Static dimensioning

Lounge with ridge beam and canopy

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The static calculation includes 51 DIN A4 pages.
The verification for the connectors was created in a separated document.

Inhaltsverzeichnis

1 Allgemeines

1.1 Project description

The Strohboid Lounge with canopy consists of a membrane construction, which serves as a roof covering 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 curved, forward-projecting canopy girders (spruce glulam) are supported on the edge girders and are secured near the ridge with two back-hanging girders (spruce LVL) between each of the canopy girders and edge girders. The load transfer of the edge beams takes place via a wall-like overlay of laminated spruce veneer lumber into the tram ceiling floor structure, which is also made of LVL spruce. The tram ceiling floor structure is covered with a layer of 33 mm thick LVL spruce. The load transfer of the entire structure is carried out via the dissipating beams into the foundation of the structure.

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 maximum snow load as well as the wind load with a basic wind speed of 33 m/s. Determination of the maximum snow load that the structure can support as a load-bearing reserve.
All internal forces for the design are determined by means of a static 3-D model using the finite element method. The constrained internal forces of the membrane effects can thus be determined realistically.

1.3 Planning documents

Strohboid GmbH	3D Modelle vom 02.02.2022
Strohboid GmbH	Übersicht Verbindungsmittel vom 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 Beurteilung der Schadensfolgenklasse

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] Die verstärkte Überwachung umfasst ergänzend zur normalen Überwachung eine unabhängige Kontrollrechnung und Überprüfung der planlichen Darstellung hinsichtlich der Tragsicherheit. [b] Die normale Überwachung umfasst eine Kontrolle der Vollständigkeit der Unterlagen (statische Berechnung, Zeichnungen und Anweisungen) und eine Plausibilitätsprüfung der wesentlichen Ergebnisse hinsichtlich Tragsicherheit.

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]	$21 \le t \le 90$	$21 \le t \le 24$	$27 \le t \le 75$	$39 \le t \le 51$	$54 \le t \le 75$
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						
		Gl 20c	Gl 22c	Gl 24c	Gl 26c	Gl 28c	Gl 30c	Gl 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						
		Gl 20h	Gl 22h	Gl 24h	Gl 26h	Gl 28h	Gl 30h	Gl 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.

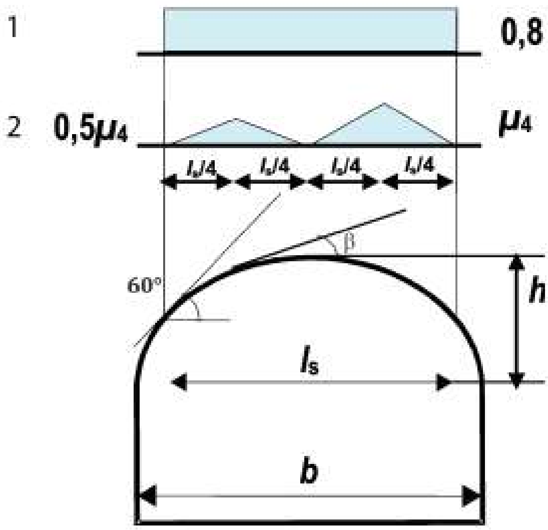
2.2 Payloads

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

The aim of the investigation was to determine the snow load via the bearing load reserve. Thus, the following snow load assumptions result for the opposing design:

Snow load on the ground: s_k=1,00 kN/m²



Legende
1 Fall (i)
2 Fall (ii)

Bild 5.5 — Formbeiwert für Schneelasten auf Tonnendächern

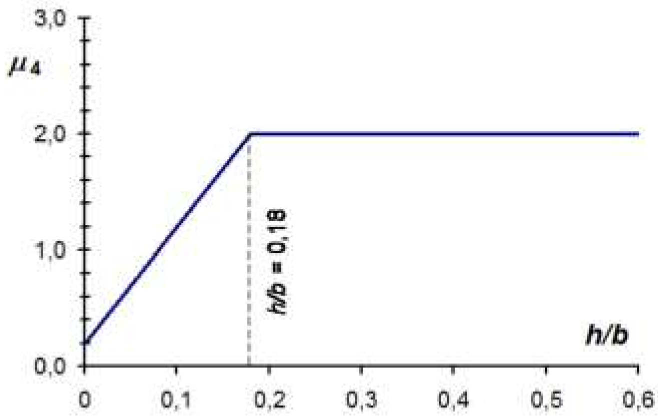


Bild 5.4 — Empfohlener Formbeiwert für Schneelasten auf Tonnendächern für unterschiedliche Höhen/Spannweiten-Verhältnisse (für $\beta \leq 60°$)

h=4,00 m b=4,36m h/b=0,92

According to the shape coefficients for snow loads, the following snow load cases or snow loads on the roof surface result:

Snow load case 1	s_k=1,00*0,8=0,80 kN/m²
Snow load case 2	windward s_k=0,5*2*1,00=1,00 kN/m² arranged as triangular load leeward s_k=2*1,00=2,00 kN/m² arranged as triangular load

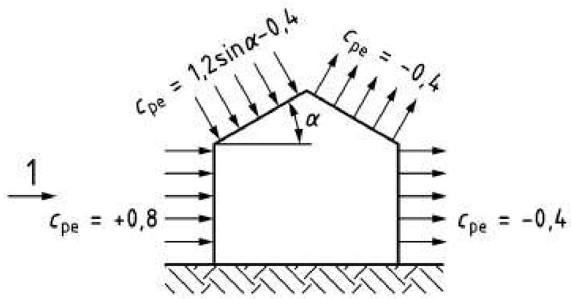
It has been shown by empirical evidence that due to the low roughness of the surface, the snow slides off even at inclinations below 60°.

2.4 Wind loads

Basis wind speed	v_b=	33 m/s	118,8 km/h		
Basis wind speed factor	q_b=	0,68 kN/m²			
Terrain category	II				
Roughness length	z_0=	0,05 m			
Terrain roughness	c_r(II)=	0,83			
Terrain factor	k_r=	0,19			
topography	c_0(II)=	1			
mean wind speed	v_m(II)=	27,48 m/s			
Turbulence intensity	I_v(II)=	0,23			
Peak wind speed pressure	q_p(II)=	1,23 kN/m²		v_p(II)=	44 m/s

The wind pressure coefficients c_{pi}=-0.30 and c_{pi}=0.20 are taken from ÖNORM B 1991-1-4.

2.4.1 External pressure coefficients for wind in Y-direction

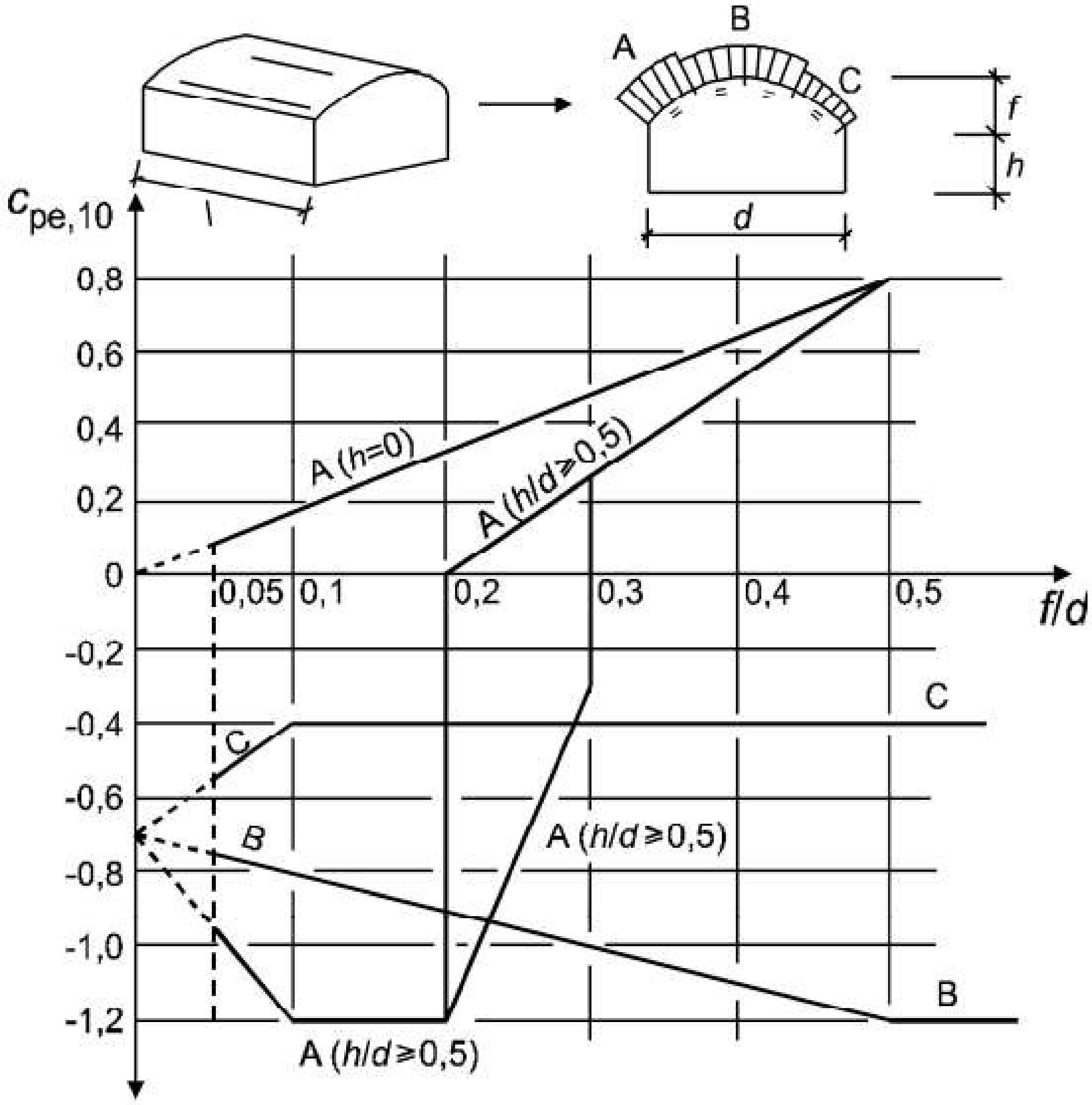


Legende
1 Windrichtung
α Winkel der Dachneigung
c_{pe} Außendruckbeiwert

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;

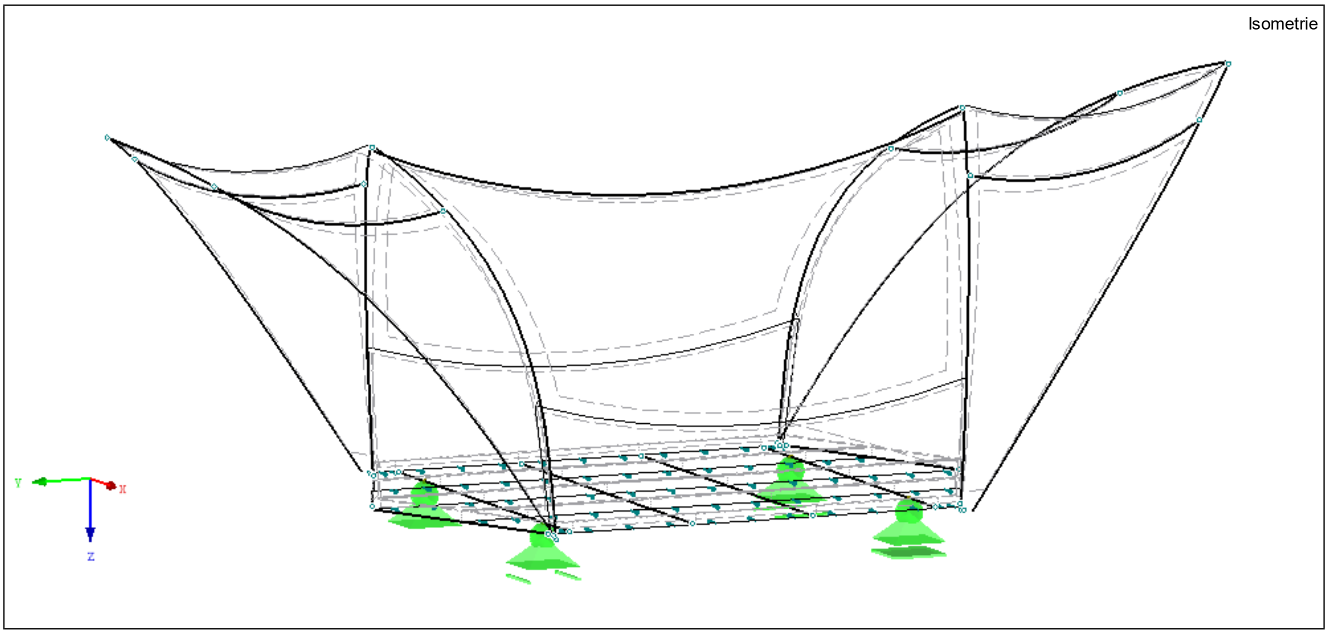
— das Diagramm gilt nicht für Flachdächer. (AC

