Static dimensioning

Lounge with ridge beam and canopy - temporary use

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The static calculation includes 50 DIN A4 pages.
The verification for the connectors was created in a separated document.

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1 General

1.1 Project description

The Strohboid Lounge consists of a membrane construction, which serves as roofing and is attached to the edge beams, consisting of spruce laminated veneer lumber (spruce LVL), the two edge beams are held together in the ridge area by means of ridge beams. The load transfer of the edge beams is carried out via a wall-like cover made of spruce laminated veneer lumber in the tram ceiling construction, which is also made of spruce LVL. The tram ceiling is planked with a covering of 33 mm thick LVL spruce. The load is dissipated from the entire construction via the dissipating trams in the foundation of the building.

1.2 Aim of the investigation

Verification of the structural components, with predefined geometry/cross-sectional dimensions, with regard to their load-bearing capacity, taking into account the actions for temporary structures in accordance with ÖNORM EN 13782. All precautions to meet the safety level shall be complied with in accordance with this ÖNORM.

1.3 Planning documents

Strohboid GmbH	3D Models as of 02.02.2022
Strohboid GmbH	Overview Fasteners as of 14.02.2022

1.4 Standards, regulation, approvals and literature

ÖNORMEN:

ÖNORM B 1990-1	EUROCODE: Grundlagen der Tragwerksplanung Teil 1: Hochbau – NA (2004)
ÖNORM EN 1990	EUROCODE: Grundlagen der Tragwerksplanung (2003)
ÖNORM EN 1990/A1	EUROCODE: Grundlagen der Tragwerksplanung (2008)
ÖNORM B 1991-1-1	EUROCODE 1: Einwirkungen auf Tragwerke; Teil 1-1: Einwirkungen auf Tragwerke – Wichten, Eigenlasten, Nutzlasten im Hochbau – NA (2006)
ÖNORM EN1991-1-1	EUROCODE 1: Einwirkungen auf Tragwerke; Teil 1-1: Einwirkungen auf Tragwerke – Wichten, Eigenlasten, Nutzlasten im Hochbau (2006)
ÖNORM B 1991-1-3	EUROCODE 1: Einwirkungen auf Tragwerke; Teil 1-1: Einwirkungen auf Tragwerke – Schneelasten – NA (2006)
ÖNORM EN 1991-1-3	EUROCODE 1: Einwirkungen auf Tragwerke; Teil 1-3: Einwirkungen auf Tragwerke – Schneelasten (2005)
ÖNORM B 1991-1-4	EUROCODE 1: Einwirkungen auf Tragwerke; Teil 1-4: Allgemeine Einwirkungen – Windlasten – NA (2009)
ÖNORM EN 1991-1-4	EUROCODE 1: Einwirkungen auf Tragwerke; Teil 1-4: Einwirkungen auf Tragwerke – Windlasten (2005)
ÖNORM B 1993-1-1	EUROCODE 3: Bemessung und Konstruktion von Stahlbauten; Teil 1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau – NA (2007)
ÖNORM EN 1993-1-1	EUROCODE 3: Bemessung und Konstruktion von Stahlbauten; Teil 1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau (2007)
ÖNORM B 1993-1-2	EUROCODE 3: Bemessung und Konstruktion von Stahlbauten; Teil 1-2: Allgemeine Regeln – Tragwerksbemessung für den Brandfall – NA (2007)
ÖNORM EN 1993-1-2	EUROCODE 3: Bemessung und Konstruktion von Stahlbauten; Teil 1-2: Allgemeine Regeln – Tragwerksbemessung für den Brandfall (2012)
ÖNORM B 1993-1-3	EUROCODE 3: Bemessung und Konstruktion von Stahlbauten; Teil 1-3: Allgemeine Regeln – Ergänzende Regeln für kaltgeformte dünnwandige Bauteile und Bleche – NA (2007)
ÖNORM EN 1993-1-3	EUROCODE 3: Bemessung und Konstruktion von Stahlbauten;

	Teil 1-3: Allgemeine Regeln – Ergänzende Regeln für kaltgeformte dünnwandige Bauteile und Bleche (2010)
ÖNORM B 1993-1-4	EUROCODE 3: Bemessung und Konstruktion von Stahlbauten; Teil 1-4: Allgemeine Regeln – Ergänzende Regeln zur Anwendung von nichtrostenden Stählen – NA (2007)
ÖNORM EN 1993-1-4	EUROCODE 3: Bemessung und Konstruktion von Stahlbauten; Teil 1-4: Allgemeine Regeln – Ergänzende Regeln zur Anwendung von nichtrostenden
ÖNORM B 1993-1-8	EUROCODE 3: Bemessung und Konstruktion von Stahlbauten; Teil 1-8: Bemessung von Anschlüssen – NA (2015)
ÖNORM EN 1993-1-8	EUROCODE 3: Bemessung und Konstruktion von Stahlbauten; Teil 1-8: Bemessung von Anschlüssen (2012)
ÖNORM B 1995-1-1	EUROCODE 5: Bemessung und Konstruktion von Holzbauten; Teil 1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau – NA (2015)
ÖNORM EN 1995-1-1	EUROCODE 5: Bemessung und Konstruktion von Holzbauten; Teil 1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau (2014)

Approvals:
General type approval Z-9.1-847 (validity 7.Mai 2019 bis 7.Mai 2024) BDesigns with laminated veneer lumber "Kerto-S", "Kerto-Q" and "Kerto-Qp"

1.5 Softwares

RFEM	spatial finite element software version 5.02	Company Dlubal
RSTAB	spatial framework program version 8.03	Company Dlubal
DUENQ	stresses in thin-walled cross-sections version 7.5	Company Dlubal
EXCEL	version Office 2013	Microsoft

1.6 Assessing the consequential damage class

damage consequence category	*Characteristics*	*Examples in building construction or other engineering*	*Zuordnung*
CC 3	Major consequences for human life **or** major economic, social or environmental consequences	- Structures (or separate parts of structures) with a dedicated capacity for more than 1,000 people (such as hospitals, shopping malls, stadiums, educational institutions). - Structures fulfilling an energy and utility function - Structures and facilities that serve for civil protection purposes - Structures covered by the SEVESO II Directive - Structures with more than 16 floors above ground level	☐
CC 2	Moderate consequences for human life, impaired economic, social, or environmental impact.	- Structures that are not assigned to the damage consequence class CC1 or CC3	☐
CC 1	Minimal consequences to human life and small or negligible economic, social, or environmental consequences.	- Buildings with no more than three above-ground floors and with an escape level of no more than 7 m, consisting of no more than five apartments or business units with a total gross floor area of no more than 400 m² of the above-ground floors. - Row houses with no more than three above-ground floors and with an escape level of no more than 7 m, consisting of apartments or business units of no more than 400 m² gross floor area each of the above-ground floors - agricultural structures with low personal traffic	☒

ÖNORM B1990-1:2013 Tabelle B.1 - Schadensfolgeklassen

1.7 Classification in the reliability class

The three reliability classes RC 1, RC 2 and RC 3 are linked to the three damage consequence classes CC 1, CC 2 and CC 3.
While complying with the respective monitoring class in design (DSL) and in execution (IL), the partial safety factors for the basic combination of action for permanent design situation can be differentiated according to the table below.

K_{FI}-Coefficient for loads	**Reliability class**		
	RC 1	RC 2	RC 3
K_{FI}	0,9	1,0	1,1
NOTE To achieve reliability class RC 3, measures other than the application of the KFI factor are usually preferred. The KFI factor is only to be applied to unfavorable actions.			

ÖNORM B1990-1:2013 Tabelle B.5 – K_{FI}-Faktoren für Einwirkungen

For the project at hand, the following partial safety factors result for unfavourable loads:
For permanent actions γ_G=1,35*0,9=1,22
For variable actions γ_Q=1,50*0,9=1,35

1.8 Monitoring Measures

1.8.1 Monitoring measures during planning

Monitoring measures during planning	Features	Minimum requirements for the verification of static calculations, drawings and instructions
DSL 3 in conjunction mit RC 3	Increased monitoring[a]	Inspection by independent third-party body: Inspection by an inspection body that is organizationally independent of the planning body (third-party inspection).
DSL 2 in conjunction mit RC 2	Normal monitoring[b]	Inspection by an inspection body independent of the planning body in its own organization (self-monitoring by own inspection body)
DSL 1 in conjunction mit RC 1	Normal monitoring[b]	Self-monitoring: testing by the planning body itself

a Enhanced monitoring includes, in addition to normal monitoring, an independent control calculation and review of the plan representation with regard to structural safety.
b Normal monitoring includes a check of the completeness of the documents (static calculation, drawings and instructions) and a plausibility check of the main results with regard to structural safety.

ÖNORM B1990-1:2013 Tabelle B.6 – Überwachungsmaßnahmen bei der Planung (DSL)

1.8.2 Production monitoring

Monitoring level	Features	Requirements
IL 3 in conjunction mit RC 3	Increased monitoring	Monitoring by independent third party
IL 2 in conjunction mit RC 2	Normal monitoring	Monitoring by monitoring body of own organization
IL 1 in conjunction mit RC 1	Normal monitoring	Self-monitoring

NOTE Together with the monitoring levels, test plans are defined for construction products and the manufacture of structures. Since these are dependent on the building material, details are given in the respective execution standards.

ÖNORM B1990-1:2013 Tabelle B.7 – Überwachungsstufen (IL) für die Herstellung

1.9 Building materials and characteristic values

1.9.1 Laminated veneer lumber Kerto-Q Fa. Metsä Wood

Charakteristische Festigkeits- und Steifigkeitskennwerte in N/mm² sowie weitere Kennwerte gemäß Leistungserklärungen des Herstellers Nr. MW/LVL/311-001/CPR/DOP (Kerto-S), Nr. MW/LVL/312-001/CPR/DOP (Kerto-Q) und Nr. MW/LVL/313-001/CPR/DOP (Kerto-Qp)

Art der Beanspruchung	Bezeichnung	Kerto S	Kerto Q		Kerto Qp	
	Nenndicke [mm]	21 ≤ t ≤ 90	21 ≤ t ≤ 24	27 ≤ t ≤ 75	39 ≤ t ≤ 51	54 ≤ t ≤ 75
Charakteristische Festigkeitskennwerte [N/mm²]						
Plattenbeanspruchung						
Biegung || z. Faser	$f_{m,0,flat,k}$	50	32	36	36	36
Biegung ⊥ z. Faser	$f_{m,90,flat,k}$	-	8[1)]	8	NPD	NPD
Druck	$f_{c,90,flat,k}$	1,8	2,2	2,2	siehe LE	siehe LE
Schub	$f_{v,flat,k}$	2,3	1,3	1,3	1,3	1,3
Scheibenbeanspruchung						
Biegung	$f_{m,0,edge,k}$	44	28	32	36	38
Zug parallel	$f_{t,0,k}$	35	19	26	28	30
Zug rechtwinklig	$f_{t,90,edge,k}$	0,8	6	6	3	2,5
Druck parallel	$f_{c,0,k}$	35	19	26	28	30
Druck senkrecht	$f_{c,90,edge,k}$	6	9	9	6	6
Schub	$f_{v,edge,k}$	4,1	4,5	4,5	4,1	4,1
Steifigkeitskennwerte [N/mm²]						
Elastizitätsmodul	$E_{0,mean}$	13800	10000	10500	11700	12300
Elastizitätsmodul	$E_{0,05}$	11600	8300	8800	9800	10300
Elastizitätsmodul	$E_{90,mean}$	-	1200[1)]	2000	NPD	NPD
Schubmodul	$G_{mean,edge}$	600	600	600	600	600
	$G_{mean,flat}$	600	60	120	120	120
Weitere Kennwerte						
Rohdichte	ρ [kg/m³]	510	510	510	510	510
char. Rohdichte	ρ [kg/m³]	480	480	480	480	480
Klasse des Brandverhaltens		D-s1,d0	D-s1,d0	D-s1,d0	D-s1,d0	D-s1,d0
Streuungsparameter s		0,12	0,12	0,12	0,12	0,12

[1)] Für B = 21 mm und den Furnieraufbau I-III-I darf $f_{m,90,flat,k}$ = 14 N/mm² bzw. E90,mean = 3300 N/mm² angenommen werden.

Since the structural elements are made on a curved plate material, the following points are valid according to the issued approval. In the design, segments with a maximum length of 30 cm were created and the strength and stiffness properties were calculated according to the existing angles between the fiber direction of the surface layer and the loading direction.

2.3.2 Beanspruchung unter einem Winkel α

Für eine Beanspruchung unter dem Winkel α (Winkel zwischen Faserrichtung der Deckschicht und der Beanspruchungsrichtung) sind für "Kerto-Q" die Werte der Leistungserklärung um einen Faktor entsprechend Tabelle 1a, für "Kerto-S" und "Kerto-Qp" um einen Faktor entsprechend Tabelle 1b abzumindern. Der Faktor bezieht sich auf Beanspruchungen "II zur Faser".

Tabelle 1a: Abminderungsfaktoren für "KERTO-Q" bei Beanspruchung unter einem Winkel α

Art der Beanspruchung	Winkel zwischen Faserrichtung der Deckschicht und der Beanspruchungsrichtung								
	0°	2,5°	5°	10°	15°	30°	45°	60°	90°
Abminderungsfaktoren für Festigkeits- und Steifigkeitskennwerte									
Biegung (Plattenbeanspruchung)	1	1	0,9	0,7	0,5	0,25	0,2	0,2	0,22
Biegung (Scheibenbeanspruchung)	1	0,9	0,75	0,55	0,4	0,25	0,2	0,2	0,22
Zug	1	1	0,9	0,7	0,4	0,25	0,2	0,2	0,23
Druck	1	1	0,9	0,7	0,5	0,35	0,25	0,25	0,35
Elastizitätsmodul	1	0,9	0,8	0,6	0,4	0,15	0,1	0,1	0,23

1.9.2 Glued laminated timber

Property [a]	**Symbol**	**Glued laminated timber strength class**						
		GI 20c	**GI 22c**	**GI 24c**	**GI 26c**	**GI 28c**	**GI 30c**	**GI 32c**
Bending strength	$f_{m,g,k}$	20	22	24	26	28	30	32
Tensile strength	$f_{t,0,g,k}$	15	16	17	19	19,5	19,5	19,5
	$f_{t,90,g,k}$	0,5						
Compressive strength	$f_{c,0,g,k}$	18,5	20	21,5	23,5	24	24,5	24,5
	$f_{c,90,g,k}$	2,5						
Schubfestigkeit (Schub und Torsion)	$f_{v,g,k}$	3,5						
Roll shear strength	$f_{r,g,k}$	1,2						
Modulus of elasticity	$E_{0,g,mean}$	10 400	10 400	11 000	12 000	12 500	13 000	13 500
	$E_{0,g,05}$	8 600	8 600	9 100	10 000	10 400	10 800	11 200
	$E_{90,g,mean}$	300						
	$E_{90,g,05}$	250						
Shear modulus	$G_{g,mean}$	650						
	$G_{g,05}$	540						
Roll shear module	$G_{r,g,mean}$	65						
	$G_{r,g,05}$	54						
Bulk Density [b]	$\rho_{g,k}$	355	355	365	385	390	390	400
	$\rho_{g,mean}$	390	390	400	420	420	430	440

[a] The properties given in this table were calculated according to 5.1.5 on the basis of the superstructures given in Table 2. Where different constructions result in different characteristic values for a given strength class, the lowest values are listed.

[b] Calculated as the weighted average of the bulk densities of the different laminar ranges, see 5.1.5.3, 5th para.

Tabelle 1: EN 14080:2013 Tab.4: - charakteristische Festigkeits- und Steifigkeitseigenschaften in N/mm², sowie Rohdichten in kg/m³, für kombiniertes Brettschichtholz

Property	Symbol	Glued laminated timber strength class						
		GI 20h	**GI 22h**	**GI 24h**	**GI 26h**	**GI 28h**	**GI 30h**	**GI 32h**
Bending strength	$f_{m,g,k}$	20	22	24	26	28	30	32
Tensile strength	$f_{t,0,g,k}$	16	17,6	19,2	20,8	22,3	24	25,6
	$f_{t,90,g,k}$	0,5						
Compressive strength	$f_{c,0,g,k}$	20	22	24	26	28	30	32
	$f_{c,90,g,k}$	2,5						
Shear strength (shear and torsion)	$f_{v,g,k}$	3,5						
Roll shear strength	$f_{r,g,k}$	1,2						
Modulus of elasticity	$E_{0,g,mean}$	8 400	10 500	11 500	12 100	12 600	13 600	14 200
	$E_{0,g,05}$	7 000	8 800	9 600	10 100	10 500	11 300	11 800
	$E_{90,g,mean}$	300						
	$E_{90,g,05}$	250						
Shear modulus	$G_{g,mean}$	650						
	$G_{g,05}$	540						
Roll shear module	$G_{r,g,mean}$	65						
	$G_{r,g,05}$	54						
Bulk density	$\rho_{g,k}$	340	370	385	405	425	430	440
	$\rho_{g,mean}$	370	410	420	445	460	480	490

Tabelle 2: EN 14080:2013 Tab.4 - charakteristische Festigkeits- und Steifigkeitseigenschaften in N/mm², sowie der Rohdichte in kg/m³, für homogenes Brettschichtholz

2 Loads

2.1 Dead weight and permanent loads

The self-weight of the construction and the planking are taken into account in the software with a weight of γ=5.50 kN/m³. The textile used as roof covering weighs 360 g/m².

2.2 Payloads

The payload for the ceiling was assumed to be pk=2.00 kN/m² or Qk=2.00 kN (at an unfavorable location) in accordance with ÖNORM B 1991-1-1 for use category A1.

2.3 Snow loads

Schneelasten sind nach EN 1991-1-3 anzusetzen.

Schneelasten brauchen nicht berücksichtigt zu werden für Zelte,

- die in Gebieten aufgestellt werden, in denen Schnee sehr unwahrscheinlich ist oder
- die nur in schneefreien Jahreszeiten betrieben werden oder
- bei denen durch die Konstruktion oder die Betriebsbedingungen das Ansammeln von Schnee auf dem Zelt verhindert wird oder
- bei denen durch vorbeugende Maßnahmen das Ansammeln von Schnee auf dem Zelt verhindert wird.

Die letztgenannte Bedingung kann erreicht werden, wenn:

- ausreichende Heizvorrichtungen installiert und betriebsbereit sind und
- die Heizung eingeschaltet wird, bevor der Schneefall einsetzt, und
- das Zelt so beheizt wird, dass die gesamte Dachverkleidung auf der Außenseite eine Temperatur von mehr als +2 °C aufweist, und
- die Verkleidung so konstruiert und vorgespannt ist, dass sich keine Wasseransammlungen oder andere Verformungen der Verkleidung bilden können.

Wenn durch Entfernen des Schnees sichergestellt ist, dass eine Schneehöhe von 8 cm nicht überschritten wird, dann darf bei Zelten eine reduzierte Schneelast q_k = 0,20 kN/m² über die gesamte Dachfläche angesetzt werden.

It has been shown by empirical evidence that due to the low roughness of the surface, the snow slides off even at inclinations below 60°.

2.4 Wind loads

Der auf die Außenflächen wirkende Winddruck w_e sollte nach folgender Gleichung ermittelt werden:

$$w_e = q_p(z_e) \cdot c_{pe} \quad (1)$$

Dabei ist

$q_p(z_e)$ der Böengeschwindigkeitsdruck (in Abhängigkeit von der Bezugshöhe für den Außendruck), in kN/m²;

z_e die Bezugshöhe für den Außendruck, in m;

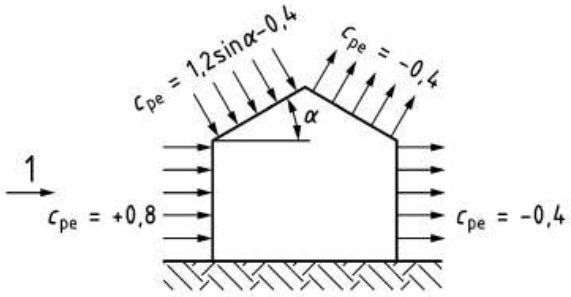
c_{pe} der Außendruckbeiwert.

Tabelle 1 — Böengeschwindigkeitsdruck $q_p(z_e)$

Bezugshöhe z_e m	Böengeschwindigkeitsdruck $q_p(z_e)$ kN/m²
$z_e \leq 5$	0,50
$5 < z_e \leq 10$	0,60
$10 < z_e \leq 15$	0,66
$15 < z_e \leq 20$	0,71
$20 < z_e \leq 25$	0,76

Abweichend von den in Tabelle 1 angegebenen Drücken darf für Zelte mit einer Breite von kleiner oder gleich 10 m und einer Höhe von kleiner oder gleich 5 m ein reduzierter Böengeschwindigkeitsdruck $q_p(z_e)$ = 0,30 kN/m² angewendet werden.

2.4.1 External pressure coefficients for wind in Y-direction

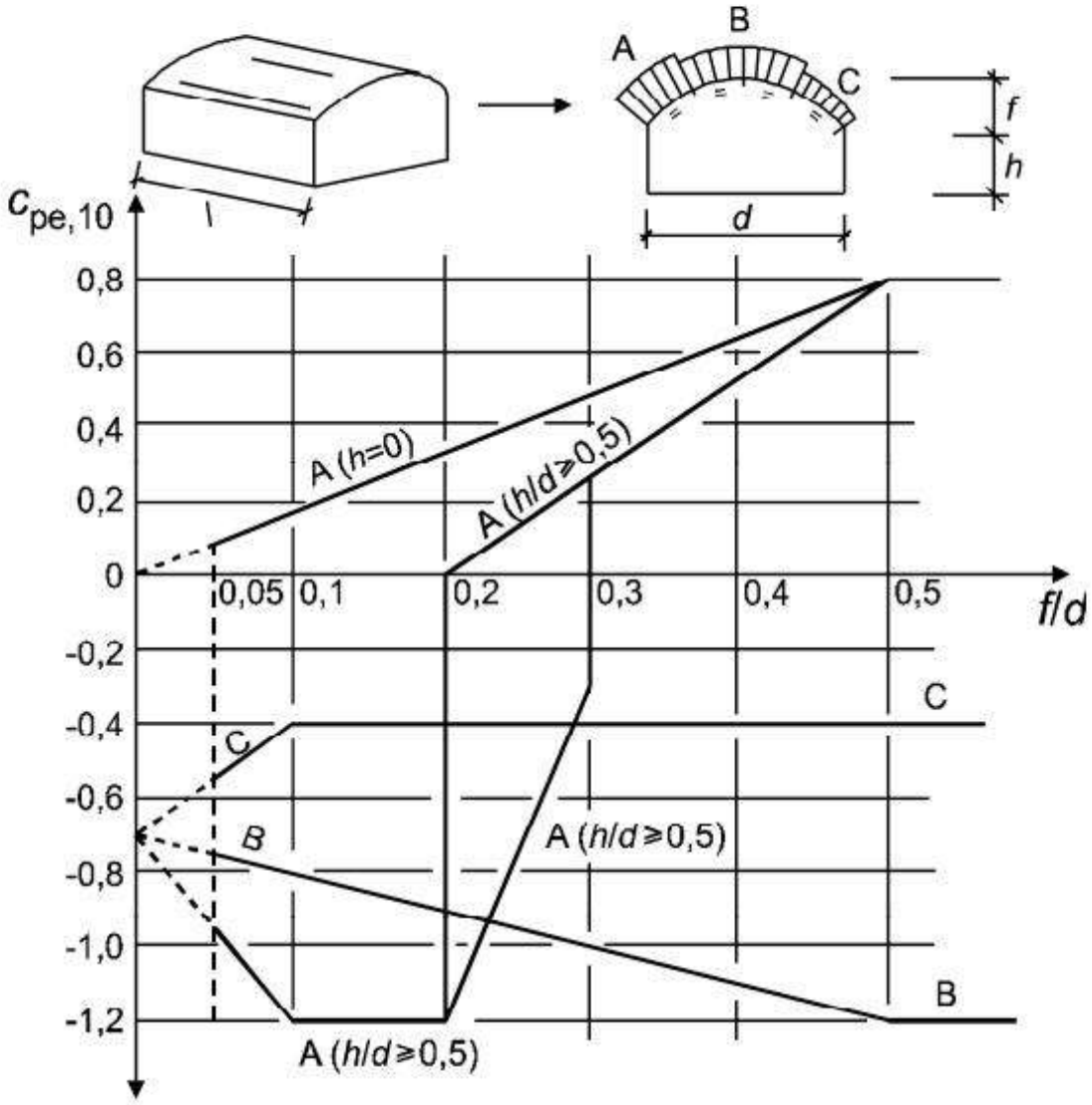


Legende
1 Windrichtung
α Winkel der Dachneigung
c_{pe} Außendruckbeiwert

Bild 2 — Außendruckbeiwert c_{pe} für geschlossene Satteldachzelte

2.4.2 External pressure coefficients for wind in X direction

ANMERKUNG Die für kreiszylindrische Dächer und Kuppeln anzusetzenden $c_{pe,10}$- und $c_{pe,1}$-Werte können im Nationalen Anhang angegeben werden. Die empfohlenen $c_{pe,10}$-Werte sind für verschiedene Bereiche in Bild 7.11 und 7.12 angegeben. Die Bezugshöhe ist $z_e = h + f$.



