.57	0.87			

$N0_{Rk,c}$ [kN]	$S_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.74	269	0.64	1.00	1.00	1.0

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]
24.93	1.5	16.62	3.63

$\alpha_p*\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}*V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.37	375	1	1

β_N	β_V	$\beta_N + \beta_V$
0.87	0.22	1.09

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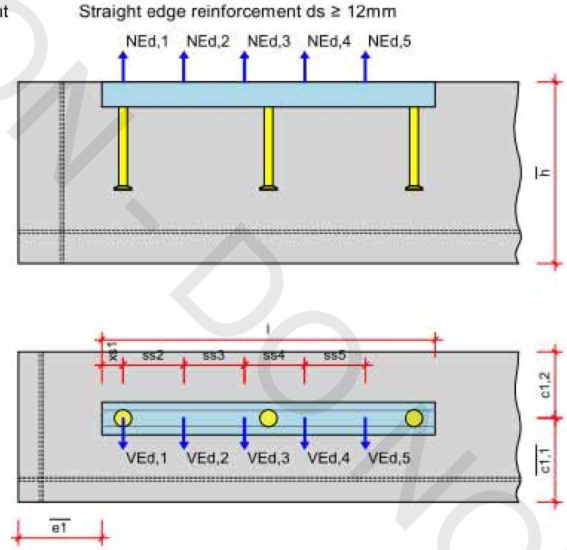
Halfen HTA-CE anchor channel - CEN/TS 1992-4, ETA-09/0339
Halfen Design Software HTA, Version 2.50

The design - including the static values - does only apply to the designated HALFEN product. The load bearing capacity of third party products, appearing to be identical in construction, might differ. For this reason, the software provider does not extend warranty if external products are used.

Input data

Anchor channel	HTA-CE 55/42 - FV - 550 / 3, 3 anchors
Channel bolt	HS 50/30 M 16 FV 4.6
Approval / Design method	CEN/TS 1992-4, ETA-09/0339
Shear force	without lever arm
Concrete	C40/50, cracked
Reinforcement	no dense reinforcement
edge reinforcement	Straight edge reinforcement ds ≥ 12mm



h = 9999 mm   l = 550 mm c_{11} = 160 mm c_{12} = 110 mm e_1 = 180 mm
c_{nom} = 30 mm

Adjusting zone ±: full variability

Bolt	x_{s1}/s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]	Bolt	s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]
1	35	0.00	4.80	2	100	21.60	0.00
3	100	28.40	0.00	4	100	0.00	0.00
5	100	0.00	4.80				

Utilisation: 90% - Proof successful

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Calculation Summary

Verifications for T-bolt

Tension	$N_{Rd,s,s}$	90%
Shear	$V_{Rd,s,s}$	21%
Combined load	$N_{Rd,s,s}$ - $V_{Rd,s,s}$	0%

Verifications for cast-in channels

Channel lips - Tension	$N_{Rd,s,l}$	70%
Channel lips - Shear	$V_{Rd,s,l}$	8%
Combined load	$N_{Rd,s,l}$ - $V_{Rd,s,l}$	0%
Local flexure of channel	$M_{Rd,s,flex}$	31%
Connection between anchor and channel (Tension)	$N_{Rd,s,c}$	62%
Connection between anchor and channel (Shear)	$V_{Rd,s,c}$	8%
Combined load	$N_{Rd,s,c}$ - $V_{Rd,s,c}$	39%

Verifications for concrete

Tension - Pull-out failure	$N_{Rd,cp}$	34%
Tension - Concrete cone failure	$N_{Rd,c}$	62%
Shear - Concrete edge failure	$V_{Rd,c}$	18%
Shear - Pry-out failure	$V_{Rd,cp}$	5%
Shear - Concrete edge failure, load parallel to edge	$V_{Rd,c90}$	7%
Combined load	$N_{Rd,c}$ - $V_{Rd,c}$	55%
Combined load	$N_{Rd,c}$ - $V_{Rd,cp}$	50%
Combined load	$N_{Rd,c}$ - $V_{Rd,c90}$	46%

Verifications:

Steel

Channel bolt

Maximum tension load (bolt): Bolt 3

$N_{Rk,s,s}$ [kN]	γ_{Ms}	$N_{Rd,s,s}$ [kN]	N_{Ed} [kN]	β_N
62.8	2.00	31.4	28.4	0.90

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,s}$ [kN]	γ_{Ms}	$V_{Rd,s,s}$ [kN]	V_{Ed} [kN]	β_V
37.7	1.67	22.57	4.8	0.21

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
0	0.00	4.8	0.21	0

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Anchor channel, channel lips

Maximum tension load (bolt): Bolt 3

$N_{Rk,s,l}$ [kN]	γ_{Ms}	$N_{Rd,s,l}$ [kN]	N_{Ed} [kN]	β_N
73.39	1.8	40.77	28.4	0.7

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,l}$ [kN]	γ_{Ms}	$V_{Rd,s,l}$ [kN]	V_{Ed} [kN]	β_V
104	1.8	57.78	4.8	0.08

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N{}^2+\beta_V{}^2$
0	0	4.8	0.08	0

Flexure of channel

Decisive span between anchors 1 and anchors 2

$N_{Ed,1}$ [kN]	load position [mm]
0	35

$N_{Ed,2}$ [kN]	load position [mm]
21.6	135

$N_{Ed,3}$ [kN]	load position [mm]
28.4	235

M_{Ed} [Nm]	$M_{Rk,s,flex}$ [Nm]	$\gamma_{Ms,flex}$	$M_{Rd,s,flex}$ [Nm]	β_{flex}
1,733.33	6,447.00	1.15	5,606.09	0.31

Connection between anchor and channel

most unfavourable anchor: 2, load position xş = 85 mm

$N_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$N_{Rd,s,c}$ [kN]	N_{Ed} [kN]	β_N
80	1.8	44.44	27.71	0.62

most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$V_{Rd,s,c}$ [kN]	V_{Ed} [kN]	β_V
80	1.8	44.44	3.55	0.08

most unfavourable anchor: 2, load position xş = 85 mm

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N{}^2+\beta_V{}^2$
27.71	0.62	3.26	0.07	0.39

Concrete

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Tensile load - Pull-out failure
most unfavourable anchor: 2, load position xş = 85 mm

$N_{Rk,cp}$ [kN]	$\gamma_{M,cp}$	$N_{Rd,cp}$ [kN]	N_{Ed} [kN]	β_N
124	1.5	82.67	27.71	0.34

$N_{Rk,p(C12/15)}$ [kN]	$\psi_{ucr,N}$
37.2	1

Tensile load - Concrete cone failure
most unfavourable anchor: 2, load position xş = 85 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N
66.86	1.5	44.57	27.71	0.62

$N0_{Rk,c}$ [kN]	$s_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.75	269	0.64	1.00	1	1

Shear load - Pry-out failure
most unfavourable anchor: 2, load position xş = 45 mm

$V_{Rk,cp}$ [kN]	γ_{Mc}	$V_{Rd,cp}$ [kN]	V_{Ed} [kN]	β_V
98.87	1.5	65.91	3.26	0.05

$\alpha_{s,N(cp)}$	k_5
0.48	2

Shear load - Concrete edge failure
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
30.29	1.5	20.19	3.55	0.18

α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.59	375	0.76	1

Shear load - Concrete edge failure (V_c_90)
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
71.72	1.5	47.81	3.55	0.07