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

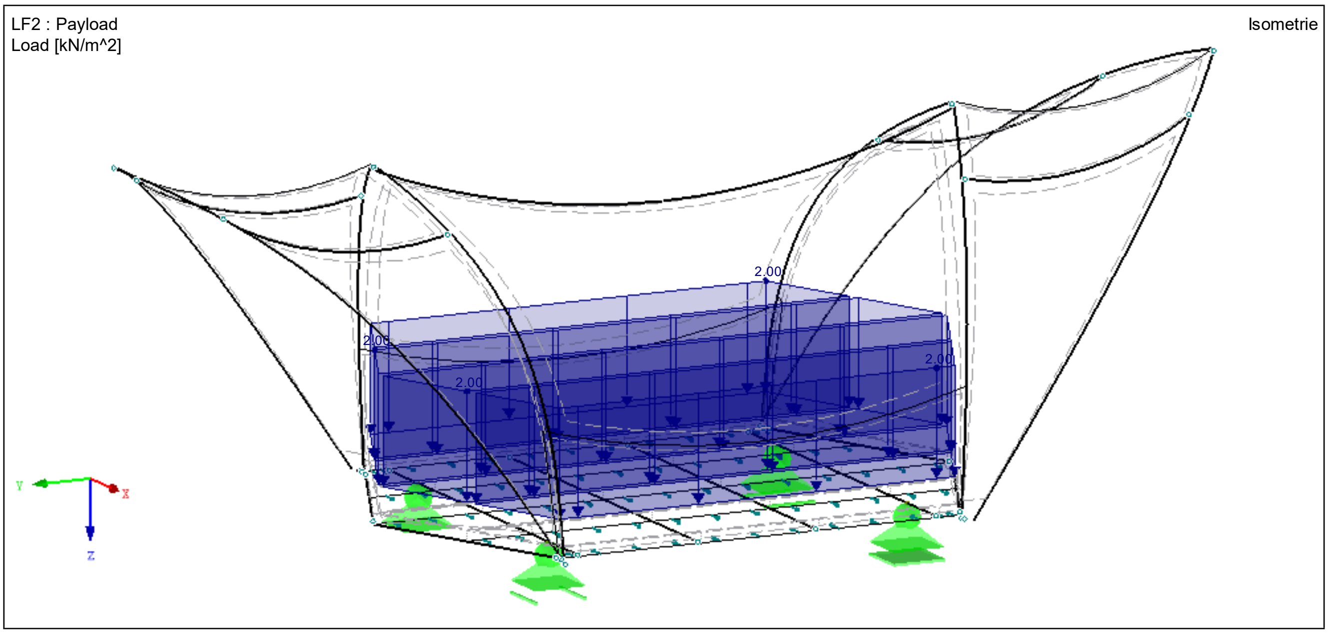
3 Structural analysis of components

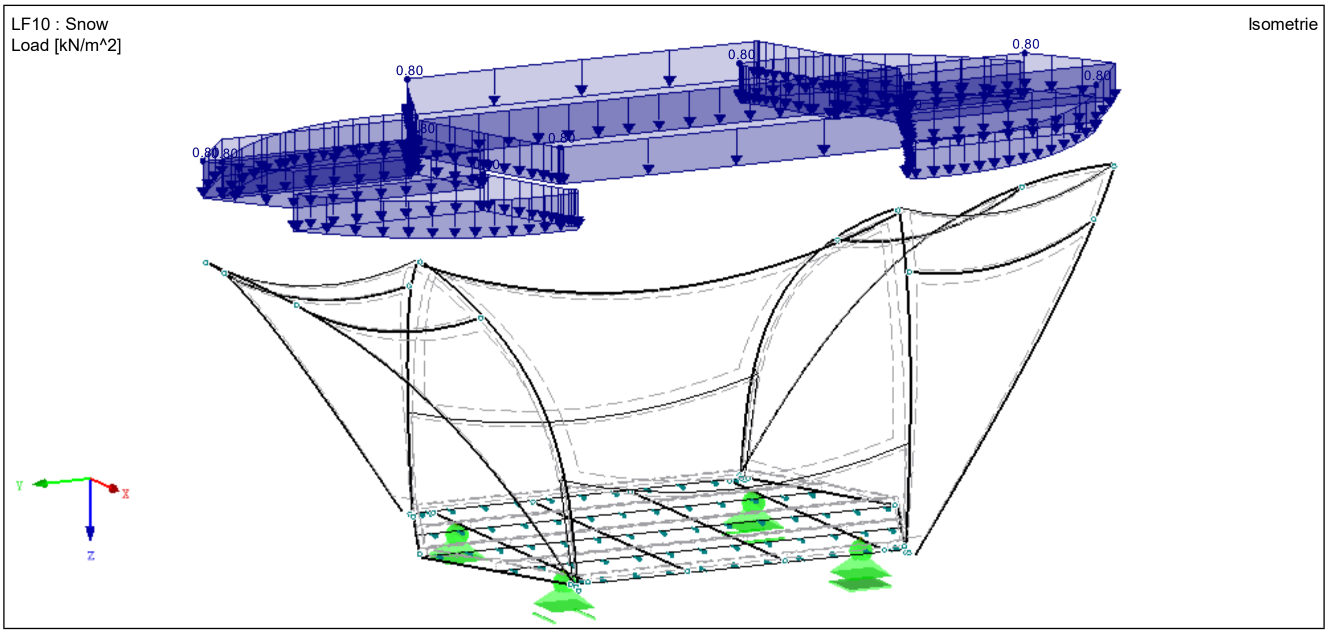
3.1 Overall Model

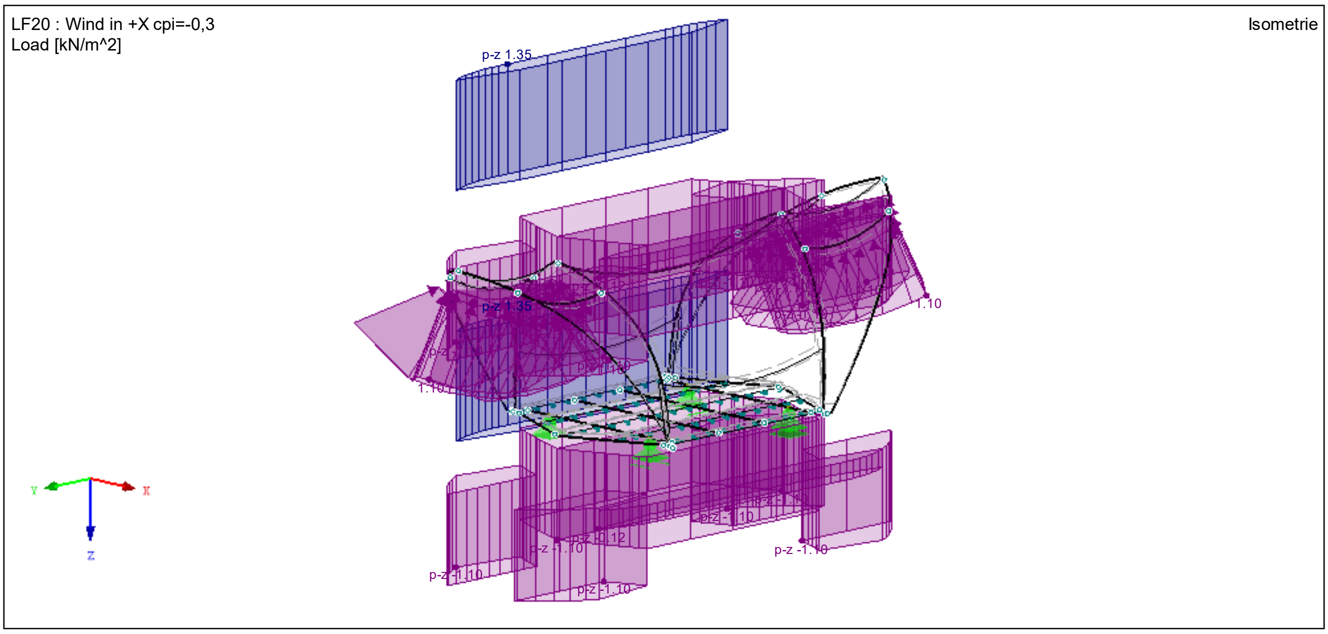
3.1.1 General overview

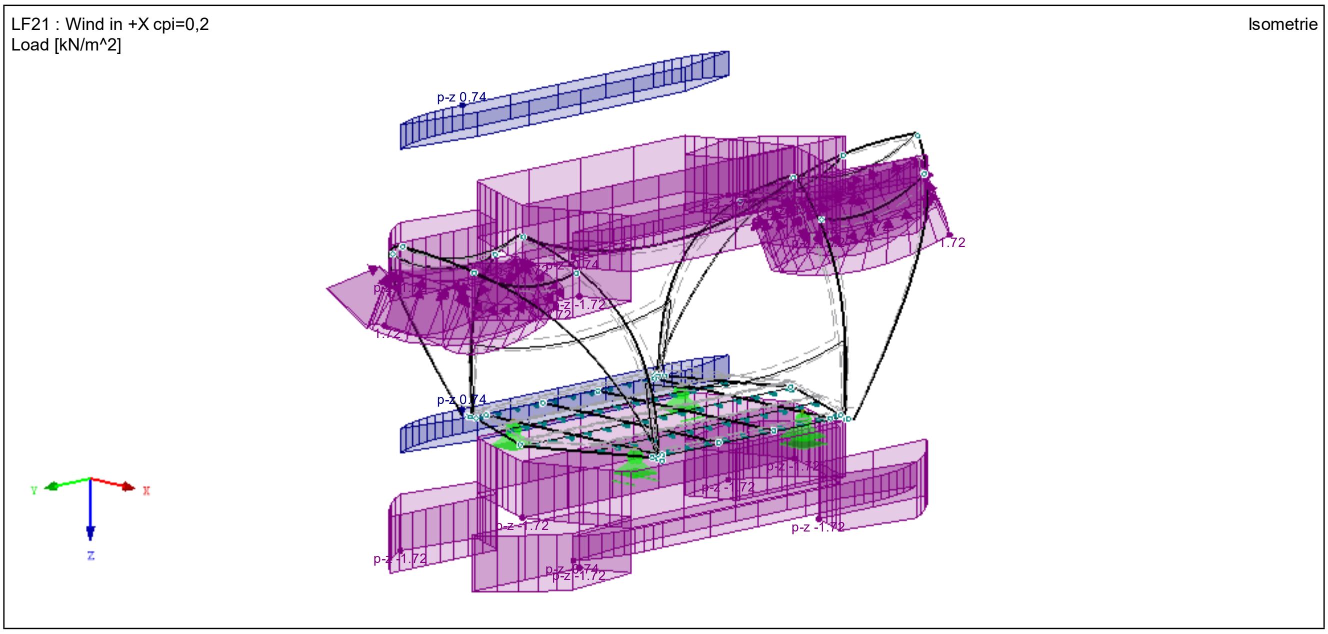


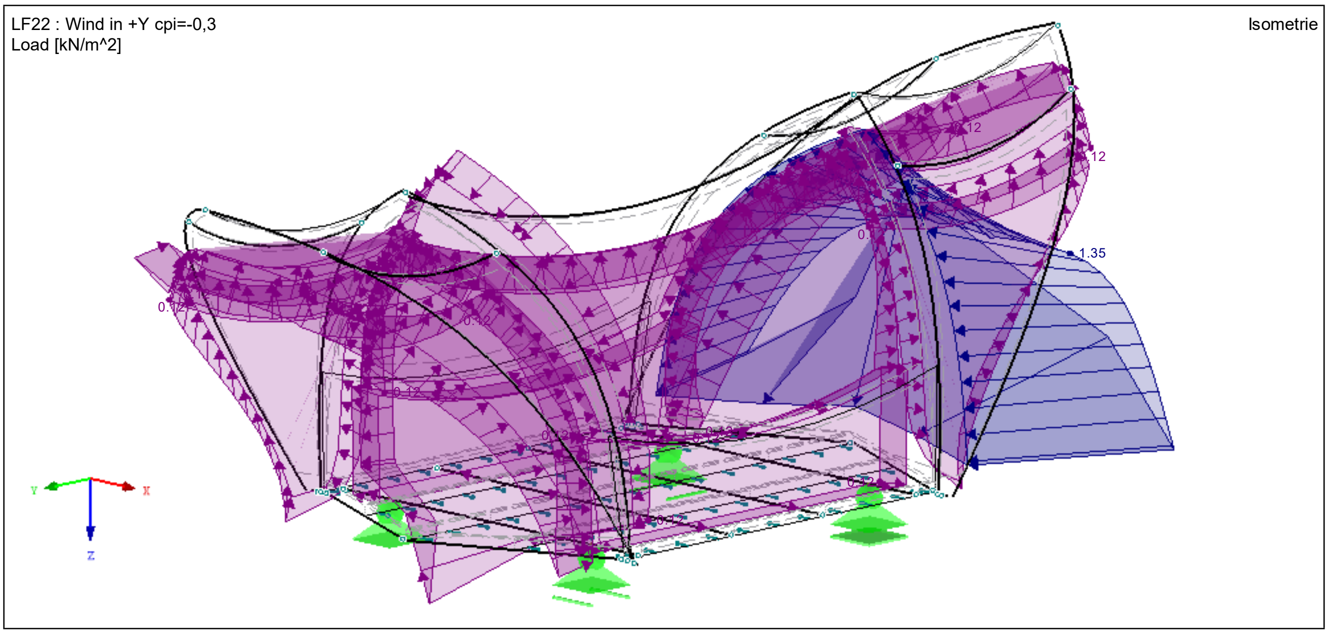
3.1.2 Loads

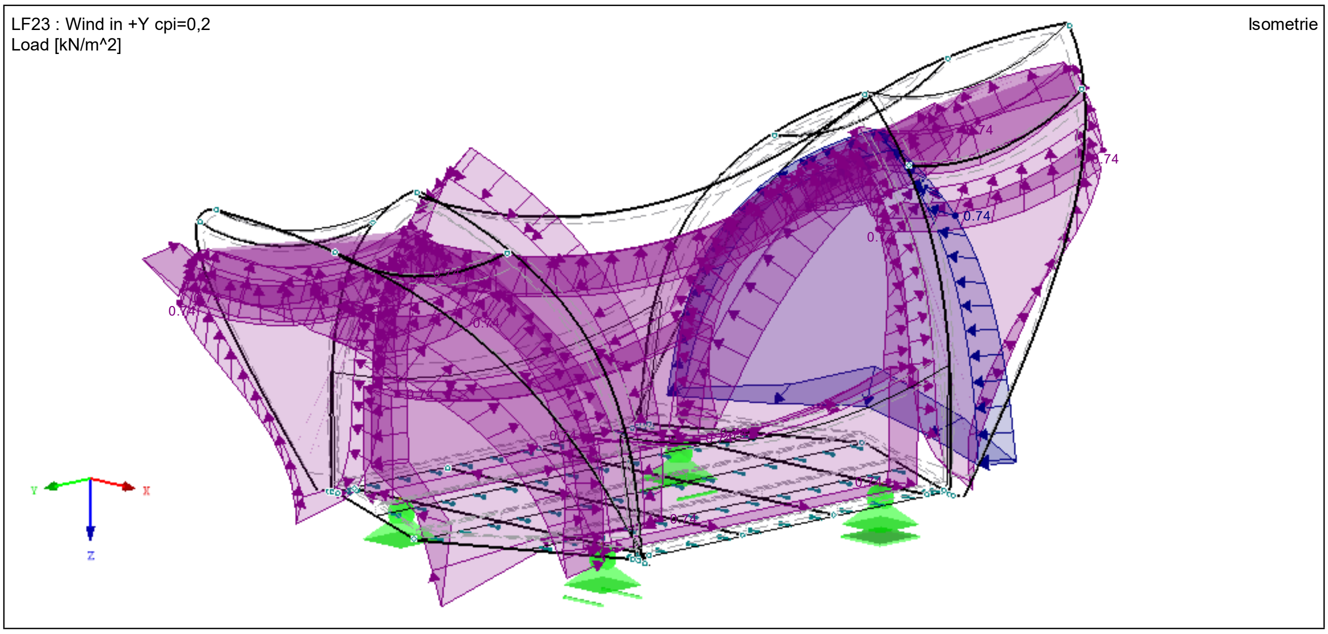



LF10 : Snow
Load [kN/m^2]
Isometrie
0.80
0.80
0.80
0.80
Y
X
Z

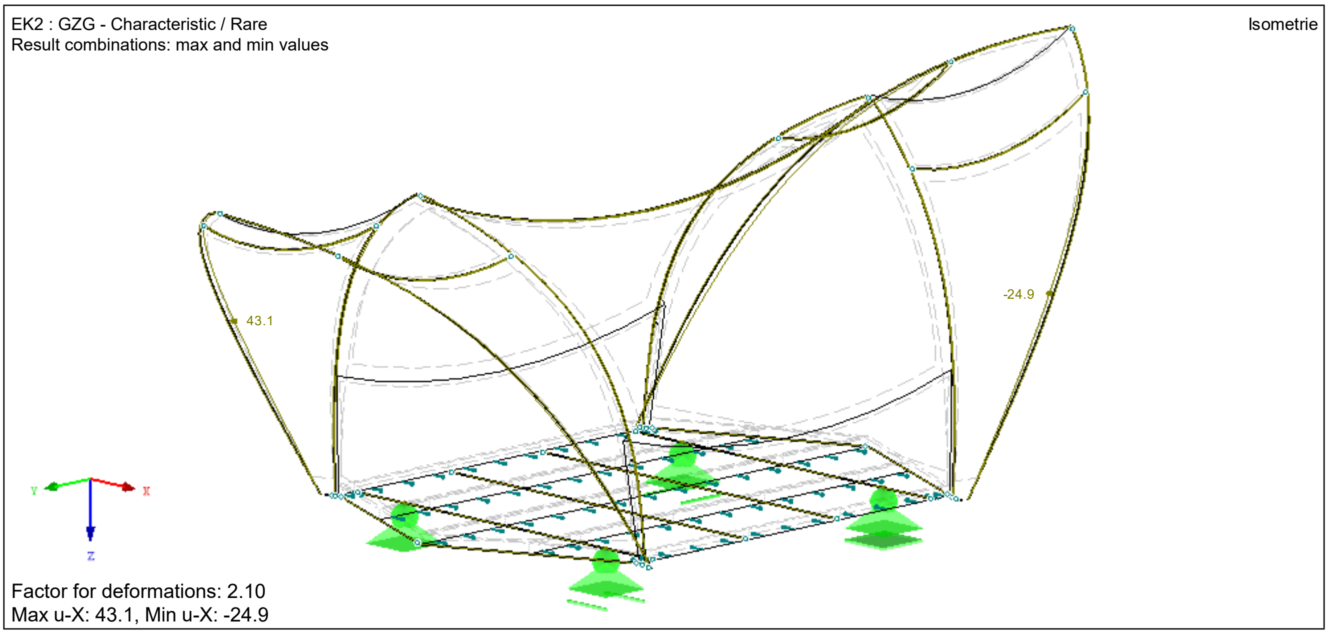

LF20 : Wind in +X cpi=-0,3
Load [kN/m^2]
Isometrie
p-z 1.35
p-z 1.35
1.10
1.10
p-z -1.10
p-z -1.10
p-z -1.10
p-z -1.10
p-z -1.10
Y
X
Z


LF21 : Wind in +X cpi=0,2
Load [kN/m^2]
Isometrie
p-z 0.74
p-z 0.74
p-z -1.72
p-z -1.72
p-z -1.72
p-z -1.72
p-z -1.72
1.72
1.72
Y
X
Z


LF22 : Wind in +Y cpi=-0,3
Load [kN/m^2]
Isometrie
1.35
Y
X
Z

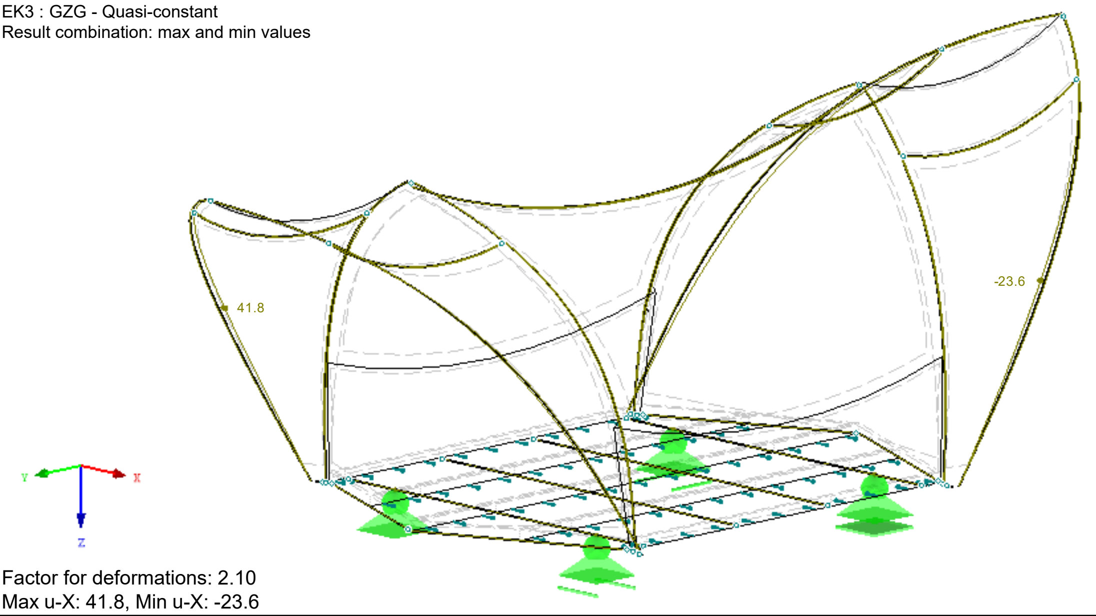


3.1.3 Deformations



EK3 : GZG - Quasi-constant
Result combination: max and min values

Isometrie

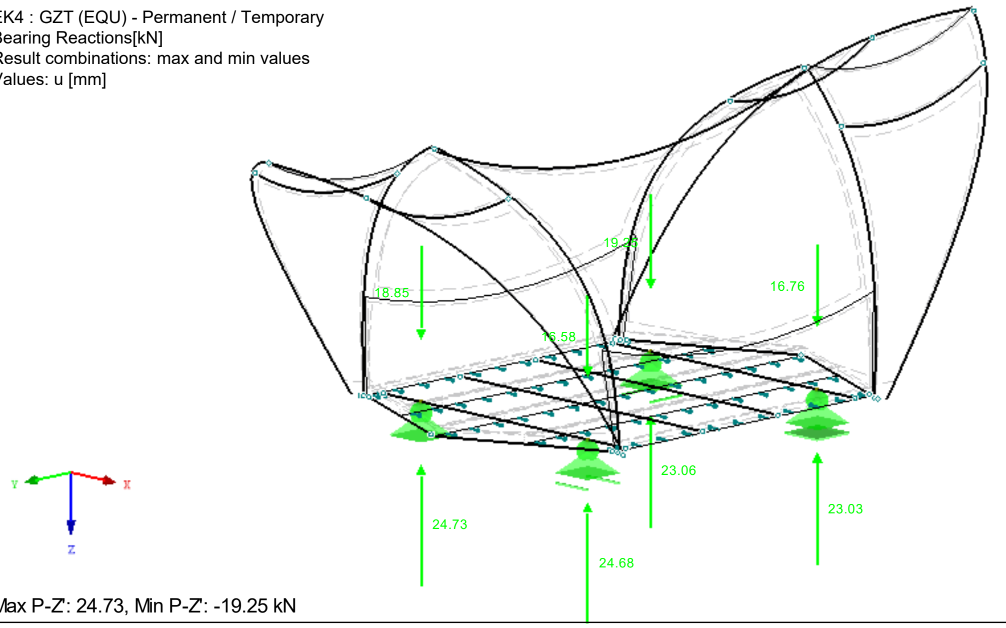


Factor for deformations: 2.10
Max u-X: 41.8, Min u-X: -23.6

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]