(AC) Für Bereich A:

— für $0 < h/d < 0,5$ ist der $c_{pe,10}$-Wert durch lineare Interpolation zu ermitteln;

— für $0,2 \leq f/d \leq 0,3$ und $h/d \geq 0,5$ müssen zwei $c_{pe,10}$-Werte berücksichtigt werden;

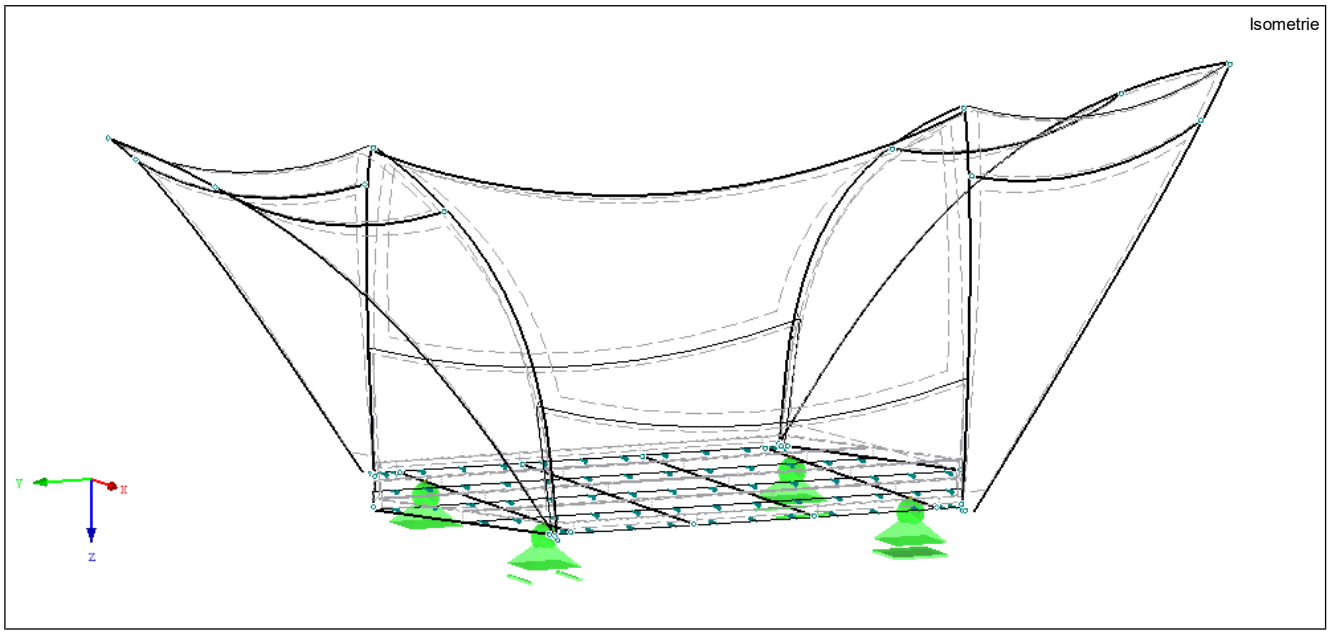
— das Diagramm gilt nicht für Flachdächer. (AB)

Bild 7.11 — Außendruckbeiwerte $c_{pe,10}$ für gekrümmte Dächer von Baukörpern mit rechteckigem Grundriss

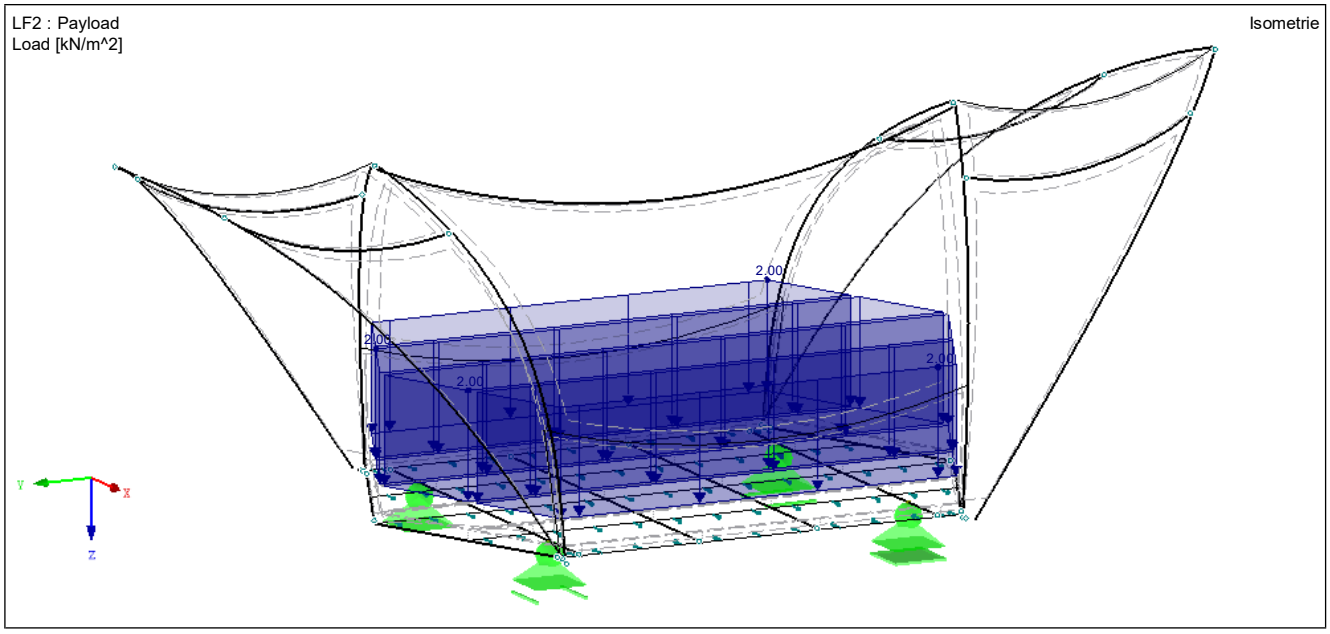
3 Structural analysis of components

3.1 General Model

3.1.1 General overview

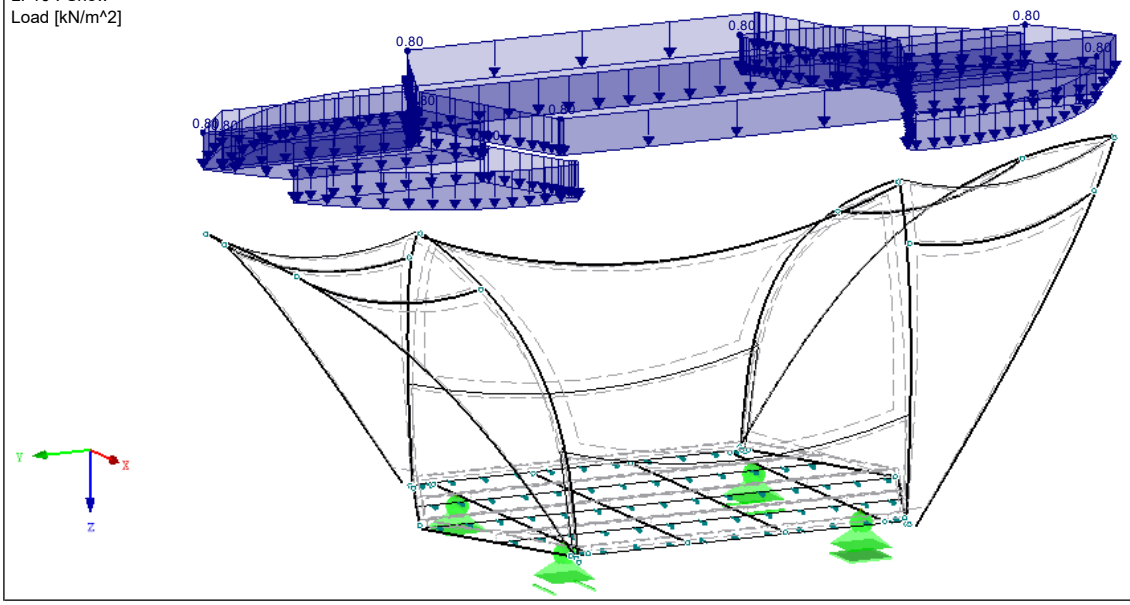


3.1.2 Loads



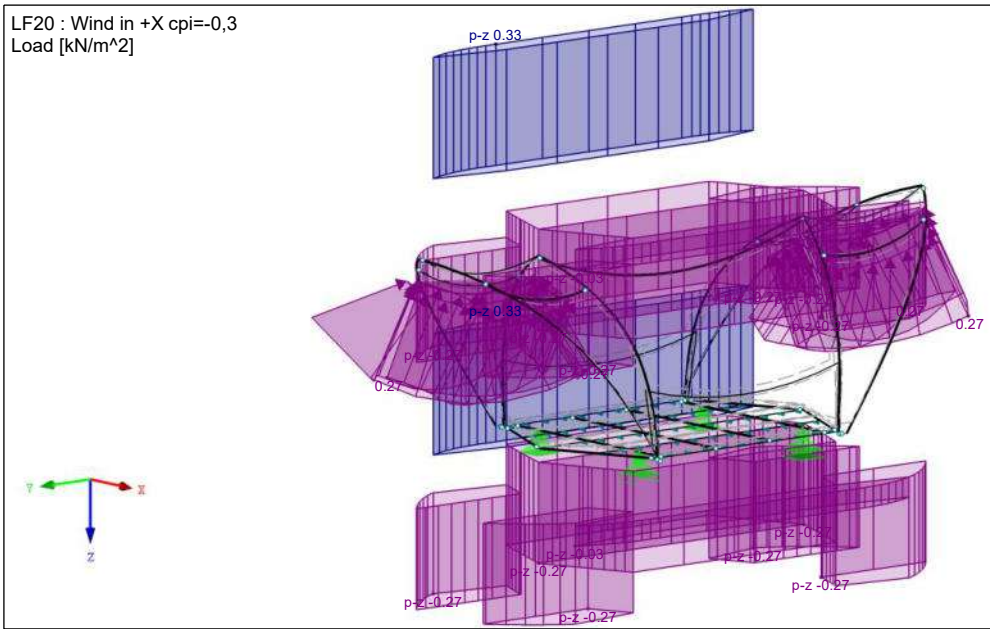
LF10 : Snow
Load [kN/m^2]

Isometrie



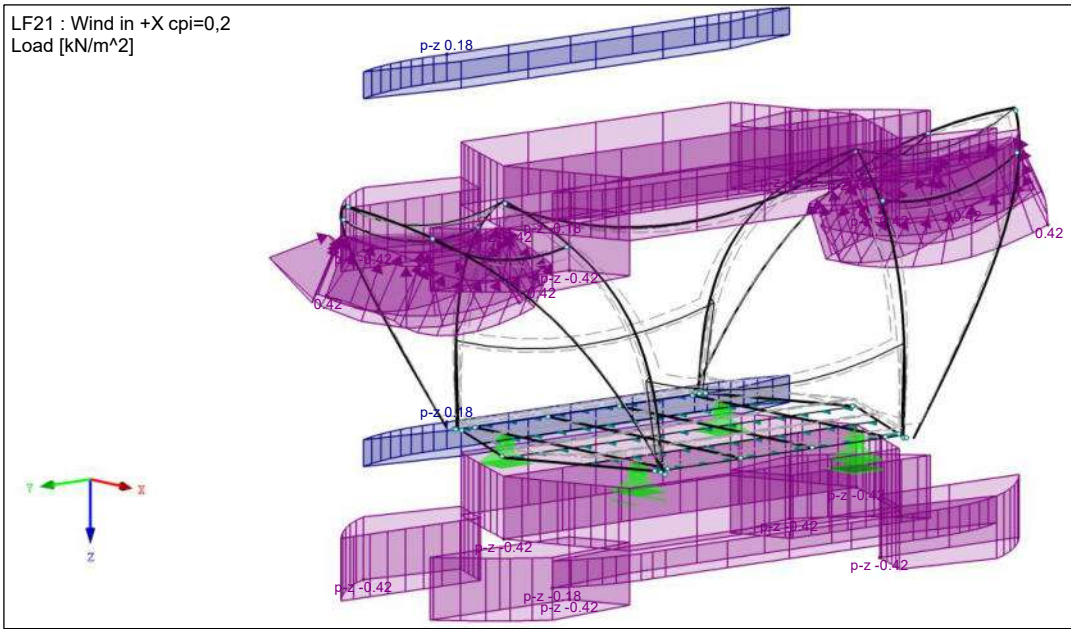
LF20 : Wind in +X cpi=-0,3
Load [kN/m^2]

Isometrie



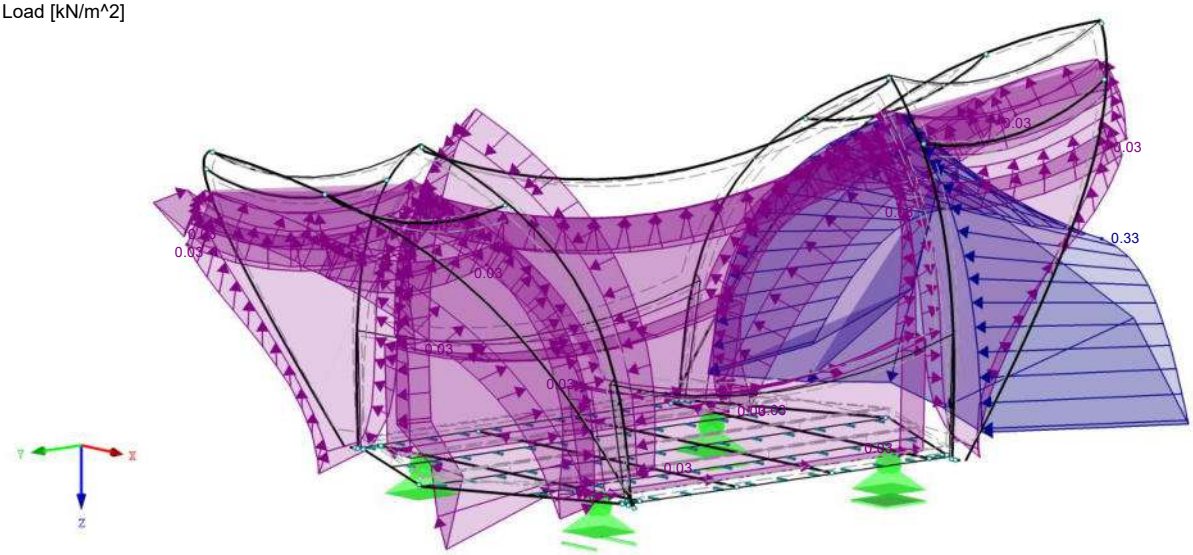
LF21 : Wind in +X cpi=0,2
Load [kN/m^2]

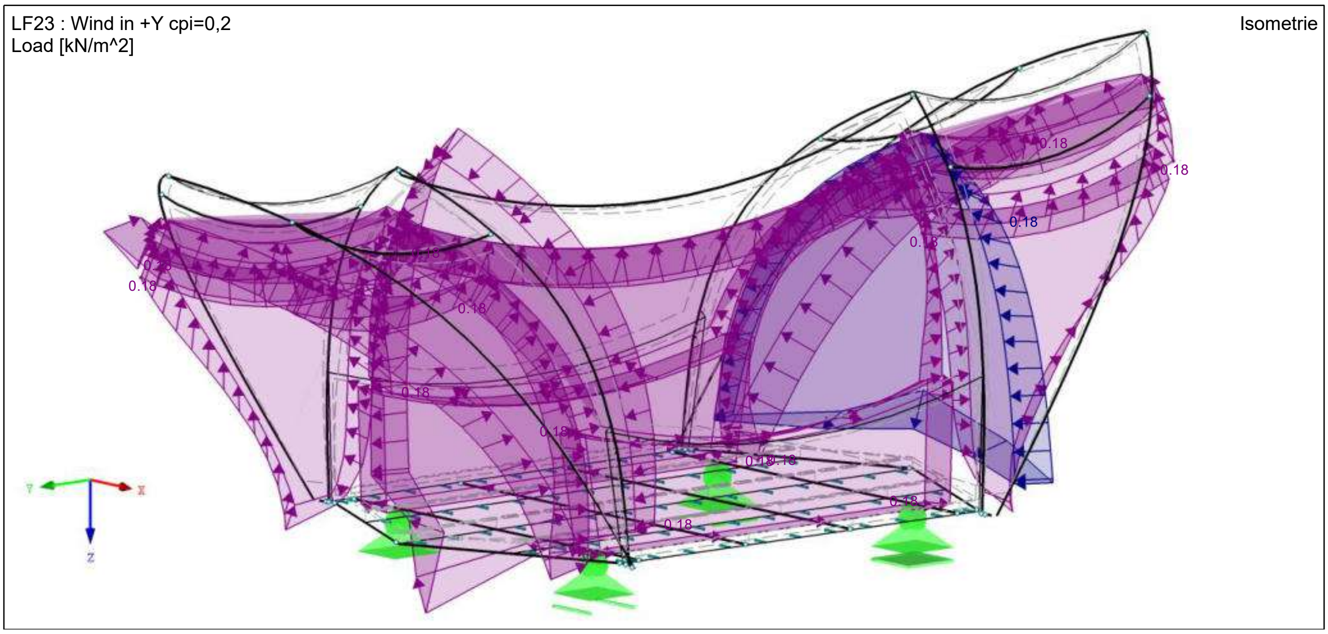
Isometrie



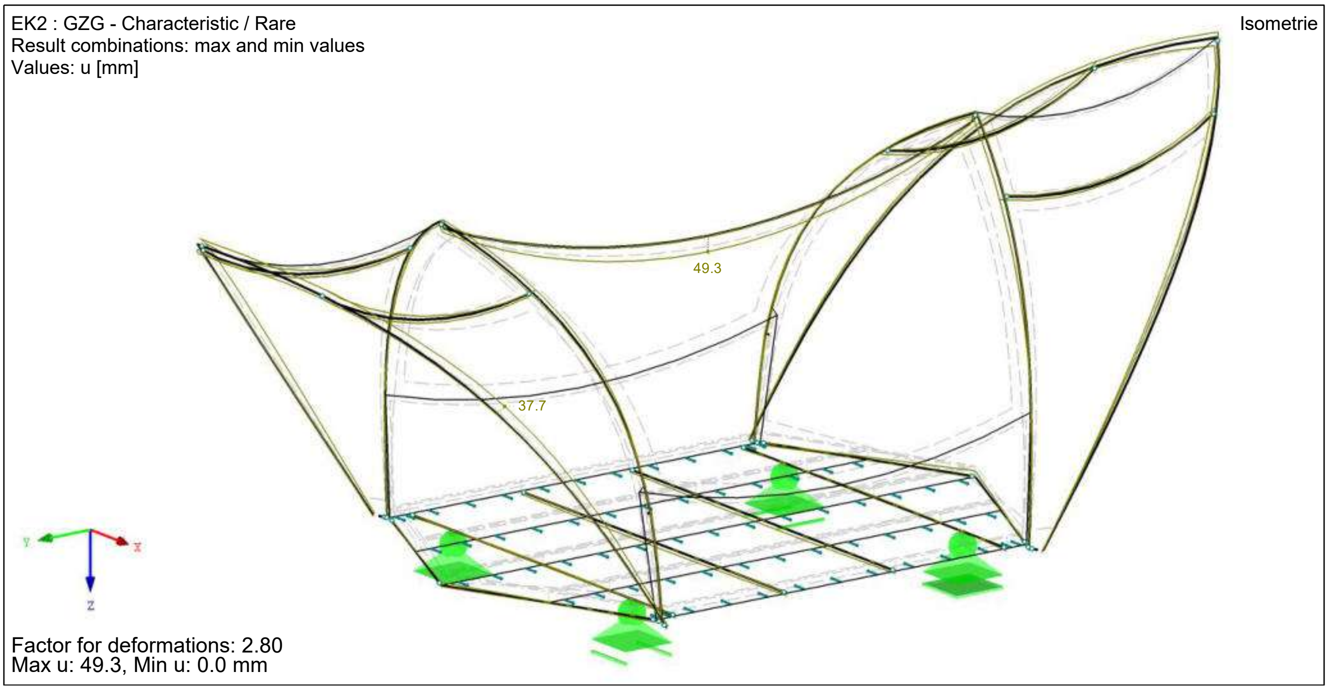
LF22 : Wind in +Y cpi=-0,3
Load [kN/m^2]

Isometrie



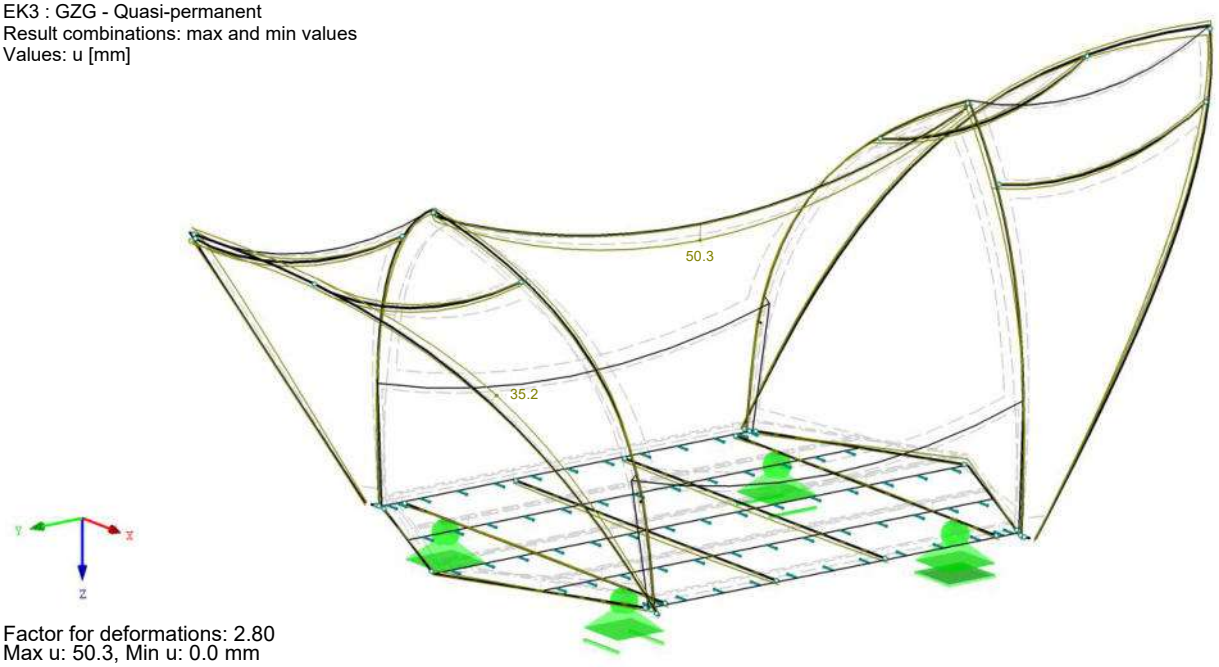


3.1.3 Deformations



EK3 : GZG - Quasi-permanent
Result combinations: max and min values
Values: u [mm]

Isometrie

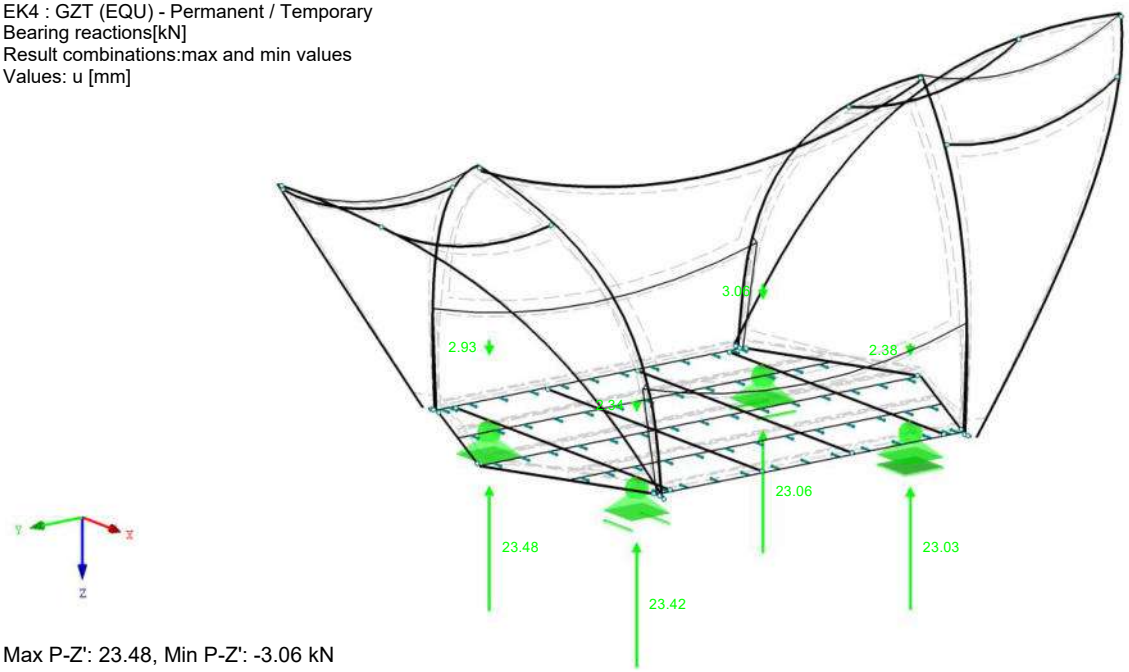


Factor for deformations: 2.80
Max u: 50.3, Min u: 0.0 mm

3.1.4 Support reactions for positional stability

EK4 : GZT (EQU) - Permanent / Temporary
Bearing reactions[kN]
Result combinations:max and min values
Values: u [mm]

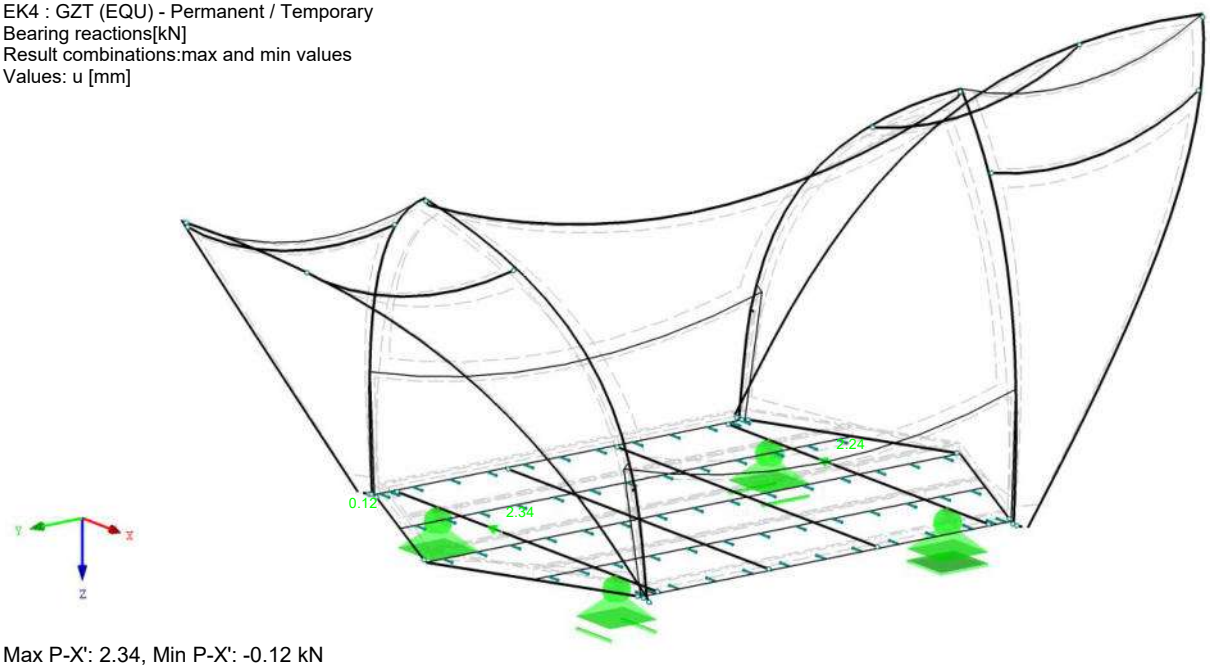
Isometrie



Max P-Z': 23.48, Min P-Z': -3.06 kN

EK4 : GZT (EQU) - Permanent / Temporary
Bearing reactions[kN]
Result combinations:max and min values
Values: u [mm]

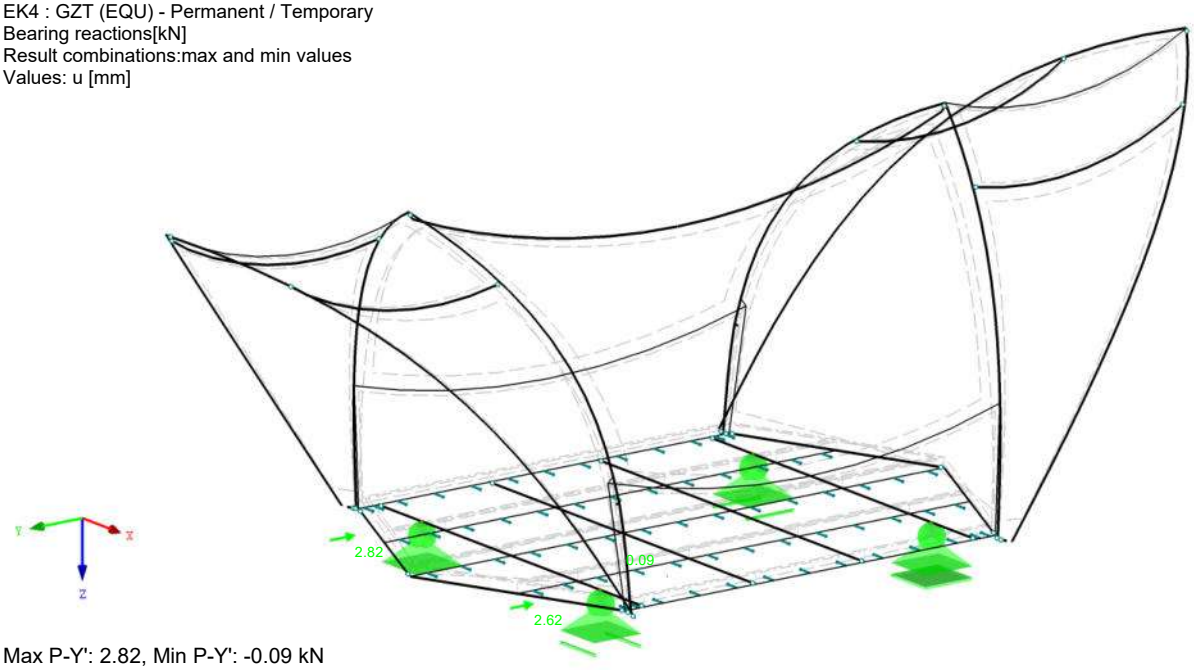
Isometrie



Max P-X': 2.34, Min P-X': -0.12 kN

EK4 : GZT (EQU) - Permanent / Temporary
Bearing reactions[kN]
Result combinations:max and min values
Values: u [mm]