α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	215	104.77	0	1	485	0.27	1

HTA 2.50
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Combined loading

most unfavourable anchor: 2, load position xș = 85 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N			
66.86	1.5	44.57	27.71	0.62			

$N0_{Rk,c}$ [kN]	$S_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.75	269	0.64	1.00	1.00	1.0

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]
32.2	1.5	21.47	3.26

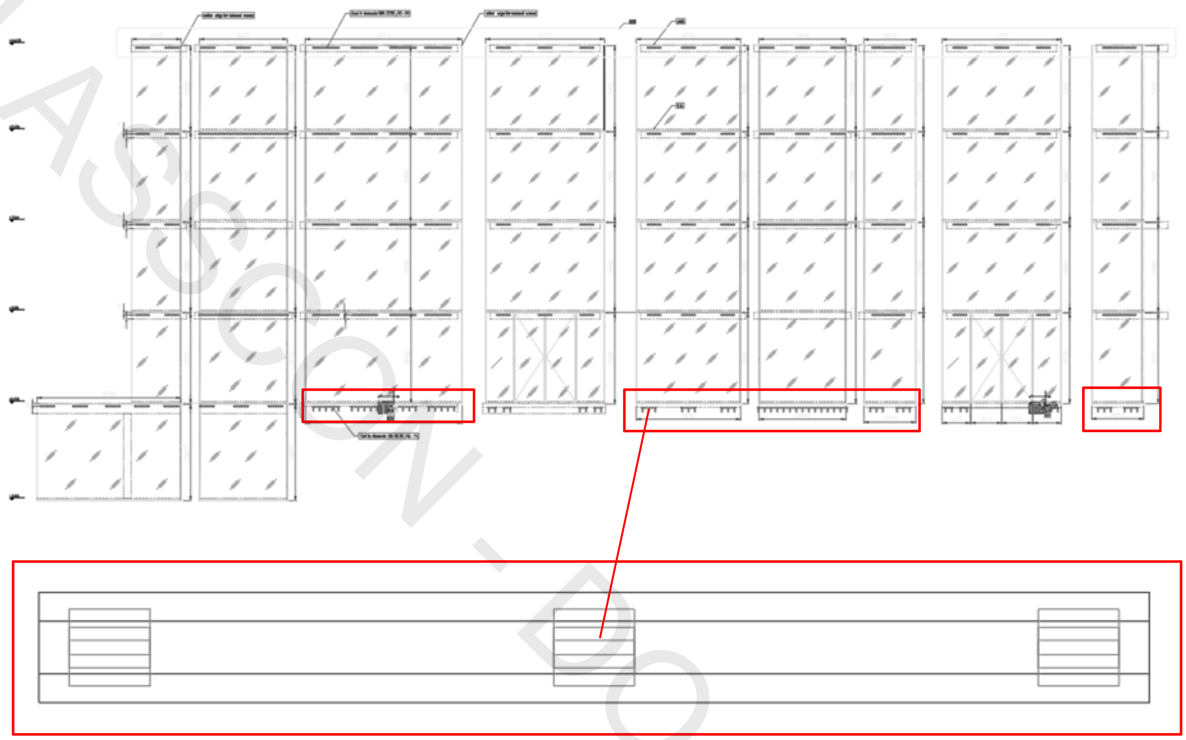
$\alpha_p{}^*\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}{}^*V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.48	375	1	1

β_N	β_V	$\beta_N{}^{1,5} + \beta_V{}^{1,5}$
0.62	0.15	0.55

HTA 2.50
05/07/2017

11.3. Pos. 5.3 – Halfen Anchor Channel (floor)

11.3.1. General



Anchor channel HTA-CE 55/42 – FV 6070 (hot rolled)

Length of channel 570 mm*

Number of anchors 3

Bolt HSR M16 8.8

*The Halfen channel is going to be cut from a standard channel with a length of 6070 mm and anchor distance of 250 mm to a channel with a length of 570 mm and three symmetric arranged anchors. For the verification on the safe side both a channel with a length of 6700 mm (variable position of screws) and a channel with a length of 550 mm (tolerance +/-15 mm) were calculated.

The calculation of the screw forces can be found in Pos. 4.3

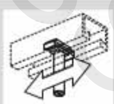
11.3.2. Verification

Longitudinal load in channel direction (HSR M16 8.8):

V_{Ed} = 10.7 kN / 4 screws = 2.7 kN

F_{Rd} = 7.0 kN

V_{Ed} / F_{Rd} = 2.7 kN / 7.0 kN = <u>0.39 ≤ 1.00 (OK)</u>

Load capacity	
 Bolt HSR	Grade 8.8 F_{Rd} in channel longitudinal direction according to expert report F_{Rd} [kN]
40/22 - M16	7.0
50/30 - M16	7.0
50/30 - M20	10.5
72/48 - M20	10.5

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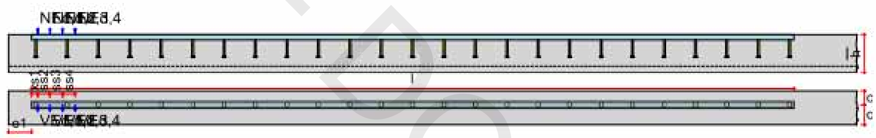
			Item Pos. 5.2 - Copy (1)

Halfen HTA-CE anchor channel - CEN/TS 1992-4, ETA-09/0339
Halfen Design Software HTA, Version 2.50

The design - including the static values - does only apply to the designated HALFEN product. The load bearing capacity of third party products, appearing to be identical in construction, might differ. For this reason, the software provider does not extend warranty if external products are used.

Input data

Anchor channel	HTA-CE 55/42 - FV - 6070 / 25, 25 anchors
Channel bolt	HS 50/30 M 16 FV 4.6
Approval / Design method	CEN/TS 1992-4, ETA-09/0339
Shear force	without lever arm
Concrete	C40/50, cracked
Reinforcement	no dense reinforcement
edge reinforcement	Straight edge reinforcement ds ≥ 12mm



h = 9999 mm l = 6070 mm c_{11} = 160 mm c_{12} = 110 mm e_1 = 180 mm
c_{nom} = 30 mm

Adjusting zone ±: full variability

Bolt	x_{s1}/s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]	Bolt	s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]
1	50	21.40	3.40	2	100	21.40	3.40
3	100	0.00	3.40	4	100	0.00	3.40

Utilisation: 68% - Proof successful

HTA 2.50
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Calculation Summary

Verifications for T-bolt

Tension	$N_{Rd,s,s}$	68% ⇦
Shear	$V_{Rd,s,s}$	15%
Combined load	$N_{Rd,s,s}$ - $V_{Rd,s,s}$	49%

Verifications for cast-in channels

Channel lips - Tension	$N_{Rd,s,l}$	52%
Channel lips - Shear	$V_{Rd,s,l}$	6%
Combined load	$N_{Rd,s,l}$ - $V_{Rd,s,l}$	28%
Local flexure of channel	$M_{Rd,s,flex}$	30%
Connection between anchor and channel (Tension)	$N_{Rd,s,c}$	62%
Connection between anchor and channel (Shear)	$V_{Rd,s,c}$	15%
Combined load	$N_{Rd,s,c}$ - $V_{Rd,s,c}$	41%