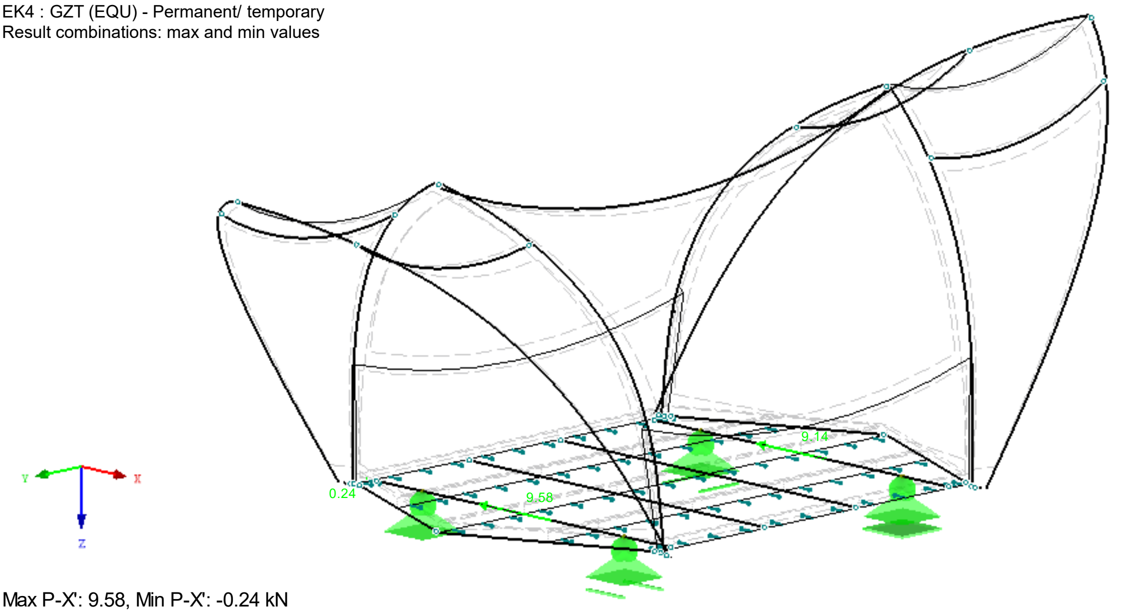
Isometrie



Max P-Z': 24.73, Min P-Z': -19.25 kN

EK4 : GZT (EQU) - Permanent/ temporary
Result combinations: max and min values

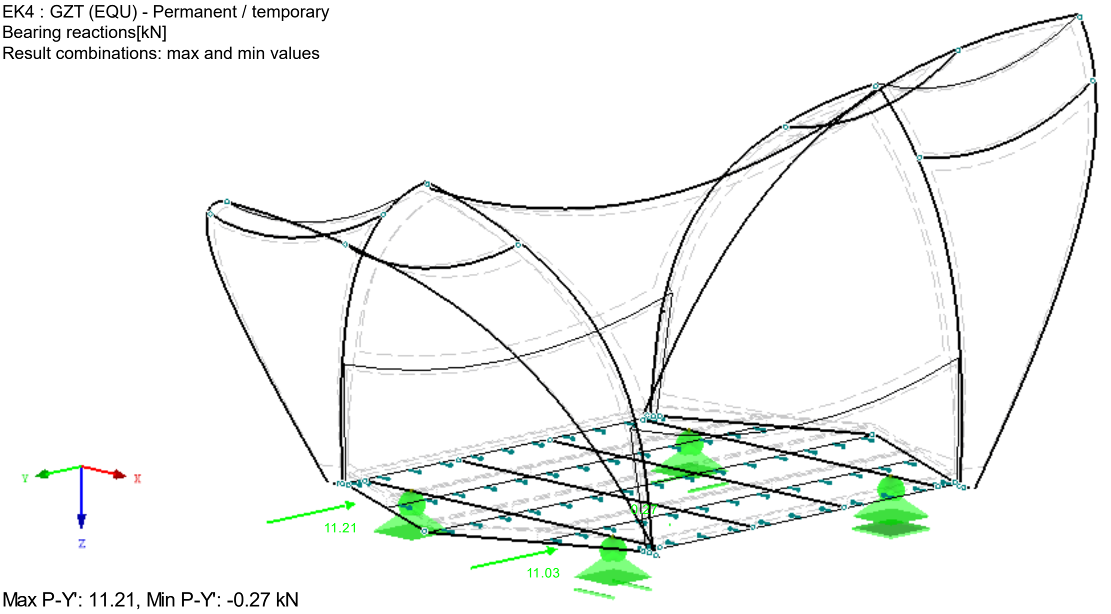
Isometrie



Max P-X': 9.58, Min P-X': -0.24 kN

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

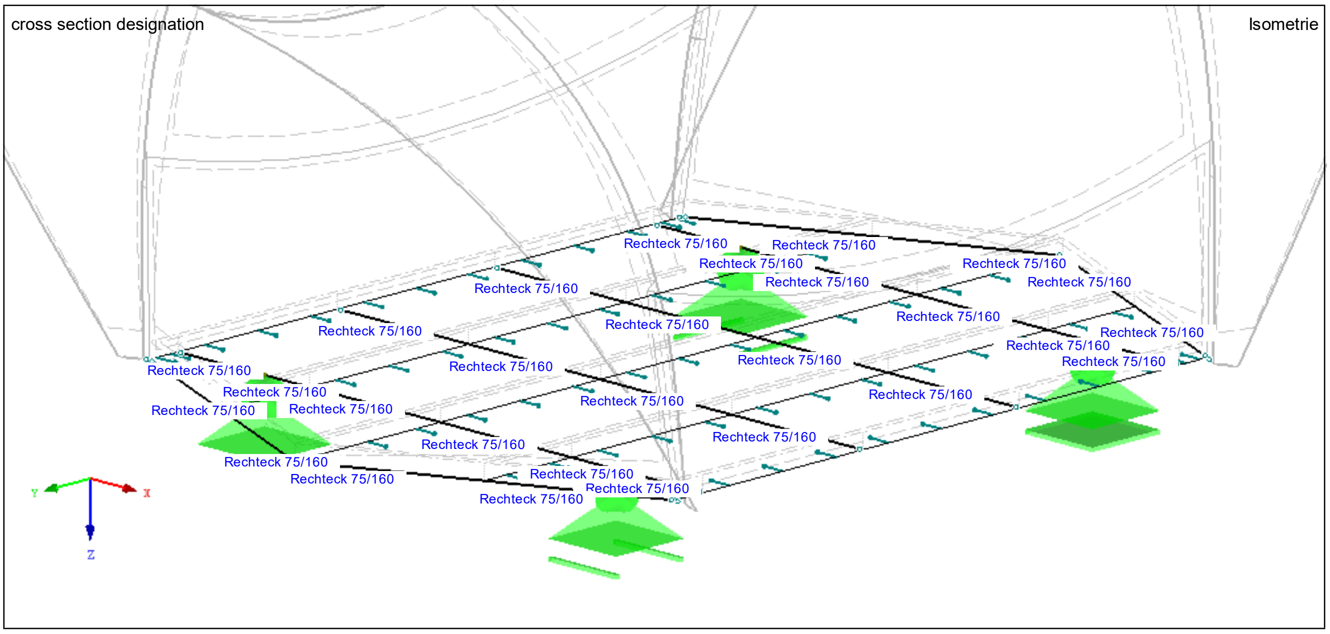
Isometrie



Max P-Y': 11.21, Min P-Y': -0.27 kN

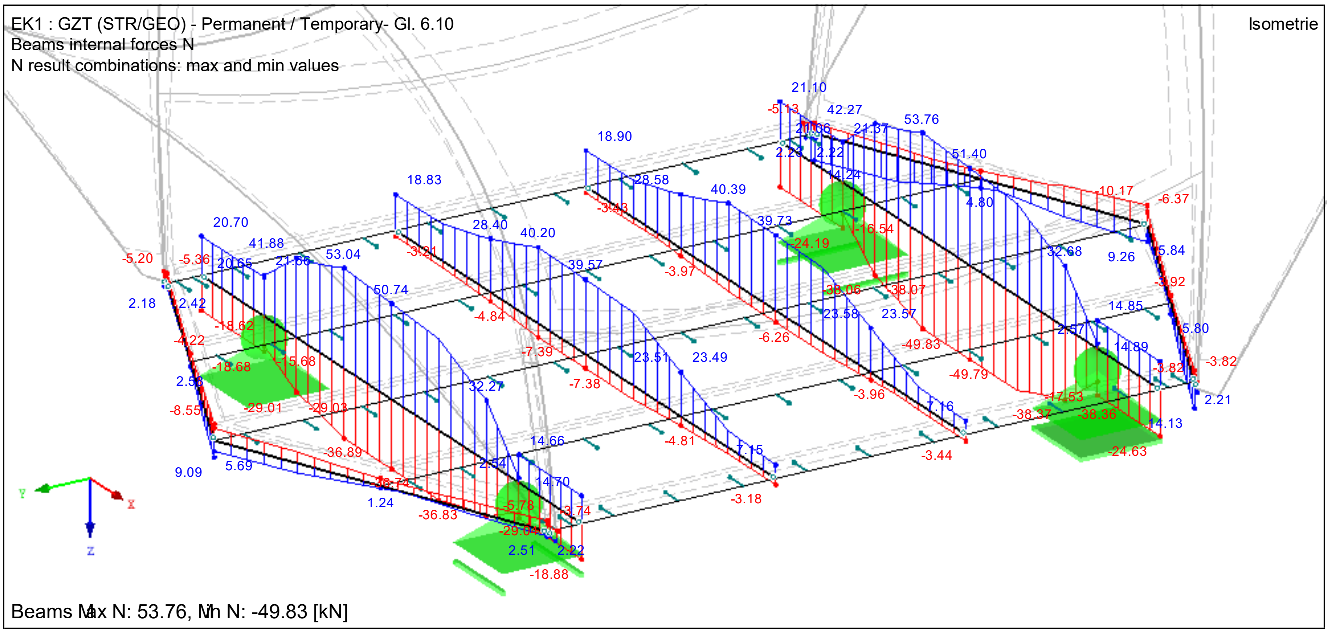
3.2 Terrace construction - Tram ceiling

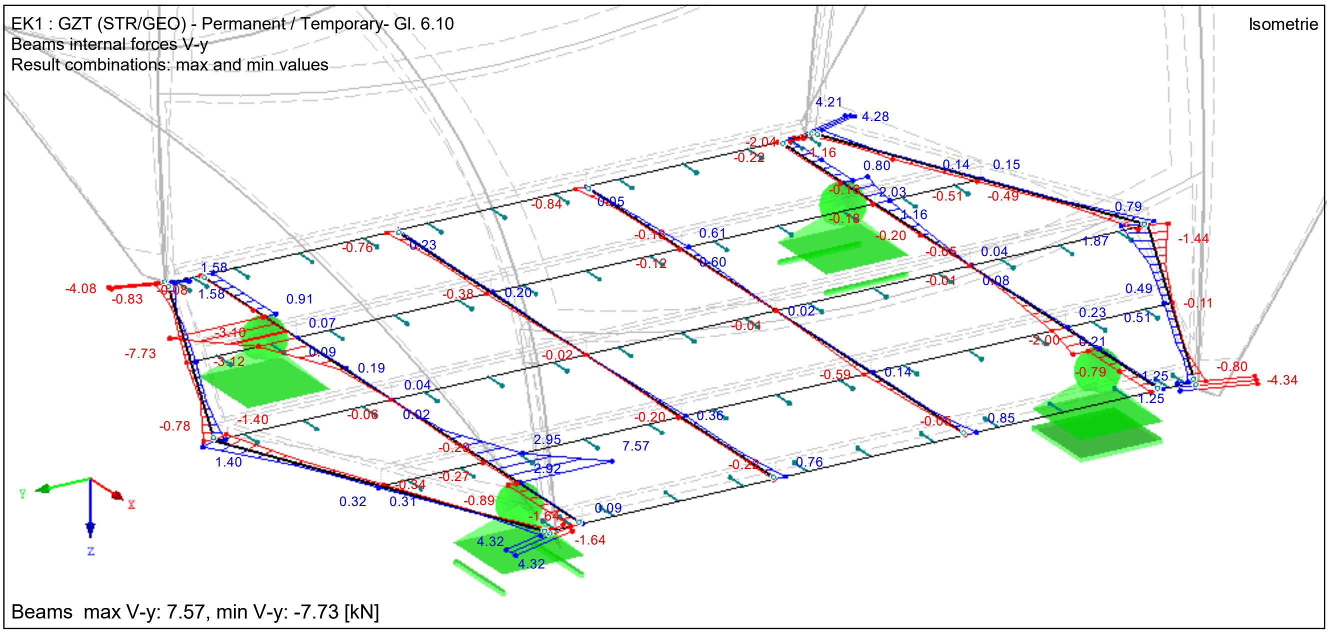
3.2.1 Cross sections

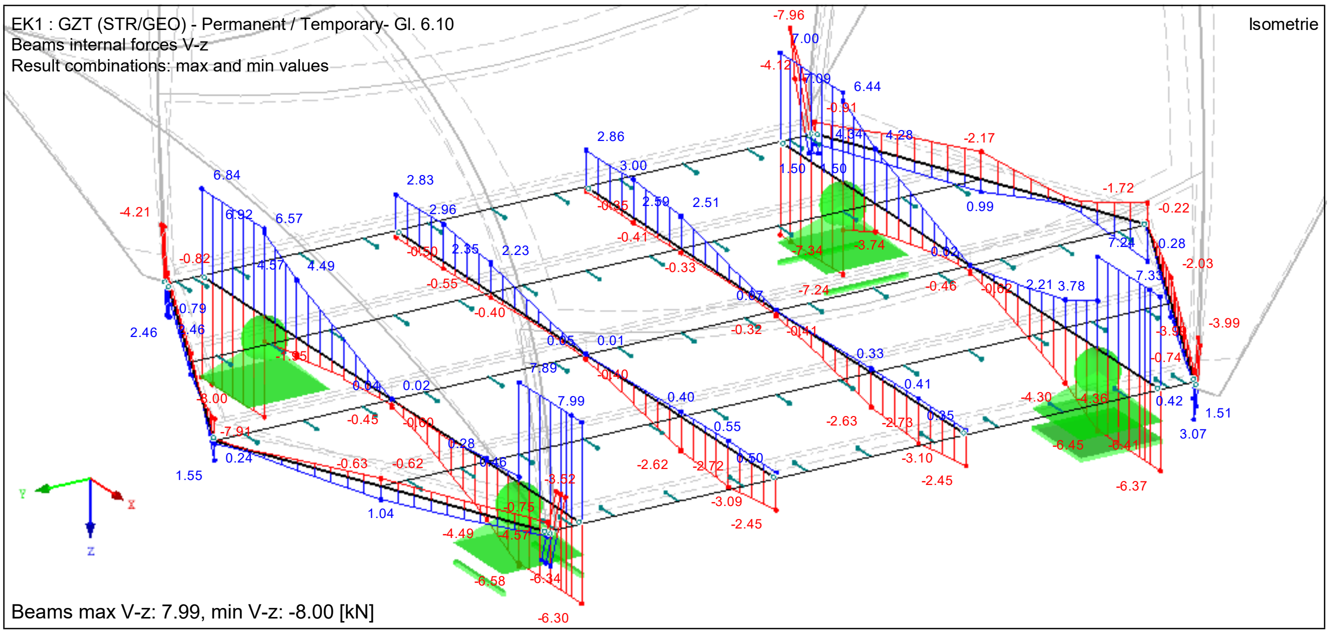


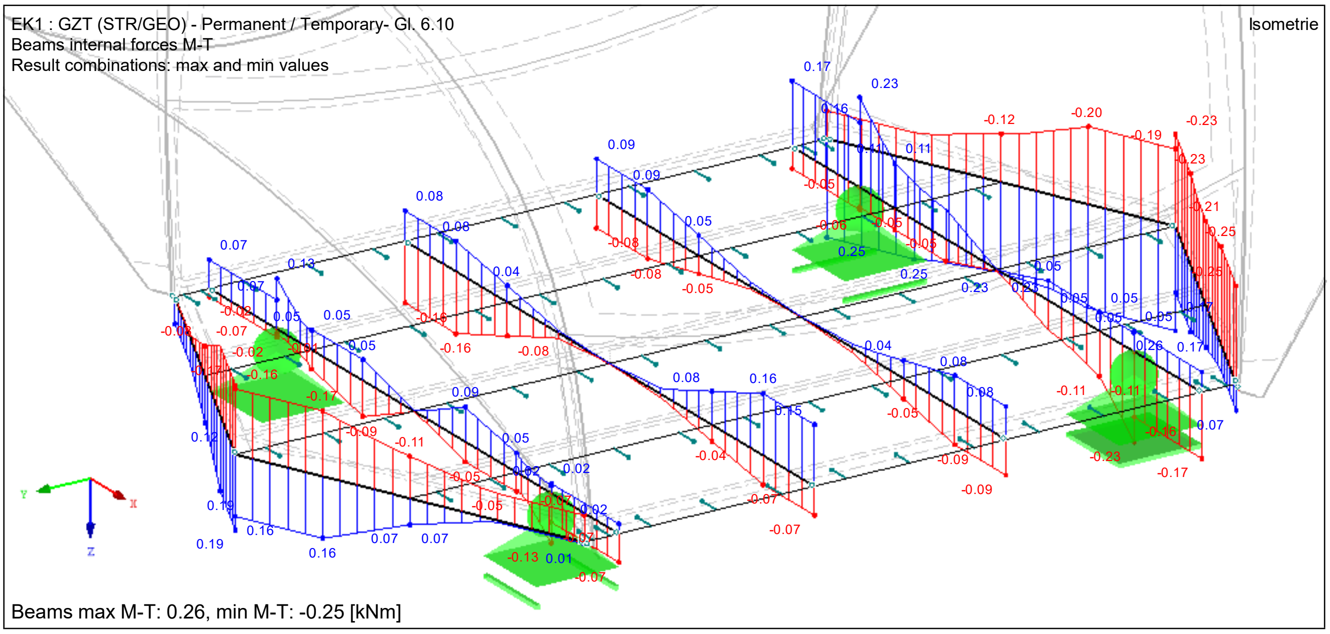
Material: LVL, KERTO-Q

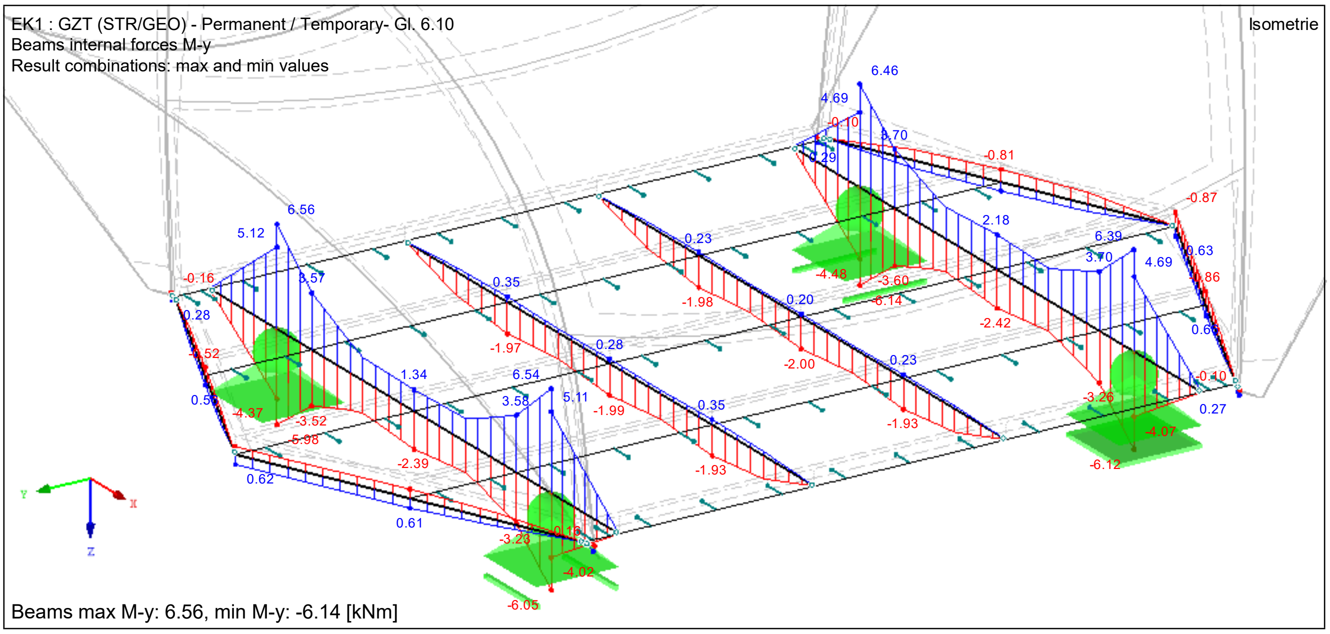
3.2.2 Design section properties

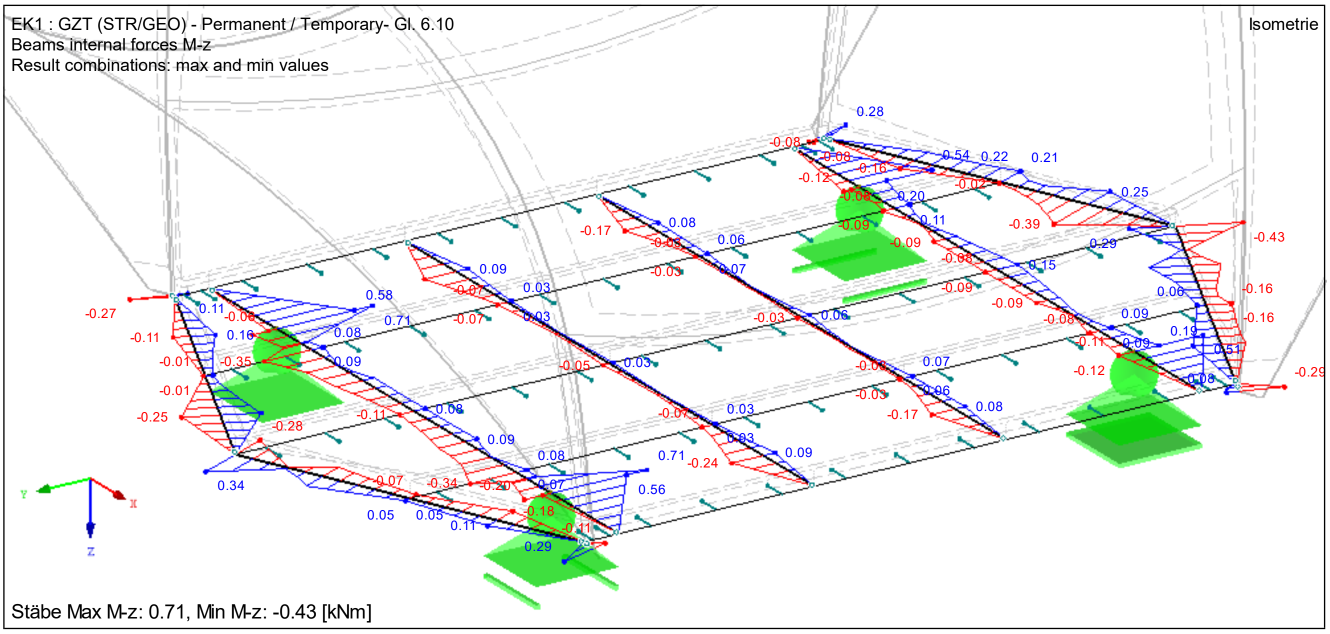



EK1 : GZT (STR/GEO) - Permanent / Temporary- Gl. 6.10
Beams internal forces V-y
Result combinations: max and min values
Isometrie
Beams max V-y: 7.57, min V-y: -7.73 [kN]

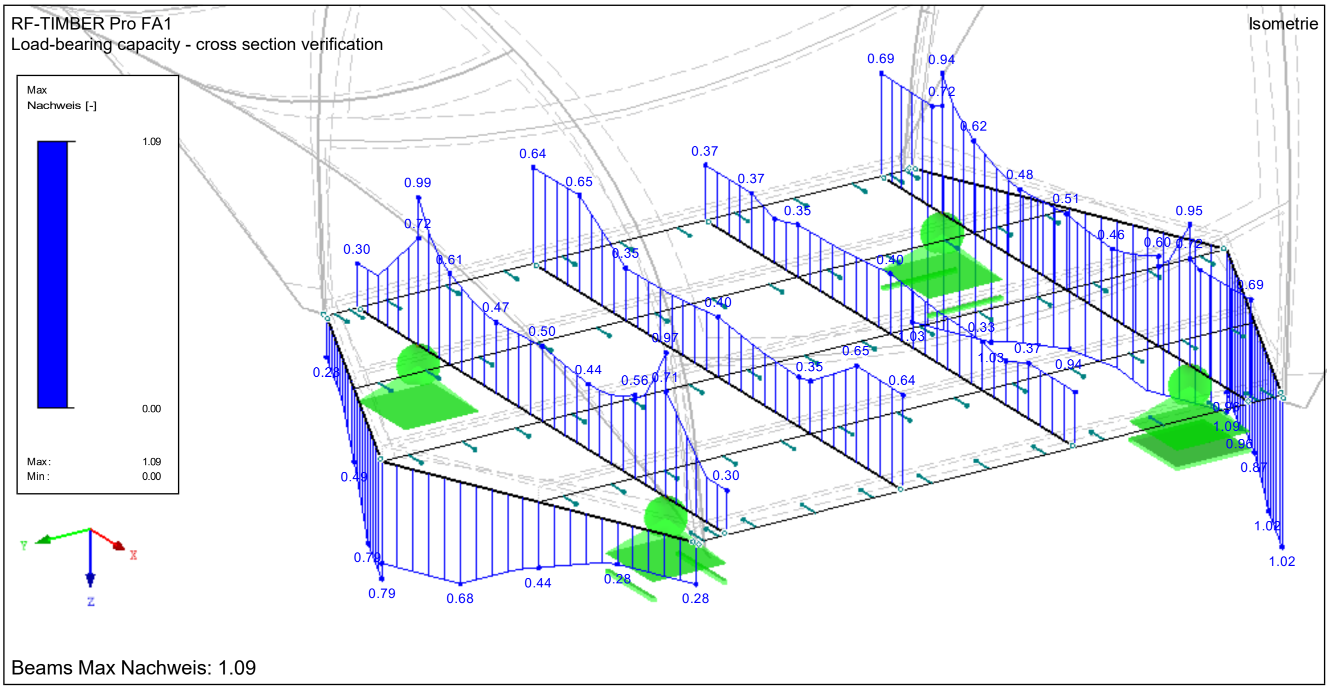

EK1 : GZT (STR/GEO) - Permanent / Temporary- Gl. 6.10
Beams internal forces V-z
Result combinations: max and min values
Isometrie
Beams max V-z: 7.99, min V-z: -8.00 [kN]