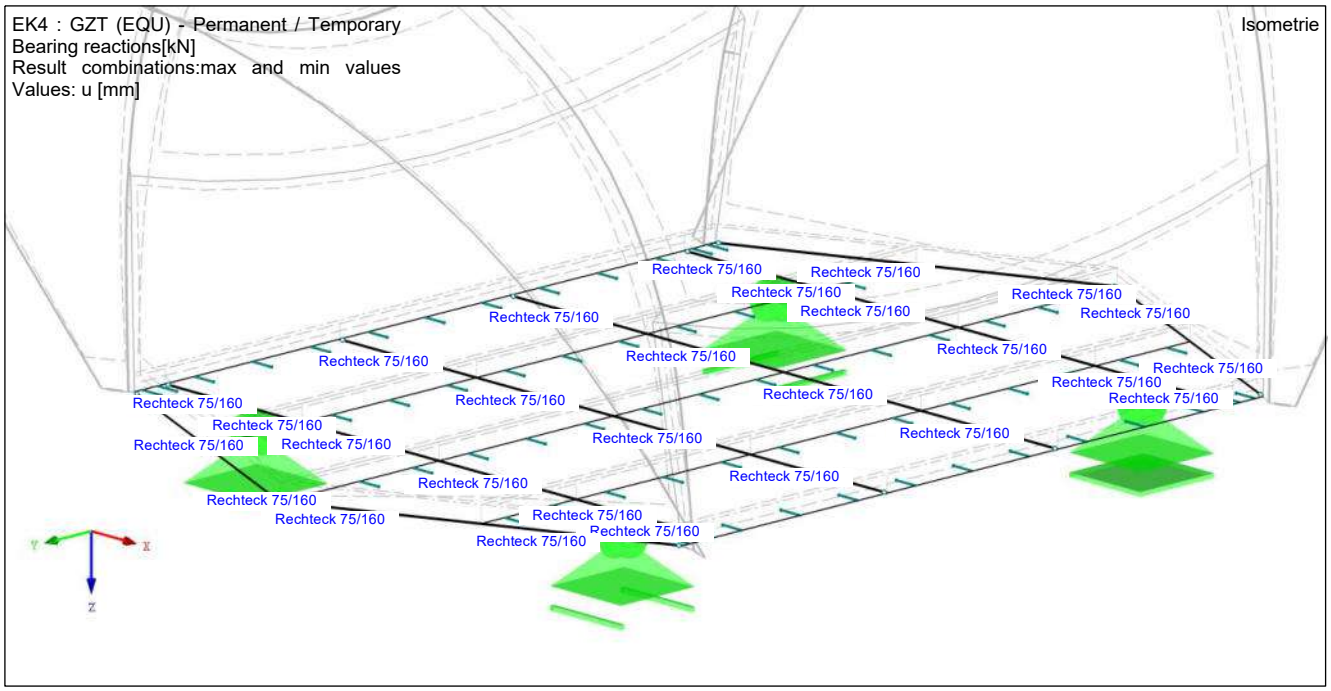
Isometrie



Max P-Y': 2.82, Min P-Y': -0.09 kN

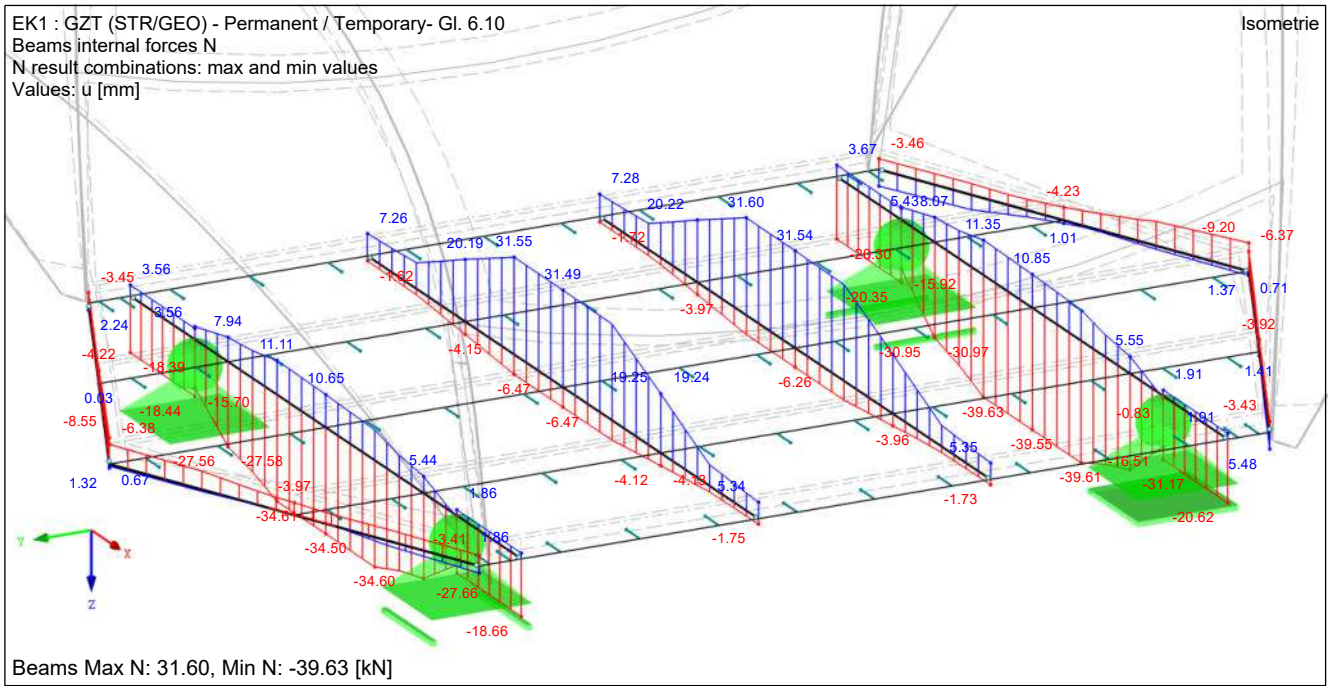
3.2 Terrace construction - Tram ceiling

3.2.1 Cross sections

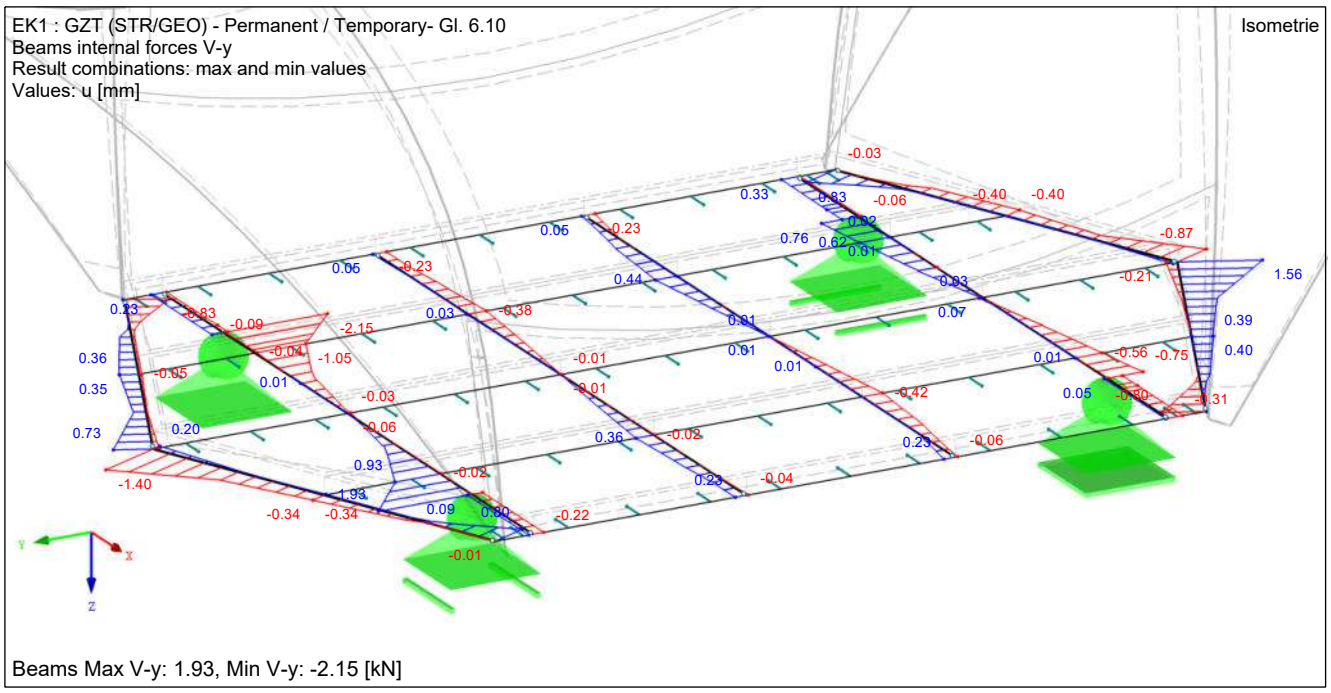


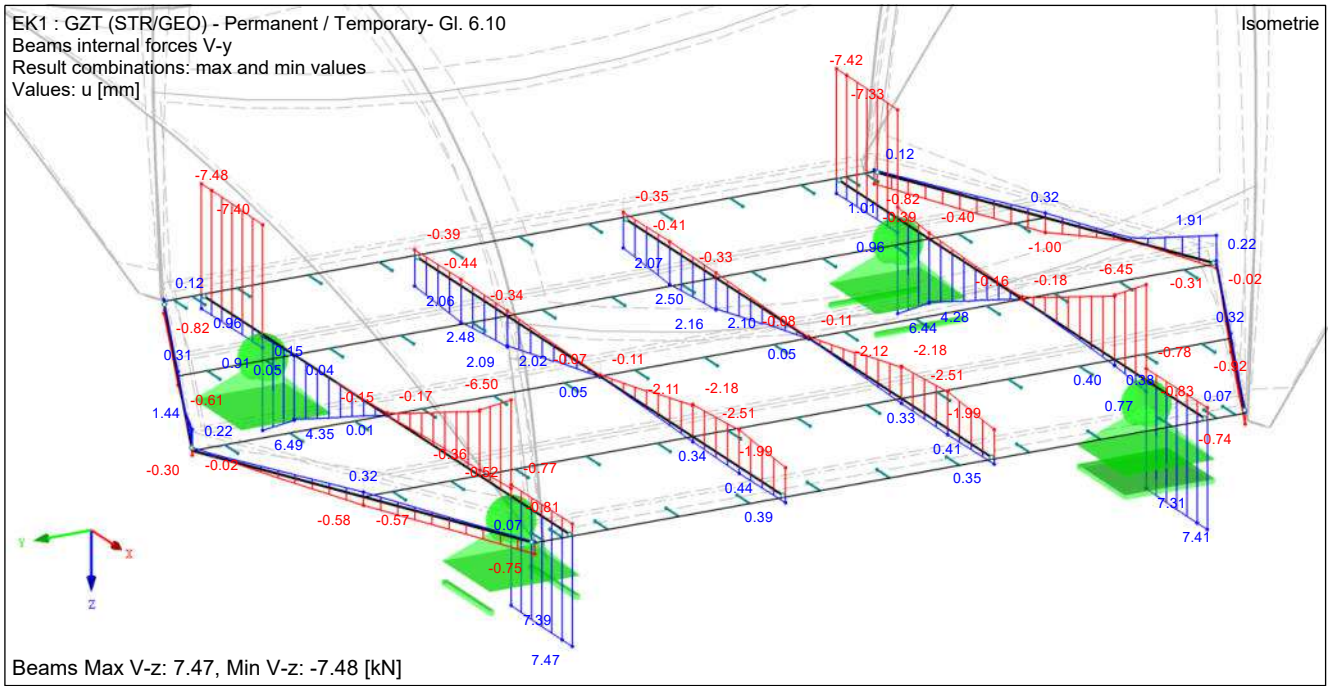
Material: spruce LVL for slice loading

3.2.2 Design section properties



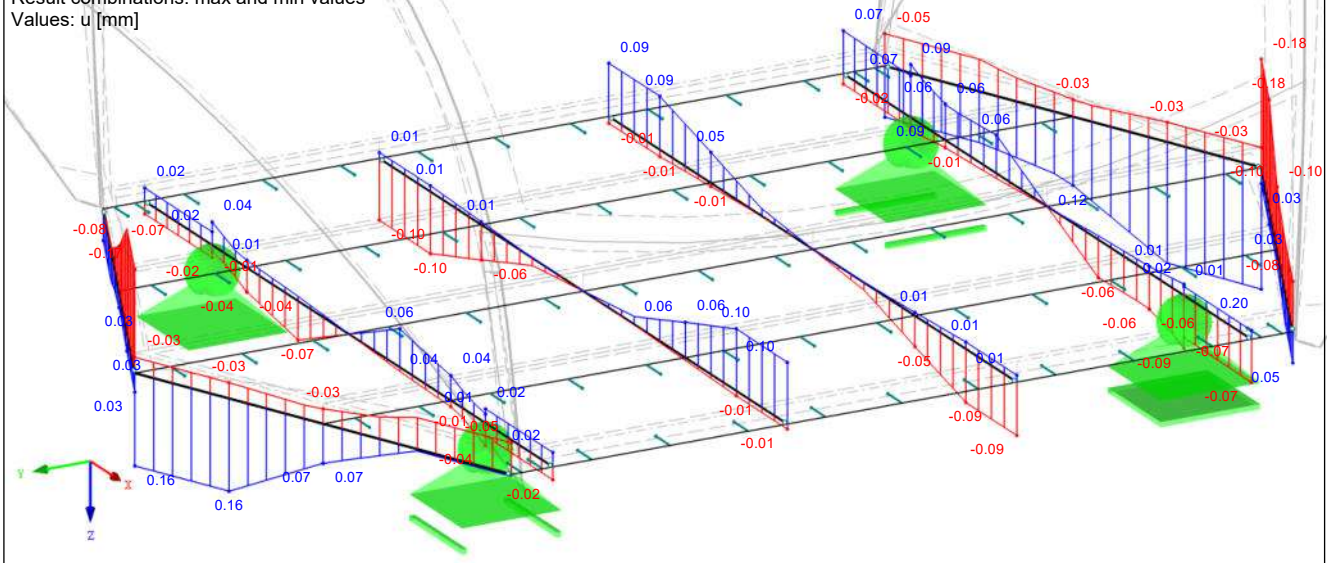
Beams Max N: 31.60, Min N: -39.63 [kN]





EK1 : GZT (STR/GEO) - Permanent / Temporary- Gl. 6.10
Beams internal forces M-T
Result combinations: max and min values
Values: u [mm]

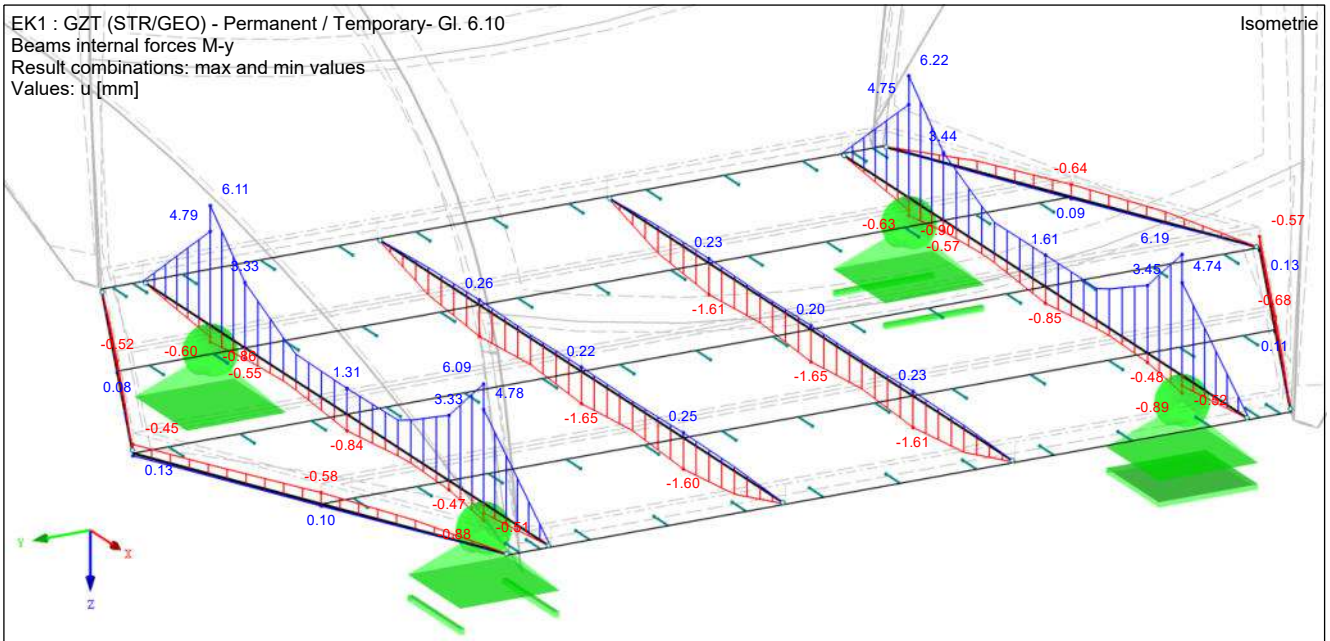
Isometrie



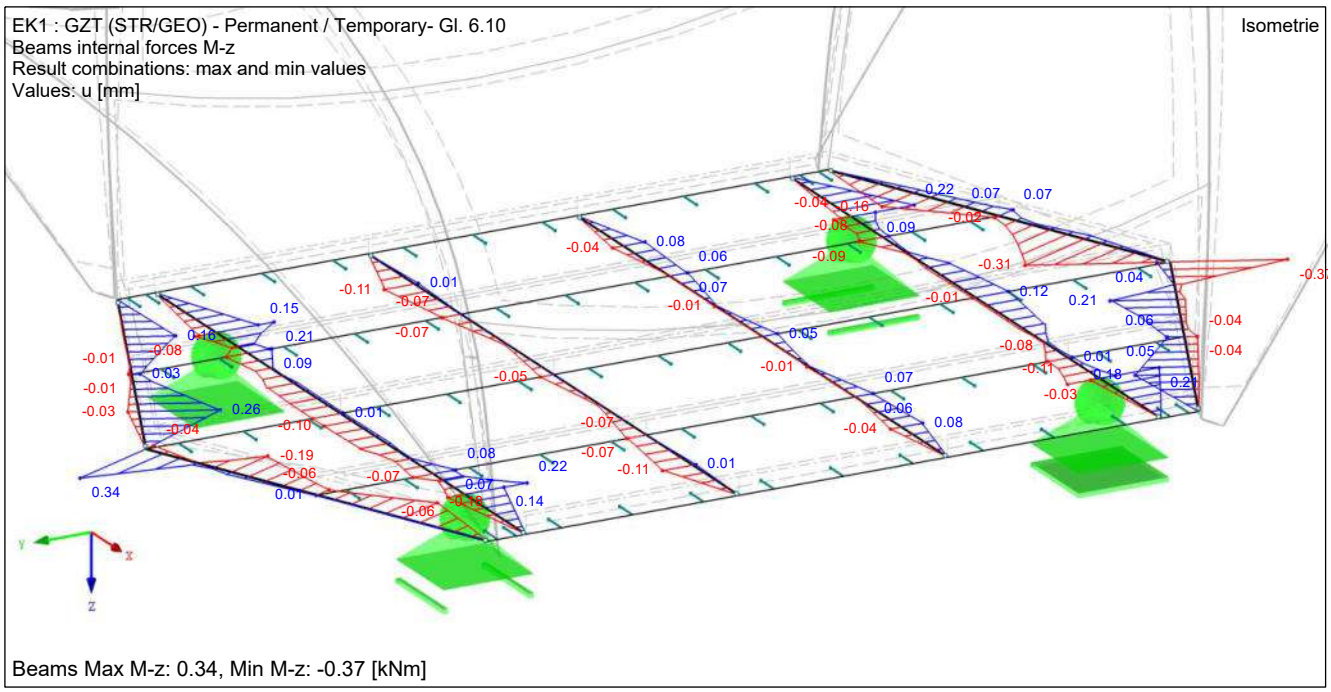
Beams Max M-T: 0.20, Min M-T: -0.18 [kNm]

EK1 : GZT (STR/GEO) - Permanent / Temporary- Gl. 6.10
Beams internal forces M-y
Result combinations: max and min values
Values: u [mm]

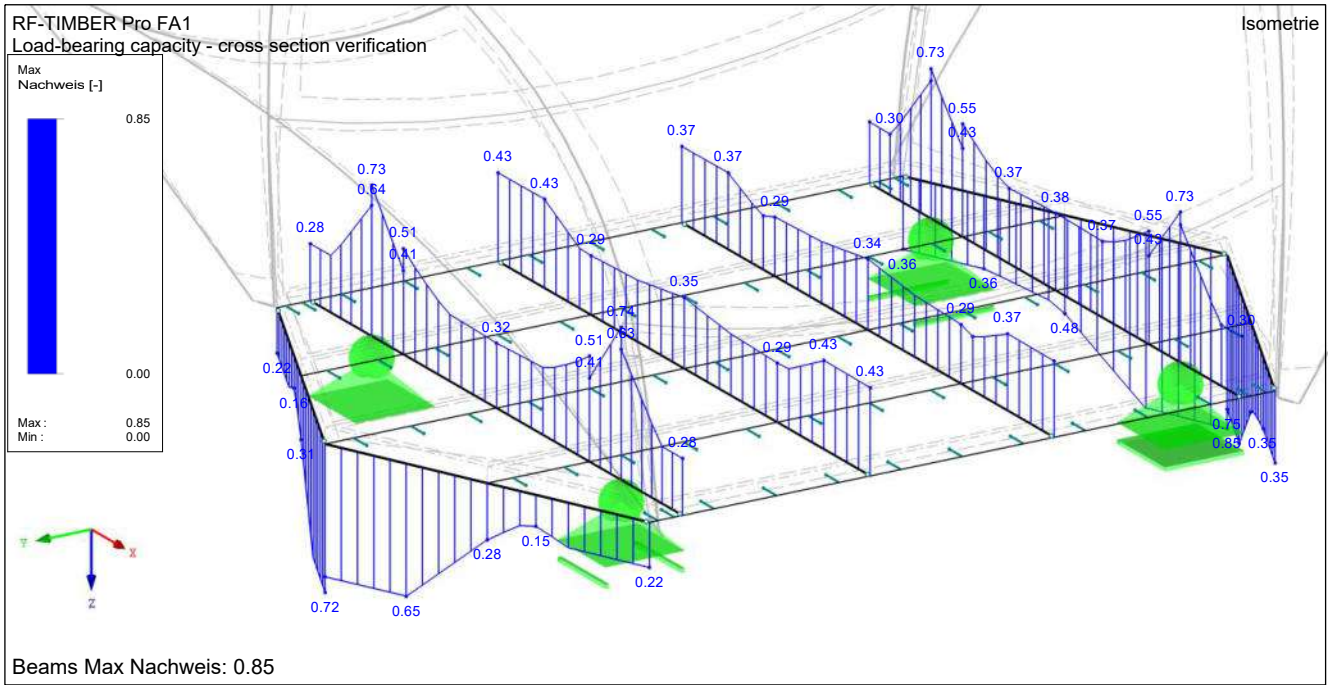
Isometrie



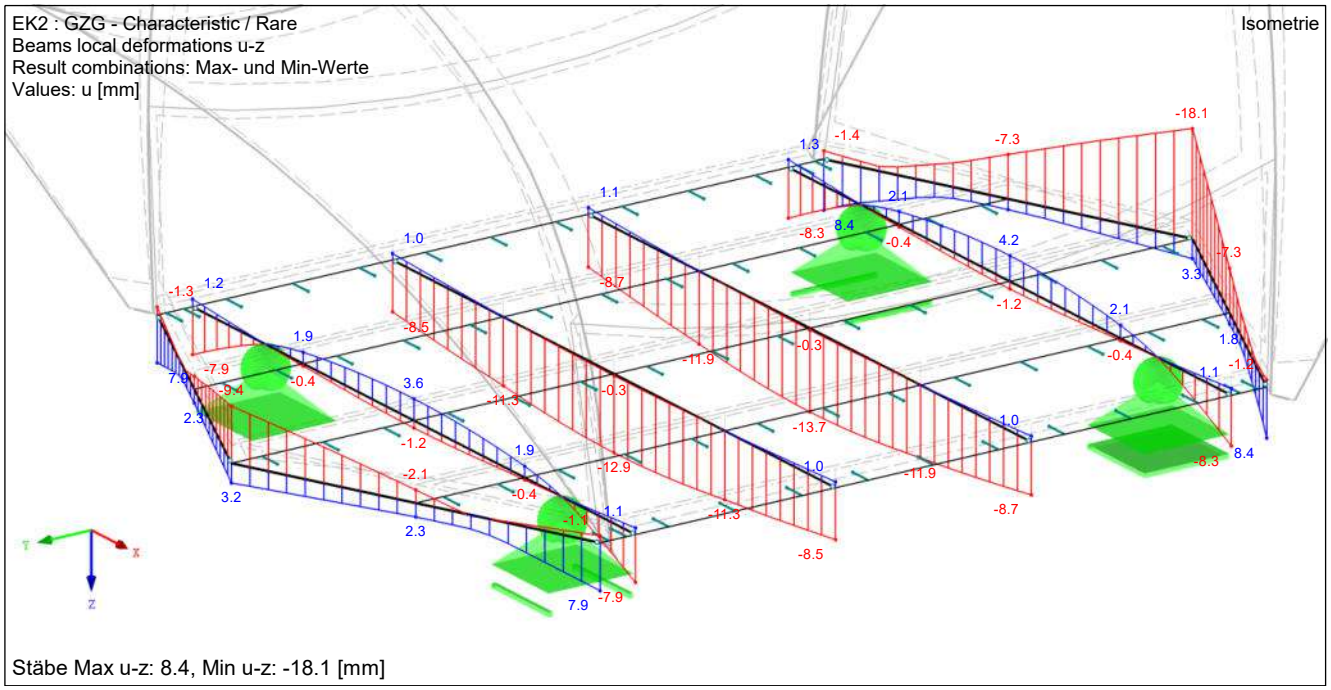
Beams Max M-y: 6.22, Min M-y: -1.65 [kNm]