Verifications for concrete

Tension - Pull-out failure	$N_{Rd,cp}$	34%
Tension - Concrete cone failure	$N_{Rd,c}$	63%
Shear - Concrete edge failure	$V_{Rd,c}$	28%
Shear - Pry-out failure	$V_{Rd,cp}$	8%
Shear - Concrete edge failure, load parallel to edge	$V_{Rd,c90}$	12%
Combined load	$N_{Rd,c}$ - $V_{Rd,c}$	65%
Combined load	$N_{Rd,c}$ - $V_{Rd,cp}$	53%
Combined load	$N_{Rd,c}$ - $V_{Rd,c90}$	55%

Verifications:

Steel

Channel bolt

Maximum tension load (bolt): Bolt 1

$N_{Rk,s,s}$ [kN]	γ_{Ms}	$N_{Rd,s,s}$ [kN]	N_{Ed} [kN]	β_N
62.8	2.00	31.4	21.4	0.68

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,s}$ [kN]	γ_{Ms}	$V_{Rd,s,s}$ [kN]	V_{Ed} [kN]	β_V
37.7	1.67	22.57	3.4	0.15

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
21.4	0.68	3.4	0.15	0.49

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HALFEN	Project	ProNo.	Page 3
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Anchor channel, channel lips

Maximum tension load (bolt): Bolt 2

$N_{Rk,s,l}$ [kN]	γ_{Ms}	$N_{Rd,s,l}$ [kN]	N_{Ed} [kN]	β_N
73.39	1.8	40.77	21.4	0.52

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,l}$ [kN]	γ_{Ms}	$V_{Rd,s,l}$ [kN]	V_{Ed} [kN]	β_V
104	1.8	57.78	3.4	0.06

Combined loading, most unfavourable bolt: 2

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
21.4	0.52	3.4	0.06	0.28

Flexure of channel

Decisive span between anchors 17 and anchors 18

$N_{Ed,1}$ [kN]	load position [mm]
21.4	4080

$N_{Ed,2}$ [kN]	load position [mm]
21.4	4180

$N_{Ed,3}$ [kN]	load position [mm]
0	4280

M_{Ed} [Nm]	$M_{Rk,s,flex}$ [Nm]	$\gamma_{Ms,flex}$	$M_{Rd,s,flex}$ [Nm]	β_{flex}
1,707.72	6,447.00	1.15	5,606.09	0.3

Connection between anchor and channel

most unfavourable anchor: 1, load position xş = 35 mm

$N_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$N_{Rd,s,c}$ [kN]	N_{Ed} [kN]	β_N
80	1.8	44.44	27.76	0.62

most unfavourable anchor: 2, load position xş = 110 mm

$V_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$V_{Rd,s,c}$ [kN]	V_{Ed} [kN]	β_V
80	1.8	44.44	6.87	0.15

most unfavourable anchor: 1, load position xş = 35 mm

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
27.76	0.62	5.9	0.13	0.41

Concrete

HTA 2.50
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HALFEN	Project	ProNo.	Page 4
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Tensile load - Pull-out failure
most unfavourable anchor: 1, load position xş = 35 mm

$N_{Rk,cp}$ [kN]	$\gamma_{M,cp}$	$N_{Rd,cp}$ [kN]	N_{Ed} [kN]	β_N
124	1.5	82.67	27.76	0.34

$N_{Rk,p(C12/15)}$ [kN]	$\psi_{ucr,N}$
37.2	1

Tensile load - Concrete cone failure
most unfavourable anchor: 1, load position xş = 35 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N
65.68	1.5	43.79	27.76	0.63

$N0_{Rk,c}$ [kN]	$s_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.83	269	0.64	0.89	1	1

Shear load - Pry-out failure
most unfavourable anchor: 2, load position xş = 110 mm

$V_{Rk,cp}$ [kN]	γ_{Mc}	$V_{Rd,cp}$ [kN]	V_{Ed} [kN]	β_V
128.74	1.5	85.83	6.87	0.08

$\alpha_{s,N(cp)}$	k_5
0.65	2

Shear load - Concrete edge failure
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
31.43	1.5	20.96	5.9	0.28

α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.62	375	0.76	1

Shear load - Concrete edge failure (V_c_90)
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
71.72	1.5	47.81	5.9	0.12

α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	215	104.77	0	1	485	0.27	1

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HALFEN	Project	ProNo.	Page 5
		Item	Pos. 5.2 - Copy (1)

Combined loading

most unfavourable anchor: 1, load position xş = 35 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N			
65.68	1.5	43.79	27.76	0.63			
$N0_{Rk,c}$ [kN]	$S_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.83	269	0.64	0.89	1.00	1.0
$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]				
31.43	1.5	20.96	5.9				
α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.62	375	0.76	1
β_N	β_V	$\beta_N^{1,5} + \beta_V^{1,5}$					
0.63	0.28	0.65					

HTA 2.50
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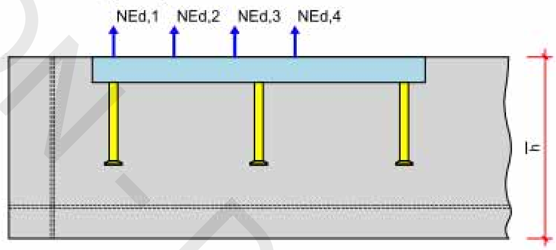
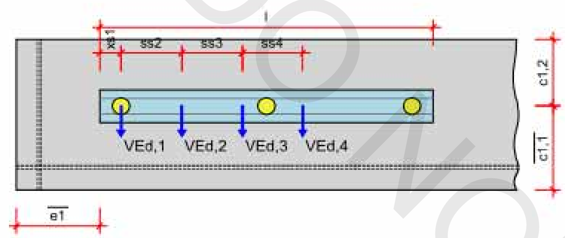
Halfen HTA-CE anchor channel - CEN/TS 1992-4, ETA-09/0339
Halfen Design Software HTA, Version 2.50

The design - including the static values - does only apply to the designated HALFEN product. The load bearing capacity of third party products, appearing to be identical in construction, might differ. For this reason, the software provider does not extend warranty if external products are used.

Input data

Anchor channel	HTA-CE 55/42 - FV - 550 / 3, 3 anchors
Channel bolt	HS 50/30 M 16 FV 4.6
Approval / Design method	CEN/TS 1992-4, ETA-09/0339
Shear force	without lever arm
Concrete	C40/50, cracked
Reinforcement	no dense reinforcement
edge reinforcement	Straight edge reinforcement ds ≥ 12mm





h = 9999 mm l = 550 mm c_{11} = 160 mm c_{12} = 110 mm e_1 = 180 mm
c_{nom} = 30 mm

Adjusting zone ±: full variability

Bolt	x_{s1}/s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]	Bolt	s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]
1	35	0.00	3.40	2	100	21.40	3.40
3	100	21.40	3.40	4	100	0.00	3.40

Utilisation: 68% - Proof successful

HTA 2.50
05/07/2017

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Calculation Summary

Verifications for T-bolt

Tension	$N_{Rd,s,s}$	68%
Shear	$V_{Rd,s,s}$	15%
Combined load	$N_{Rd,s,s}$ - $V_{Rd,s,s}$	49%

Verifications for cast-in channels

Channel lips - Tension	$N_{Rd,s,l}$	52%
Channel lips - Shear	$V_{Rd,s,l}$	6%
Combined load	$N_{Rd,s,l}$ - $V_{Rd,s,l}$	28%
Local flexure of channel	$M_{Rd,s,flex}$	29%
Connection between anchor and channel (Tension)	$N_{Rd,s,c}$	53%
Connection between anchor and channel (Shear)	$V_{Rd,s,c}$	15%
Combined load	$N_{Rd,s,c}$ - $V_{Rd,s,c}$	31%