EK1 : GZT (STR/GEO) - Permanent / Temporary- Gl. 6.10
Beams internal forces M-T
Result combinations: max and min values
Isometrie
Beams max M-T: 0.26, min M-T: -0.25 [kNm]

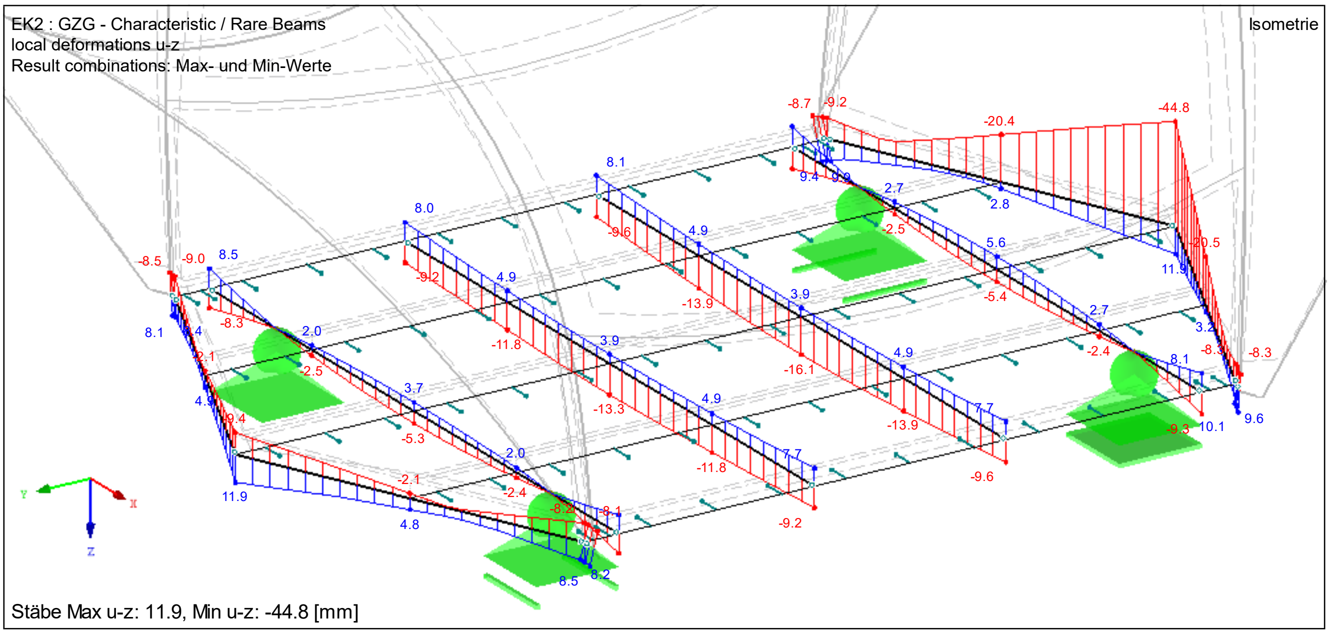

EK1 : GZT (STR/GEO) - Permanent / Temporary- Gl. 6.10
Beams internal forces M-y
Result combinations: max and min values
Isometrie
Beams max M-y: 6.56, min M-y: -6.14 [kNm]

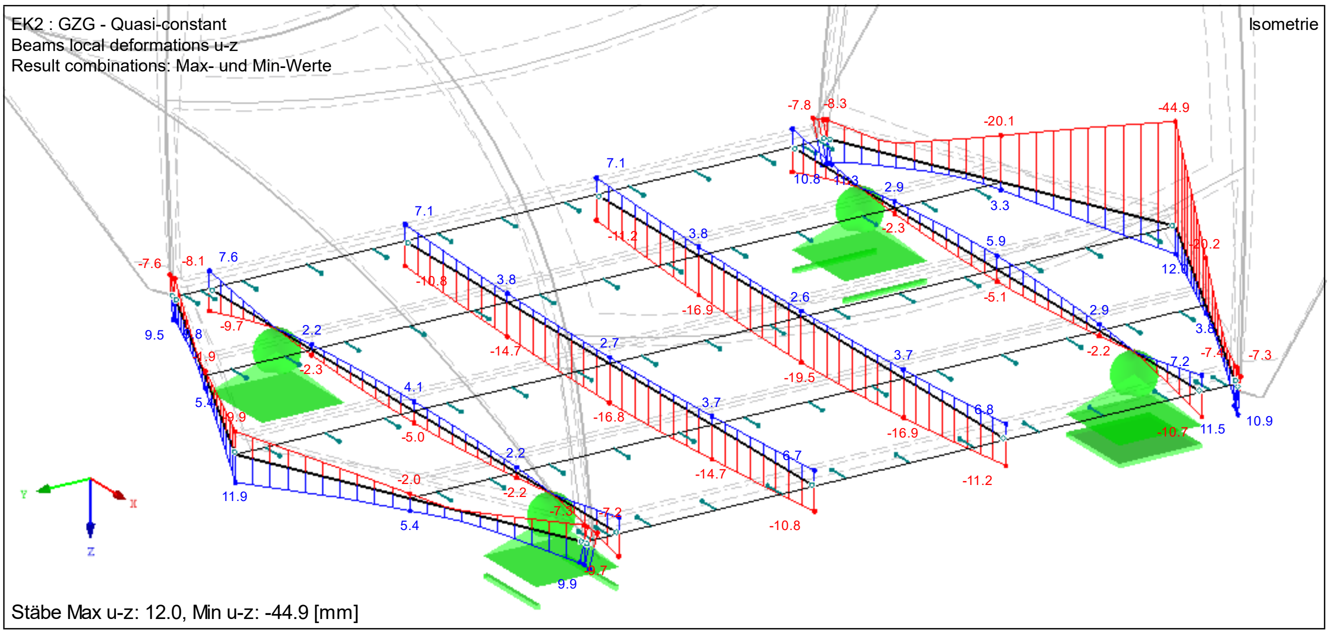


3.2.3 Proof of structural safety



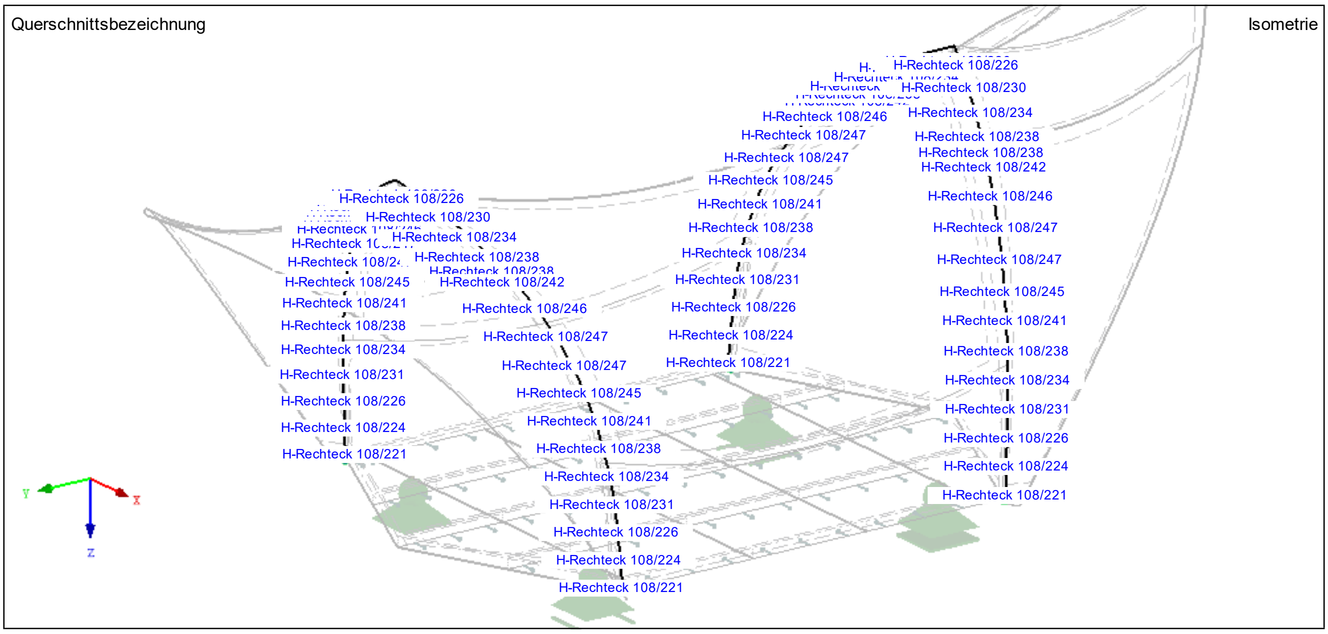
3.2.4 Ceilings deformations





3.3 Edge Beam

3.3.1 Cross sections

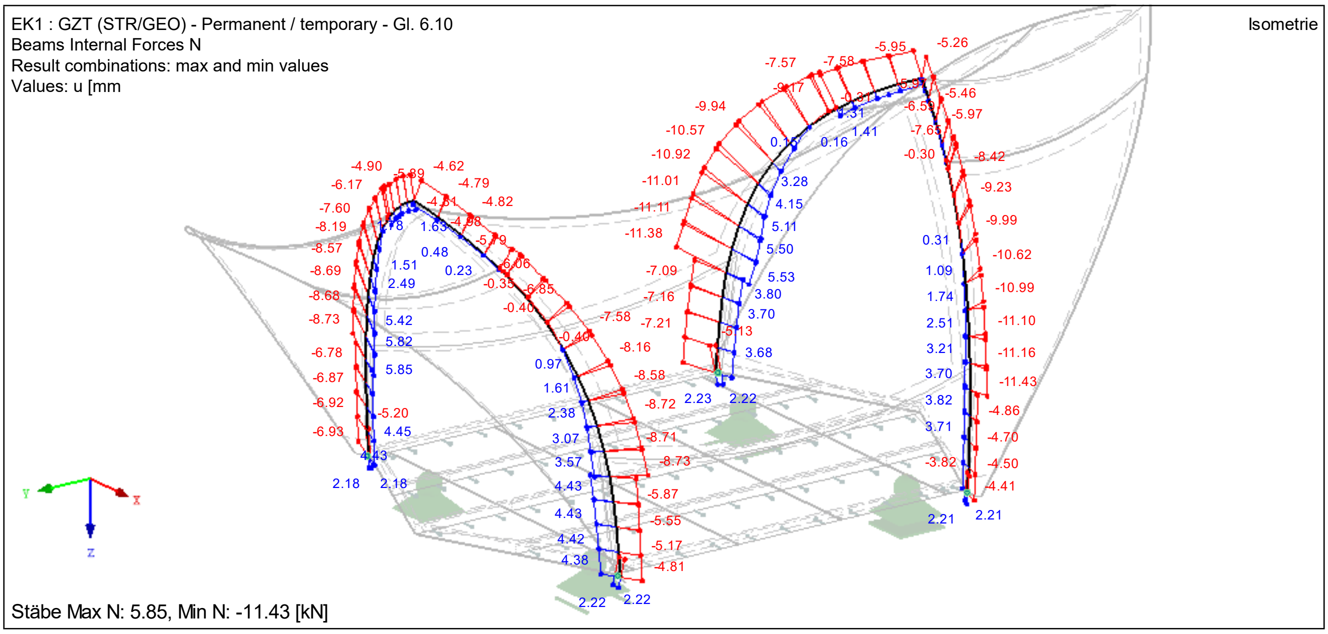


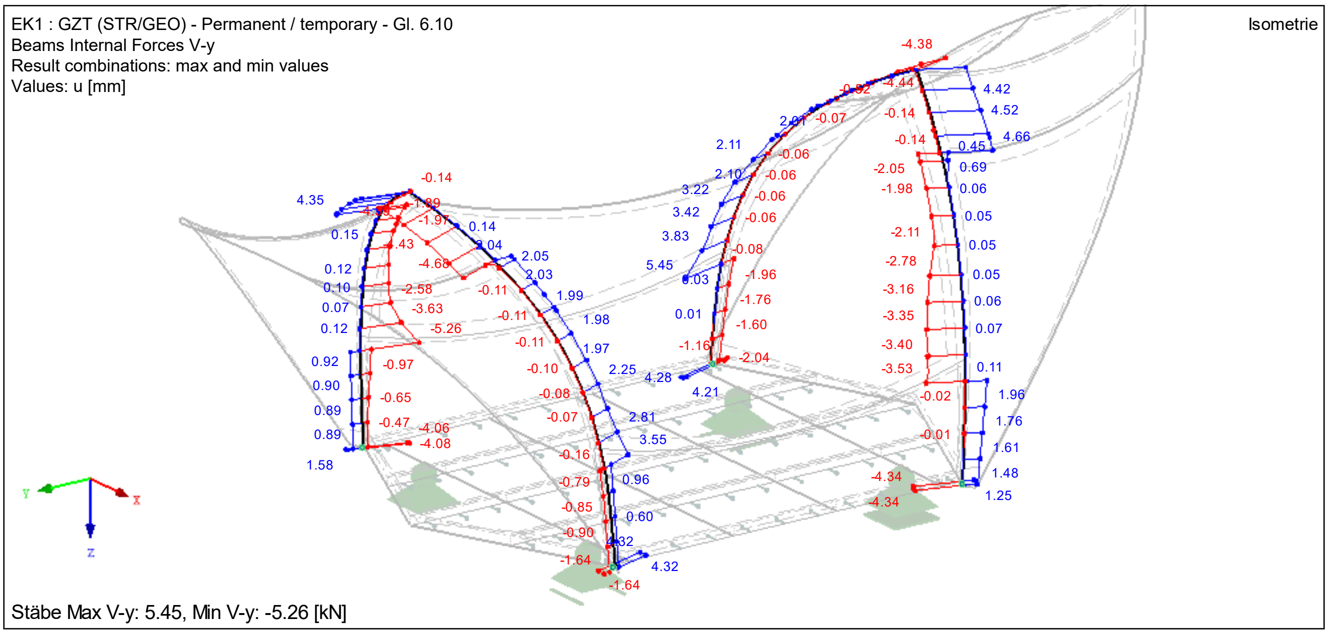
Material: LVL, KERTO-Q

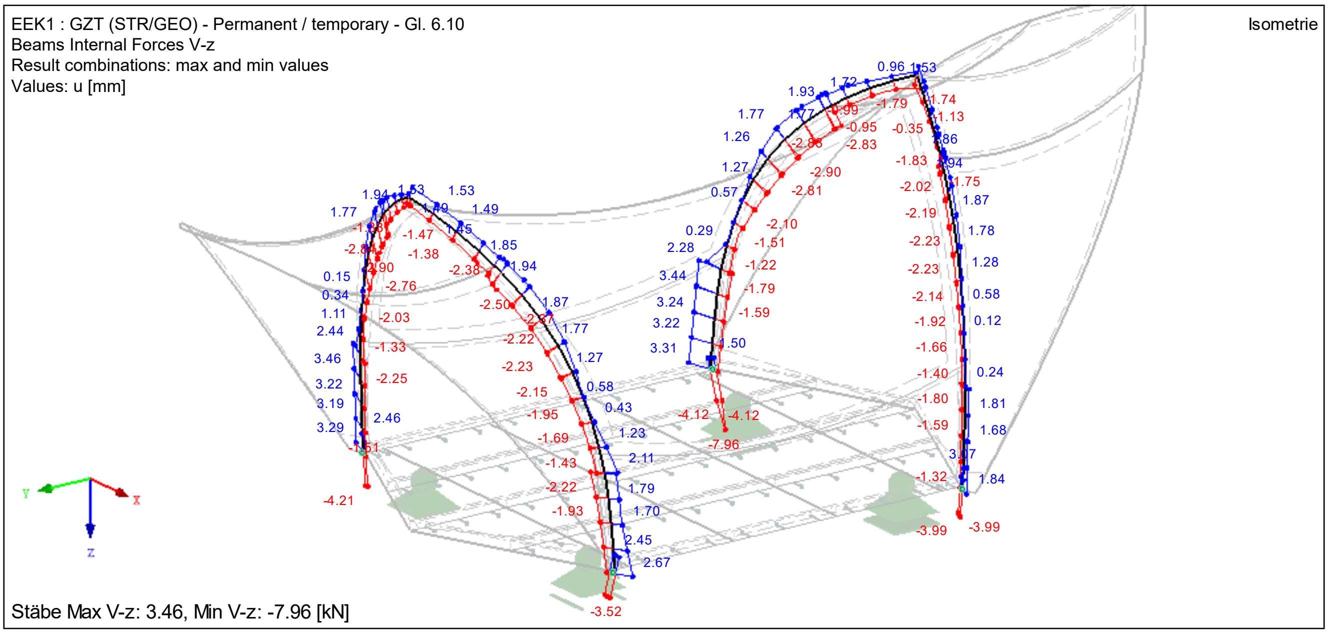
KERTO-Q strength properties with regard to the force fiber angle

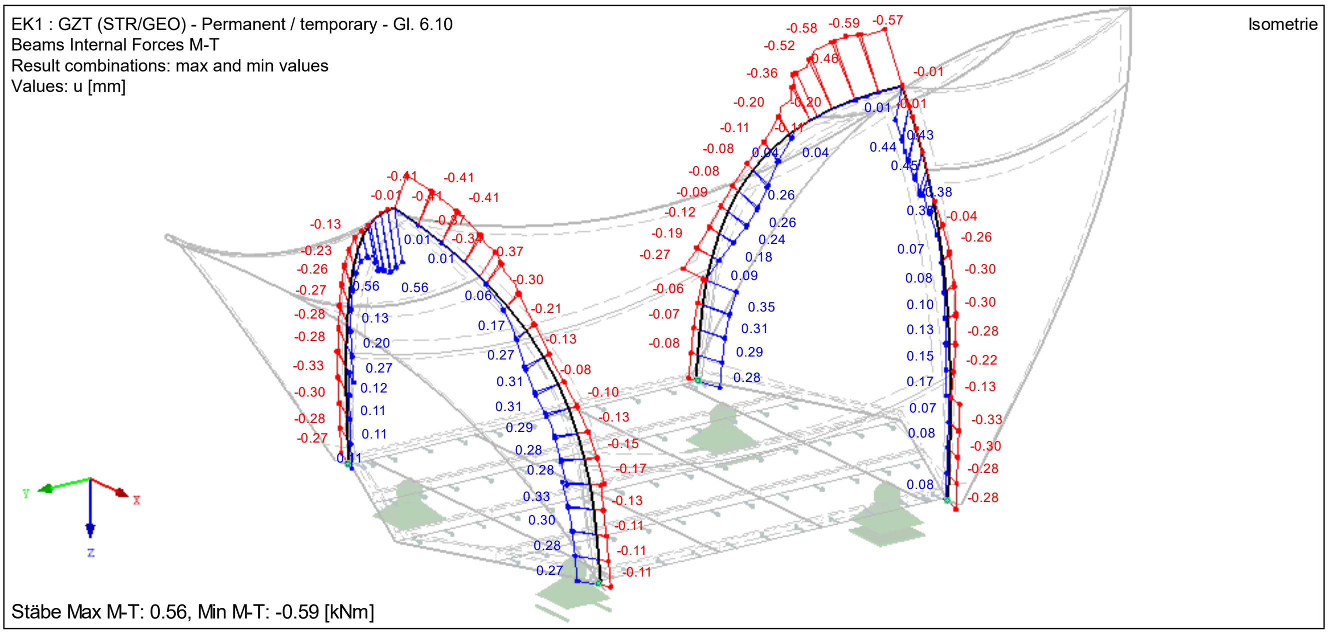
Edge Beam (1st segment = at ridge)												
	Faserwinkel		$E_{\alpha,mean}$		$f_{m,\alpha,k}$		$f_{t,\alpha,k}$		$f_{c,\alpha,k}$		$f_{v,0,k}$	
1. Segment	33,96	°	1436,4	N/mm²	7,58	N/mm²	6,16	N/mm²	8,41	N/mm²	4,50	N/mm²
2. Segment	30,60	°	1554,0	N/mm²	7,94	N/mm²	6,45	N/mm²	9,00	N/mm²	4,50	N/mm²
3. 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