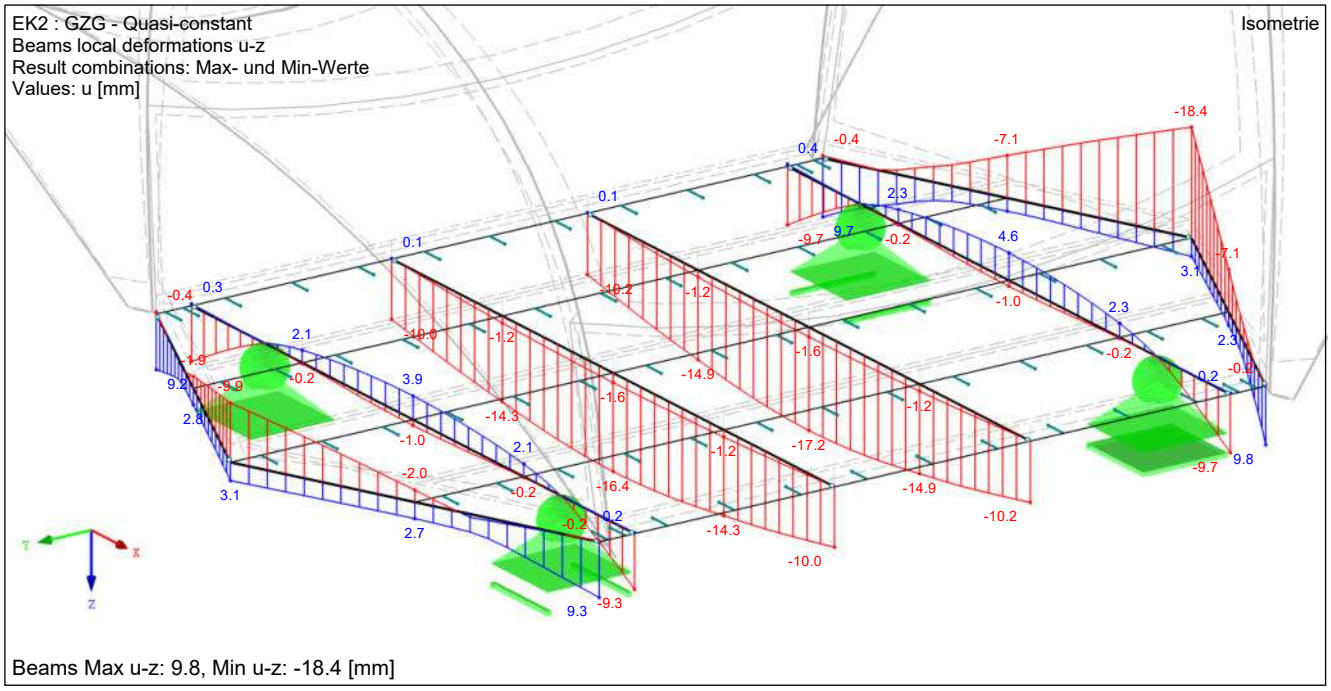
3.2.3 Proof of structural safety



3.2.4 Ceiling deformations



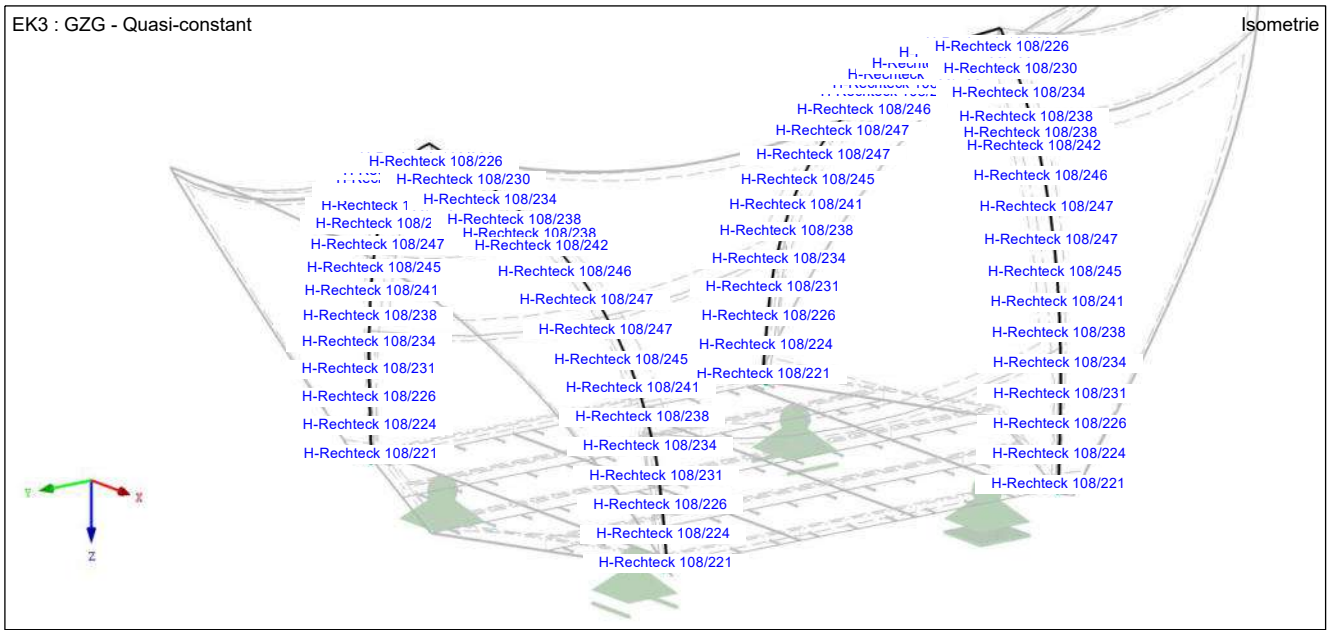
Stäbe Max u-z: 8.4, Min u-z: -18.1 [mm]



Beams Max u-z: 9.8, Min u-z: -18.4 [mm]

3.3 Edge Beam

3.3.1 Cross sections



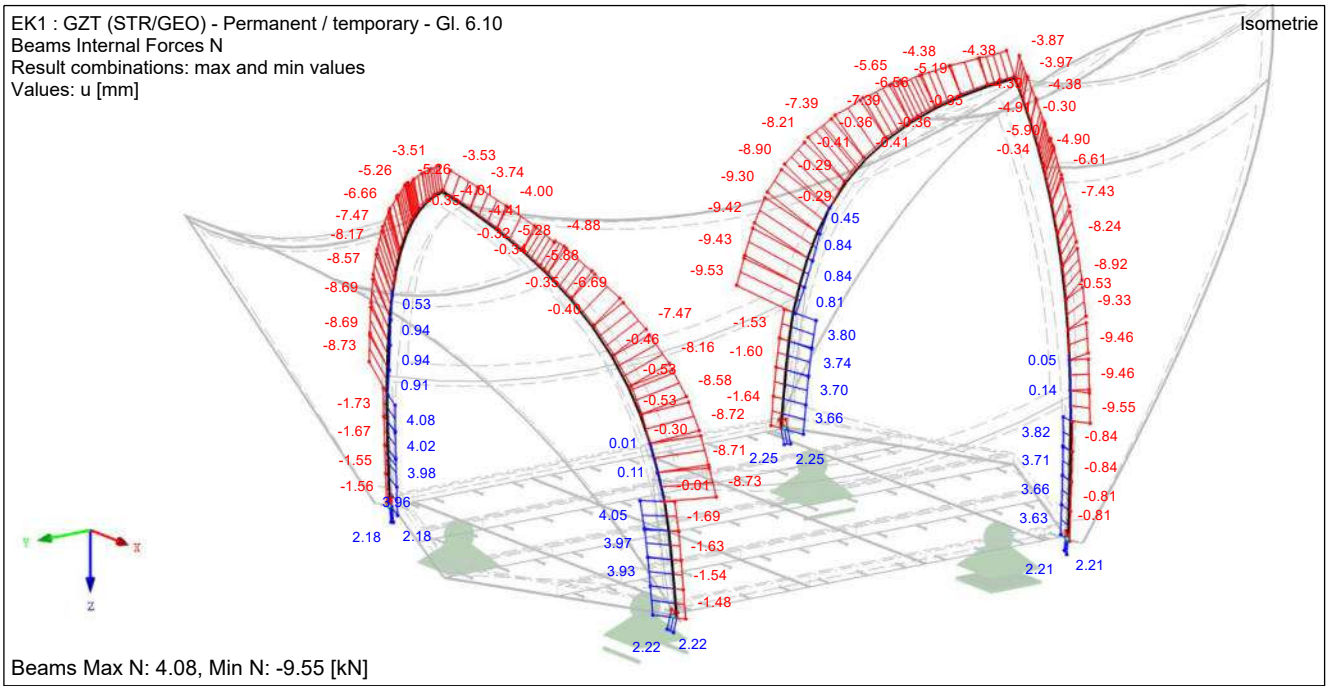
Material: LVL, KERTO-Q

KERTO-Q strength properties with regard to the force fiber angle

Edge Beam (1st segment = at ridge)															
	Faserwinkel		$E_{\alpha,mean}$		$f_{m,\alpha,k}$		$f_{t,\alpha,k}$		$f_{c,\alpha,k}$		$f_{v,0,k}$			
1. Segment	33,96	°	1436,4	N/mm²	7,58	N/mm²	6,16	N/mm²	8,41	N/mm²	4,50	N/mm²		
2. Segment	30,60	°	1554,0	N/mm²	7,94	N/mm²	6,45	N/mm²	9,00	N/mm²	4,50	N/mm²		
3. Segment	27,09	°	2084,3	N/mm²	8,93	N/mm²	7,26	N/mm²	9,86	N/mm²	4,50	N/mm²		
4. Segment	22,96	°	2807,0	N/mm²	10,25	N/mm²	8,33	N/mm²	10,93	N/mm²	4,50	N/mm²		
5. Segment	18,11	°	3655,8	N/mm²	11,80	N/mm²	9,59	N/mm²	12,19	N/mm²	4,50	N/mm²		
6. Segment	12,50	°	5250,0	N/mm²	15,20	N/mm²	14,30	N/mm²	15,60	N/mm²	4,50	N/mm²		
7. Segment	6,19	°	7900,2	N/mm²	22,48	N/mm²	22,16	N/mm²	22,16	N/mm²	4,50	N/mm²		
8. Segment	0,50	°	10290,0	N/mm²	31,36	N/mm²	26,00	N/mm²	26,00	N/mm²	4,50	N/mm²		
9. Segment	6,74	°	7669,2	N/mm²	21,77	N/mm²	21,59	N/mm²	21,59	N/mm²	4,50	N/mm²		
10. Segment	12,25	°	5355,0	N/mm²	19,52	N/mm²	14,69	N/mm²	15,86	N/mm²	4,50	N/mm²		
11. Segment	17,16	°	3822,0	N/mm²	14,85	N/mm²	9,84	N/mm²	12,44	N/mm²	4,50	N/mm²		
12. Segment	20,97	°	3155,3	N/mm²	12,82	N/mm²	8,85	N/mm²	11,45	N/mm²	4,50	N/mm²		
13. Segment	24,75	°	2493,8	N/mm²	10,80	N/mm²	7,87	N/mm²	10,47	N/mm²	4,50	N/mm²		
14. Segment	28,33	°	1867,3	N/mm²	8,89	N/mm²	6,93	N/mm²	9,53	N/mm²	4,50	N/mm²		
15. Segment	30,80	°	1547,0	N/mm²	7,91	N/mm²	6,43	N/mm²	8,96	N/mm²	4,50	N/mm²		
16. Segment	31,86	°	1509,9	N/mm²	7,80	N/mm²	6,34	N/mm²	8,78	N/mm²	4,50	N/mm²		

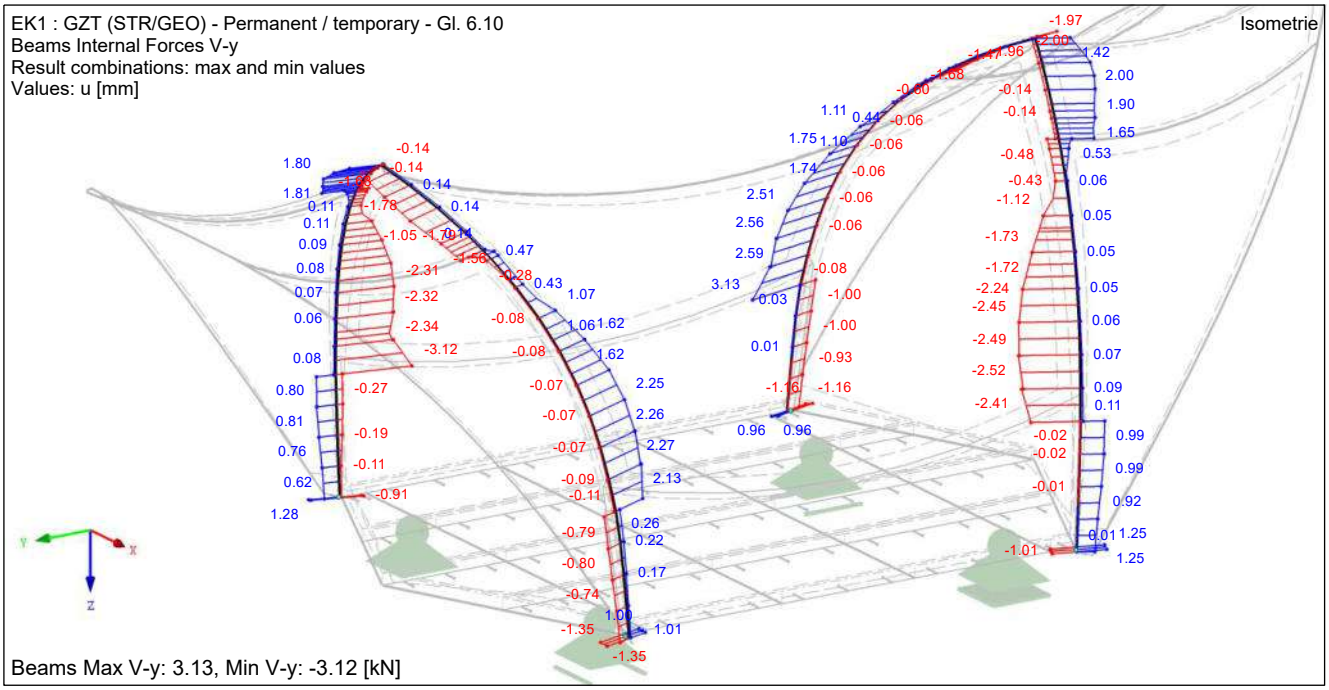
3.3.2 Design sections properties

EK1 : GZT (STR/GEO) - Permanent / temporary - Gl. 6.10
Beams Internal Forces N
Result combinations: max and min values
Values: u [mm]



Beams Max N: 4.08, Min N: -9.55 [kN]

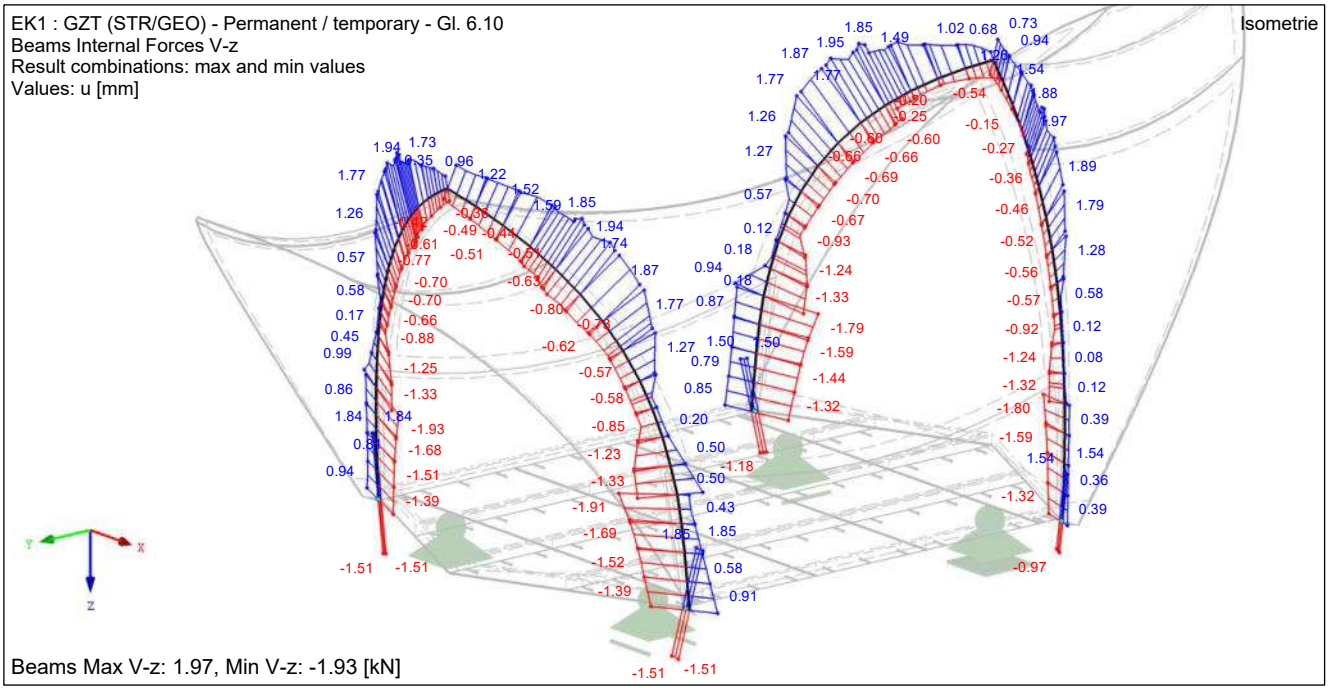
EK1 : GZT (STR/GEO) - Permanent / temporary - Gl. 6.10
Beams Internal Forces V-y
Result combinations: max and min values
Values: u [mm]



Beams Max V-y: 3.13, Min V-y: -3.12 [kN]

EK1 : GZT (STR/GEO) - Permanent / temporary - Gl. 6.10
Beams Internal Forces V-z
Result combinations: max and min values
Values: u [mm]

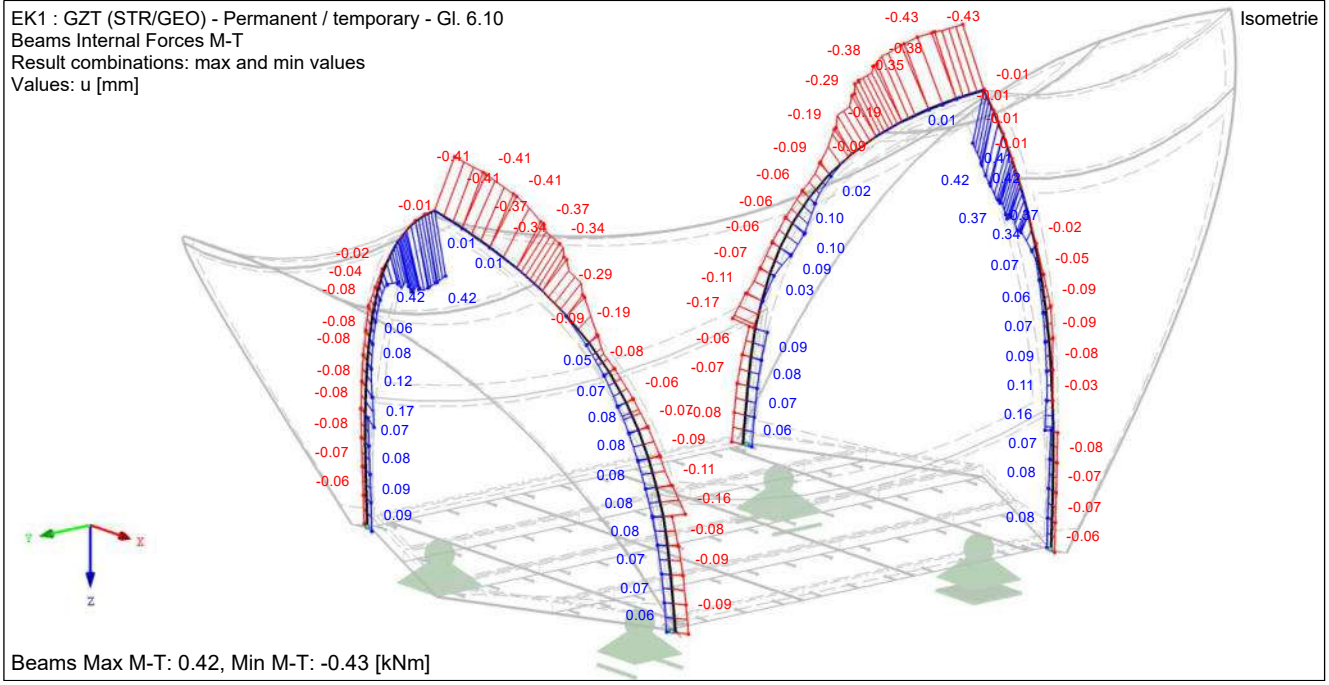
Isometrie



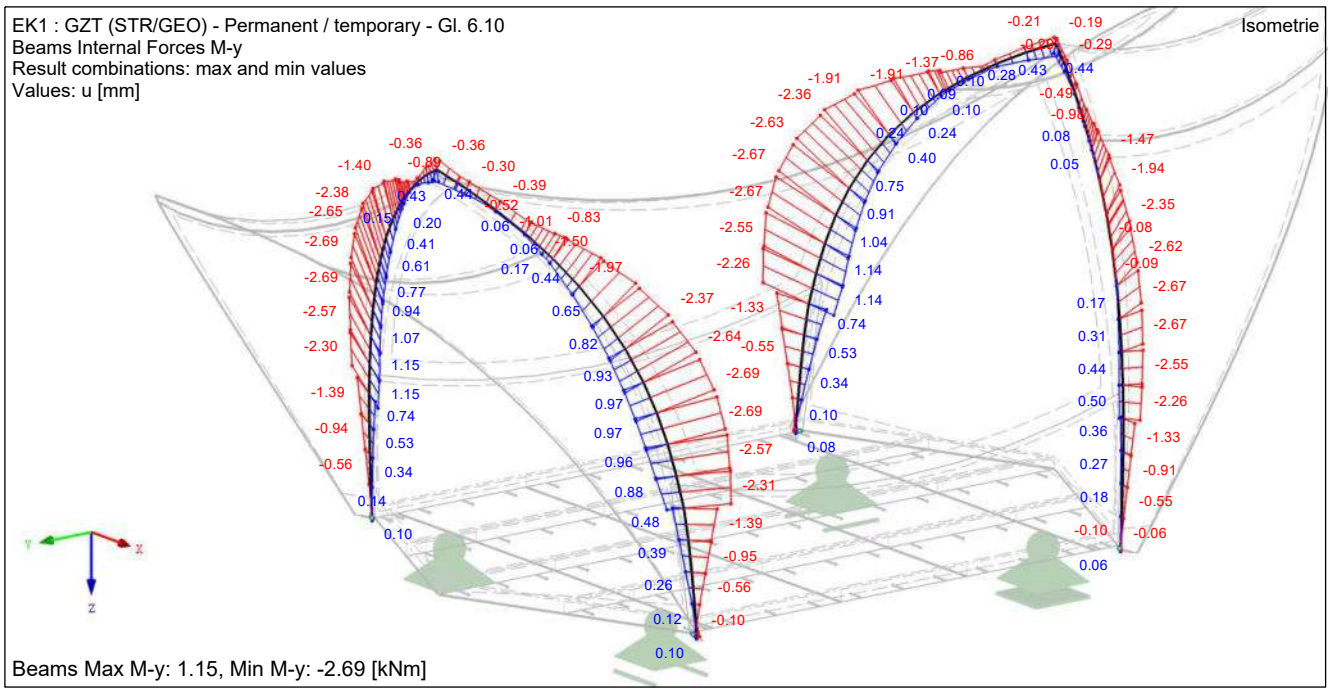
Beams Max V-z: 1.97, Min V-z: -1.93 [kN]

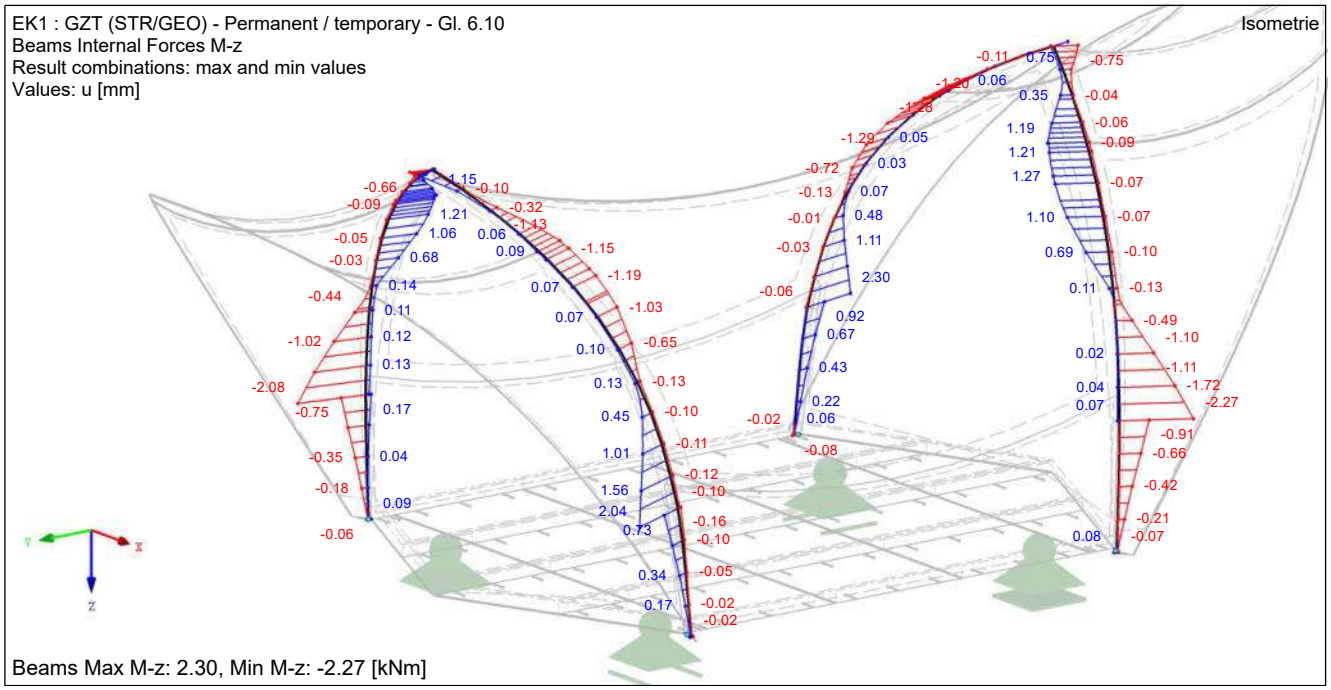
EK1 : GZT (STR/GEO) - Permanent / temporary - Gl. 6.10
Beams Internal Forces M-T
Result combinations: max and min values
Values: u [mm]

Isometrie



Beams Max M-T: 0.42, Min M-T: -0.43 [kNm]





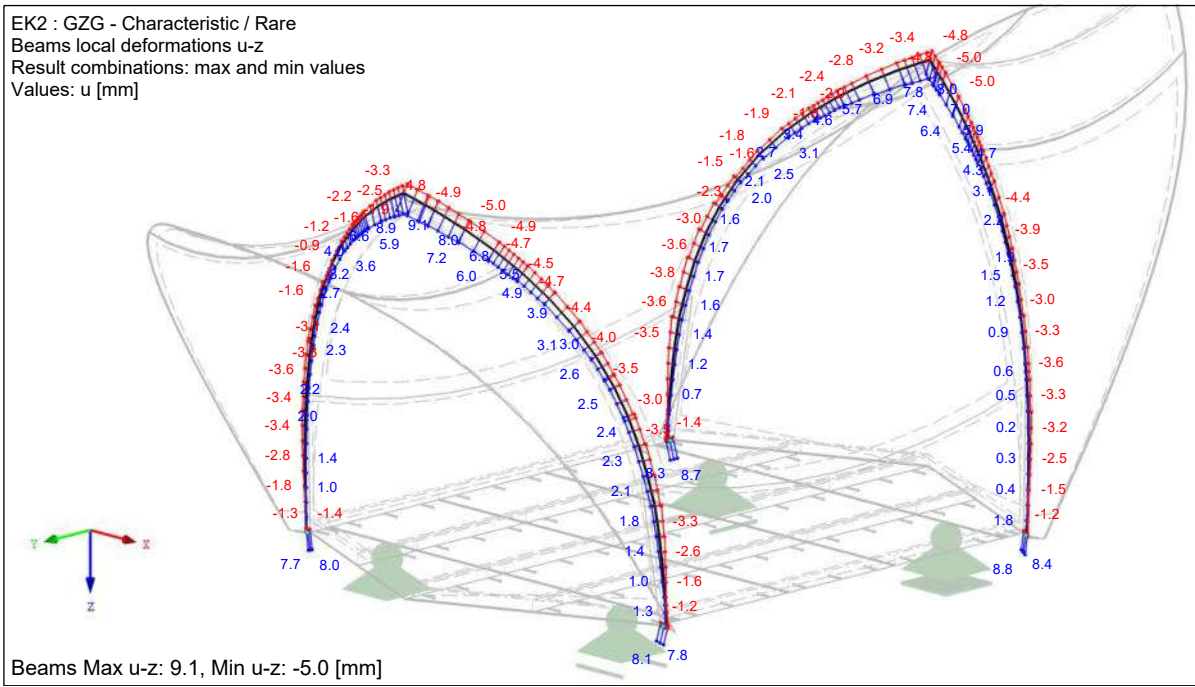
3.3.3 Proof of structural safety

The lower loads due to the temporary use do not require the verification of the load-bearing capacity, as this is not necessary for the lounge with canopy with increased loads.