Verifications for concrete

Tension - Pull-out failure	$N_{Rd,cp}$	29%
Tension - Concrete cone failure	$N_{Rd,c}$	53%
Shear - Concrete edge failure	$V_{Rd,c}$	28%
Shear - Pry-out failure	$V_{Rd,cp}$	8%
Shear - Concrete edge failure, load parallel to edge	$V_{Rd,c90}$	12%
Combined load	$N_{Rd,c}$ - $V_{Rd,c}$	51%
Combined load	$N_{Rd,c}$ - $V_{Rd,cp}$	41%
Combined load	$N_{Rd,c}$ - $V_{Rd,c90}$	40%

Verifications:

Steel

Channel bolt

Maximum tension load (bolt): Bolt 2

$N_{Rk,s,s}$ [kN]	γ_{Ms}	$N_{Rd,s,s}$ [kN]	N_{Ed} [kN]	β_N
62.8	2.00	31.4	21.4	0.68

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,s}$ [kN]	γ_{Ms}	$V_{Rd,s,s}$ [kN]	V_{Ed} [kN]	β_V
37.7	1.67	22.57	3.4	0.15

Combined loading, most unfavourable bolt: 2

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
21.4	0.68	3.4	0.15	0.49

HTA 2.50
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HALFEN	Project	ProNo.	Page 3
		Item Pos. 5.3b	

Anchor channel, channel lips
Maximum tension load (bolt): Bolt 2

$N_{Rk,s,l}$ [kN]	γ_{Ms}	$N_{Rd,s,l}$ [kN]	N_{Ed} [kN]	β_N
73.39	1.8	40.77	21.4	0.52

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,l}$ [kN]	γ_{Ms}	$V_{Rd,s,l}$ [kN]	V_{Ed} [kN]	β_V
104	1.8	57.78	3.4	0.06

Combined loading, most unfavourable bolt: 2

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
21.4	0.52	3.4	0.06	0.28

Flexure of channel
Decisive span between anchors 1 and anchors 2

$N_{Ed,1}$ [kN]	load position [mm]
0	35

$N_{Ed,2}$ [kN]	load position [mm]
21.4	135

$N_{Ed,3}$ [kN]	load position [mm]
21.4	235

M_{Ed} [Nm]	$M_{Rk,s,flex}$ [Nm]	$\gamma_{Ms,flex}$	$M_{Rd,s,flex}$ [Nm]	β_{flex}
1,605.00	6,447.00	1.15	5,606.09	0.29

Connection between anchor and channel
most unfavourable anchor: 2, load position xş = 125 mm

$N_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$N_{Rd,s,c}$ [kN]	N_{Ed} [kN]	β_N
80	1.8	44.44	23.63	0.53

most unfavourable anchor: 2, load position xş = 125 mm

$V_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$V_{Rd,s,c}$ [kN]	V_{Ed} [kN]	β_V
80	1.8	44.44	6.75	0.15

most unfavourable anchor: 2, load position xş = 125 mm

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
23.63	0.53	6.75	0.15	0.31

Concrete

HTA 2.50
05/07/2017

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Tensile load - Pull-out failure
most unfavourable anchor: 2, load position xş = 125 mm

$N_{Rk,cp}$ [kN]	$\gamma_{M,cp}$	$N_{Rd,cp}$ [kN]	N_{Ed} [kN]	β_N
124	1.5	82.67	23.63	0.29

$N_{Rk,p(C12/15)}$ [kN]	$\psi_{ucr,N}$
37.2	1

Tensile load - Concrete cone failure
most unfavourable anchor: 2, load position xş = 125 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N			
66.72	1.5	44.48	23.63	0.53			
$N0_{Rk,c}$ [kN]	$s_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.75	269	0.64	1.00	1	1

Shear load - Pry-out failure
most unfavourable anchor: 2, load position xş = 125 mm

$V_{Rk,cp}$ [kN]	γ_{Mc}	$V_{Rd,cp}$ [kN]	V_{Ed} [kN]	β_V
125.5	1.5	83.67	6.75	0.08

$\alpha_{s,N(cp)}$	k_5
0.64	2

Shear load - Concrete edge failure
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V			
30.59	1.5	20.39	5.75	0.28			
α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.6	375	0.76	1

Shear load - Concrete edge failure (V_c_90)
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V			
71.72	1.5	47.81	5.75	0.12			
α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	215	104.77	0	1	485	0.27	1

HTA 2.50
05/07/2017

HALFEN	Project	ProNo.	Page 5
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Combined loading
most unfavourable anchor: 1, load position xş = 35 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N			
52.59	1.5	35.06	17.72	0.51			
$N0_{Rk,c}$ [kN]	$S_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.66	269	0.64	0.89	1.00	1.0
$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]				
30.59	1.5	20.39	5.75				
α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.6	375	0.76	1
β_N	β_V	$\beta_N^{1,5} + \beta_V^{1,5}$					
0.51	0.28	0.51					

HTA 2.50
05/07/2017

11.4. Pos. 5.4 – Halfen Anchor Channel (floor)

11.4.1. General

Anchor channel HTA-CE 55/42 – FV 6070 (hot rolled)

Length of channel 320 mm*

Number of anchors 2

Bolt HSR M16 8.8

*The Halfen channel is going to be cut from a standard channel with a length of 6070 mm and anchor distance of 250 mm to a channel with a length of 320 mm and two symmetric arranged anchors. For the verification on the safe side both a channel with a length of 6700 mm (variable position of screws) and a channel with a length of 550 mm (tolerance +/-15 mm) were calculated.

The calculation of the screw forces can be found in Pos. 4.4.

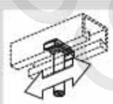
11.4.2. Verification

Longitudinal load in channel direction (HSR M16 8.8):

V_{Ed} = 5.4 kN / 2 screws = 2.7 kN

F_{Rd} = 7.0 kN

V_{Ed} / F_{Rd} = 2.7 kN / 7.0 kN = 0.39 ≤ 1.00 (OK)

Load capacity	
 Bolt HSR	Grade 8.8 F_{Rd} in channel longitudinal direction according to expert report F_{Rd} [kN]
40/22 - M16	7.0
50/30 - M16	7.0
50/30 - M20	10.5
72/48 - M20	10.5

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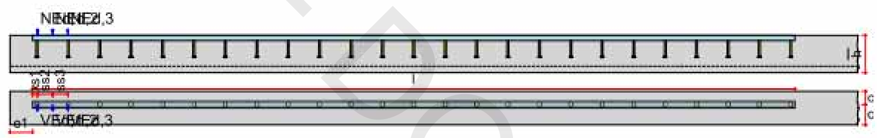
Halfen HTA-CE anchor channel - CEN/TS 1992-4, ETA-09/0339
Halfen Design Software HTA, Version 2.50

The design - including the static values - does only apply to the designated HALFEN product. The load bearing capacity of third party products, appearing to be identical in construction, might differ. For this reason, the software provider does not extend warranty if external products are used.