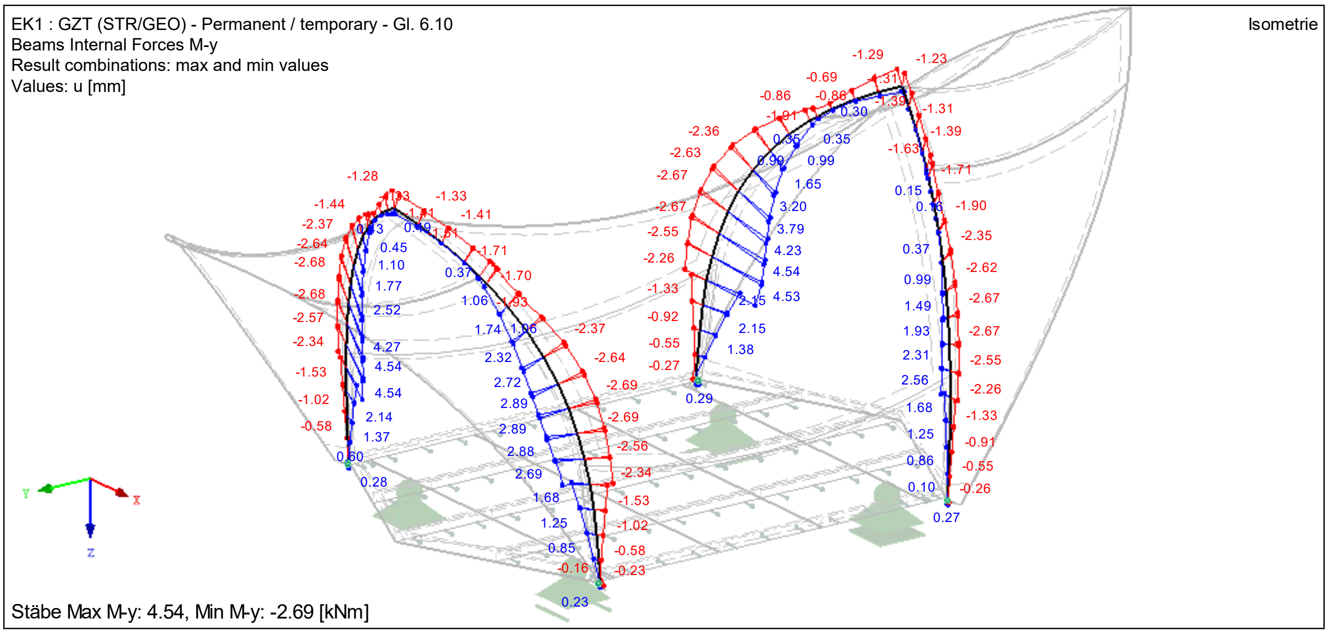
3.3.2 Design sections properties

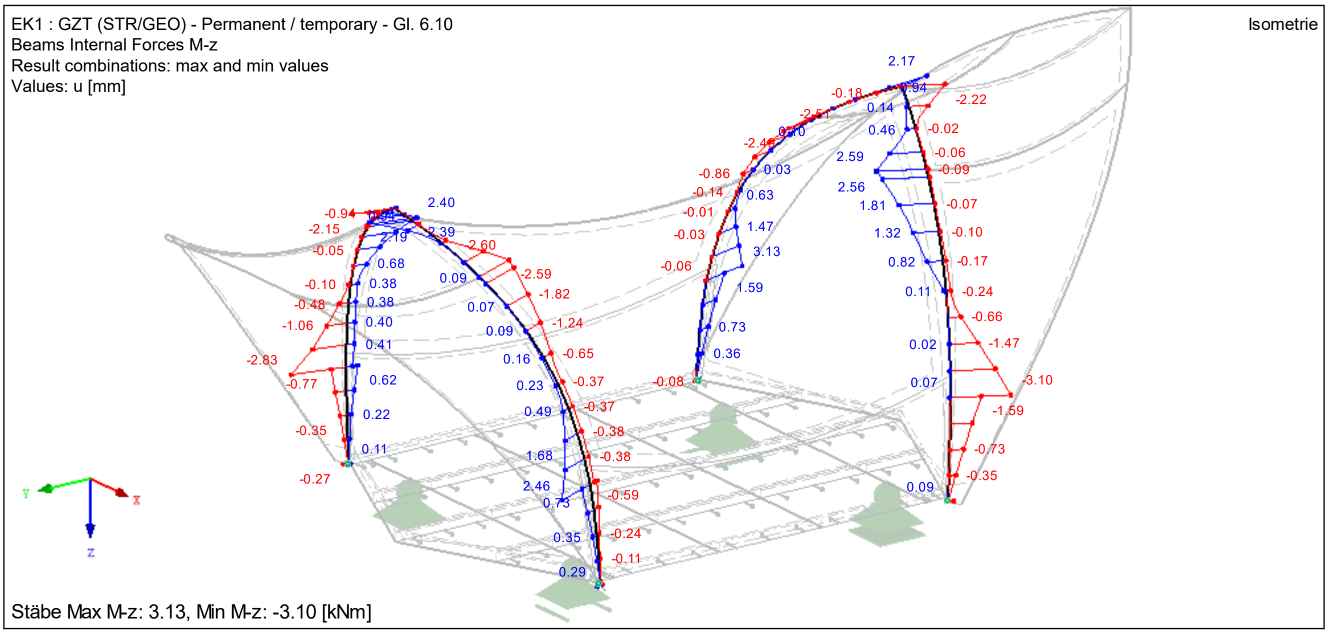




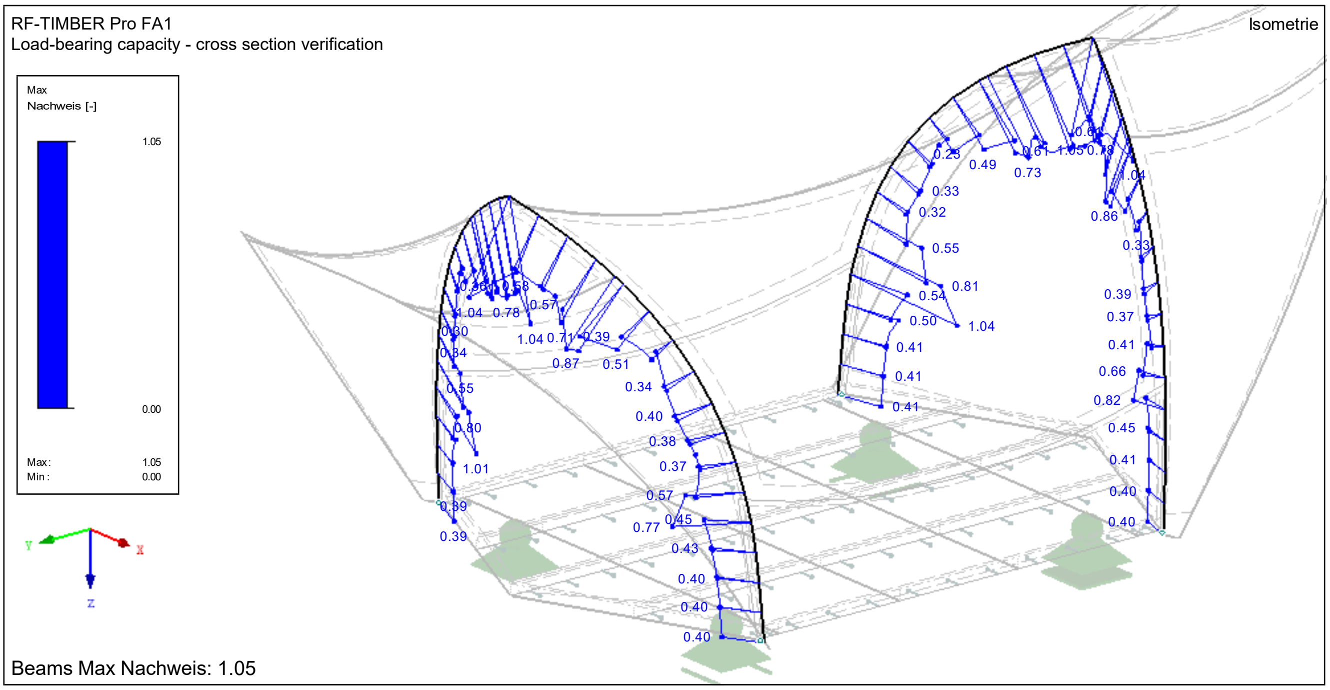

EEK1 : GZT (STR/GEO) - Permanent / temporary - Gl. 6.10
Beams Internal Forces V-z
Result combinations: max and min values
Values: u [mm]
Isometrie
Stäbe Max V-z: 3.46, Min V-z: -7.96 [kN]


EK1 : GZT (STR/GEO) - Permanent / temporary - Gl. 6.10
Beams Internal Forces M-T
Result combinations: max and min values
Values: u [mm]
Isometrie
Stäbe Max M-T: 0.56, Min M-T: -0.59 [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
Stäbe Max M-y: 4.54, Min M-y: -2.69 [kNm]

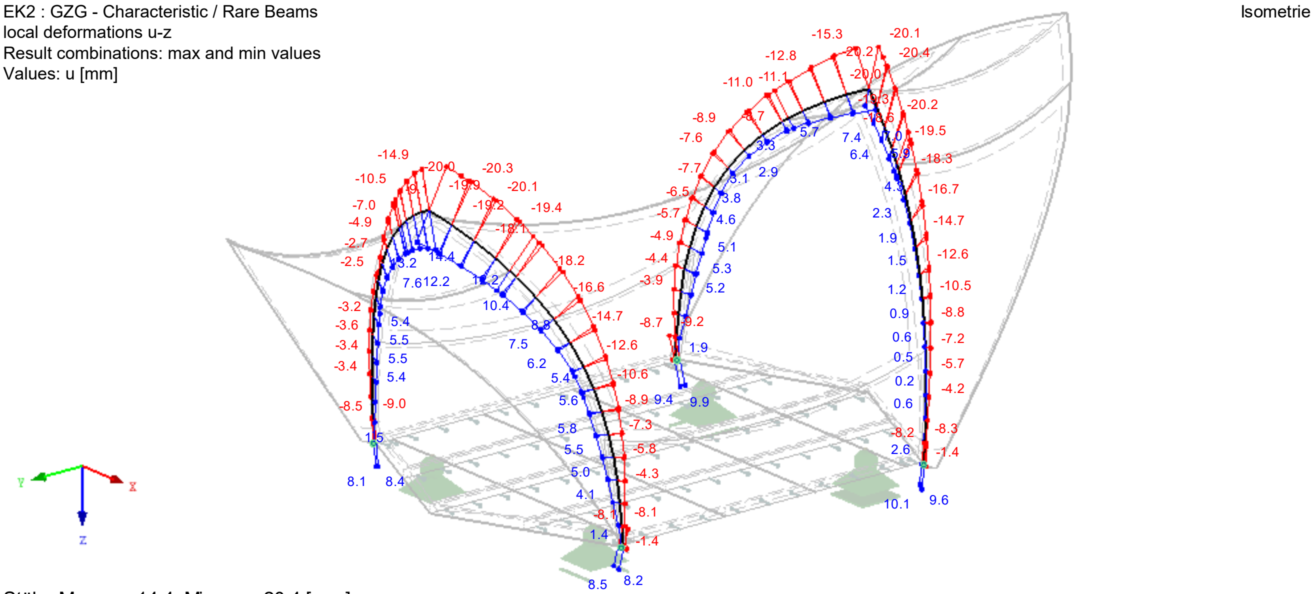

EK1 : GZT (STR/GEO) - Permanent / temporary - Gl. 6.10
Beams Internal Forces M-z
Result combinations: max and min values
Values: u [mm]
Isometrie
Stäbe Max M-z: 3.13, Min M-z: -3.10 [kNm]

3.3.3 Proof of structural safety



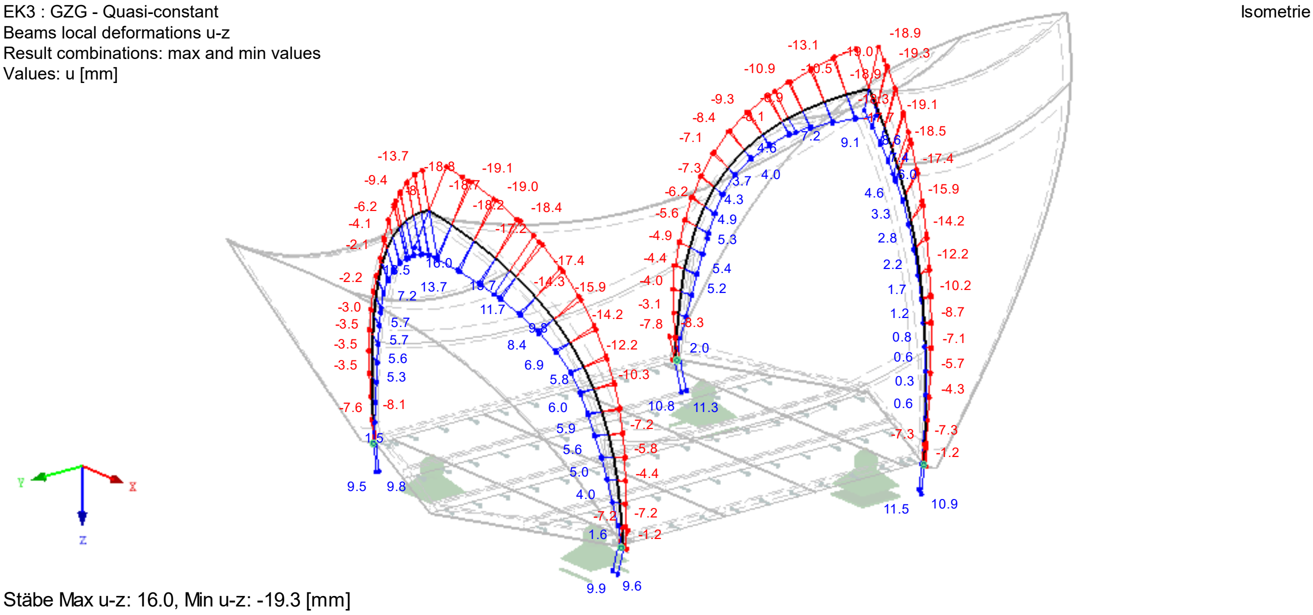
3.3.4 Verformungen

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



Stäbe Max u-z: 14.4, Min u-z: -20.4 [mm]

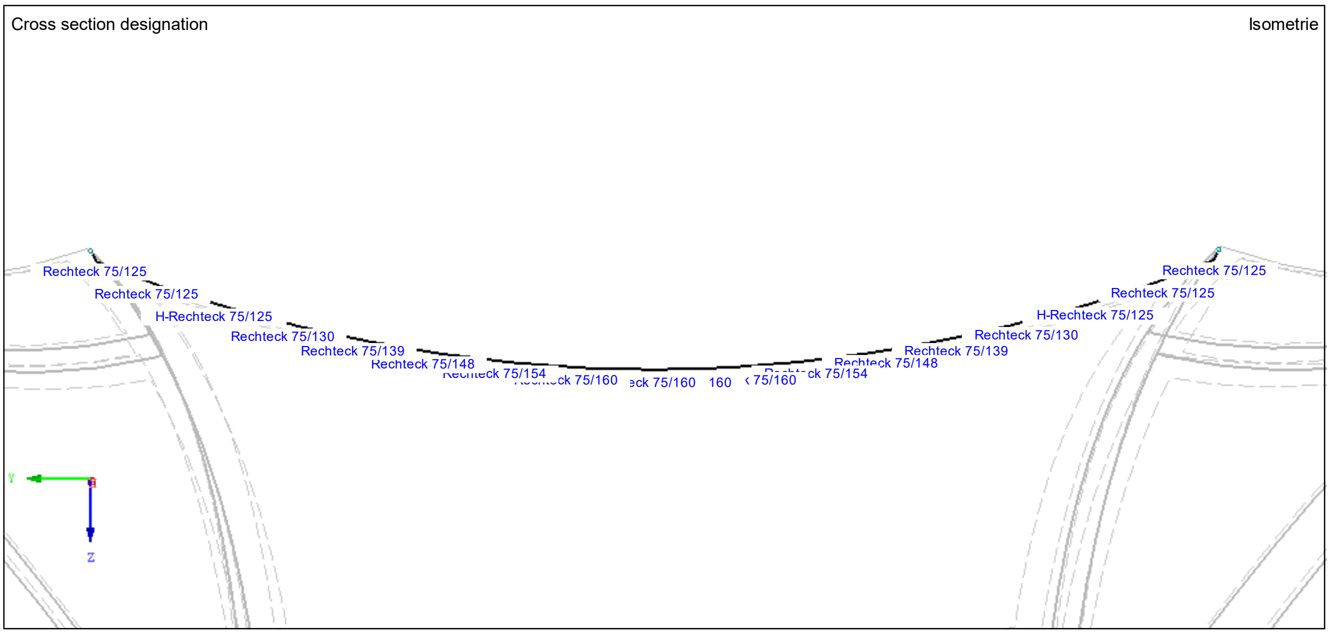
EK3 : GZG - Quasi-constant
Beams local deformations u-z
Result combinations: max and min values
Values: u [mm]



Stäbe Max u-z: 16.0, Min u-z: -19.3 [mm]