3.3.4 Deformations

EK2 : GZG - Characteristic / Rare
Beams local deformations u-z
Result combinations: max and min values
Values: u [mm]

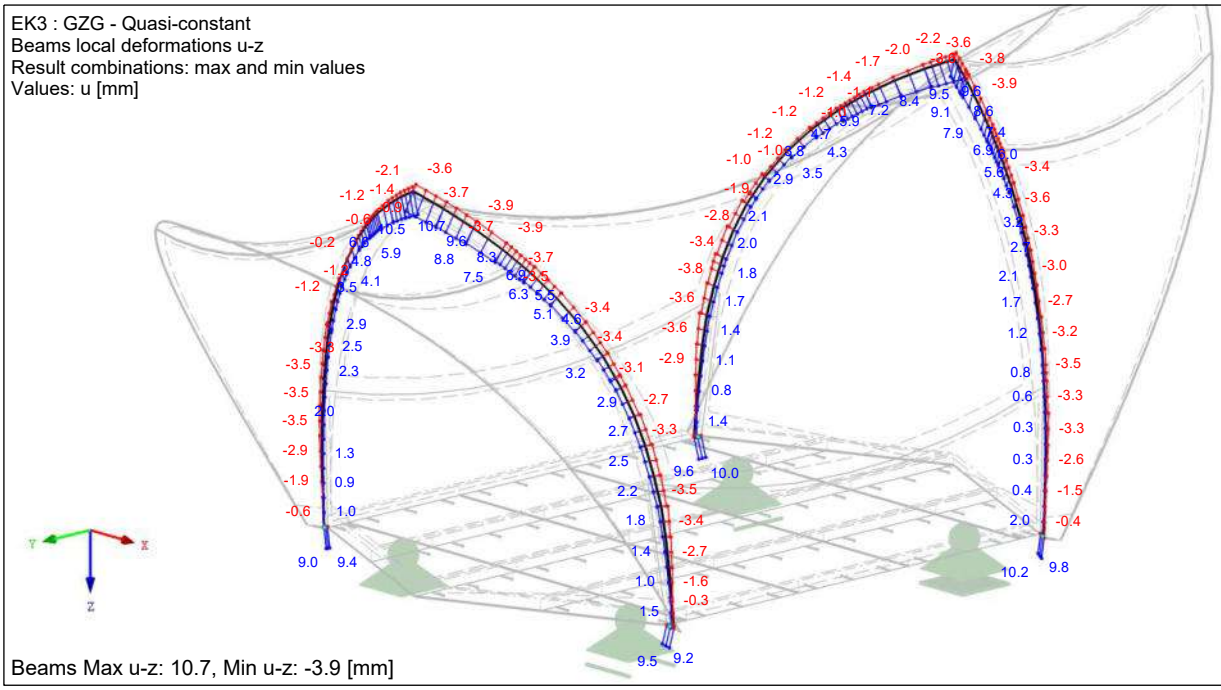
Isometrie



Beams Max u-z: 9.1, Min u-z: -5.0 [mm]

EK3 : GZG - Quasi-constant
Beams local deformations u-z
Result combinations: max and min values
Values: u [mm]

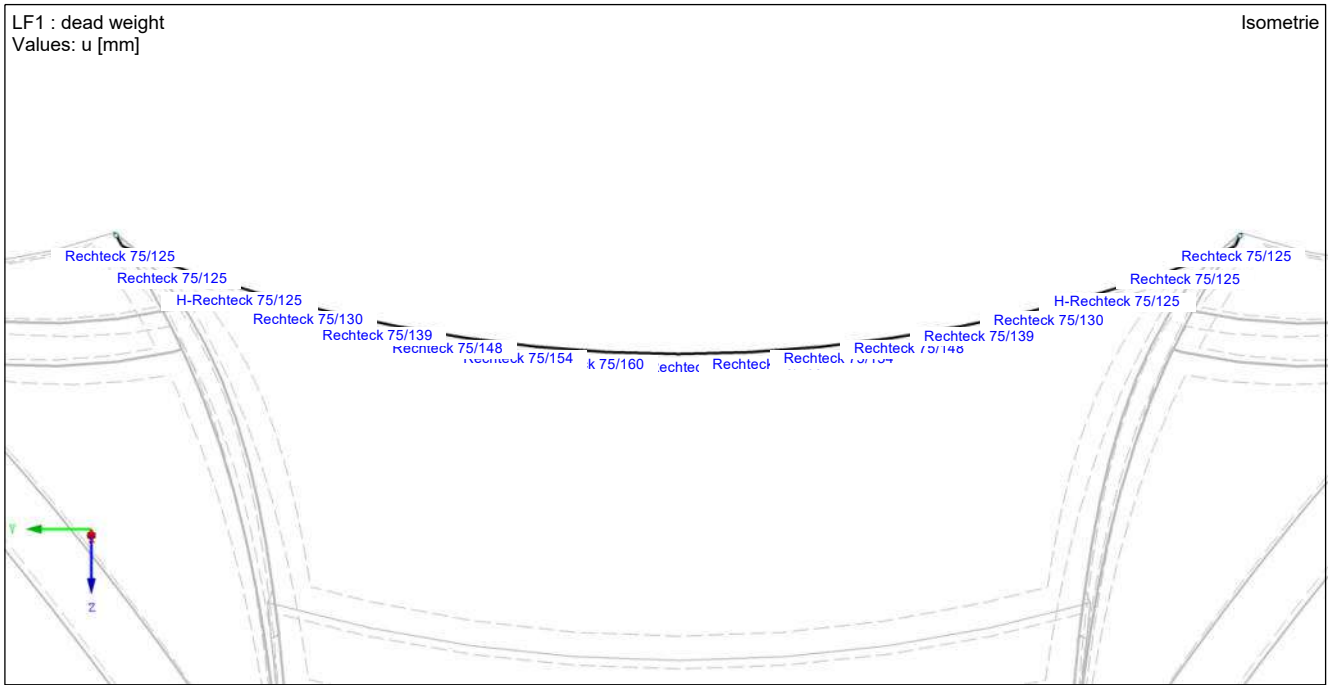
Isometrie



Beams Max u-z: 10.7, Min u-z: -3.9 [mm]

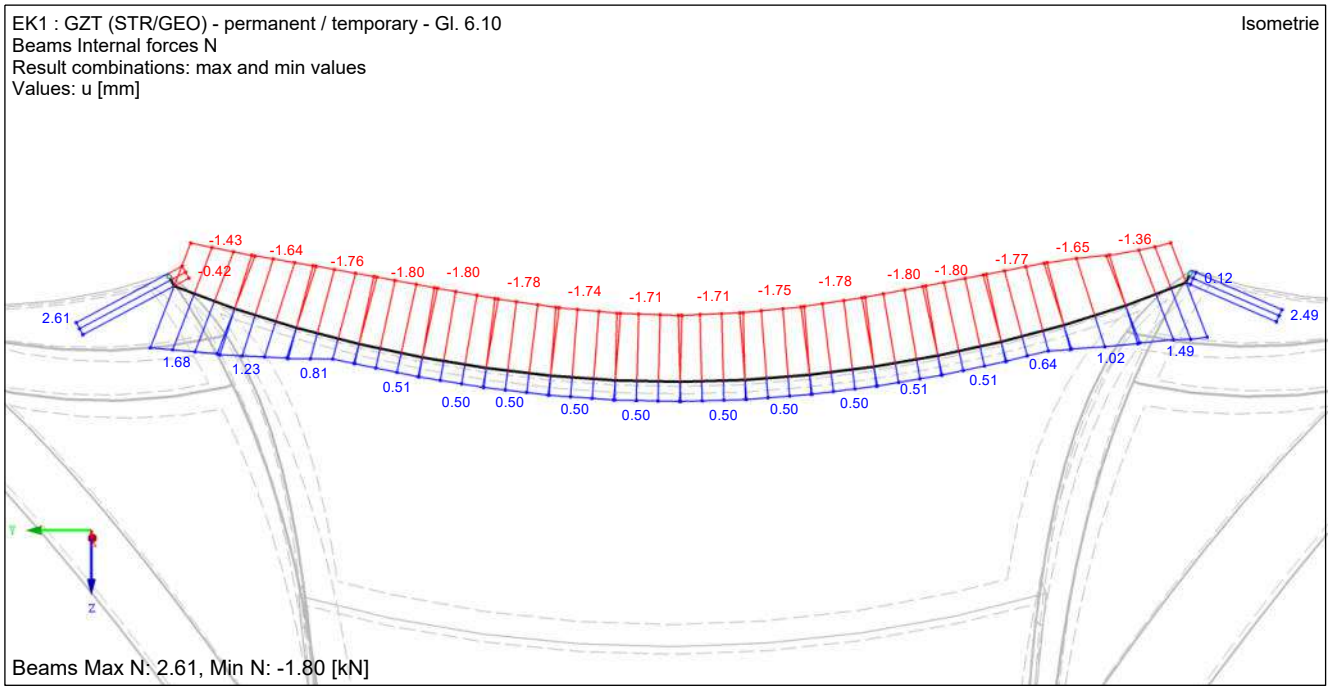
3.4 Ridge Beam

3.4.1 Cross sections



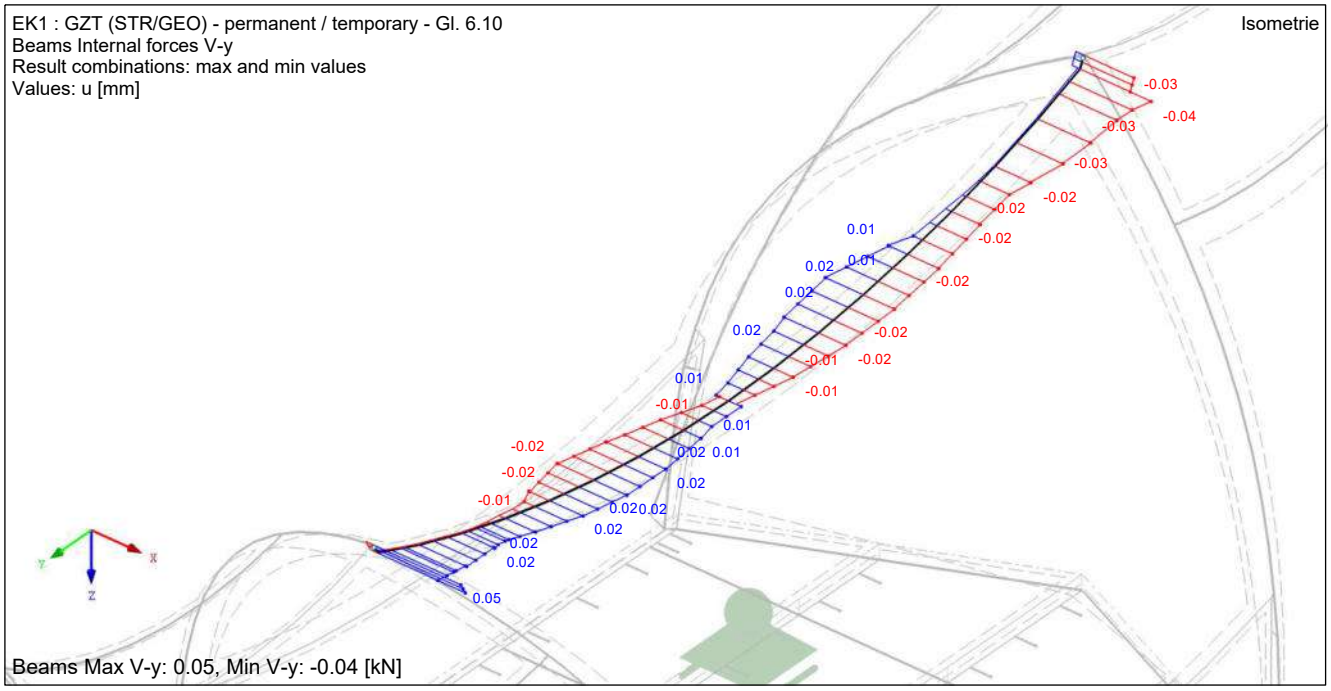
Material: BSH, GL24h

3.4.2 Design Internal forces



EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces V-y
Result combinations: max and min values
Values: u [mm]

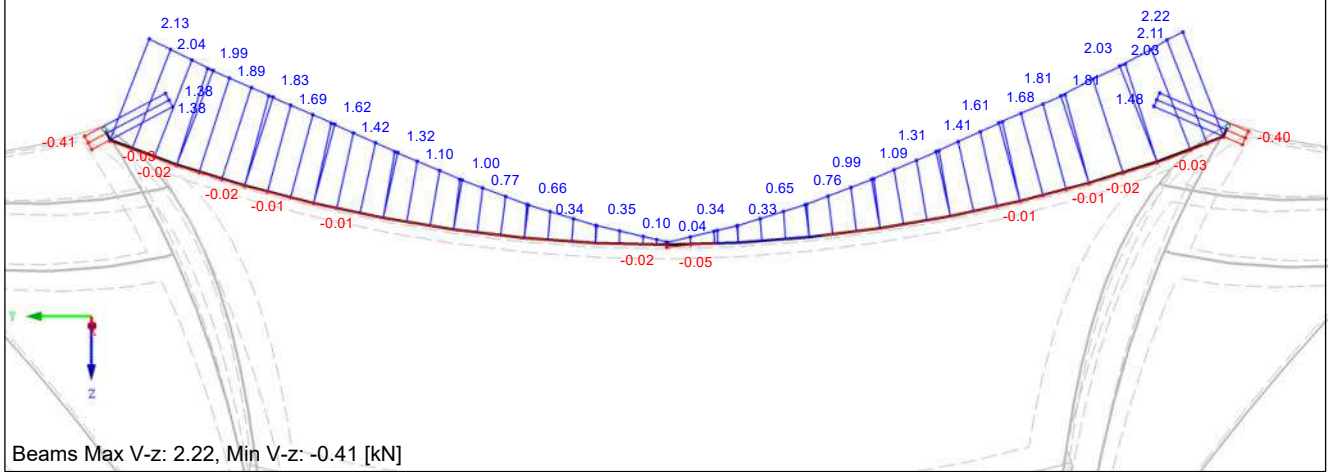
Isometrie



Beams Max V-y: 0.05, Min V-y: -0.04 [kN]

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces V-z
Result combinations: max and min values
Values: u [mm]

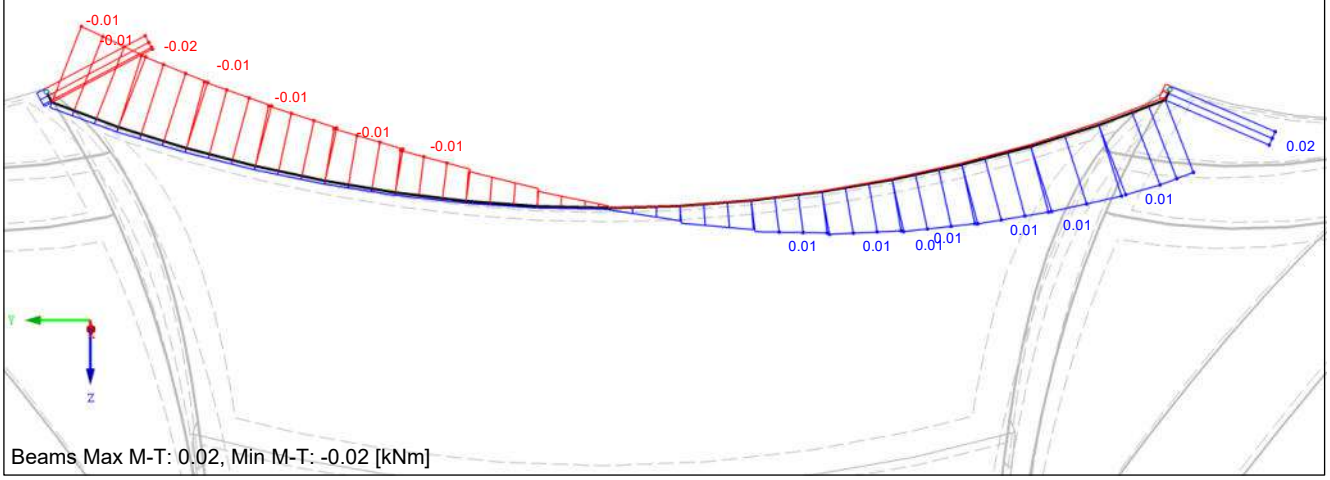
Isometrie



Beams Max V-z: 2.22, Min V-z: -0.41 [kN]

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-T
Result combinations: max and min values
Values: u [mm]

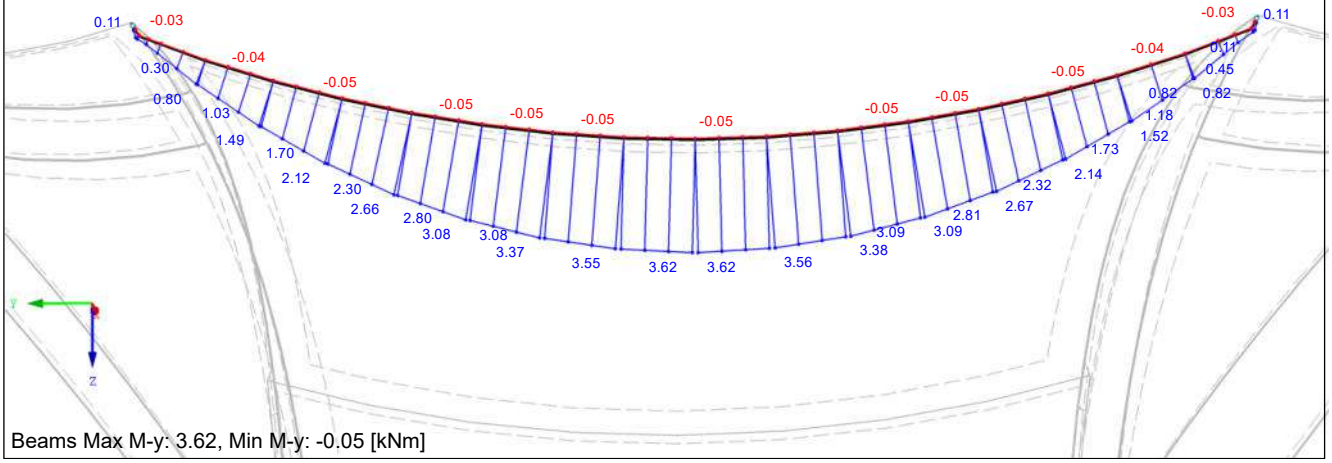
Isometrie



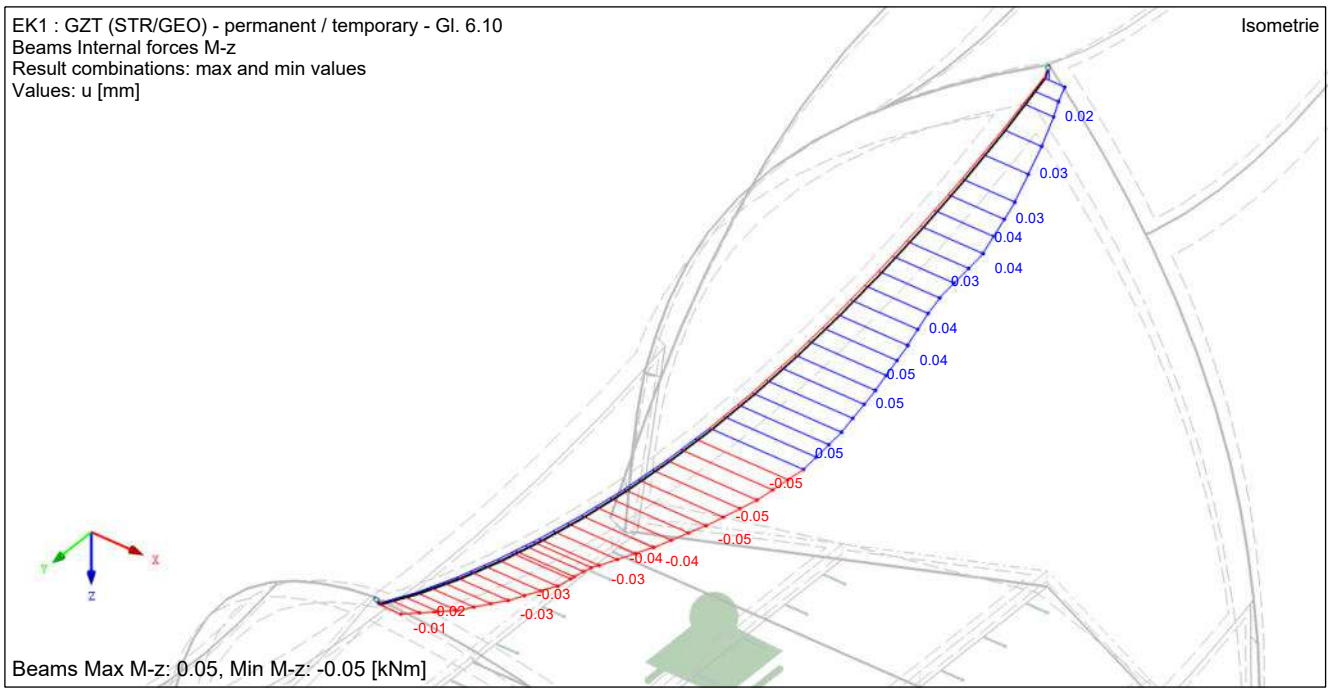
Beams Max M-T: 0.02, Min M-T: -0.02 [kNm]

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-y
Result combinations: max and min values
Values: u [mm]

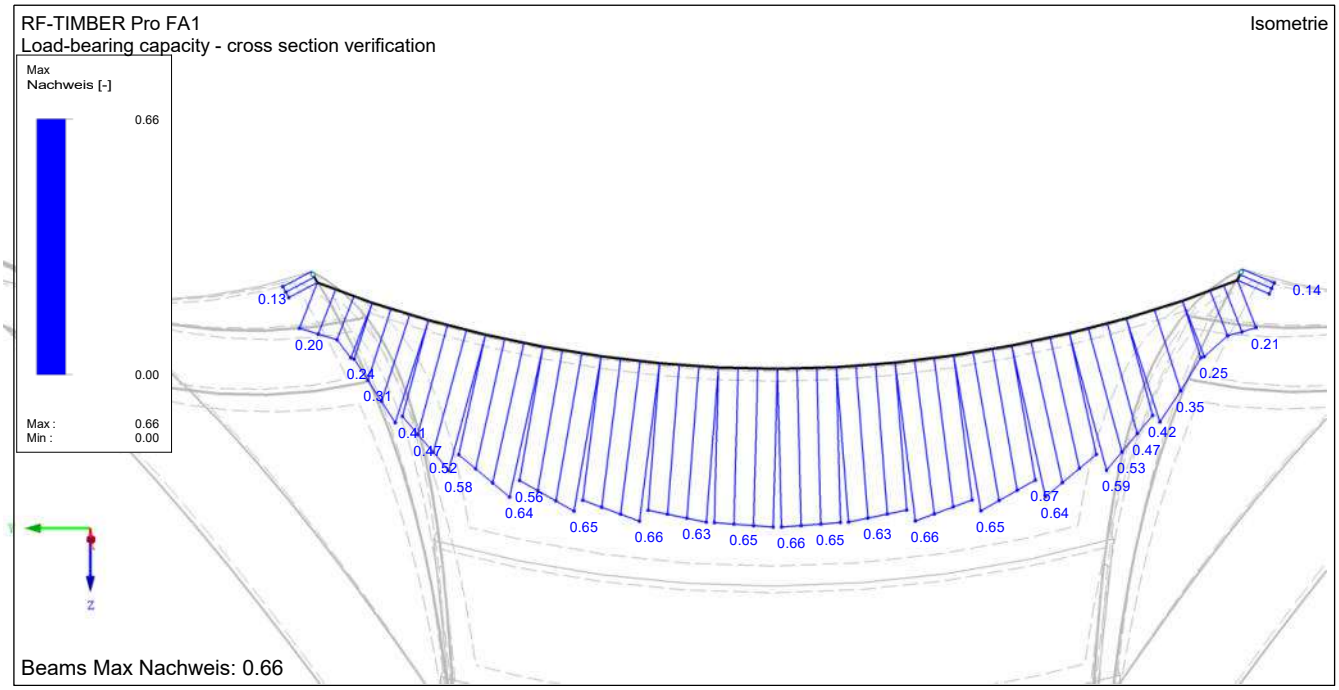
Isometrie



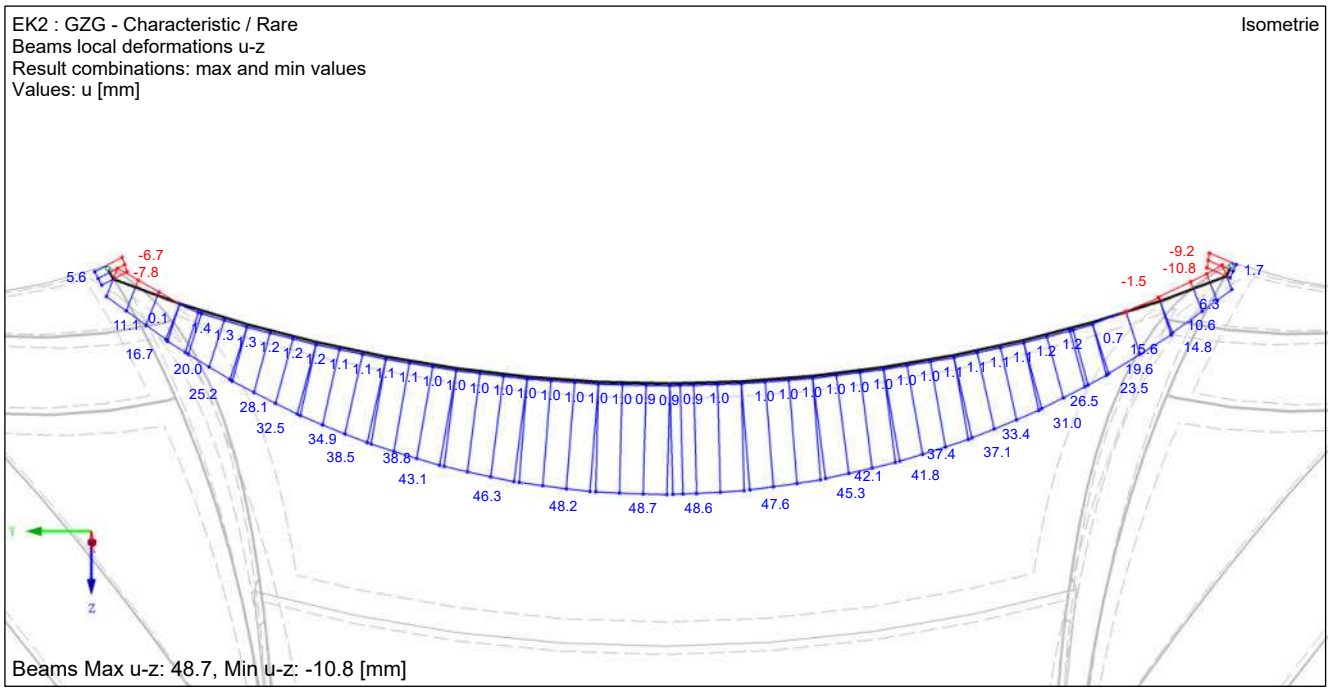
Beams Max M-y: 3.62, Min M-y: -0.05 [kNm]