Input data

Anchor channel	HTA-CE 55/42 - FV - 6070 / 25, 25 anchors
Channel bolt	HS 50/30 M 16 FV 4.6
Approval / Design method	CEN/TS 1992-4, ETA-09/0339
Shear force	without lever arm
Concrete	C40/50, cracked
Reinforcement	no dense reinforcement
edge reinforcement	Straight edge reinforcement ds ≥ 12mm



h = 9999 mm l = 6070 mm c_{11} = 160 mm c_{12} = 110 mm e_1 = 180 mm
c_{nom} = 30 mm

Adjusting zone ±: full variability

Bolt	x_{s1}/s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]	Bolt	s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]
1	40	7.20	3.50	2	120	5.10	3.50
3	120	0.00	3.50				

Utilisation: 23% - Proof successful

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Calculation Summary

Verifications for T-bolt

Tension	$N_{Rd,s,s}$	23%
Shear	$V_{Rd,s,s}$	16%
Combined load	$N_{Rd,s,s}$ - $V_{Rd,s,s}$	8%

Verifications for cast-in channels

Channel lips - Tension	$N_{Rd,s,l}$	16%
Channel lips - Shear	$V_{Rd,s,l}$	6%
Combined load	$N_{Rd,s,l}$ - $V_{Rd,s,l}$	3%
Local flexure of channel	$M_{Rd,s,flex}$	9%
Connection between anchor and channel (Tension)	$N_{Rd,s,c}$	18%
Connection between anchor and channel (Shear)	$V_{Rd,s,c}$	13%
Combined load	$N_{Rd,s,c}$ - $V_{Rd,s,c}$	5%

Verifications for concrete

Tension - Pull-out failure	$N_{Rd,cp}$	10%
Tension - Concrete cone failure	$N_{Rd,c}$	18%
Shear - Concrete edge failure	$V_{Rd,c}$	23% ⇦
Shear - Pry-out failure	$V_{Rd,cp}$	7%
Shear - Concrete edge failure, load parallel to edge	$V_{Rd,c90}$	11%
Combined load	$N_{Rd,c}$ - $V_{Rd,c}$	19%
Combined load	$N_{Rd,c}$ - $V_{Rd,cp}$	9%
Combined load	$N_{Rd,c}$ - $V_{Rd,c90}$	11%

Verifications:

Steel

Channel bolt

Maximum tension load (bolt): Bolt 1

$N_{Rk,s,s}$ [kN]	γ_{Ms}	$N_{Rd,s,s}$ [kN]	N_{Ed} [kN]	β_N
62.8	2.00	31.4	7.2	0.23

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,s}$ [kN]	γ_{Ms}	$V_{Rd,s,s}$ [kN]	V_{Ed} [kN]	β_V
37.7	1.67	22.57	3.5	0.16

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N{}^2+\beta_V{}^2$
7.2	0.23	3.5	0.16	0.08

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Anchor channel, channel lips

Maximum tension load (bolt): Bolt 1

$N_{Rk,s,l}$ [kN]	γ_{Ms}	$N_{Rd,s,l}$ [kN]	N_{Ed} [kN]	β_N
80	1.8	44.44	7.2	0.16

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,l}$ [kN]	γ_{Ms}	$V_{Rd,s,l}$ [kN]	V_{Ed} [kN]	β_V
104	1.8	57.78	3.5	0.06

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
7.2	0.16	3.5	0.06	0.03

Flexure of channel

Decisive span between anchors 16 and anchors 17

$N_{Ed,1}$ [kN]	load position [mm]
7.2	3890

$N_{Ed,2}$ [kN]	load position [mm]
5.1	4010

M_{Ed} [Nm]	$M_{Rk,s,flex}$ [Nm]	$\gamma_{Ms,flex}$	$M_{Rd,s,flex}$ [Nm]	β_{flex}
492.03	6,447.00	1.15	5,606.09	0.09

Connection between anchor and channel

most unfavourable anchor: 1, load position x$_s$ = 35 mm

$N_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$N_{Rd,s,c}$ [kN]	N_{Ed} [kN]	β_N
80	1.8	44.44	7.98	0.18

most unfavourable anchor: 2, load position x$_s$ = 160 mm

$V_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$V_{Rd,s,c}$ [kN]	V_{Ed} [kN]	β_V
80	1.8	44.44	5.6	0.13

most unfavourable anchor: 1, load position x$_s$ = 35 mm

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
7.98	0.18	5.17	0.12	0.05

Concrete

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Tensile load - Pull-out failure
most unfavourable anchor: 1, load position xş = 35 mm

$N_{Rk,cp}$ [kN]	$\gamma_{M,cp}$	$N_{Rd,cp}$ [kN]	N_{Ed} [kN]	β_N
124	1.5	82.67	7.98	0.10

$N_{Rk,p(C12/15)}$ [kN]	$\psi_{ucr,N}$
37.2	1

Tensile load - Concrete cone failure
most unfavourable anchor: 1, load position xş = 35 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N
65.71	1.5	43.8	7.98	0.18

$N0_{Rk,c}$ [kN]	$s_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.83	269	0.64	0.89	1	1

Shear load - Pry-out failure
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,cp}$ [kN]	γ_{Mc}	$V_{Rd,cp}$ [kN]	V_{Ed} [kN]	β_V
117.48	1.5	78.32	5.17	0.07

$\alpha_{s,N(cp)}$	k_5
0.66	2

Shear load - Concrete edge failure
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
33.65	1.5	22.43	5.17	0.23

α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.66	375	0.76	1

Shear load - Concrete edge failure (V_c_90)
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
71.72	1.5	47.81	5.17	0.11

α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	215	104.77	0	1	485	0.27	1

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Combined loading

most unfavourable anchor: 1, load position xş = 35 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N			
65.71	1.5	43.8	7.98	0.18			
$N0_{Rk,c}$ [kN]	$S_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.83	269	0.64	0.89	1.00	1.0
$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]				
33.65	1.5	22.43	5.17				
α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.66	375	0.76	1
β_N	β_V	$\beta_N^{1.5} + \beta_V^{1.5}$					
0.18	0.23	0.19					

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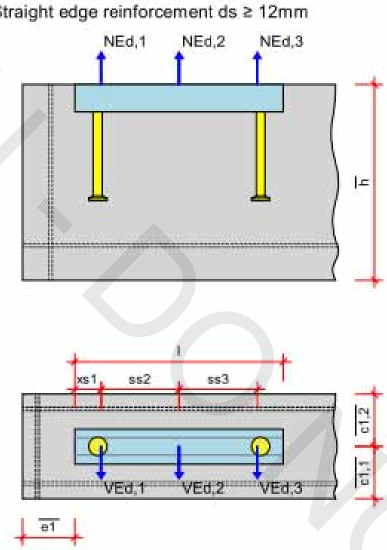
Halfen HTA-CE anchor channel - CEN/TS 1992-4, ETA-09/0339
Halfen Design Software HTA, Version 2.50

The design - including the static values - does only apply to the designated HALFEN product. The load bearing capacity of third party products, appearing to be identical in construction, might differ. For this reason, the software provider does not extend warranty if external products are used.