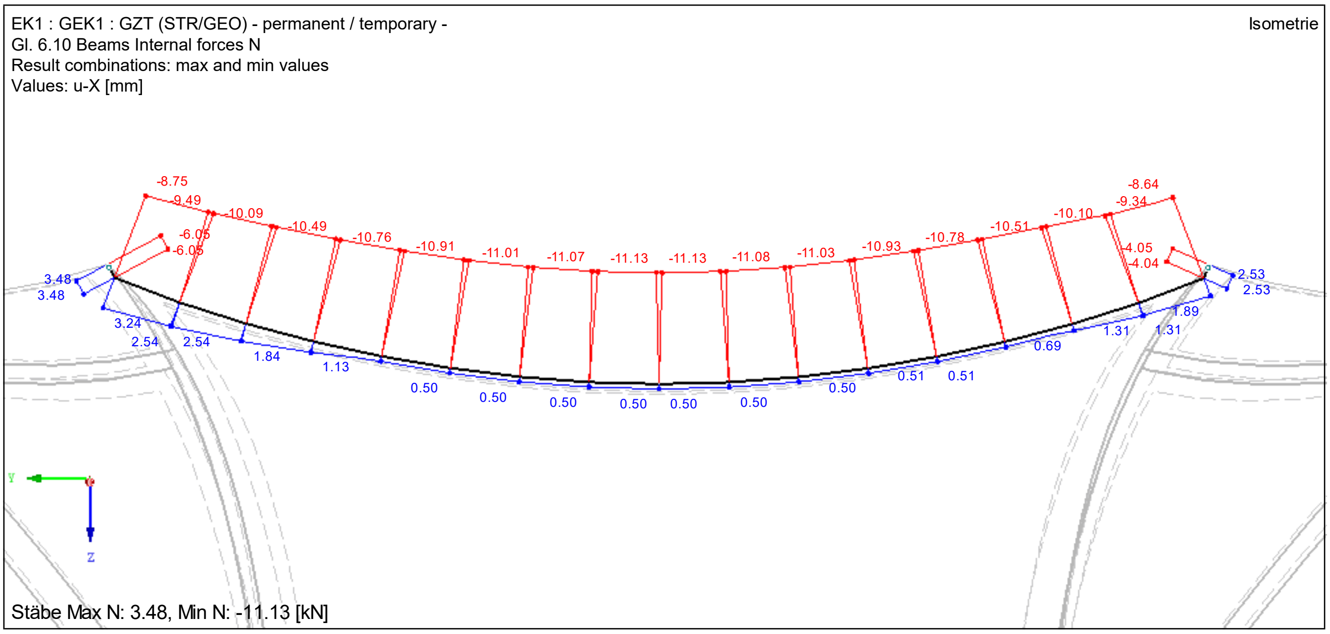
3.4 Ridge Beam

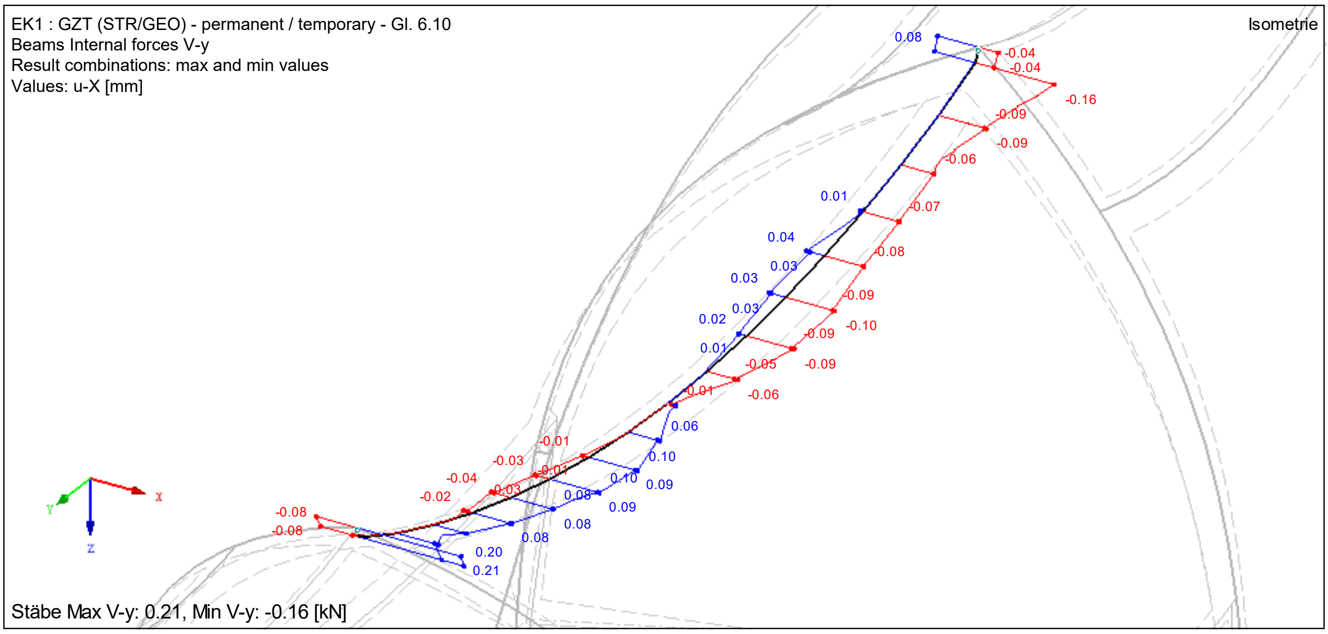
3.4.1 Cross sections

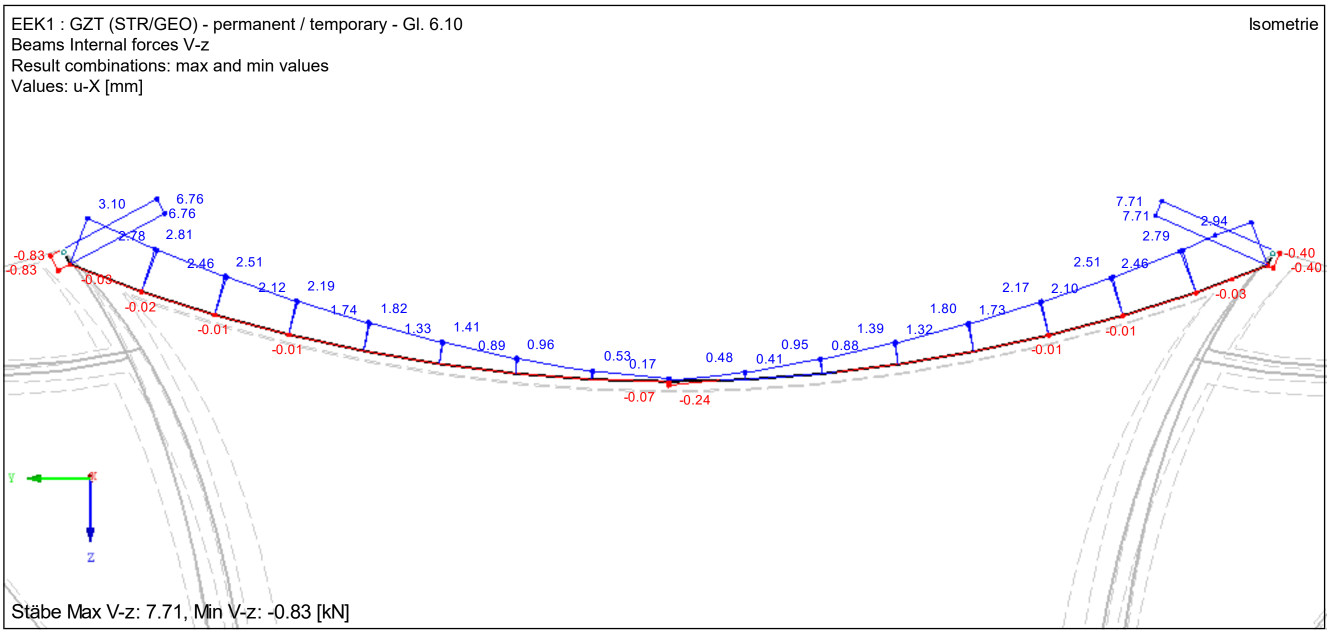


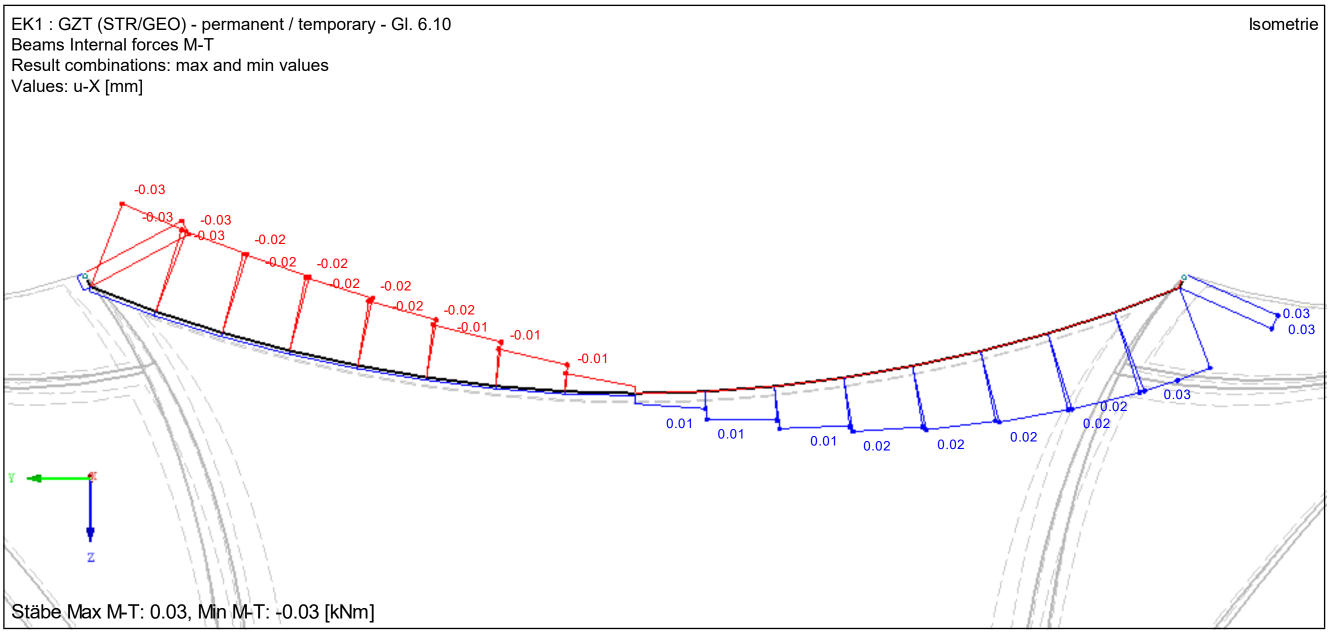
Material: BSH, GL24h

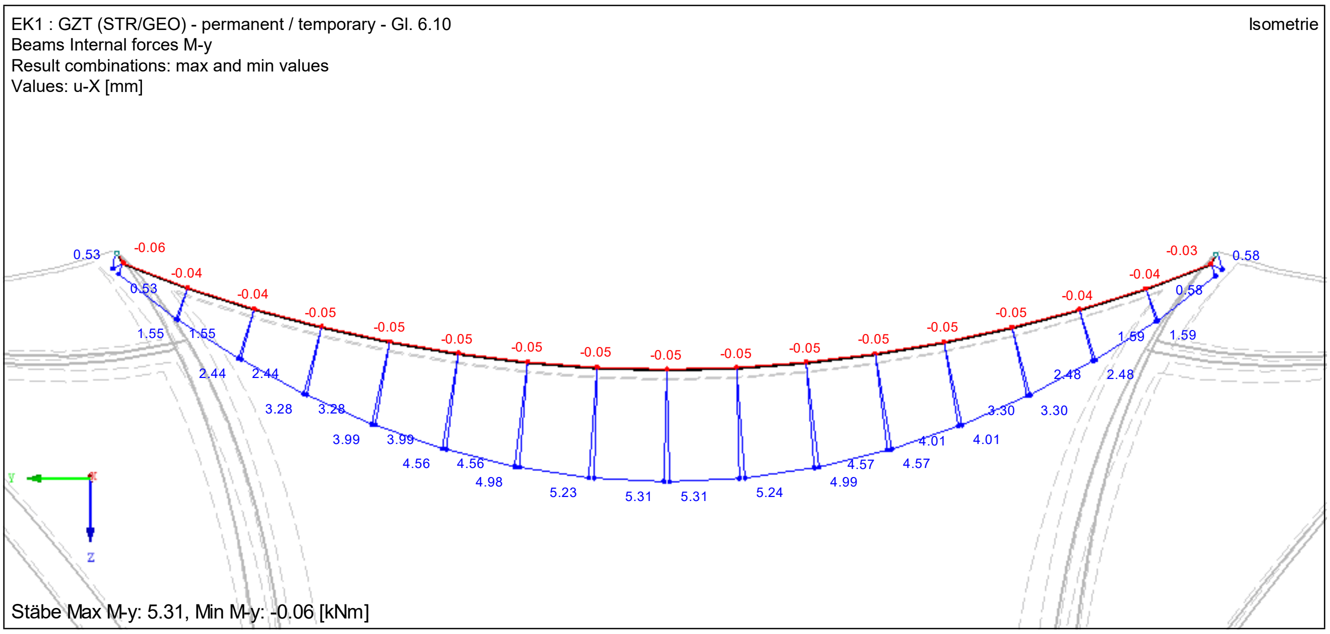
3.4.2 Design Internal forces

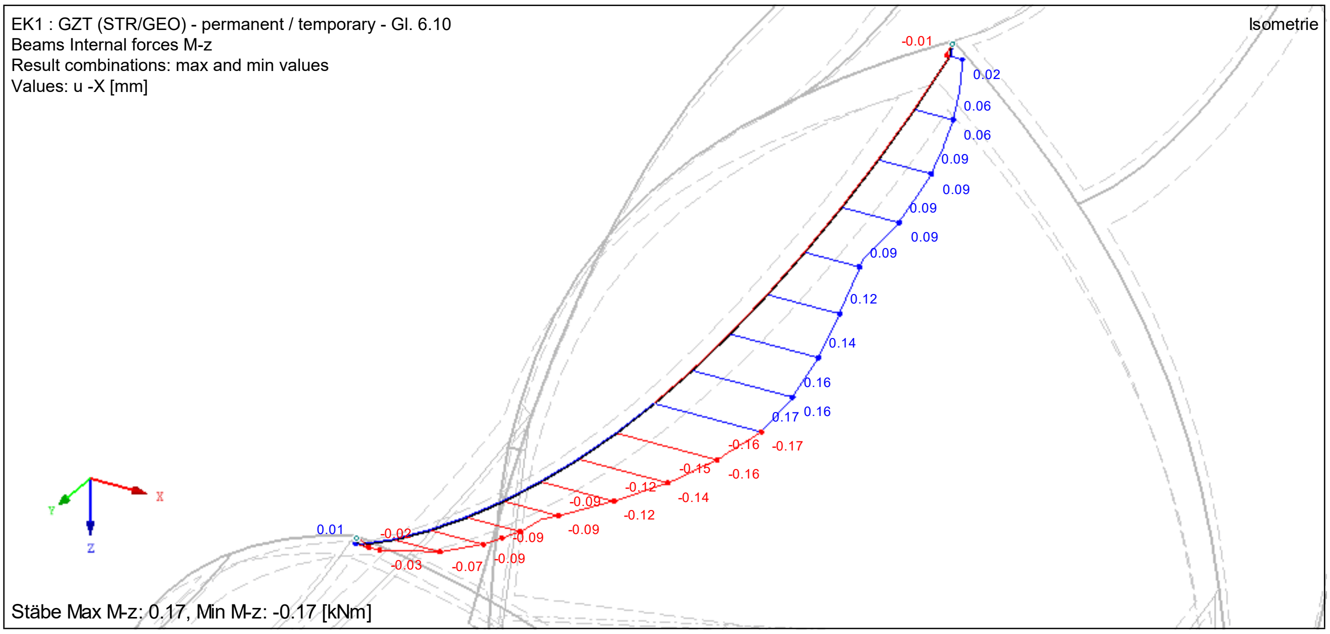



EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces V-y
Result combinations: max and min values
Values: u-X [mm]
Isometrie
Stäbe Max V-y: 0.21, Min V-y: -0.16 [kN]

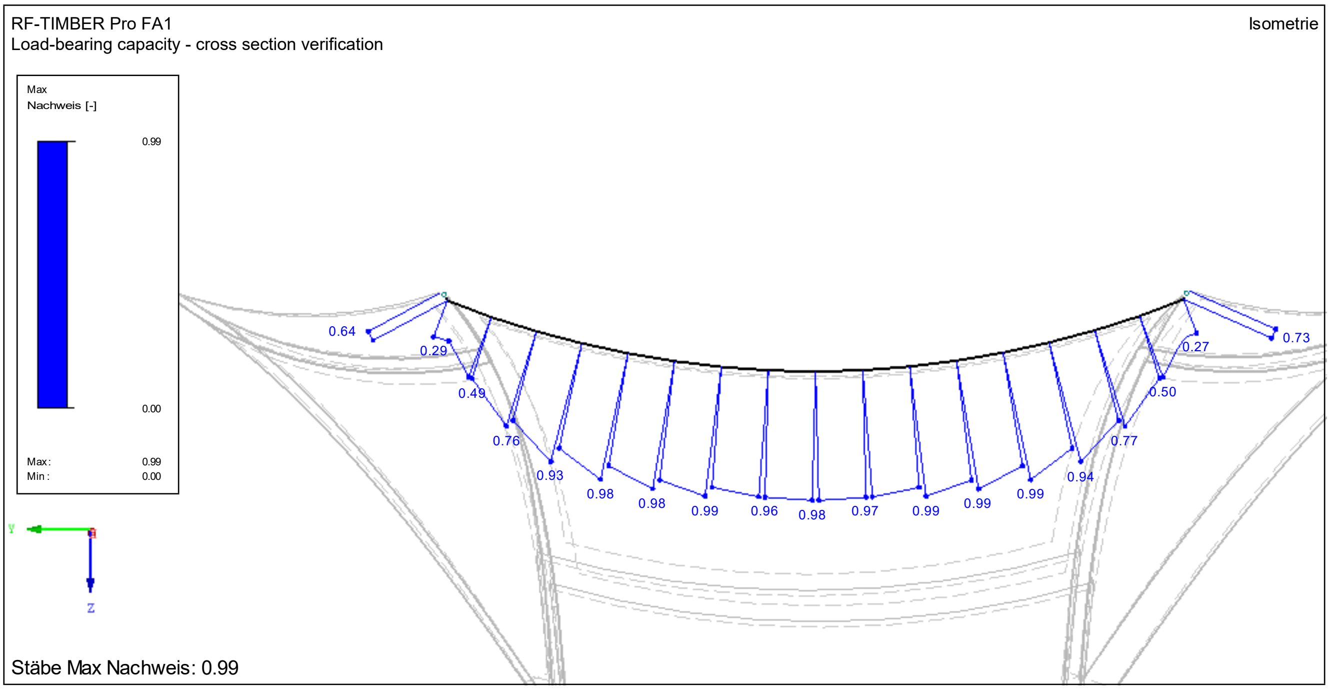

EEK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces V-z
Result combinations: max and min values
Values: u-X [mm]
Isometrie
Stäbe Max V-z: 7.71, Min V-z: -0.83 [kN]


EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-T
Result combinations: max and min values
Values: u-X [mm]
Isometrie
Stäbe Max M-T: 0.03, Min M-T: -0.03 [kNm]

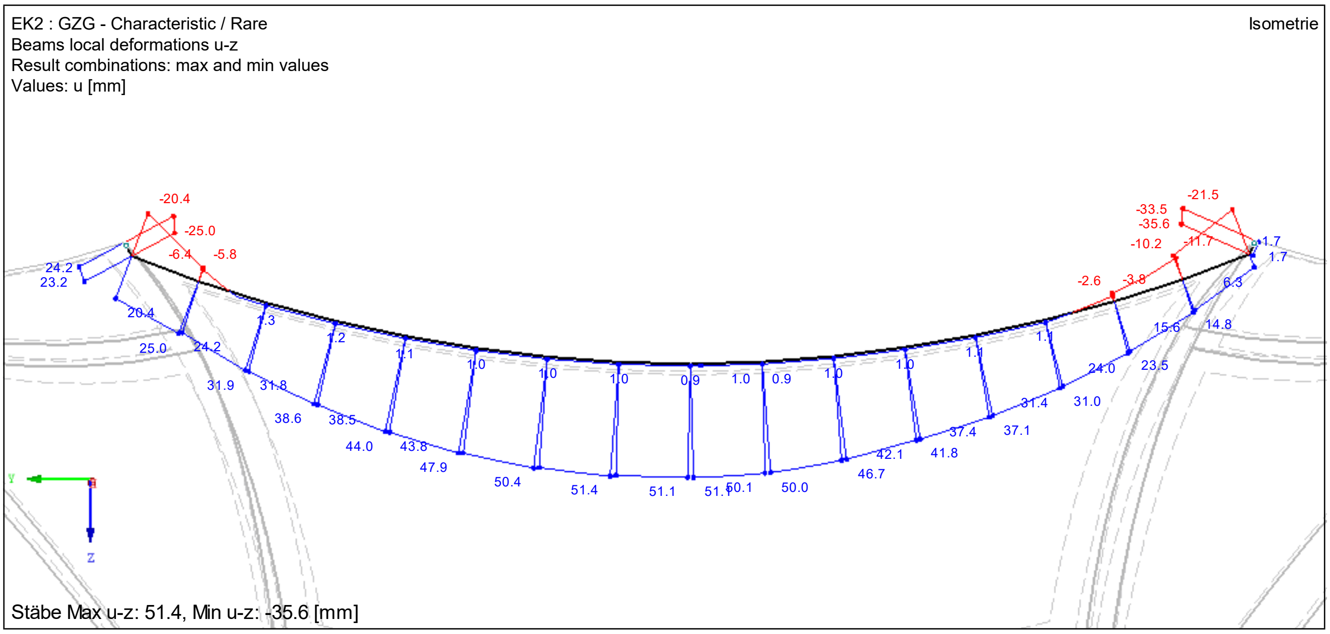

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-y
Result combinations: max and min values
Values: u-X [mm]
Isometrie
Stäbe Max M-y: 5.31, Min M-y: -0.06 [kNm]