3.4.3 Proof of structural safety

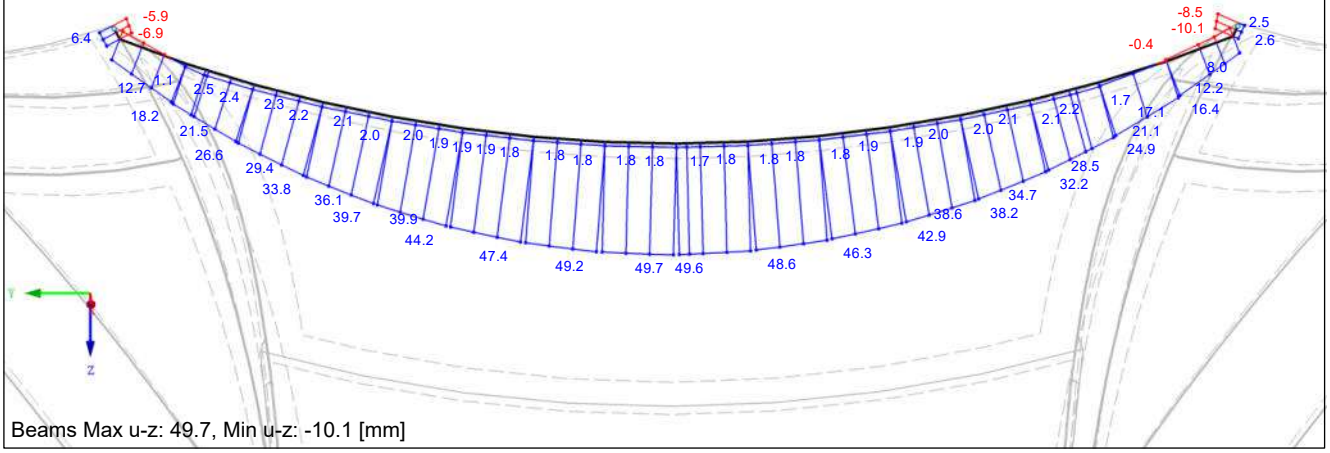


3.4.4 Deformations



EK3 : GZG - quasi-constant
Beams local deformations u-z
Result combinations: max and min values
Values: u [mm]

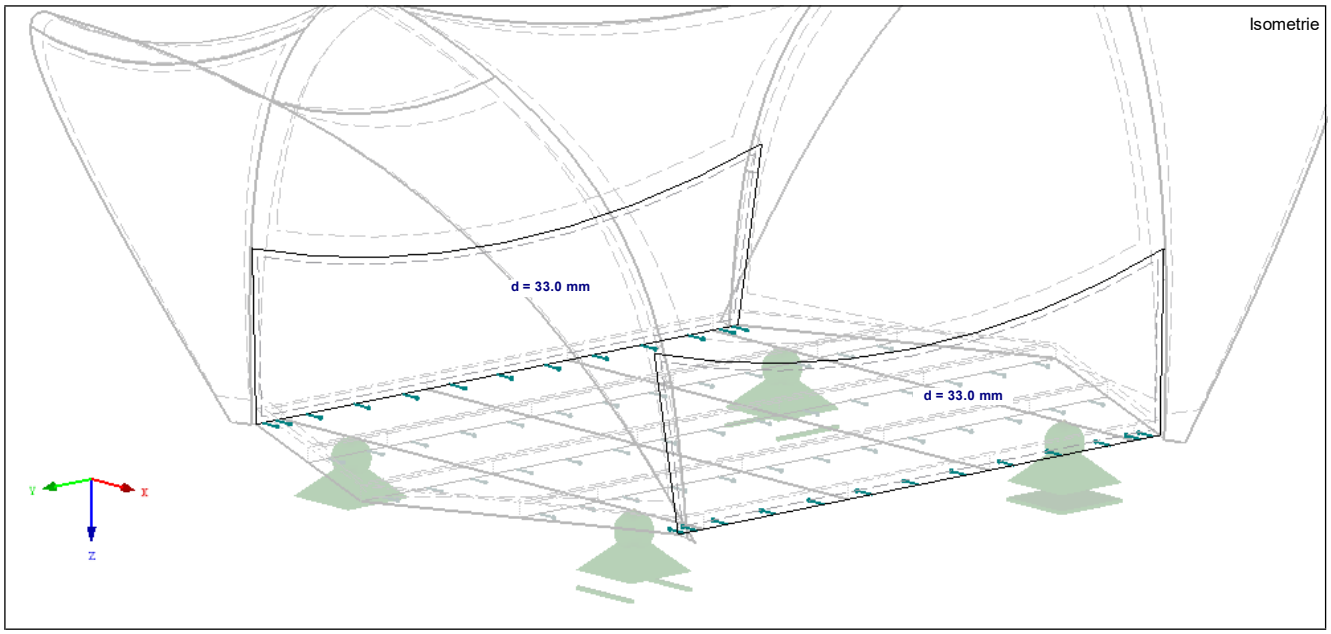
Isometrie



Beams Max u-z: 49.7, Min u-z: -10.1 [mm]

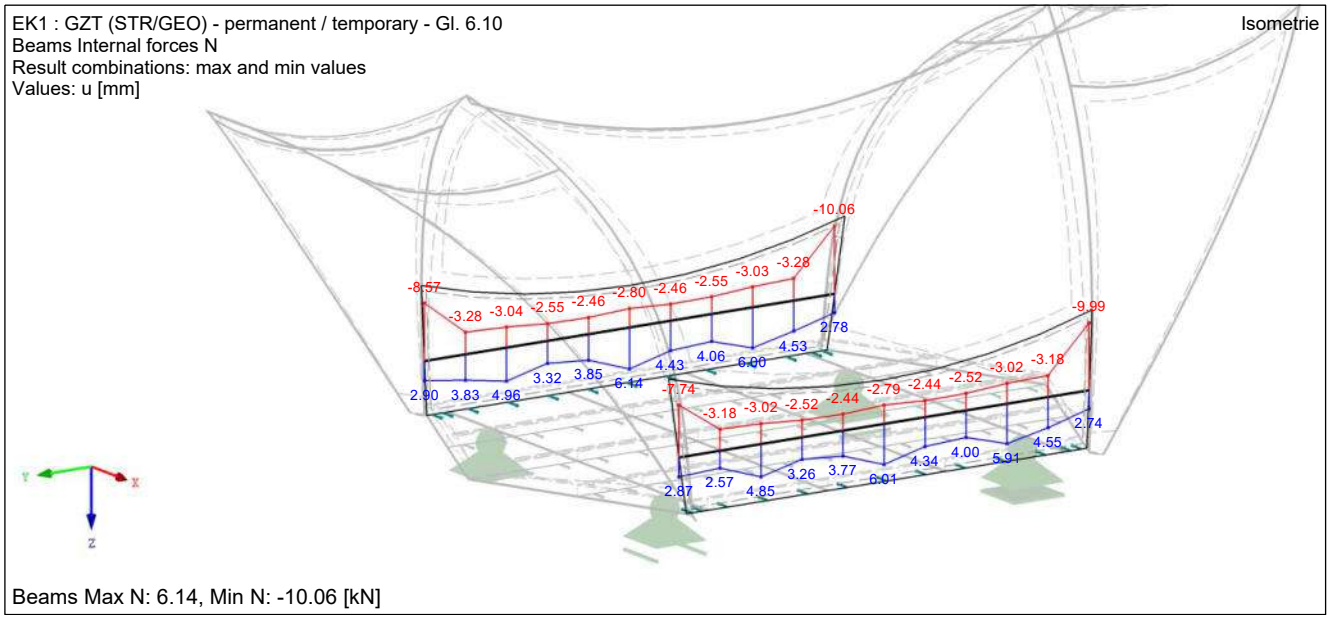
3.5 Overhang

3.5.1 Cross Section



Material: LVL, KERTO Q

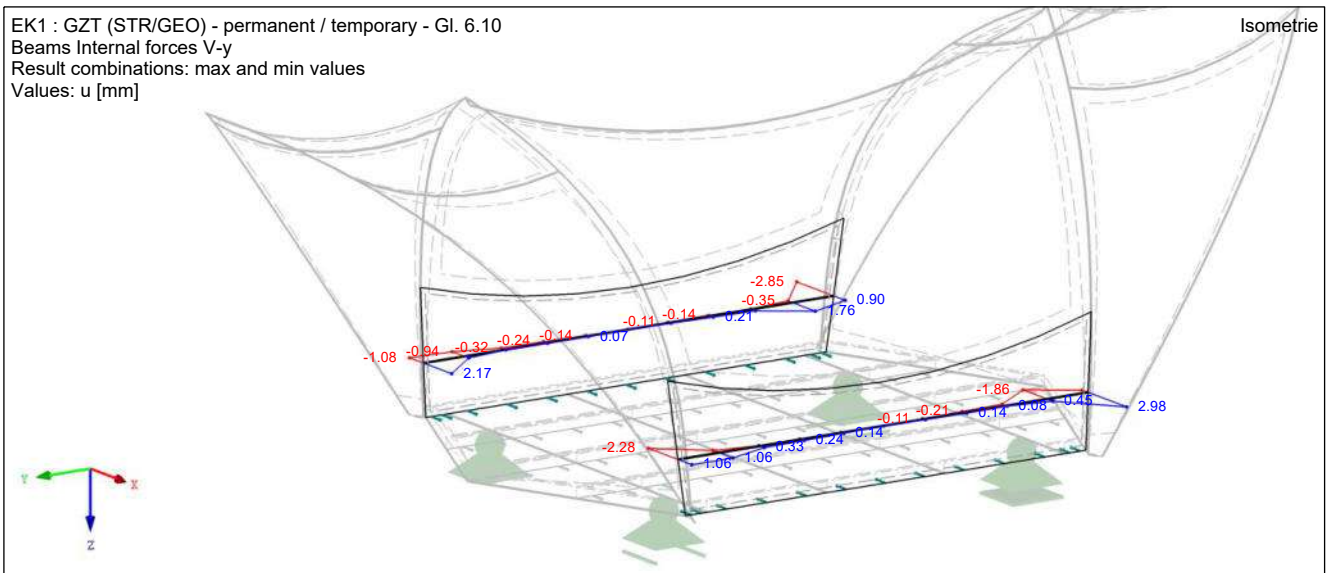
3.5.2 Design section properties



Beams Max N: 6.14, Min N: -10.06 [kN]

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces V-y
Result combinations: max and min values
Values: u [mm]

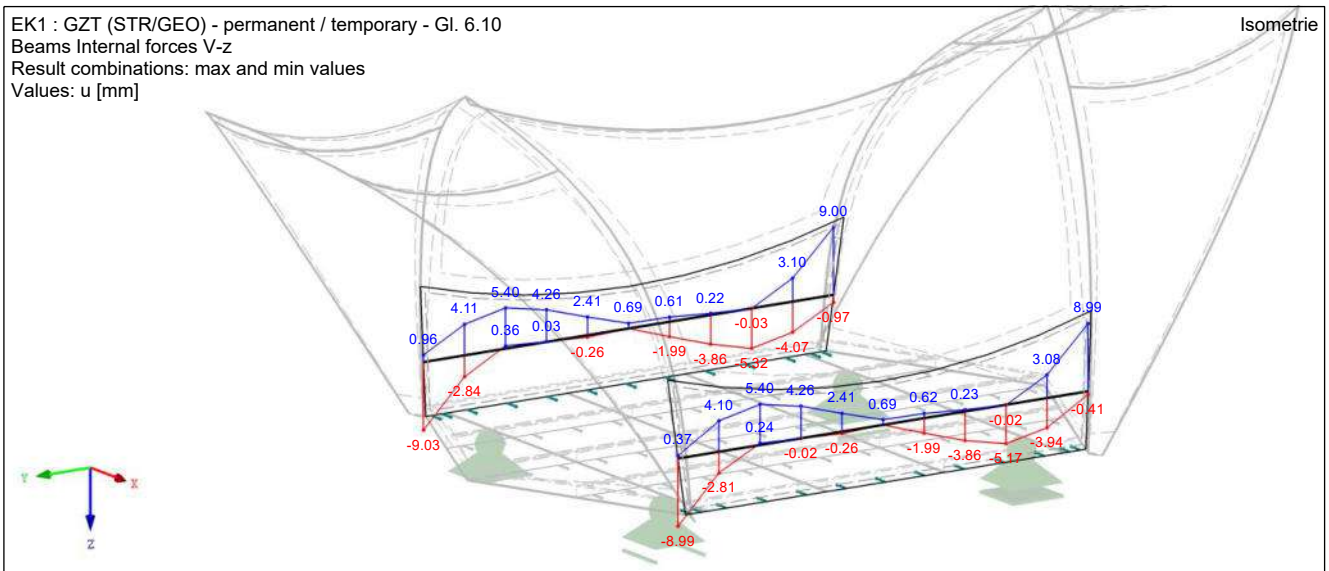
Isometrie



Beams Max V-y: 2.98, Min V-y: -2.85 [kN]

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces V-z
Result combinations: max and min values
Values: u [mm]

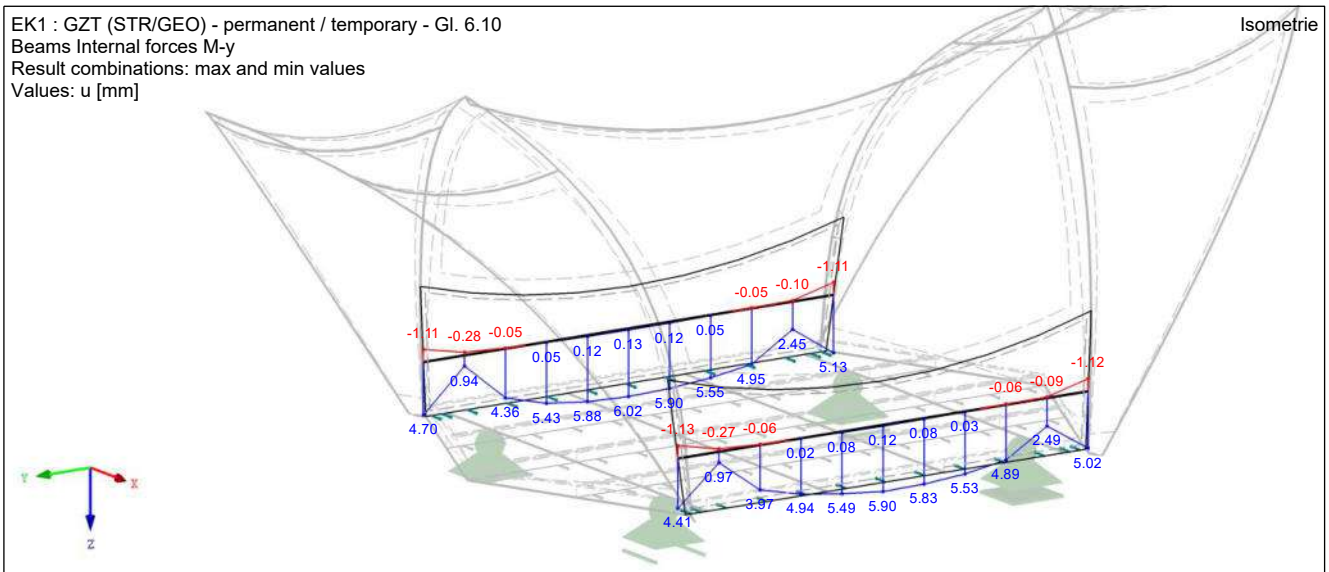
Isometrie



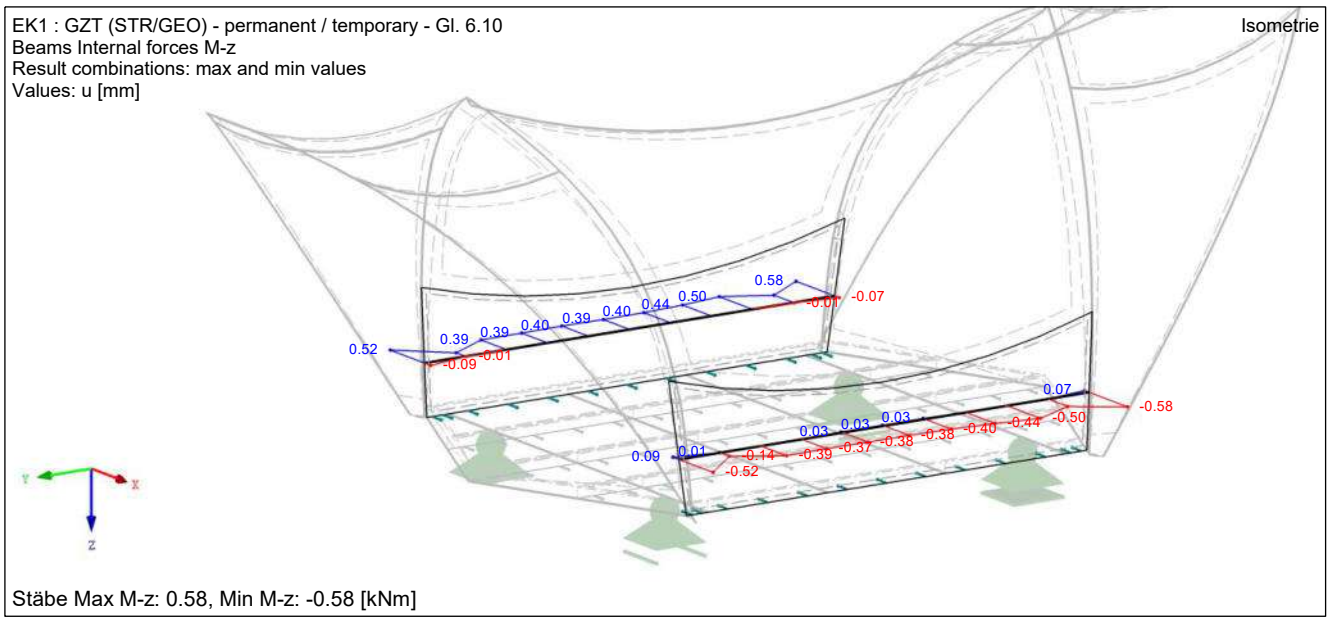
Beams Max V-z: 9.00, Min V-z: -9.03 [kN]

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-y
Result combinations: max and min values
Values: u [mm]

Isometrie



Beams Max M-y: 6.02, Min M-y: -1.13 [kNm]



3.5.3 Proof of structural safety

General Parameters

Plate thickness	d=	33	mm
Plate height midspan	h_1=	840	mm
Plate height support	h_2=	1154	mm
Class of use	NKL 2		
Exposure time class	short/very short		
Partial safety factor	k_{mod}=	1,00	
Modification coef.	γ_M=	1,30	

Strenght Values

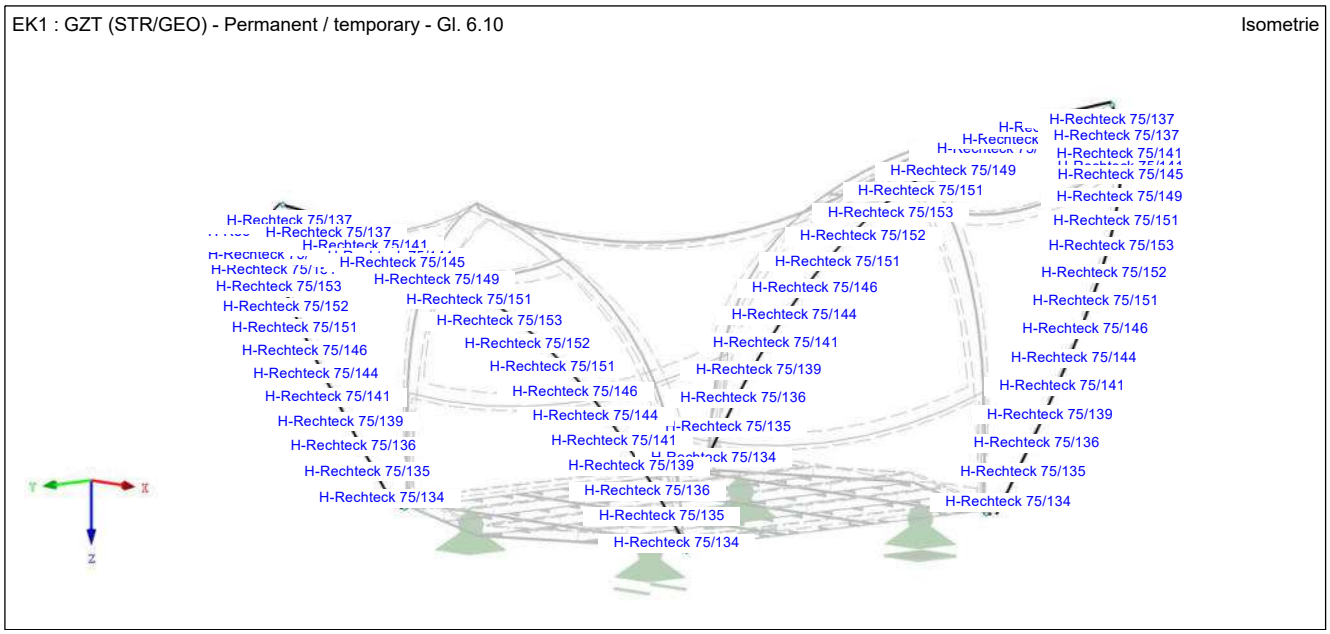
Plate stress						
Bending parallel to fiber	$f_{m,0,flat,k}$=	36,00	N/mm²	$f_{m,0,flat,d}$=	27,69	N/mm²
Bending perpendicular to fiber	$f_{m,90,flat,k}$=	8,00	N/mm²	$f_{m,90,flat,d}$=	6,15	N/mm²
Compressive strenght	$f_{c,90,flat,k}$=	2,20	N/mm²	$f_{c,90,flat,d}$=	1,69	N/mm²
Shear	$f_{v,flat,k}$=	1,30	N/mm²	$f_{v,flat,d}$=	1,00	N/mm²
Disc stress						
Bending	$f_{m,0,edge,k}$=	32,00	N/mm²	$f_{m,0,edge,d}$=	24,62	N/mm²
Pulling parallel	$f_{t,0,k}$=	26,00	N/mm²	$f_{t,0,d}$=	20,00	N/mm²
Pulling perpendicular	$f_{t,90,edge,k}$=	6,00	N/mm²	$f_{t,90,edge,d}$=	4,62	N/mm²
Compression parallel	$f_{c,0,k}$=	26,00	N/mm²	$f_{c,0,d}$=	20,00	N/mm²
Compression vertical	$f_{c,90,edge,k}$=	9,00	N/mm²	$f_{c,90,edge,d}$=	6,92	N/mm²
Shear	$f_{v,edge,k}$=	4,50	N/mm²	$f_{v,edge,d}$=	3,46	N/mm²

Proofs of structural safety

Bending disc	$M_{y,E,d}$=	6,02	kNm	<	$M_{y,R,d}$=	95,53 kNm	6,30%
Bending plate	$M_{z,E,d}$=	0,58	kNm	<	$M_{z,R,d}$=	1,29 kNm	45,00%
Shear disc	$V_{z,E,d}$=	9,03	kN	<	$V_{z,R,d}$=	63,97 kN	14,12%
Shear plate	$V_{y,E,d}$=	2,98	kN	<	$V_{y,R,d}$=	18,48 kN	16,13%
Compression	$N_{c,E,d}$=	-10,06	kN	<	$N_{c,R,d}$=	-554,4 kN	1,81%
Pulling	$N_{t,E,d}$=	6,14	kN	<	$N_{t,R,d}$=	554,4 kN	1,11%

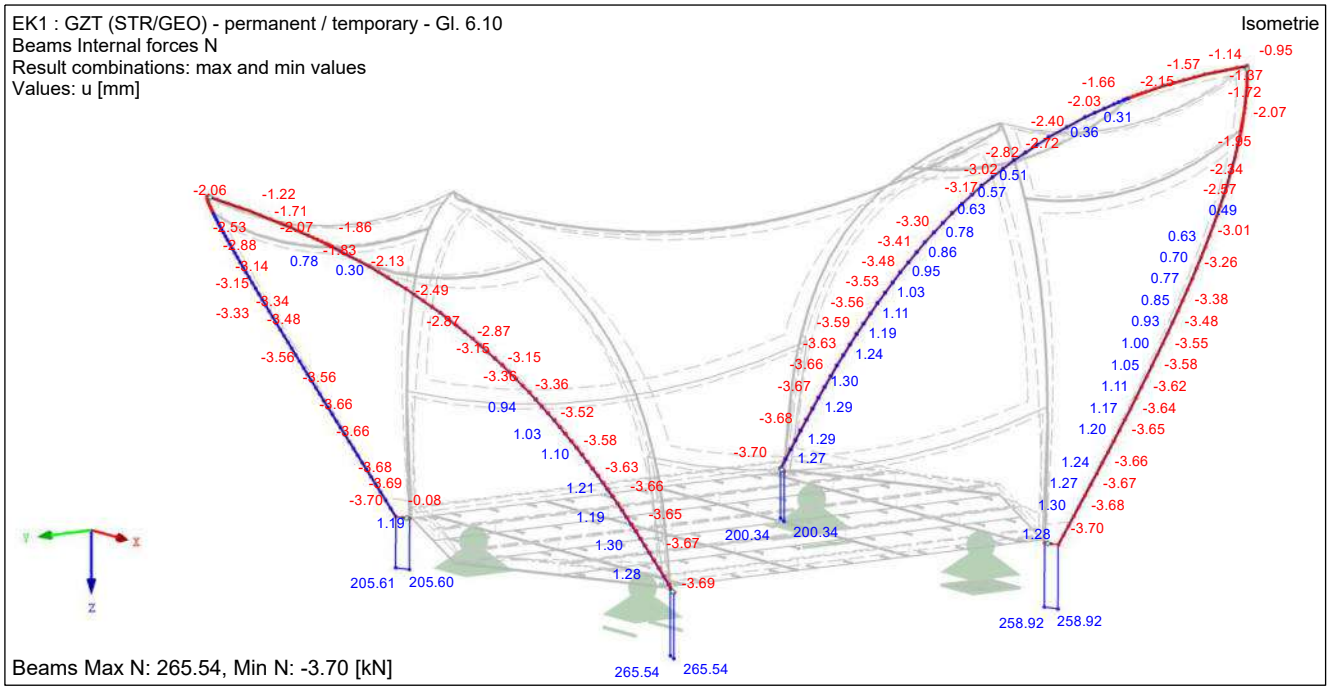
3.6 Canopy edge support

3.6.1 Cross sections



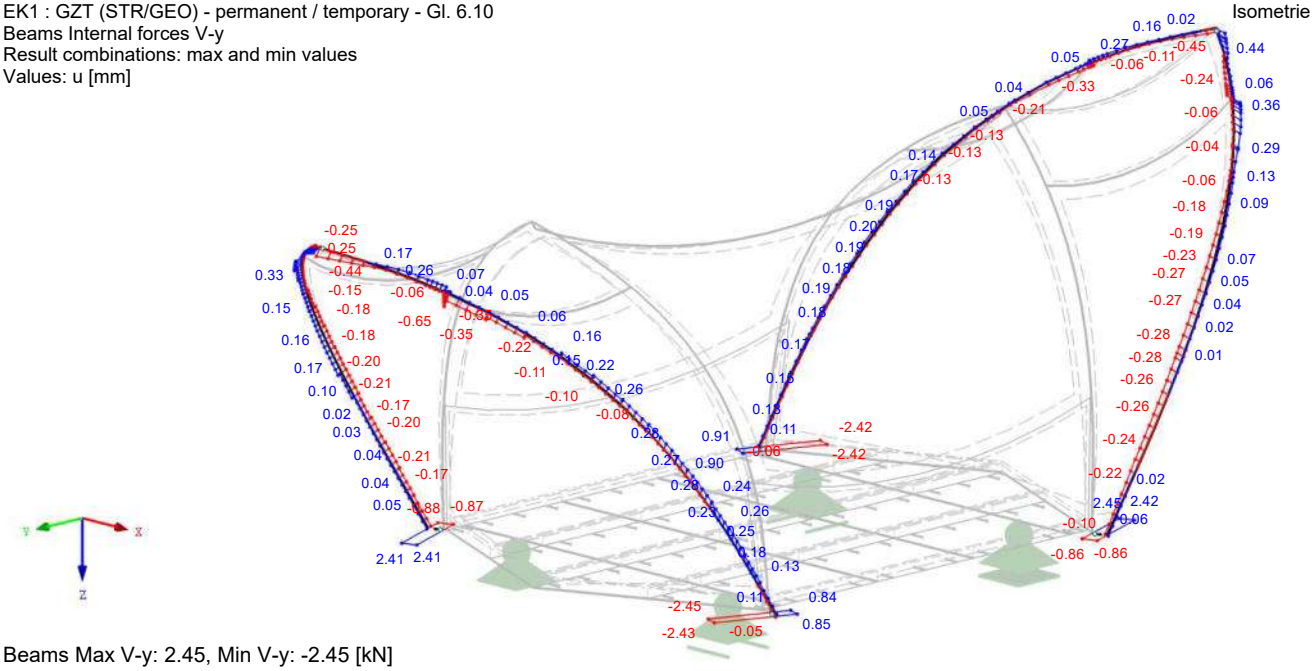
Material: BSH, GL24h

3.6.2 Design section properties



EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces V-y
Result combinations: max and min values
Values: u [mm]