Input data

Anchor channel	HTA-CE 55/42 - FV - 320 / 2, 2 anchors
Channel bolt	HS 50/30 M 16 FV 4.6
Approval / Design method	CEN/TS 1992-4, ETA-09/0339
Shear force	without lever arm
Concrete	C40/50, cracked
Reinforcement	no dense reinforcement
edge reinforcement	Straight edge reinforcement ds ≥ 12mm



h = 9999 mm l = 320 mm c_{11} = 160 mm c_{12} = 110 mm e_1 = 180 mm
c_{nom} = 30 mm

Adjusting zone ±: full variability

Bolt	x_{s1}/s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]	Bolt	s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]
1	40	7.20	3.50	2	120	5.10	3.50
3	120	0.00	3.50				

Utilisation: 24% - Proof successful

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05/07/2017

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Calculation Summary

Verifications for T-bolt

Tension	$N_{Rd,s,s}$	23%
Shear	$V_{Rd,s,s}$	16%
Combined load	$N_{Rd,s,s}$ - $V_{Rd,s,s}$	8%

Verifications for cast-in channels

Channel lips - Tension	$N_{Rd,s,l}$	16%
Channel lips - Shear	$V_{Rd,s,l}$	6%
Combined load	$N_{Rd,s,l}$ - $V_{Rd,s,l}$	3%
Local flexure of channel	$M_{Rd,s,flex}$	6%
Connection between anchor and channel (Tension)	$N_{Rd,s,c}$	18%
Connection between anchor and channel (Shear)	$V_{Rd,s,c}$	12%
Combined load	$N_{Rd,s,c}$ - $V_{Rd,s,c}$	5%

Verifications for concrete

Tension - Pull-out failure	$N_{Rd,cp}$	10%
Tension - Concrete cone failure	$N_{Rd,c}$	18%
Shear - Concrete edge failure	$V_{Rd,c}$	24% ⇦
Shear - Pry-out failure	$V_{Rd,cp}$	7%
Shear - Concrete edge failure, load parallel to edge	$V_{Rd,c90}$	11%
Combined load	$N_{Rd,c}$ - $V_{Rd,c}$	20%
Combined load	$N_{Rd,c}$ - $V_{Rd,cp}$	10%
Combined load	$N_{Rd,c}$ - $V_{Rd,c90}$	12%

Verifications:

Steel

Channel bolt

Maximum tension load (bolt): Bolt 1

$N_{Rk,s,s}$ [kN]	γ_{Ms}	$N_{Rd,s,s}$ [kN]	N_{Ed} [kN]	β_N
62.8	2.00	31.4	7.2	0.23

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,s}$ [kN]	γ_{Ms}	$V_{Rd,s,s}$ [kN]	V_{Ed} [kN]	β_V
37.7	1.67	22.57	3.5	0.16

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
7.2	0.23	3.5	0.16	0.08

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Anchor channel, channel lips
Maximum tension load (bolt): Bolt 1

$N_{Rk,s,l}$ [kN]	γ_{Ms}	$N_{Rd,s,l}$ [kN]	N_{Ed} [kN]	β_N
80	1.8	44.44	7.2	0.16

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,l}$ [kN]	γ_{Ms}	$V_{Rd,s,l}$ [kN]	V_{Ed} [kN]	β_V
104	1.8	57.78	3.5	0.06

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
7.2	0.16	3.5	0.06	0.03

Flexure of channel
Decisive span between anchors 1 and anchors 2

$N_{Ed,1}$ [kN]	load position [mm]
7.2	45

$N_{Ed,2}$ [kN]	load position [mm]
5.1	165

$N_{Ed,3}$ [kN]	load position [mm]
0	285

M_{Ed} [Nm]	$M_{Rk,s,flex}$ [Nm]	$\gamma_{Ms,flex}$	$M_{Rd,s,flex}$ [Nm]	β_{flex}
352.80	6,447.00	1.15	5,606.09	0.06

Connection between anchor and channel
most unfavourable anchor: 1, load position xş = 35 mm

$N_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$N_{Rd,s,c}$ [kN]	N_{Ed} [kN]	β_N
80	1.8	44.44	7.98	0.18

most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$V_{Rd,s,c}$ [kN]	V_{Ed} [kN]	β_V
80	1.8	44.44	5.35	0.12

most unfavourable anchor: 1, load position xş = 35 mm

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
7.98	0.18	5.35	0.12	0.05

Concrete

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Tensile load - Pull-out failure
most unfavourable anchor: 1, load position xş = 35 mm

$N_{Rk,cp}$ [kN]	$\gamma_{M,cp}$	$N_{Rd,cp}$ [kN]	N_{Ed} [kN]	β_N
124	1.5	82.67	7.98	0.10

$N_{Rk,p(C12/15)}$ [kN]	$\psi_{ucr,N}$
37.2	1

Tensile load - Concrete cone failure
most unfavourable anchor: 1, load position xş = 35 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N
65.71	1.5	43.8	7.98	0.18

$N0_{Rk,c}$ [kN]	$s_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.83	269	0.64	0.89	1	1

Shear load - Pry-out failure
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,cp}$ [kN]	γ_{Mc}	$V_{Rd,cp}$ [kN]	V_{Ed} [kN]	β_V
115.69	1.5	77.13	5.35	0.07

$\alpha_{s,N(cp)}$	k_5
0.66	2

Shear load - Concrete edge failure
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
33.47	1.5	22.31	5.35	0.24

α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.66	375	0.76	1

Shear load - Concrete edge failure (V_c_90)
most unfavourable anchor: 1, load position xş = 35 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
71.72	1.5	47.81	5.35	0.11

α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	215	104.77	0	1	485	0.27	1

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Combined loading

most unfavourable anchor: 1, load position xş = 35 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N			
65.71	1.5	43.8	7.98	0.18			

$N0_{Rk,c}$ [kN]	$S_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.83	269	0.64	0.89	1.00	1.0

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]
33.47	1.5	22.31	5.35

$\alpha_p{}^*\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}{}^*V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4.7	160	67.26	749	0.66	375	0.76	1

β_N	β_V	$\beta_N{}^{1.5} + \beta_V{}^{1.5}$
0.18	0.24	0.20

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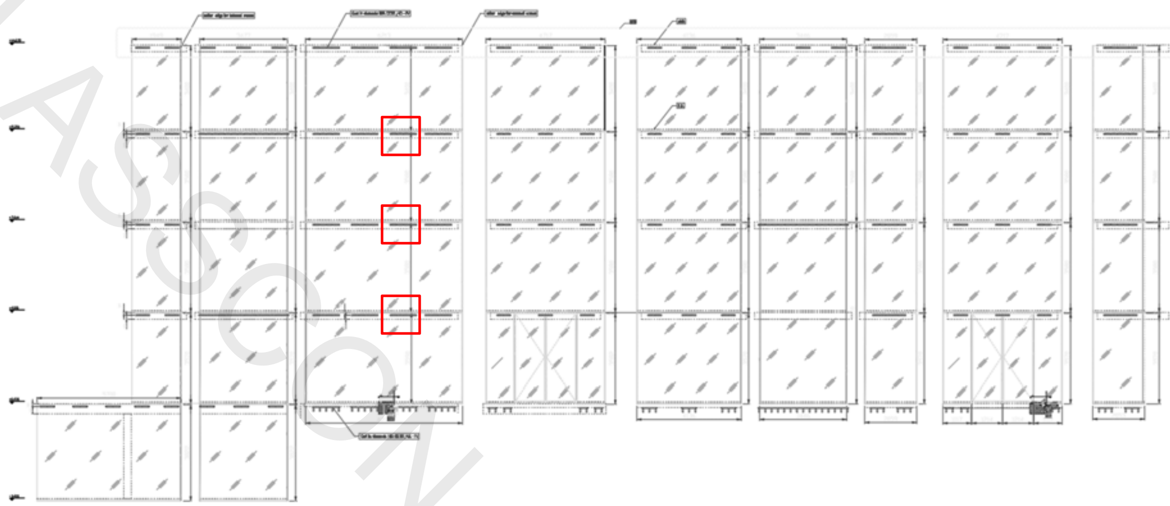
11.5. Pos. 5.5 – Halfen Anchor Channel (Steel Frame)