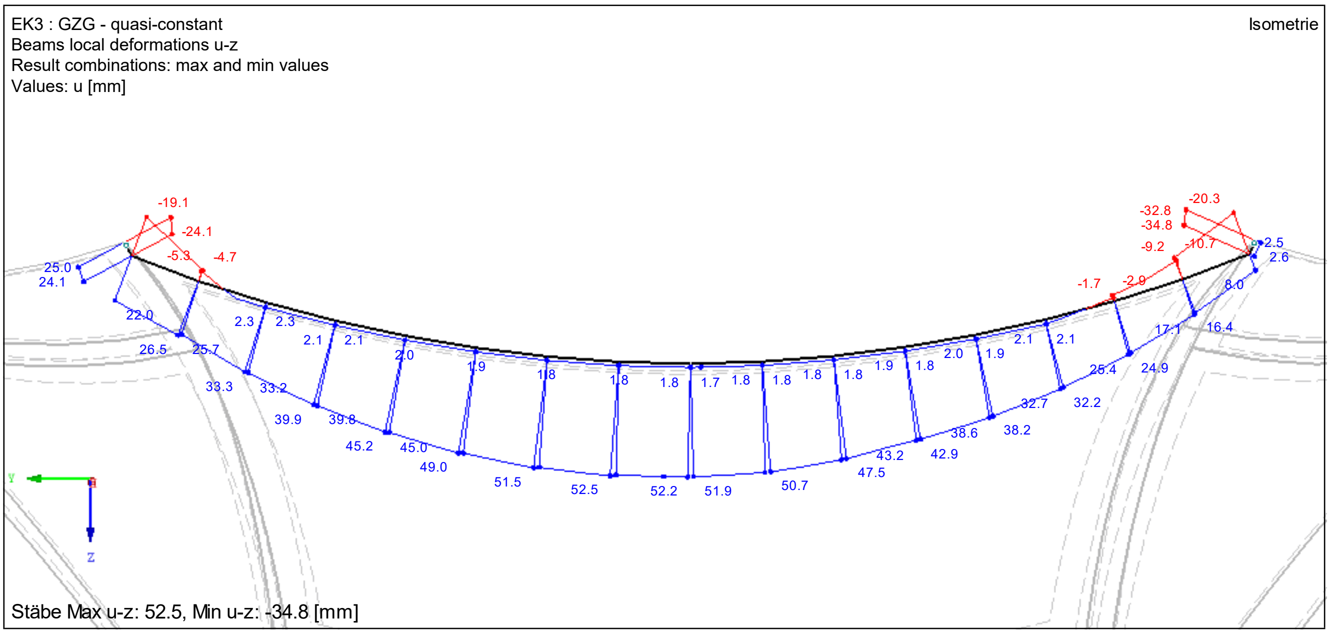

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-z
Result combinations: max and min values
Values: u -X [mm]
Isometrie
-0.01
0.02
0.06
0.06
0.09
0.09
0.09
0.09
0.09
0.12
0.14
0.16
0.17
0.16
-0.16
-0.17
-0.15
-0.16
-0.12
-0.14
-0.09
-0.12
-0.09
0.01
-0.02
-0.09
-0.03
-0.07
-0.09
X
Y
Z
Stäbe Max M-z: 0.17, Min M-z: -0.17 [kNm]

3.4.3 Proof of structural safety



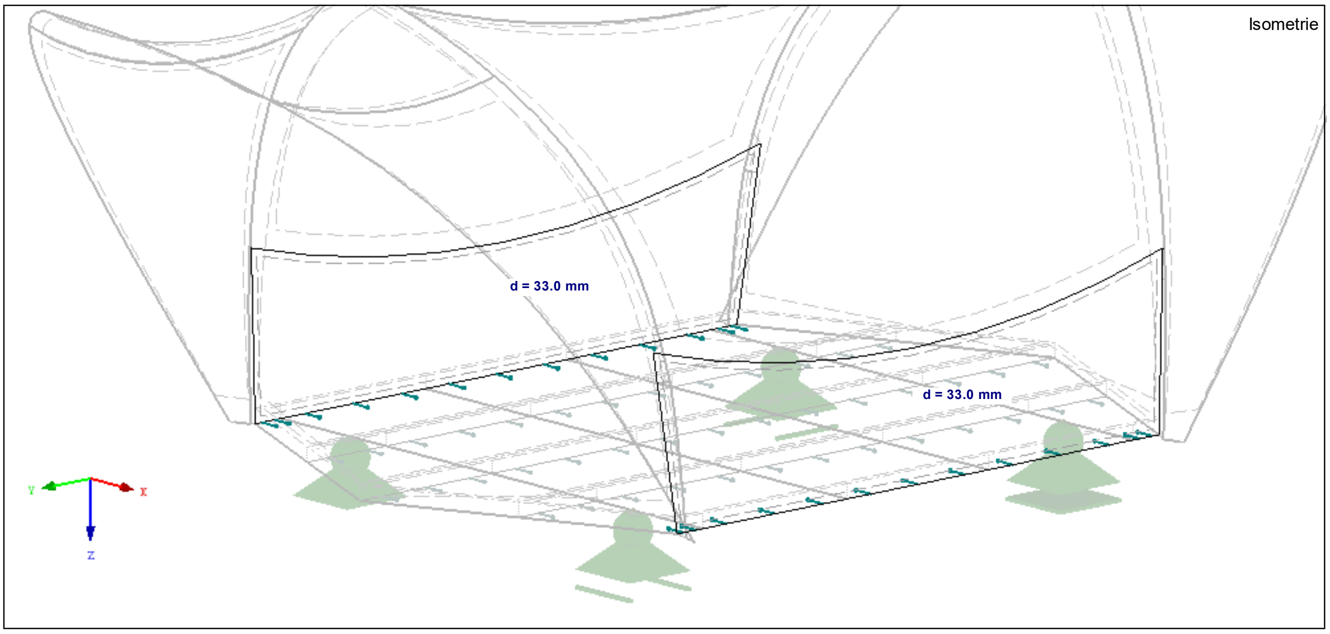
3.4.4 Deformations




EK3 : GZG - quasi-constant
Beams local deformations u-z
Result combinations: max and min values
Values: u [mm]
Isometrie
-19.1
-24.1
-5.3
-4.7
25.0
24.1
22.0
26.5
25.7
33.3
33.2
2.3
2.3
2.1
2.1
2.0
39.9
39.8
45.2
45.0
49.0
1.9
1.8
51.5
52.5
1.8
1.8
52.2
1.7
51.9
1.8
1.8
50.7
1.8
1.8
47.5
43.2
1.9
1.8
42.9
38.6
2.0
1.9
38.2
32.7
2.1
2.1
32.2
25.4
24.9
17.1
16.4
8.0
2.5
2.6
-1.7
-2.9
-9.2
-10.7
-32.8
-34.8
-20.3
Y
Z
Stäbe Max u-z: 52.5, Min u-z: -34.8 [mm]

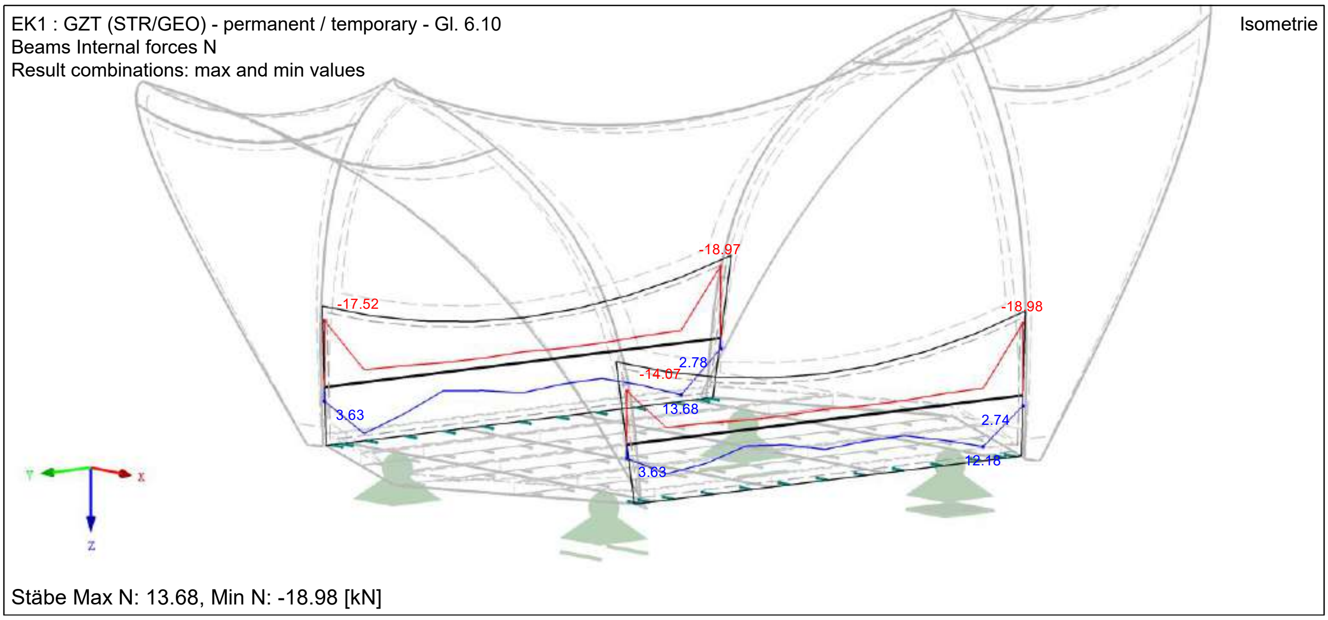
3.5 Overhang

3.5.1 Cross Section



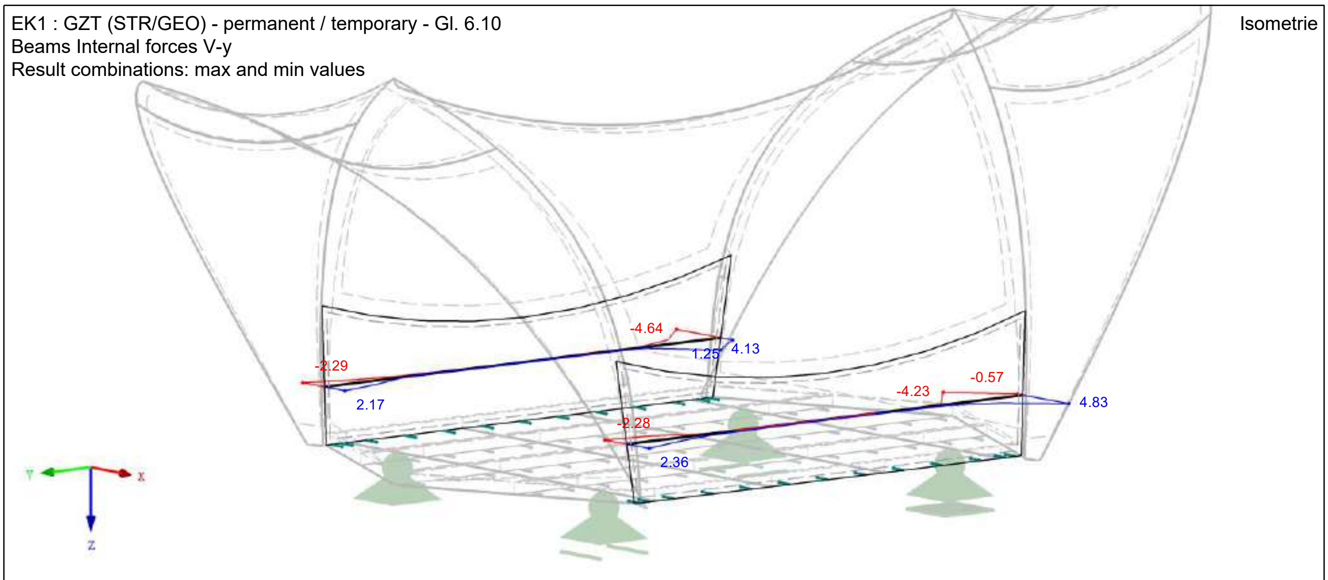
Material: LVL, KERTO Q

3.5.2 Design section properties



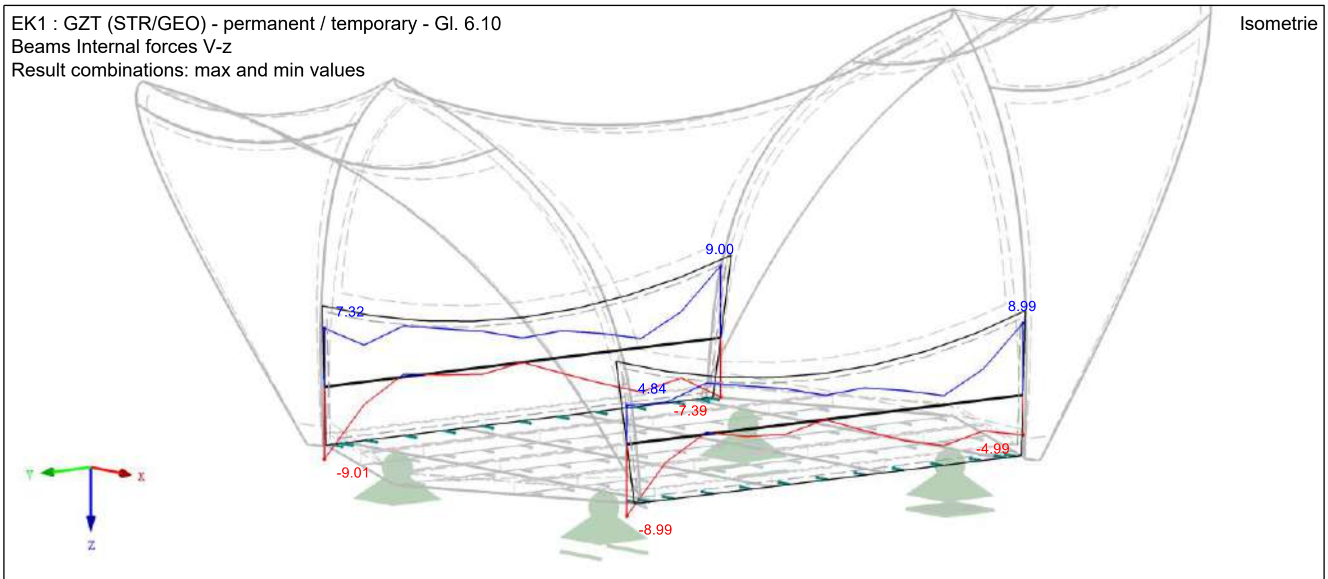
Machine Translated by Google

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



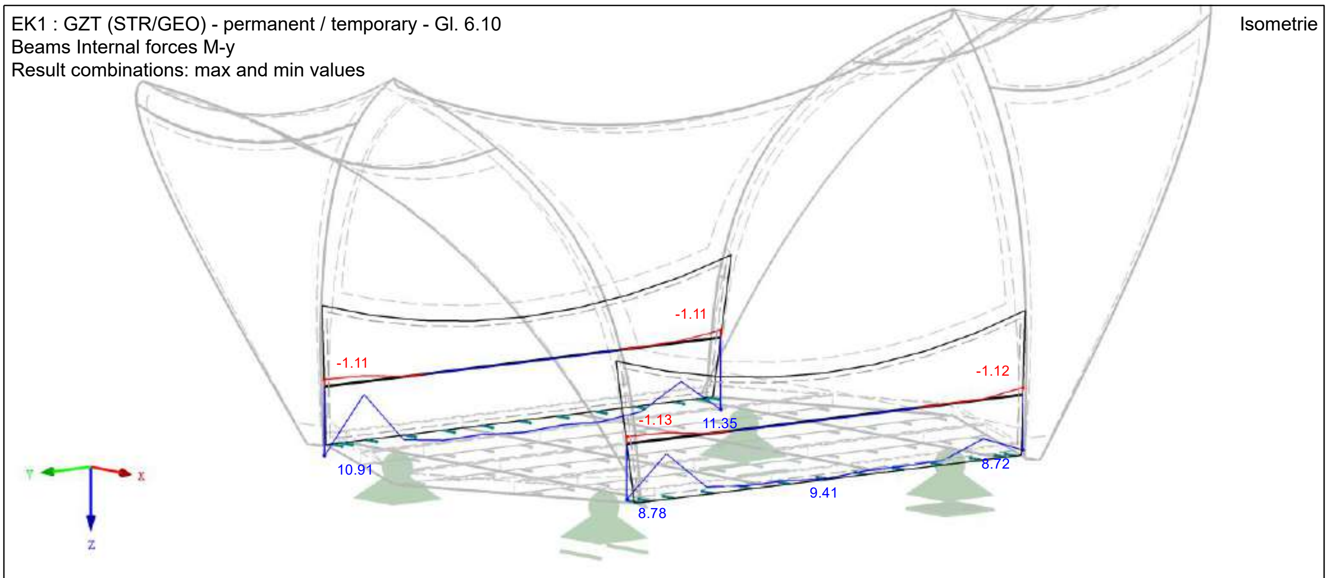
Stäbe Max V-y: 4.83, Min V-y: -4.64 [kN]

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

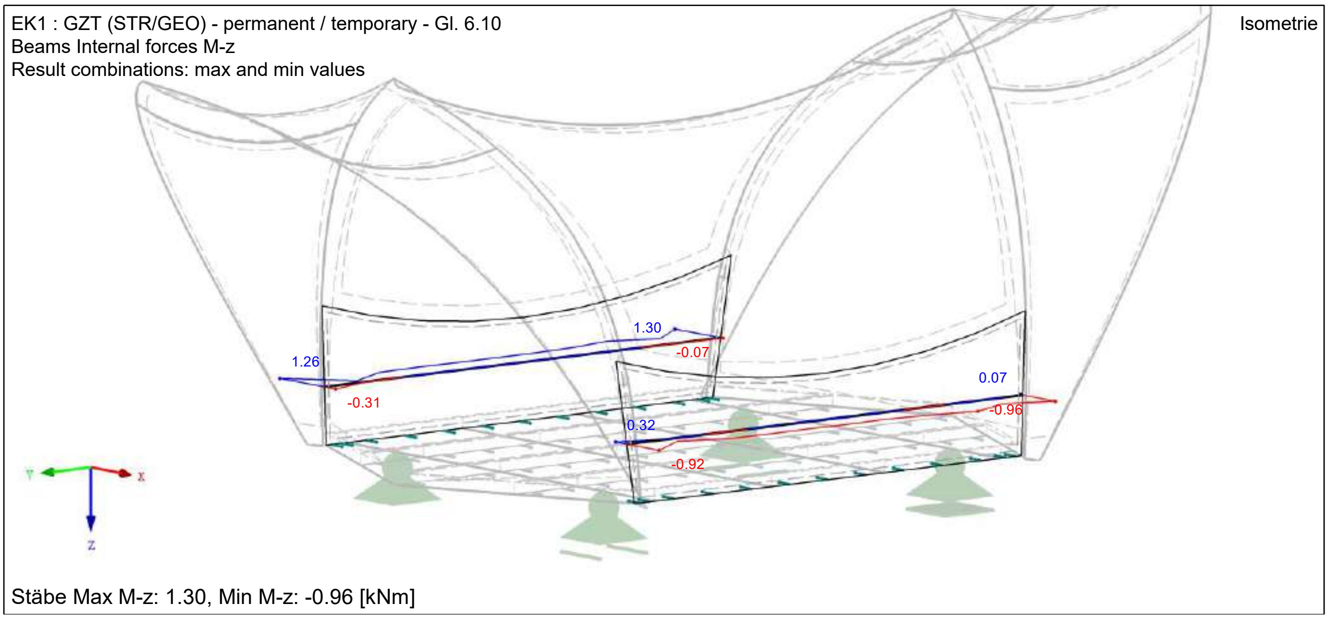


Stäbe Max V-z: 9.00, Min V-z: -9.01 [kN]

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



Stäbe Max M-y: 11.35, 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	kurz/sehr kurz		
Partial safety factor	k_{mod}=	1,00	
Modification coef.	γ_M=	1,30	

Strenght Values

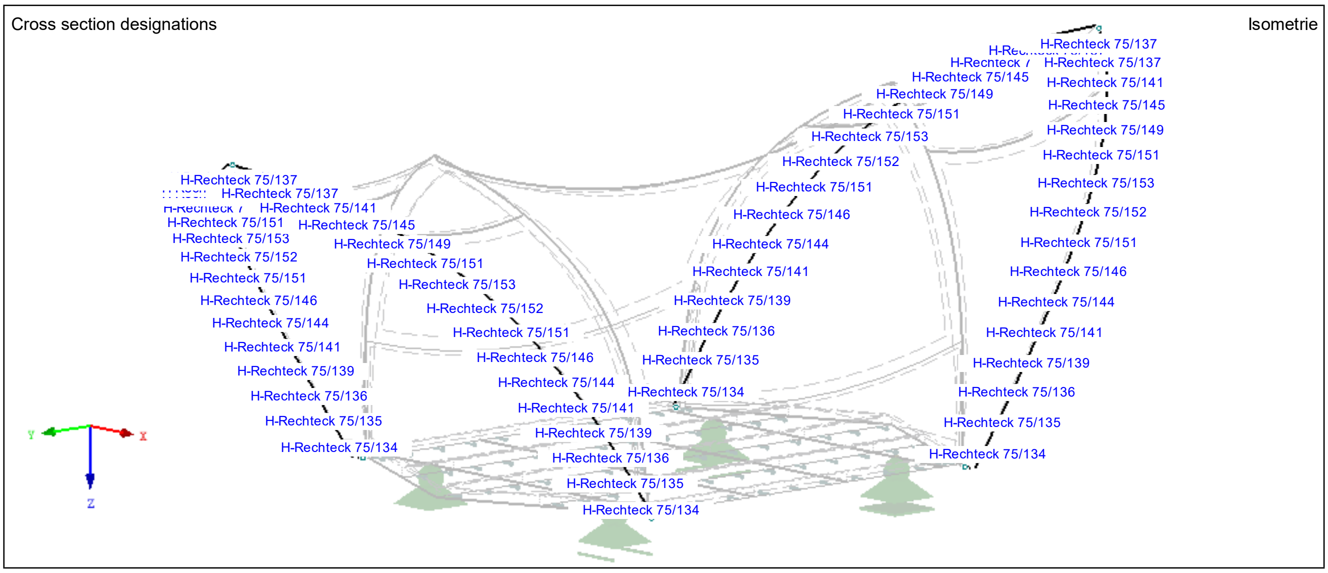
Plate stress				
Bending parallel to fiber		36,00 N/mm²	$f_{m,0,flat,d}$=	27,69 N/mm²
Bending perpendicular to fiber		8,00 N/mm²	$f_{m,90,flat,d}$=	6,15 N/mm²
Compressive strenght	$f_{c,90,flat,k}$=	2,20 N/mm²	$f_{c,90,flat,d}$=	1,69 N/mm²
Shear	$f_{v,flat,k}$=	1,30 N/mm²	$f_{v,flat,d}$=	1,00 N/mm²
Disc 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	$M_{y,E,d}$=	11,35 kNm	<	$M_{y,R,d}$=	95,53 kNm	11,88%
Bending plate	$M_{z,E,d}$=	1,3 kNm	>	$M_{z,R,d}$=	1,29 kNm	100,86%
Shear disc	$V_{z,E,d}$=	9,01 kN	<	$V_{z,R,d}$=	63,97 kN	14,08%
Shear plate	$V_{y,E,d}$=	4,83 kN	<	$V_{y,R,d}$=	18,48 kN	26,14%
Compression	$N_{c,E,d}$=	-18,98 kN	<	$N_{c,R,d}$=	-554,4 kN	3,42%
Pulling	$N_{t,E,d}$=	13,68 kN	<	$N_{t,R,d}$=	554,4 kN	2,47%