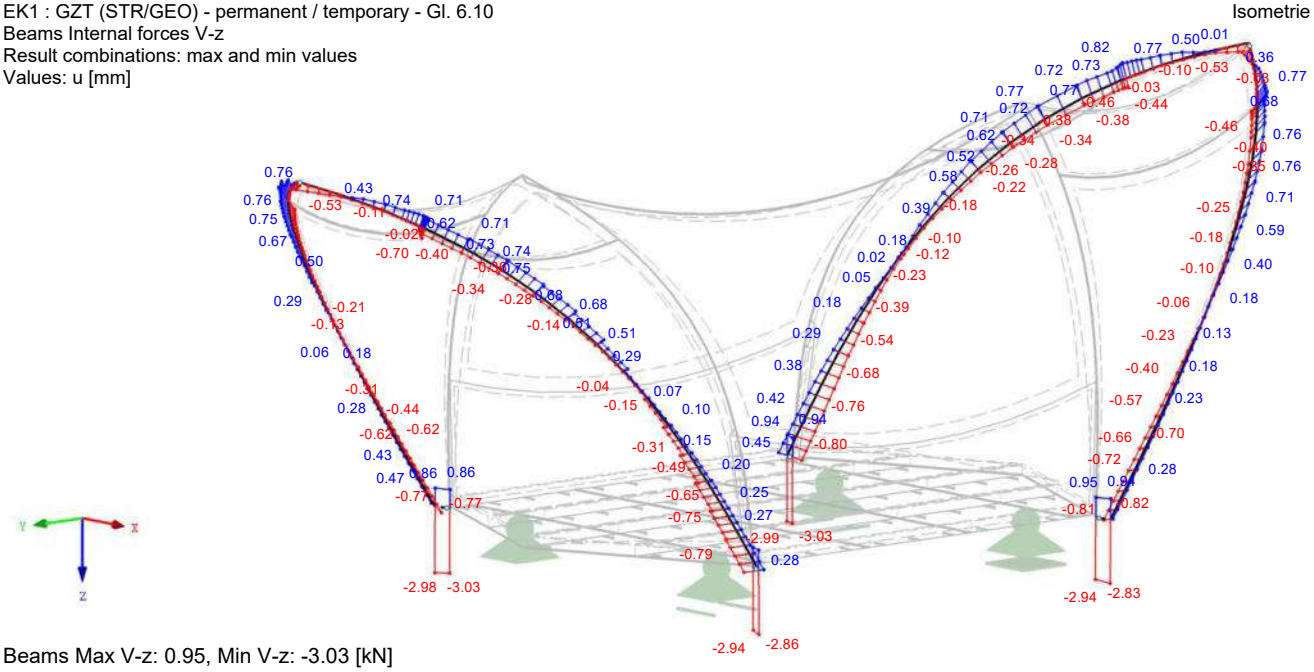
Isometrie



Beams Max V-y: 2.45, Min V-y: -2.45 [kN]

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces V-z
Result combinations: max and min values
Values: u [mm]

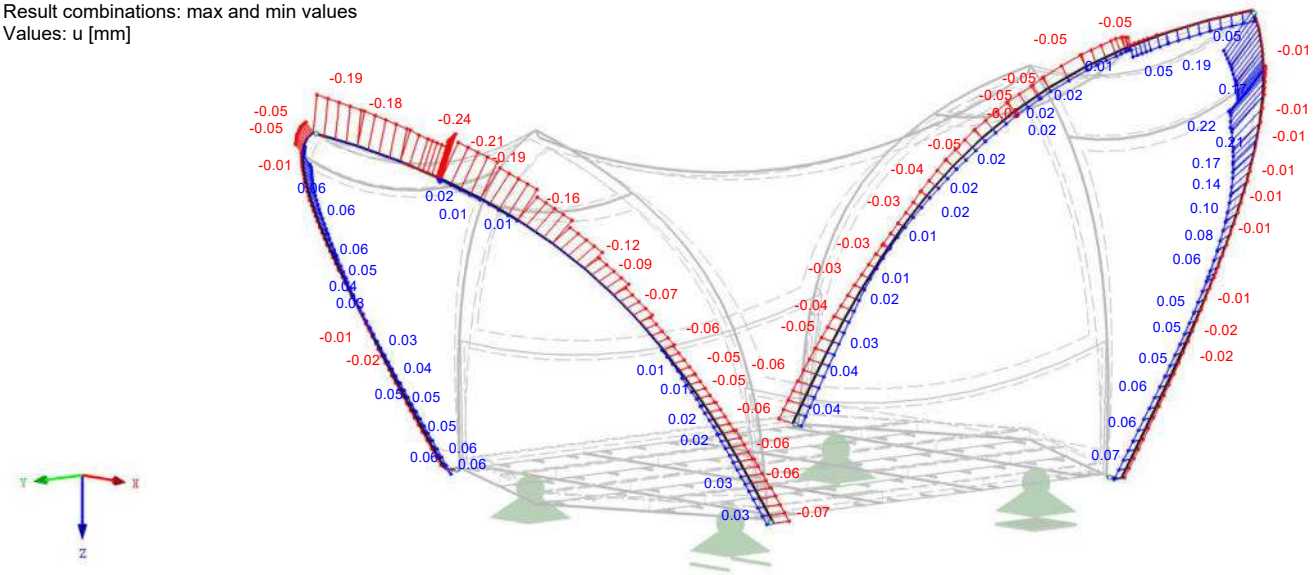
Isometrie



Beams Max V-z: 0.95, Min V-z: -3.03 [kN]

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-T
Result combinations: max and min values
Values: u [mm]

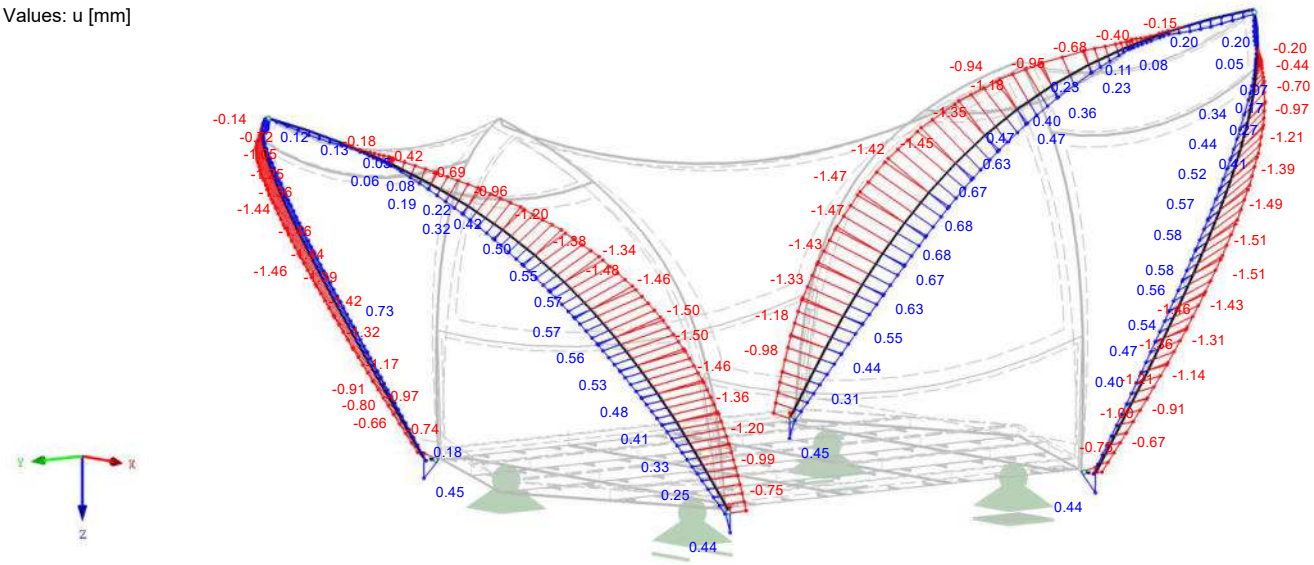
Isometrie



Beams Max M-T: 0.22, Min M-T: -0.24 [kNm]

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-y
Result combinations: max and min values
Values: u [mm]

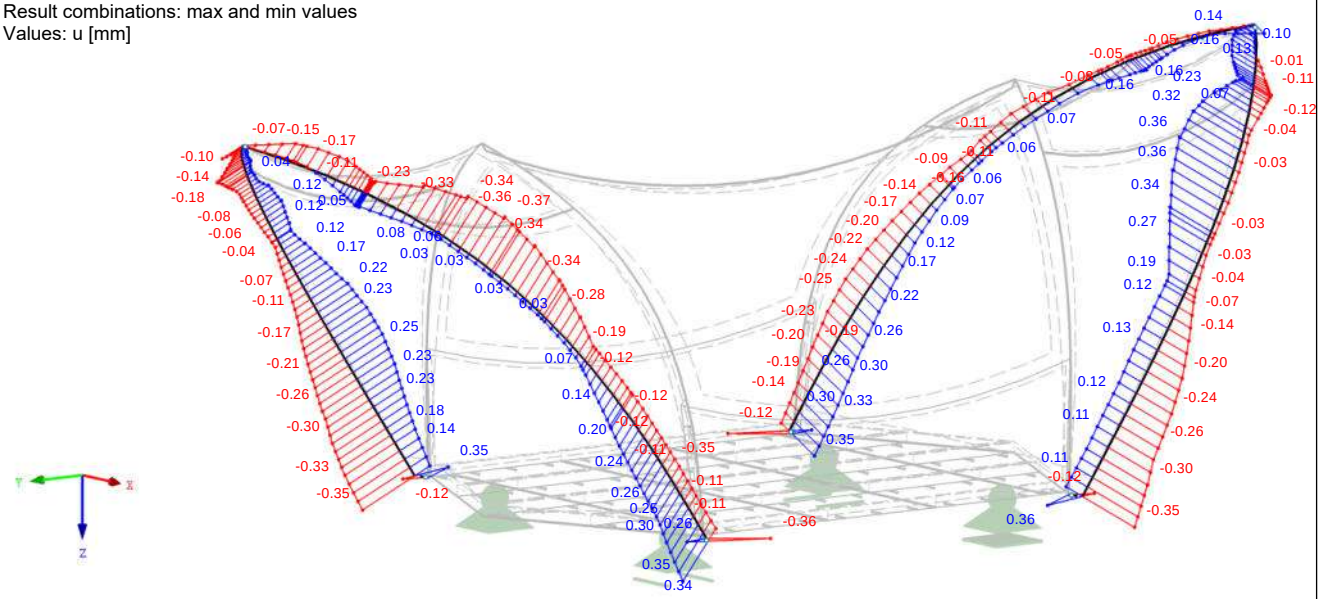
Isometrie



Beams Max M-y: 0.75, Min M-y: -1.51 [kNm]

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-z
Result combinations: max and min values
Values: u [mm]

Isometrie

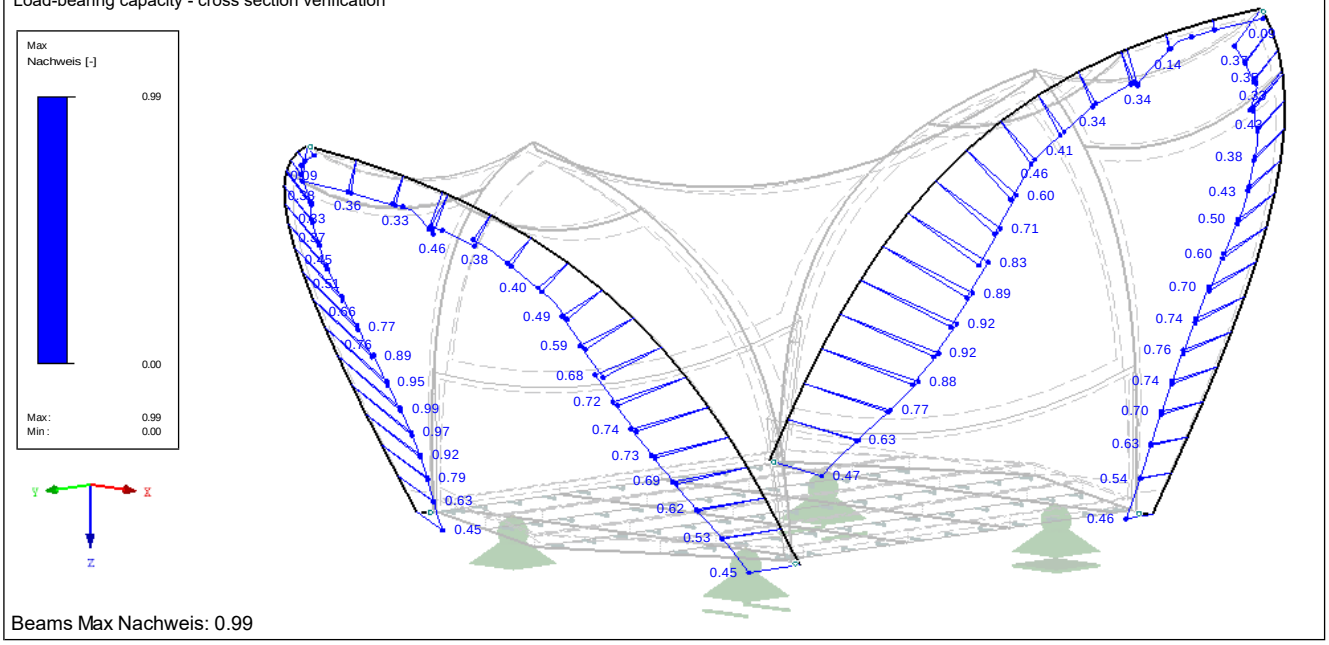


Beams Max M-z: 0.36, Min M-z: -0.37 [kNm]

3.6.3 Proof of structural safety

RF-TIMBER Pro FA1
Load-bearing capacity - cross section verification

Isometrie

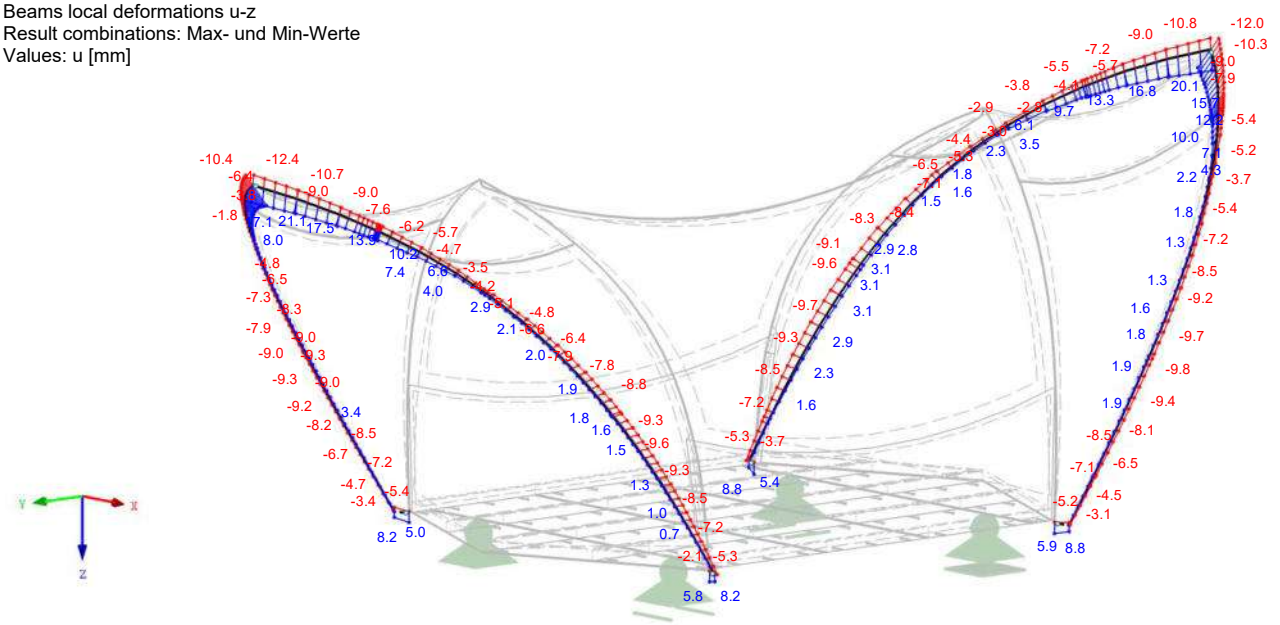


Beams Max Nachweis: 0.99

3.6.4 Deformations

EK2 : GZG - Characteristic / Rare
Beams local deformations u-z
Result combinations: Max- und Min-Werte
Values: u [mm]

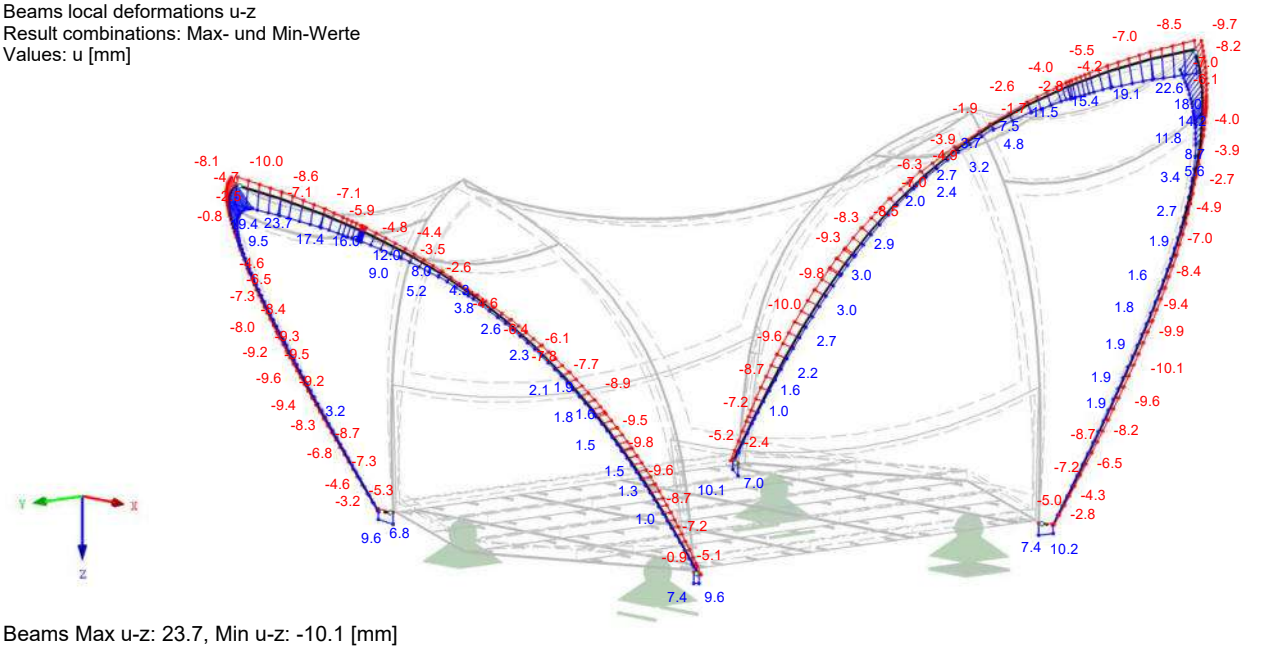
Isometrie



Beams Max u-z: 21.1, Min u-z: -12.4 [mm]

EK2 : GZG - Quasi-constant
Beams local deformations u-z
Result combinations: Max- und Min-Werte
Values: u [mm]

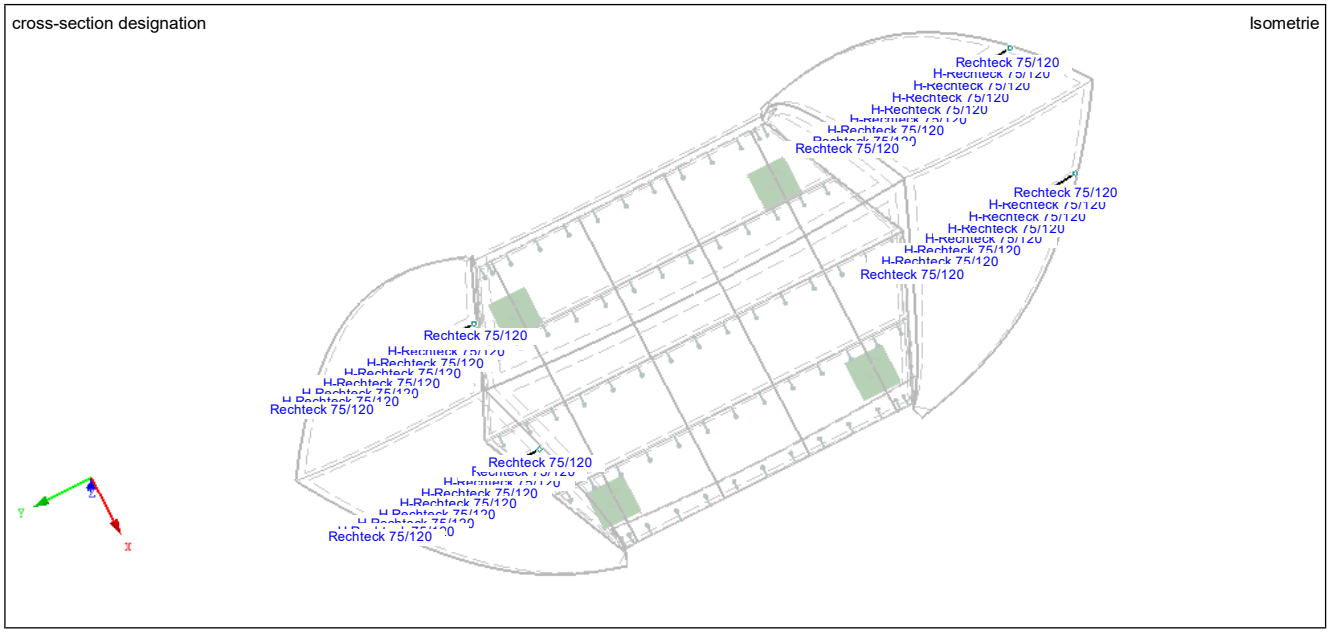
Isometrie



Beams Max u-z: 23.7, Min u-z: -10.1 [mm]

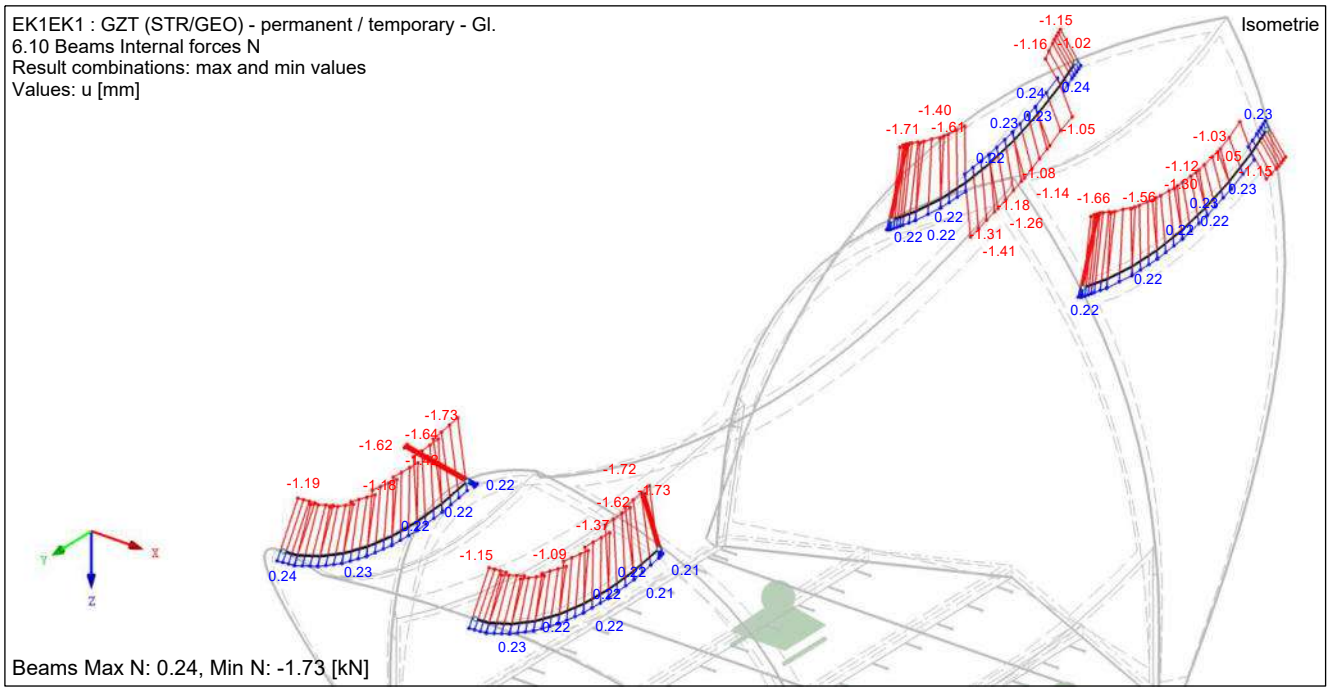
3.7 Canopy drop beam

3.7.1 Cross sections



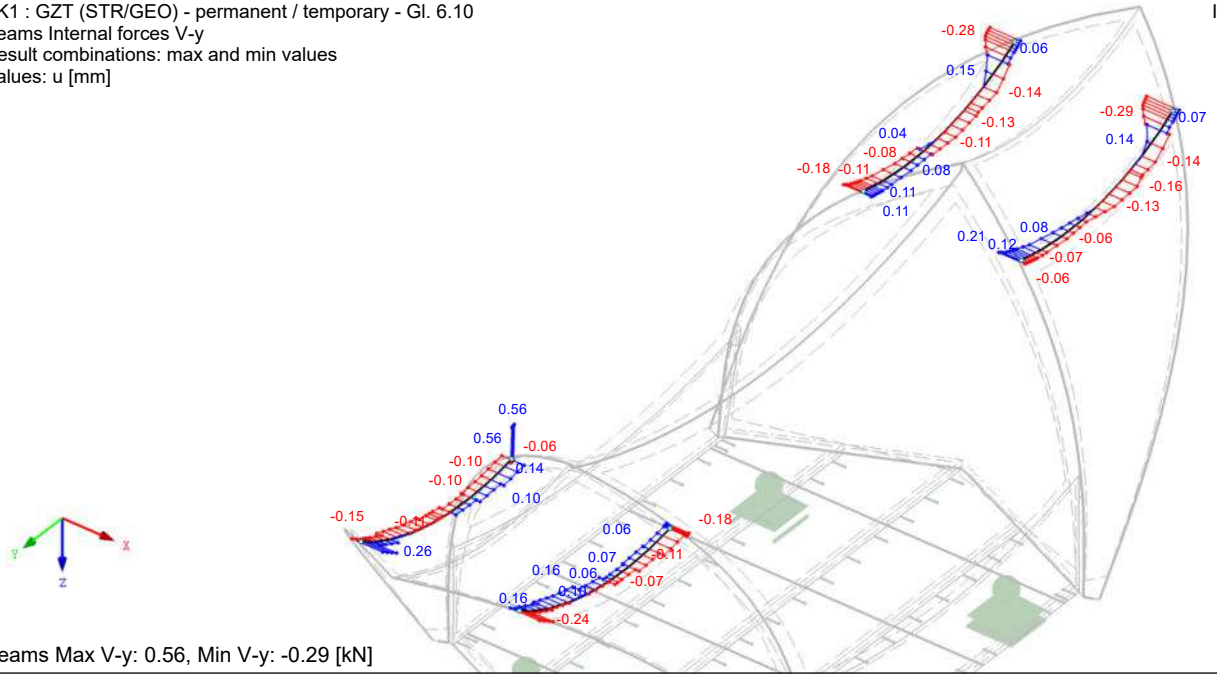
Material: LVL, KERTO-Q

3.7.2 Design section properties



EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces V-y
Result combinations: max and min values
Values: u [mm]