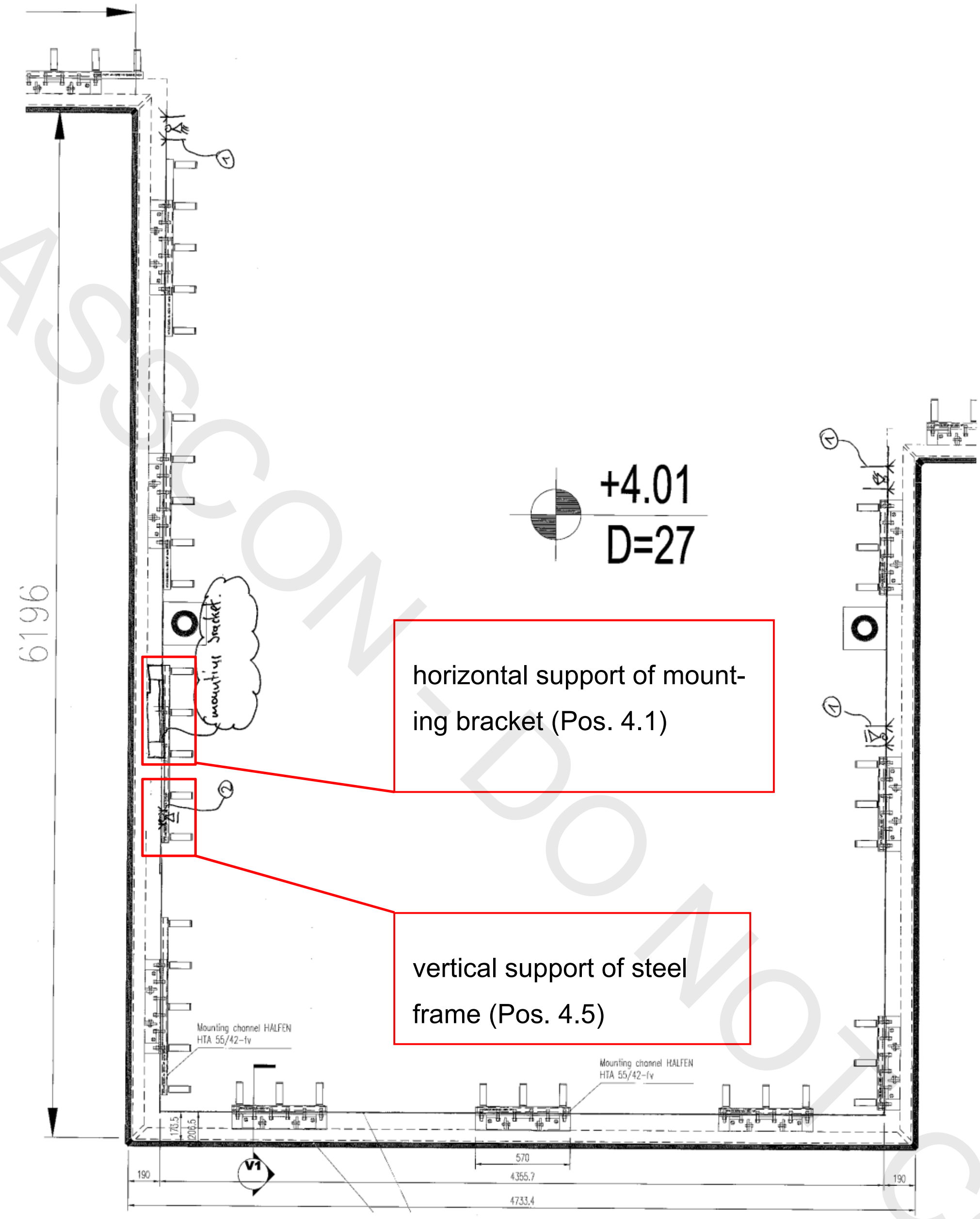
11.5.1. General



Anchor channel	HTA-CE 55/42 – FV 6070 (hot rolled)
Length of channel	1070 mm*
Number of anchors	5
Bolt	see next page

*The Halfen channel is going to be cut from a standard channel with a length of 6070 mm and anchor distance of 250 mm to a channel with a length of 1070 mm and five symmetric arranged anchors. For the verification a channel with a length of 1070 mm (tolerance +/-15 mm) was calculated.

The calculation of the screw forces can be found in Pos. 4.1 and Pos. 4.5



<u>Support of mounting bracket:</u>

Bolt: HSR M16 8.8

Number: 6

<u>Support of steel frame:</u>

Bolt: HS M16 8.8

Number: 2

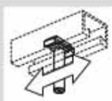
11.5.2. Verification

Support of mounting bracket
Longitudinal load in channel direction (HSR M16 8.8):

V_{Ed} = 2 x 10.7 kN / 6 screws = 3.6 kN

F_{Rd} = 7.0 kN

V_{Ed} / F_{Rd} = 3.6 kN / 7.0 kN = 0.52 ≤ 1.00 (OK)

Load capacity	
 Bolt HSR	Grade 8.8 F_{Rd} in channel longitudinal direction according to expert report F_{Rd} [kN]
40/22 - M16	7.0
50/30 - M16	7.0
50/30 - M20	10.5
72/48 - M20	10.5

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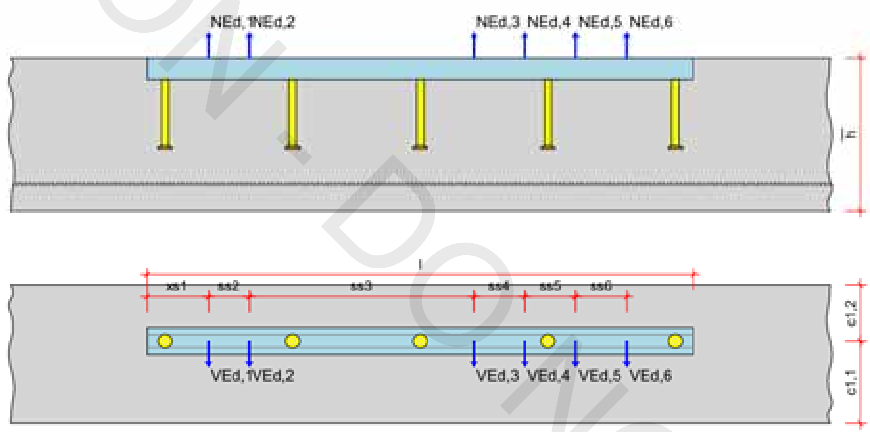
Halfen HTA-CE anchor channel - CEN/TS 1992-4, ETA-09/0339
Halfen Design Software HTA, Version 2.50

The design - including the static values - does only apply to the designated HALFEN product. The load bearing capacity of third party products, appearing to be identical in construction, might differ. For this reason, the software provider does not extend warranty if external products are used.