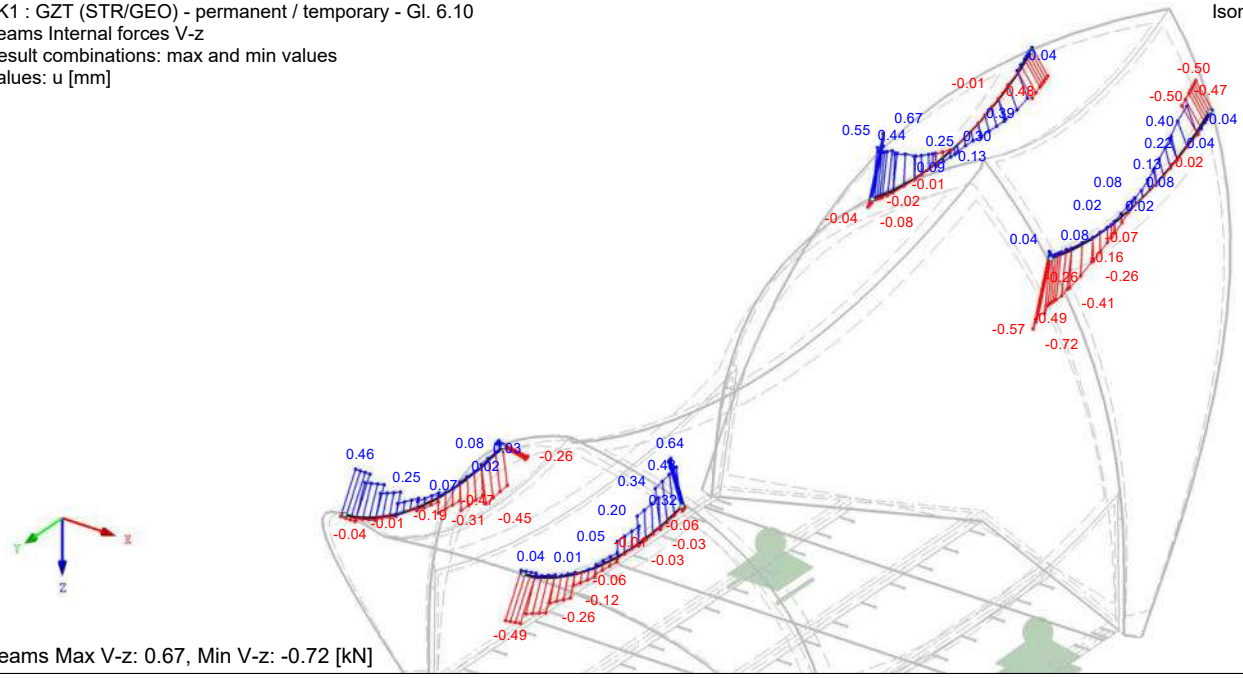
Isometrie



Beams Max V-y: 0.56, Min V-y: -0.29 [kN]

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces V-z
Result combinations: max and min values
Values: u [mm]

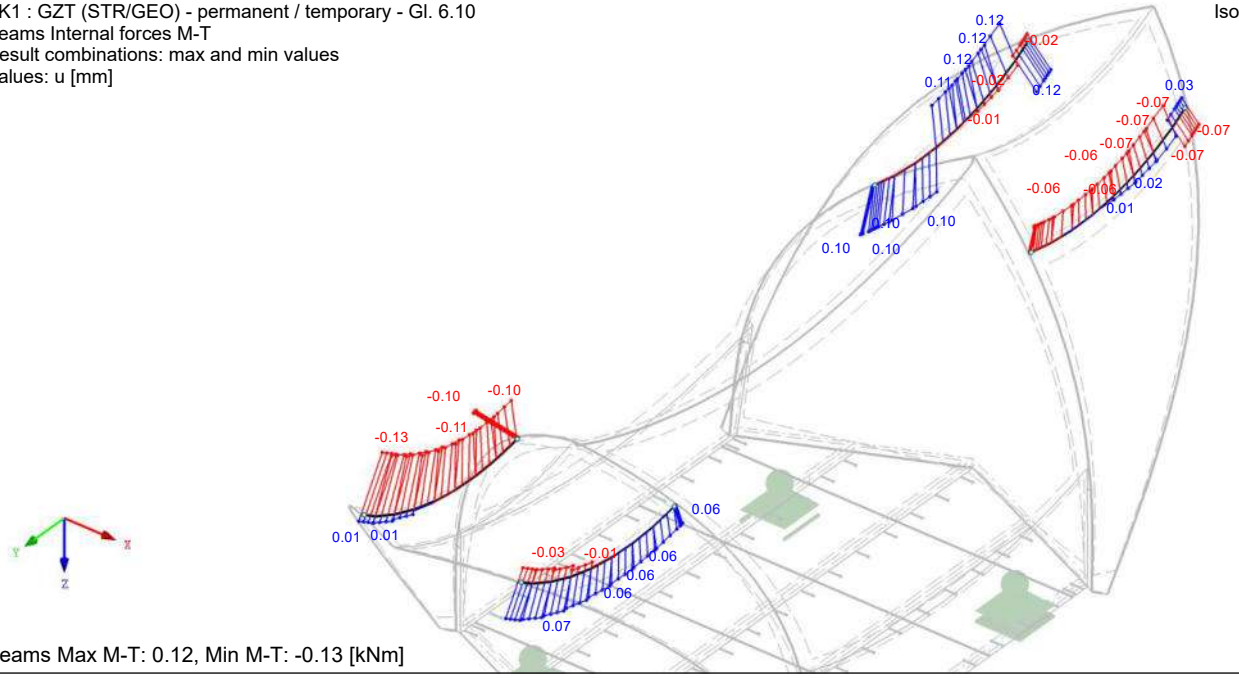
Isometrie



Beams Max V-z: 0.67, Min V-z: -0.72 [kN]

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-T
Result combinations: max and min values
Values: u [mm]

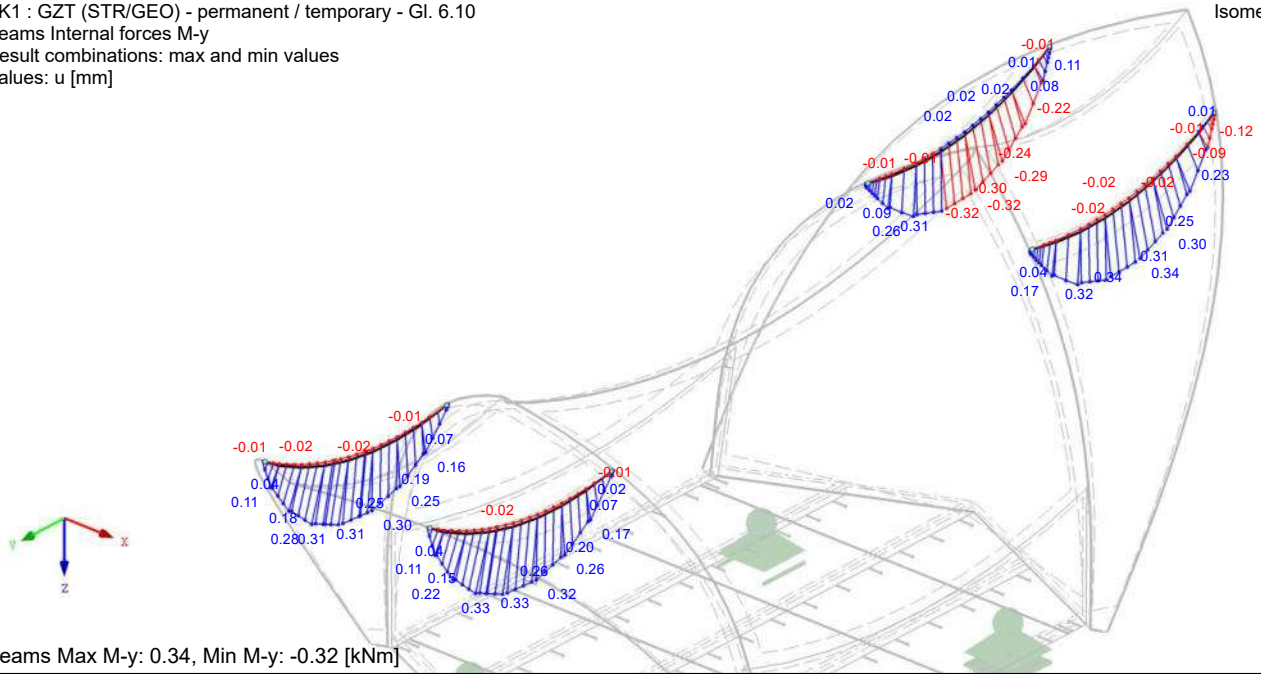
Isometrie



Beams Max M-T: 0.12, Min M-T: -0.13 [kNm]

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-y
Result combinations: max and min values
Values: u [mm]

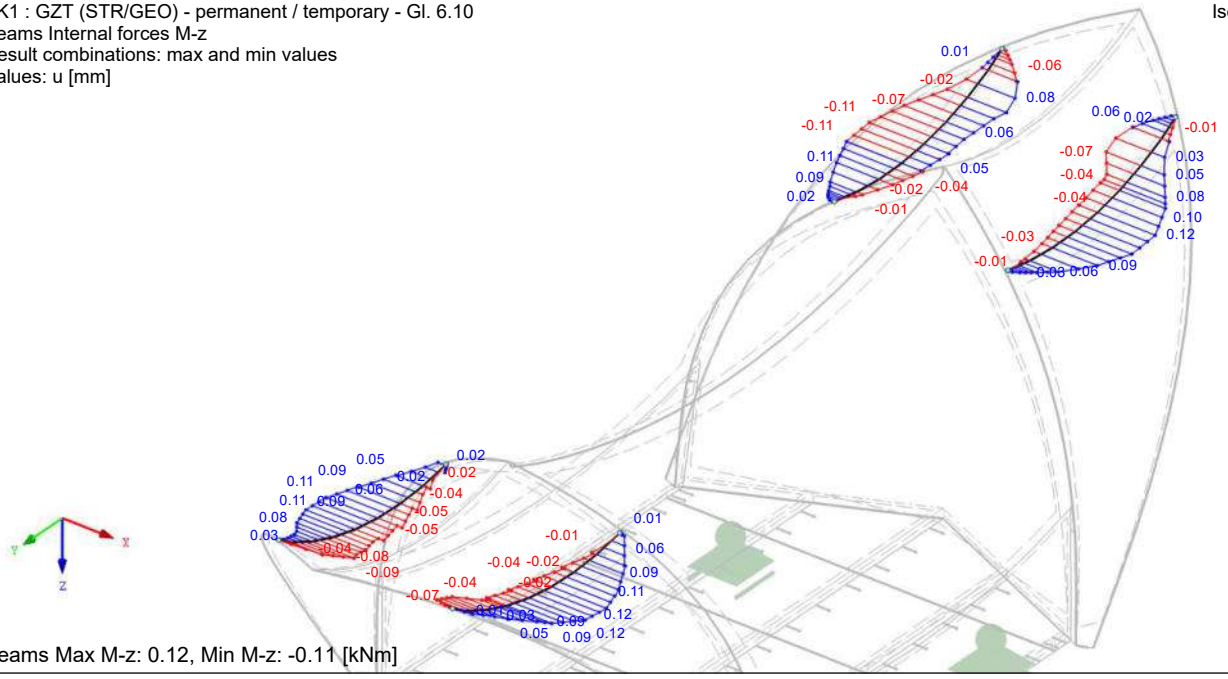
Isometrie



Beams Max M-y: 0.34, Min M-y: -0.32 [kNm]

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-z
Result combinations: max and min values
Values: u [mm]

Isometrie

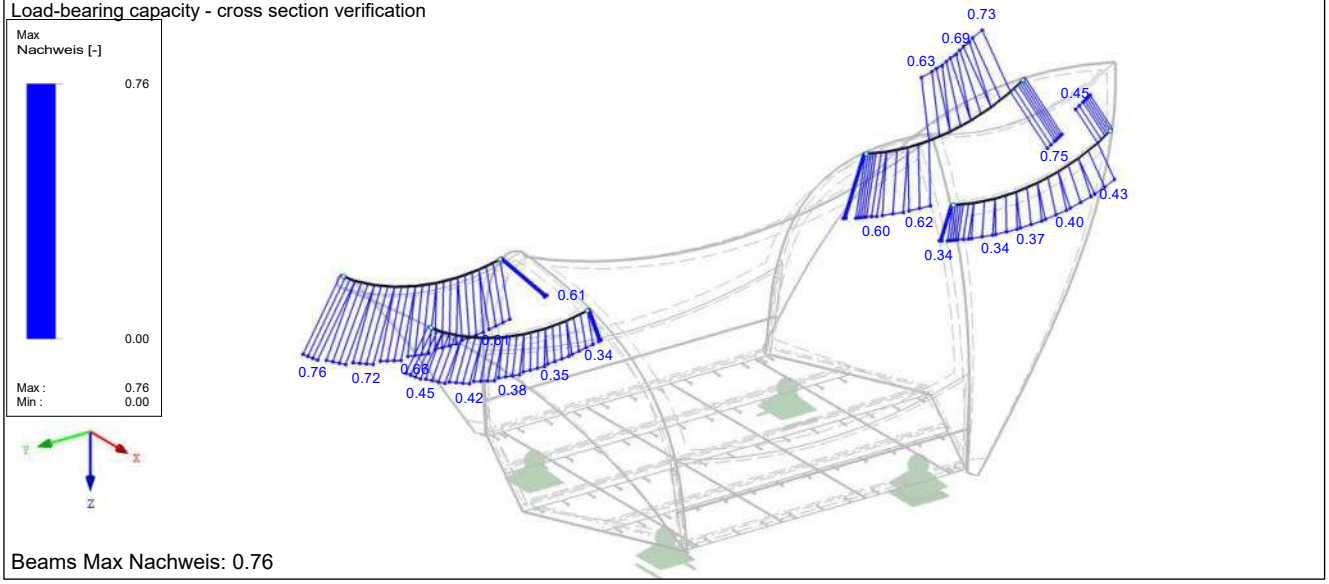


Beams Max M-z: 0.12, Min M-z: -0.11 [kNm]

3.7.3 Proof of structural safety

RF-TIMBER Pro FA1
Load-bearing capacity - cross section verification

Isometrie

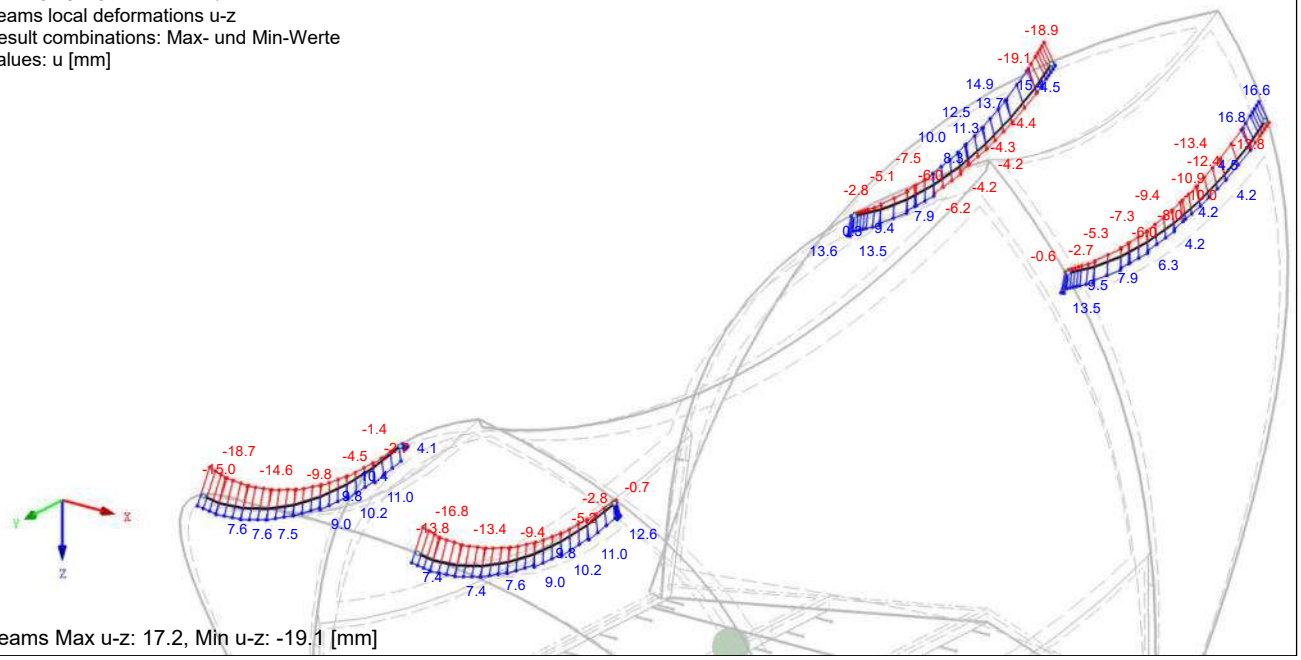


Beams Max Nachweis: 0.76

3.7.4 Deformations

EK2 : GZG - Characteristic / Rare
Beams local deformations u-z
Result combinations: Max- und Min-Werte
Values: u [mm]

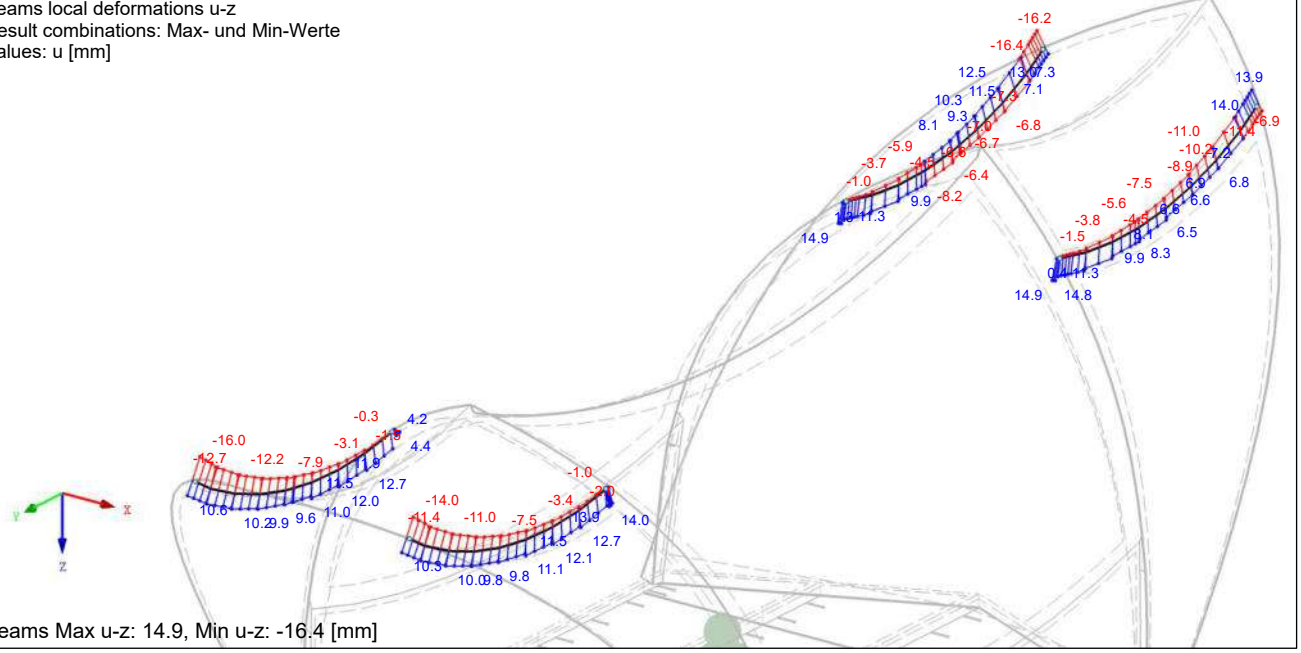
Isometrie



Beams Max u-z: 17.2, Min u-z: -19.1 [mm]

EK2 : GZG - Quasi-constant
Beams local deformations u-z
Result combinations: Max- und Min-Werte
Values: u [mm]

Isometrie



Beams Max u-z: 14.9, Min u-z: -16.4 [mm]

3.8 Foundation

3.8.1 Uplift safety

characteristic uplift safety	$P_{w,z,k}$=	3,59 kN	
design value uplif safety	$P_{w,z,d}$=	4,31 kN	unfavorable effect γ_Q=1,20 according to ÖNORM EN 13782
characteristic self-weight	$G_{Konstr.,z,k}$=	2,55 kN	
design value self-weight		2,55 kN	favorable effect γ_G=1,00 according to ÖNORM EN 13782
Self-weight foundation	$G_{Fund.,z,k}$=	1,93 kN	7 concrete slabs 50x50x5 cm
design value foundation	$G_{Fund.,z,d}$=	1,93 kN	favorable effect γG=1,00 according to ÖNORM EN 13782
Proof of uplift safety	$P_{w,z,d}$=	4,31 kN < $R_{z,d}$= 4,48 kN	**96,27% proof fulfilled**

3.8.2 Anti-skid

characteristic horizontal force	$P_{w,x,y,k}$=	0,94 kN	
design value horizontal force	$P_{w,x,y,d}$=	1,13 kN	unfavorable effect γQ=1,20 gem. ÖNORM EN 13782
charactersitc self-weight	$G_{Konstr.,z,k}$=	2,55 kN	
design value self-weight		2,55 kN	favorable effect γG=1,00 gem. ÖNORM EN 13782
Self-weight foundation	$G_{Fund.,z,k}$=	1,93 kN	7 concrete slabs 50x50x5 cm
design value foundation	$G_{Fund.,z,d}$=	1,93 kN	favorable effect γG=1,00 gem. ÖNORM EN 13782
Coefficient of friction on concrete	μ=	0,50	
Proof of uplift safety	$P_{w,x,y,d}$=	1,13 kN < $R_{x,y,d}$= 2,24 kN	**50,41% proof fulfilled**

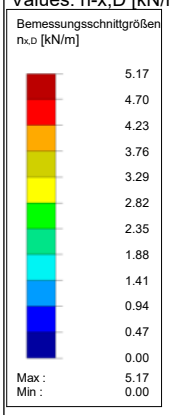
When installing on clay or loam soil, the foundations must be increased or passive earth pressure applied to ensure safety against sliding.

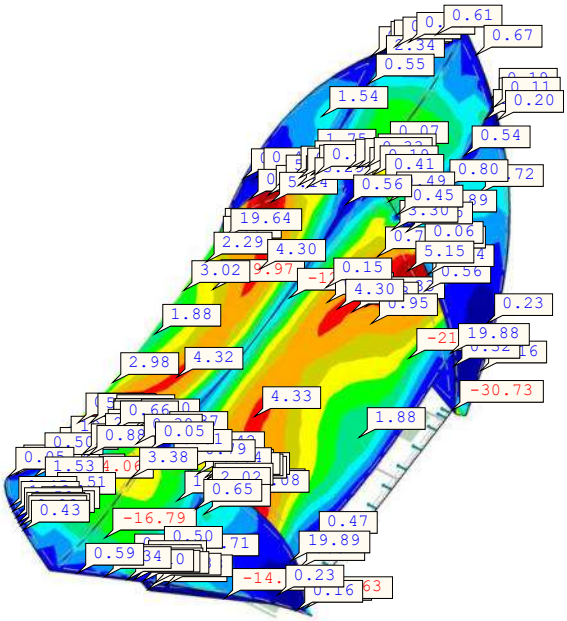
3.9 Membrane

3.9.1 Design section properties

EK1 : GZT (STR/GEO) - Permanent / temporary- Gl. 6.10
Beams local deformations u-z
Result combinations: max and min values
Values: n-x,D [kN/m]

Isometrie

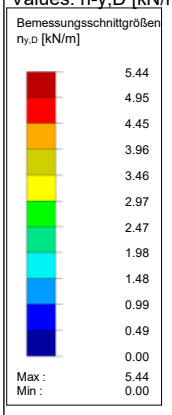


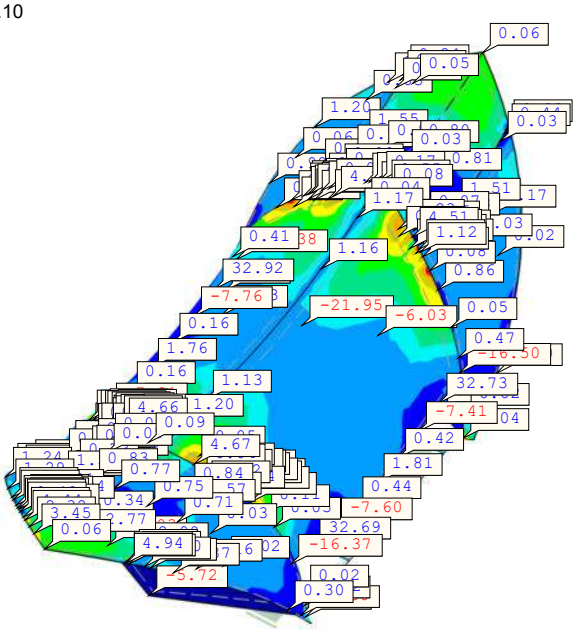


Beams Max u-z: -, Min u-z: -
Max n-x,D: 5.17, Min n-x,D: 0.00 kN/m

EK1 : GZT (STR/GEO) - Permanent / temporary- Gl. 6.10
Beams local deformations u-z
Result combinations: max and min values
Values: n-y,D [kN/m]

Isometrie





Beams Max u-z: -, Min u-z: -
Max n-y,D: 5.44, Min n-y,D: 0.00 kN/m

4 Summary

All components were pre-designed with the support of software programs.
The very slender tent-like structure was modeled with the RFEM statics software, among other things, because this allows cross-sections to be adapted promptly and their structural safety verified. The design parameters from RFEM listed above were also used for the verification of the fasteners in Excel programmed structural analysis templates.
The loads are induced via curved truss constructions (edge beams) with ridge beams in a disc-shaped coating and further into the tram ceiling substructure. The curved, forward-projecting canopy supports are supported on the edge supports and are secured near the ridge with rear suspension supports between the canopy supports and edge supports. A membrane that is stretched over the entire supporting structure serves as a shell.
Appropriate foundations, as listed above, must be used so that all impacts from the tram substructure can be induced into the subsoil.
All materials used, statically dimensioned, must be planned according to the usage classes according to the valid and specific ÖNORM.

Timbatec Holzbauingenieure GmbH
Bmstr. Hbmstr. Marcel Wansch

Wien, am 13. Juni 2022