Input data

Anchor channel	HTA-CE 55/42 - FV - 1070 / 5, 5 anchors
Channel bolt	HS 50/30 M 16 FV 4.6
Approval / Design method	CEN/TS 1992-4, ETA-09/0339
Shear force	without lever arm
Concrete	C40/50, cracked
Reinforcement	no dense reinforcement
edge reinforcement	no edge reinforcement



h = 1000 mm l = 1070 mm c_{11} = 160 mm c_{12} = 110 mm
c_{nom} = 20 mm

Adjusting zone ±: Defined adjustment 15 mm, Shift interval 5 mm

Bolt	x_{s1}/s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]	Bolt	s_s [mm]	N_{Ed} [kN]	V_{Ed} [kN]
1	120	0.00	22.50	2	80	0.00	22.50
3	440	30.70	0.00	4	100	30.70	0.00
5	100	2.20	0.00	6	100	10.10	0.00

Utilisation: 100% - Proof successful

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Calculation Summary

Verifications for T-bolt

Tension	$N_{Rd,s,s}$	98%
Shear	$V_{Rd,s,s}$	100% ✩
Combined load	$N_{Rd,s,s}$ - $V_{Rd,s,s}$	0%

Verifications for cast-in channels

Channel lips - Tension	$N_{Rd,s,l}$	75%
Channel lips - Shear	$V_{Rd,s,l}$	39%
Combined load	$N_{Rd,s,l}$ - $V_{Rd,s,l}$	0%
Local flexure of channel	$M_{Rd,s,flex}$	44%
Connection between anchor and channel (Tension)	$N_{Rd,s,c}$	85%
Connection between anchor and channel (Shear)	$V_{Rd,s,c}$	52%
Combined load	$N_{Rd,s,c}$ - $V_{Rd,s,c}$	36%

Verifications for concrete

Tension - Pull-out failure	$N_{Rd,cp}$	46%
Tension - Concrete cone failure	$N_{Rd,c}$	87%
Shear - Concrete edge failure	$V_{Rd,c}$	91%
Shear - Pry-out failure	$V_{Rd,cp}$	26%
Shear - Concrete edge failure, load parallel to edge	$V_{Rd,c90}$	N/A
Combined load	$N_{Rd,c}$ - $V_{Rd,c}$	88%
Combined load	$N_{Rd,c}$ - $V_{Rd,cp}$	61%
Combined load	$N_{Rd,c}$ - $V_{Rd,c90}$	N/A

Verifications:

Steel

Channel bolt

Maximum tension load (bolt): Bolt 3

$N_{Rk,s,s}$ [kN]	γ_{Ms}	$N_{Rd,s,s}$ [kN]	N_{Ed} [kN]	β_N
62.8	2.00	31.4	30.7	0.98

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,s}$ [kN]	γ_{Ms}	$V_{Rd,s,s}$ [kN]	V_{Ed} [kN]	β_V
37.7	1.67	22.57	22.5	1

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N^2+\beta_V^2$
0	0.00	22.5	1	0

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Anchor channel, channel lips
Maximum tension load (bolt): Bolt 4

$N_{Rk,s,l}$ [kN]	γ_{Ms}	$N_{Rd,s,l}$ [kN]	N_{Ed} [kN]	β_N
73.39	1.8	40.77	30.7	0.75

Maximum shear load without lever arm (bolt): Bolt 1

$V_{Rk,s,l}$ [kN]	γ_{Ms}	$V_{Rd,s,l}$ [kN]	V_{Ed} [kN]	β_V
104	1.8	57.78	22.5	0.39

Combined loading, most unfavourable bolt: 1

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N{}^2+\beta_V{}^2$
0	0	22.5	0.39	0

Flexure of channel
Decisive span between anchors 3 and anchors 4

$N_{Ed,3}$ [kN]	load position [mm]
30.7	635

$N_{Ed,4}$ [kN]	load position [mm]
30.7	735

M_{Ed} [Nm]	$M_{Rk,s,flex}$ [Nm]	$\gamma_{Ms,flex}$	$M_{Rd,s,flex}$ [Nm]	β_{flex}
2,456.00	6,447.00	1.15	5,606.09	0.44

Connection between anchor and channel
most unfavourable anchor: 4, load position xş = 135 mm

$N_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$N_{Rd,s,c}$ [kN]	N_{Ed} [kN]	β_N
80	1.8	44.44	37.9	0.85

most unfavourable anchor: 1, load position xş = 105 mm

$V_{Rk,s,c}$ [kN]	$\gamma_{Ms,ca}$	$V_{Rd,s,c}$ [kN]	V_{Ed} [kN]	β_V
80	1.8	44.44	23.32	0.52

most unfavourable anchor: 3, load position xş = 105 mm

N_{Ed} [kN]	β_N	V_{Ed} [kN]	β_V	$\beta_N{}^2+\beta_V{}^2$
26.66	0.60	1.15	0.03	0.36

<u>Concrete</u>

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Tensile load - Pull-out failure
most unfavourable anchor: 4, load position xs = 135 mm

$N_{Rk,cp}$ [kN]	$\gamma_{M,cp}$	$N_{Rd,cp}$ [kN]	N_{Ed} [kN]	β_N
124	1.5	82.67	37.9	0.46

$N_{Rk,p(C12/15)}$ [kN]	$\psi_{ucr,N}$
37.2	1

Tensile load - Concrete cone failure
most unfavourable anchor: 4, load position xs = 135 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N
65.19	1.5	43.46	37.9	0.87

$N0_{Rk,c}$ [kN]	$s_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.73	269	0.64	1.00	1	1

Shear load - Pry-out failure
most unfavourable anchor: 1, load position xs = 105 mm

$V_{Rk,cp}$ [kN]	γ_{Mc}	$V_{Rd,cp}$ [kN]	V_{Ed} [kN]	β_V
132.31	1.5	88.21	23.32	0.26

$\alpha_{s,N(cp)}$	k_5
0.67	2

Shear load - Concrete edge failure
most unfavourable anchor: 2, load position xs = 135 mm

$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]	β_V
37.01	1.5	24.68	22.44	0.91

$\alpha_p * \psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V} * V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4	160	57.24	749	0.65	375	1	1

Combined loading
most unfavourable anchor: 3, load position xs = 105 mm

$N_{Rk,c}$ [kN]	$\gamma_{M,c}$	$N_{Rd,c}$ [kN]	N_{Ed} [kN]	β_N
57.18	1.5	38.12	26.66	0.7

$N0_{Rk,c}$ [kN]	$S_{cr,N}$ [mm]	$\alpha_{s,N}$	$c_{cr,N}$ [mm]	$\alpha_{e,N}$	$\alpha_{c,N}$	$\psi_{re,N}$	$\psi_{ucr,N}$
139.14	538	0.64	269	0.64	1.00	1.00	1.0

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$V_{Rk,c}$ [kN]	γ_{Mc}	$V_{Rd,c}$ [kN]	V_{Ed} [kN]
7.14	1.5	4.76	2.29

α_p*$\psi_{re,V}$	$c_{1,1}$ [mm]	$\psi_{re,V}$*$V0_{Rk,c}$ [kN]	$s_{cr,V}$ [mm]	$\alpha_{s,V}$	$c_{cr,V}$ [mm]	$\alpha_{c,V}$	$\alpha_{h,V}$
4	160	57.24	749	0.12	375	1	1

β_N	β_V	$\beta_N^{1,5} + \beta_V^{1,5}$
0.7	0.48	0.88

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