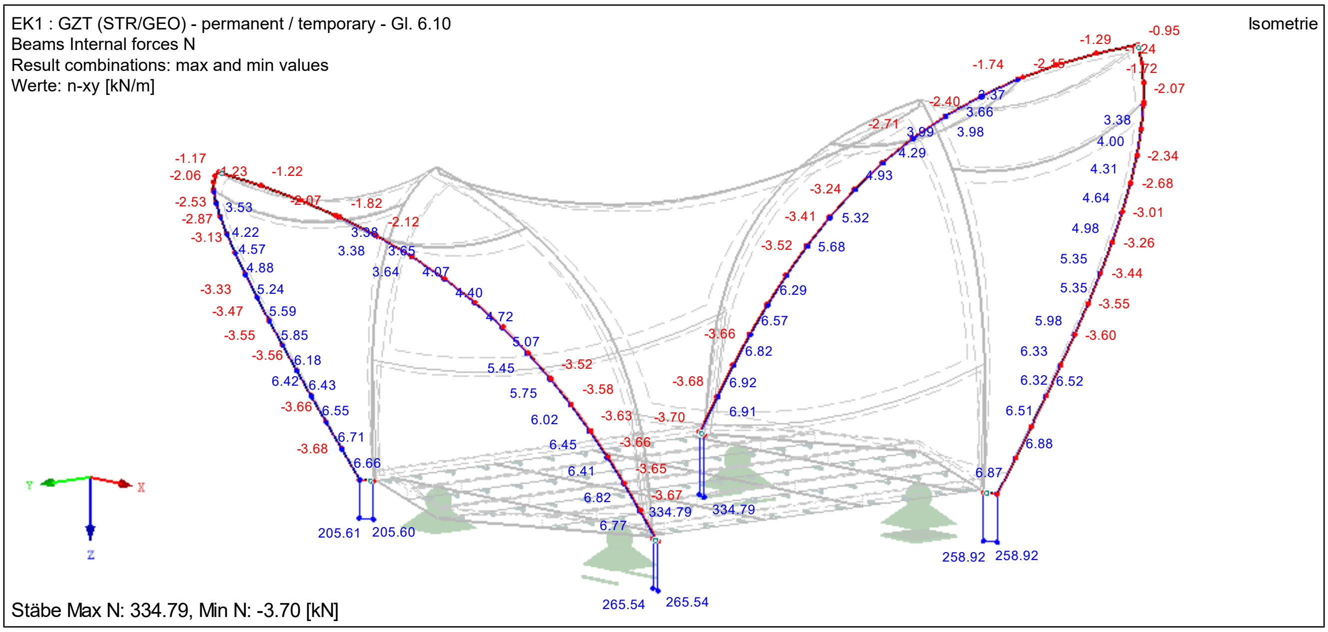
3.6 Canopy edge support

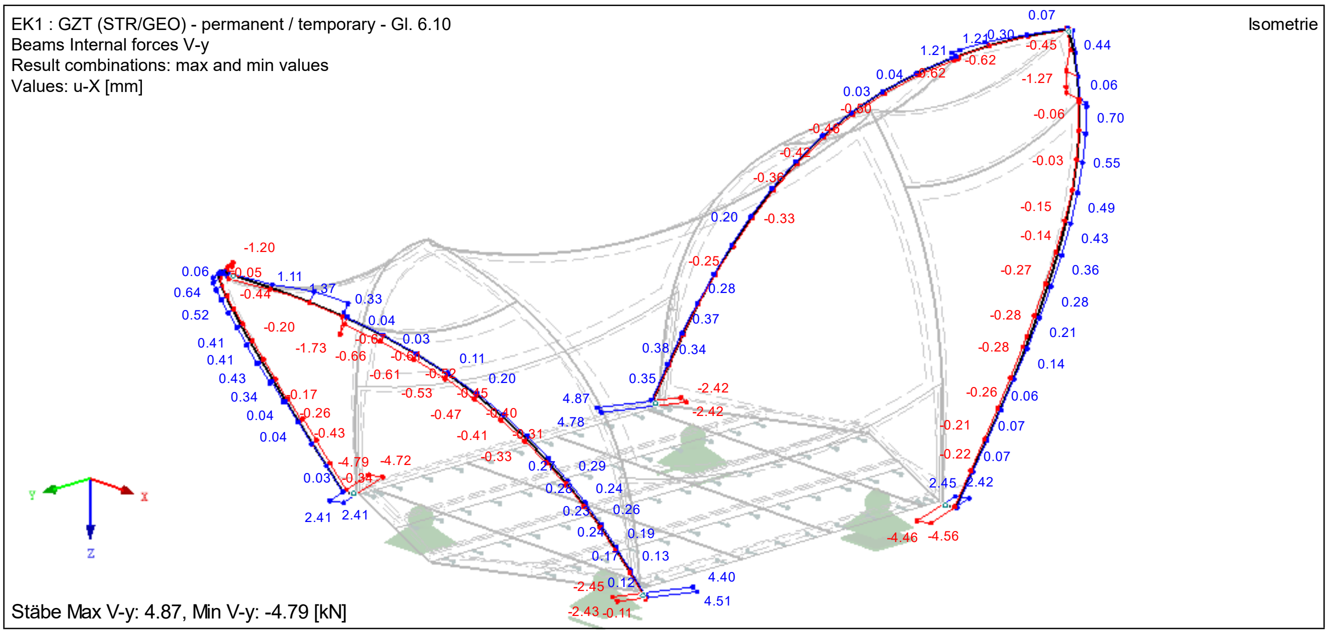
3.6.1 Cross sections

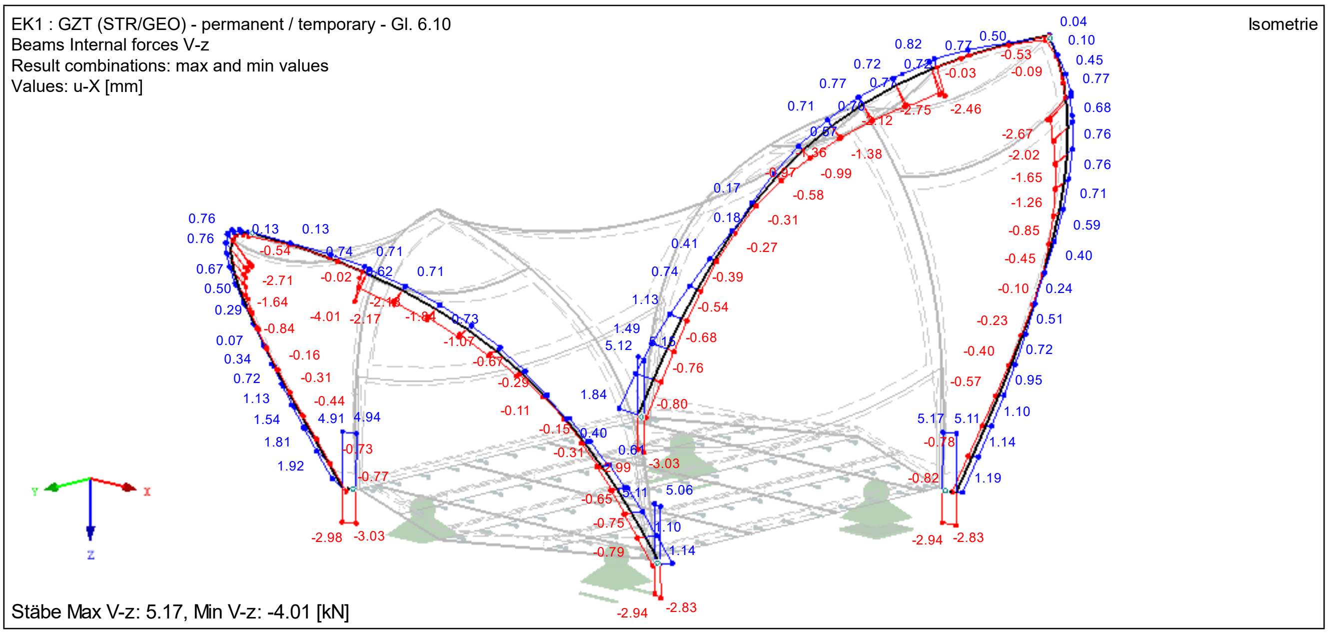


Material: BSH, GL24h

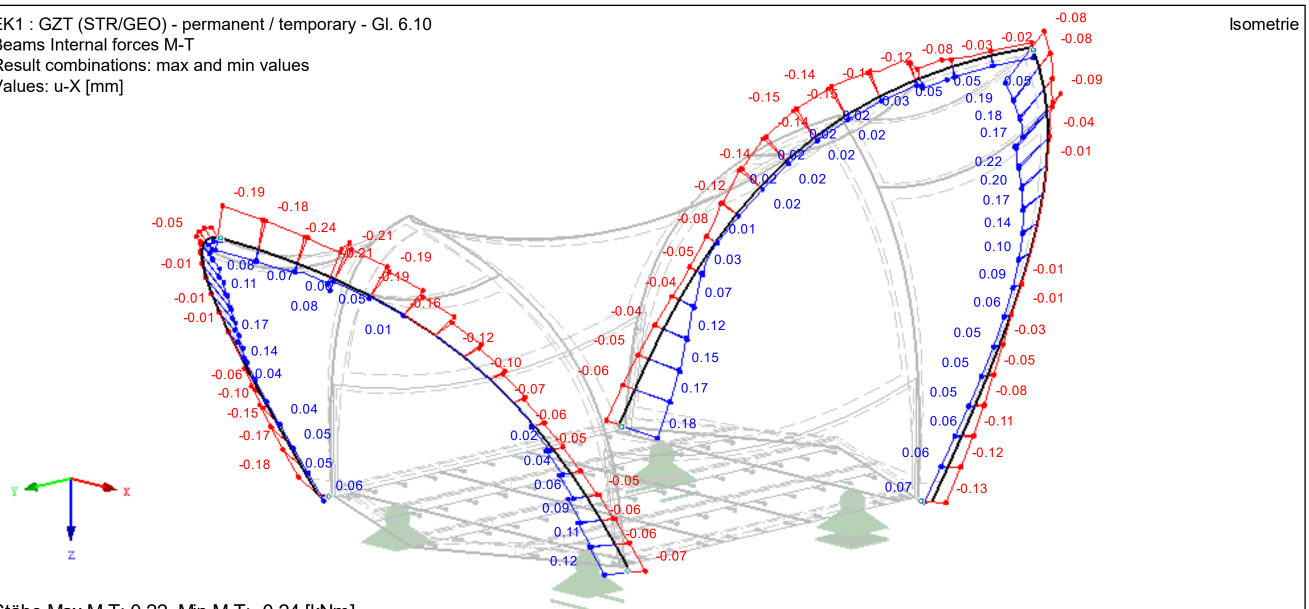
3.6.2 Maßgebende Bemessungsschnittgrößen




EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces V-y
Result combinations: max and min values
Values: u-X [mm]
Isometrie
Stäbe Max V-y: 4.87, Min V-y: -4.79 [kN]

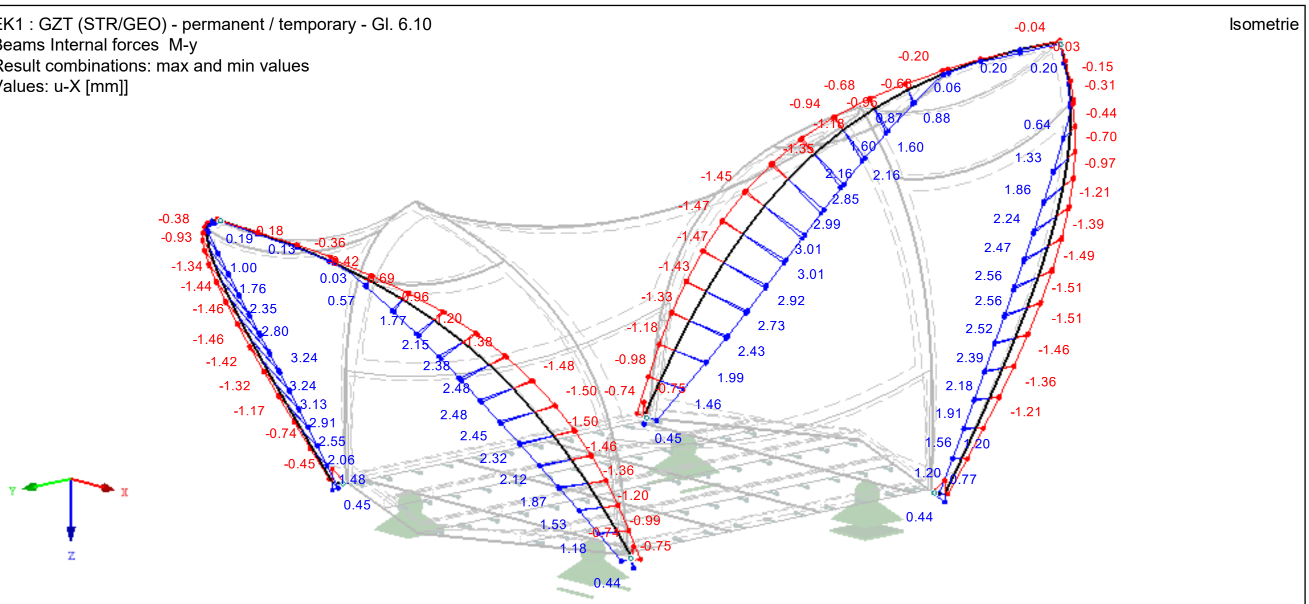

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces V-z
Result combinations: max and min values
Values: u-X [mm]
Isometrie
Stäbe Max V-z: 5.17, Min V-z: -4.01 [kN]

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

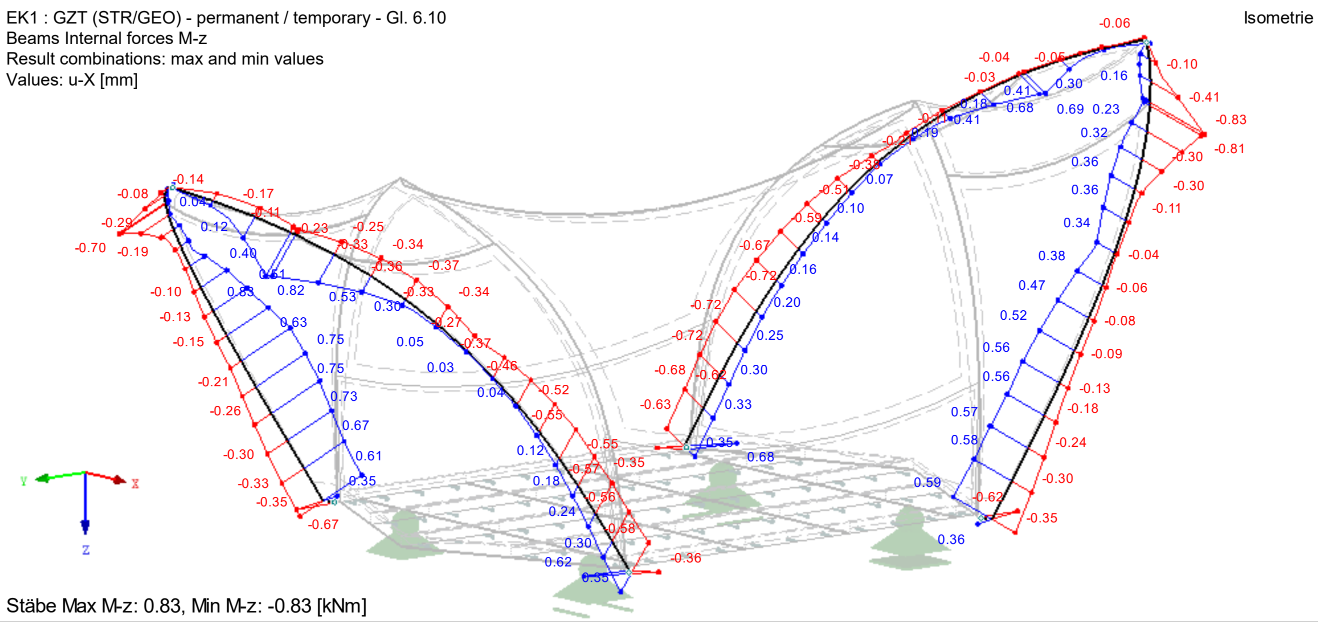


Stäbe Max M-T: 0.22, Min M-T: -0.24 [kNm]

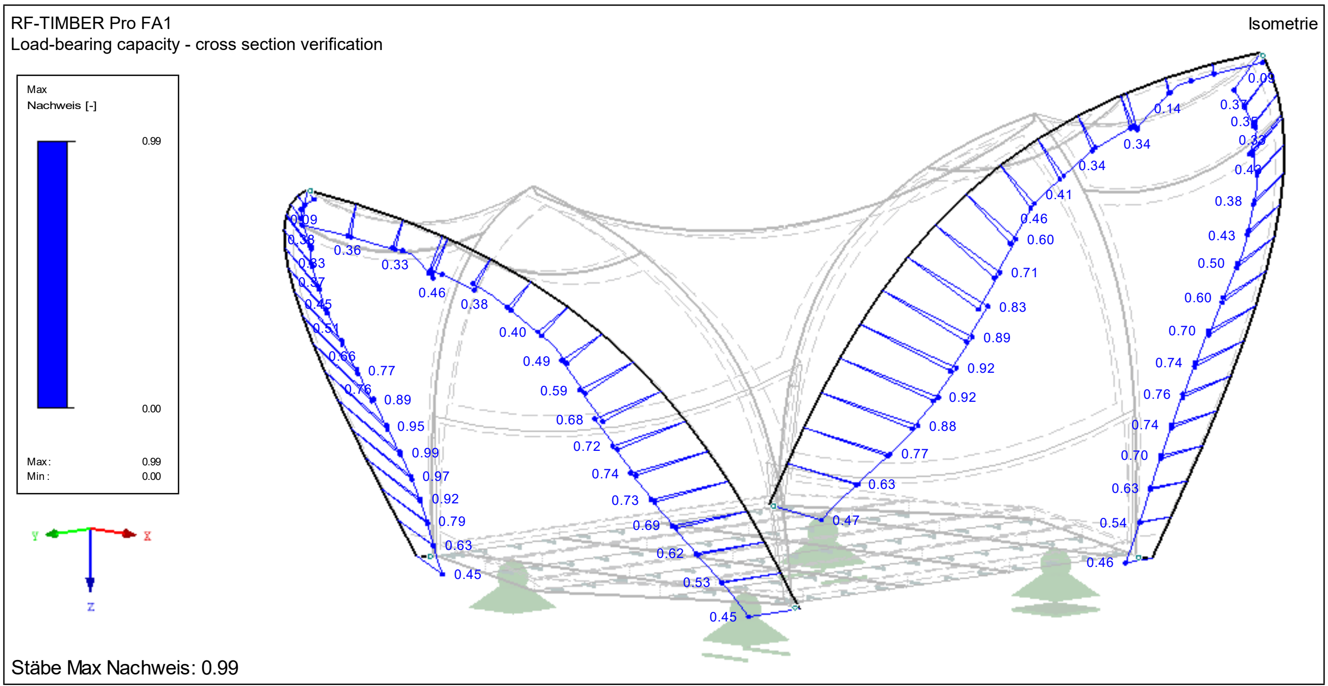
EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-y
Result combinations: max and min values
Values: u-X [mm]]



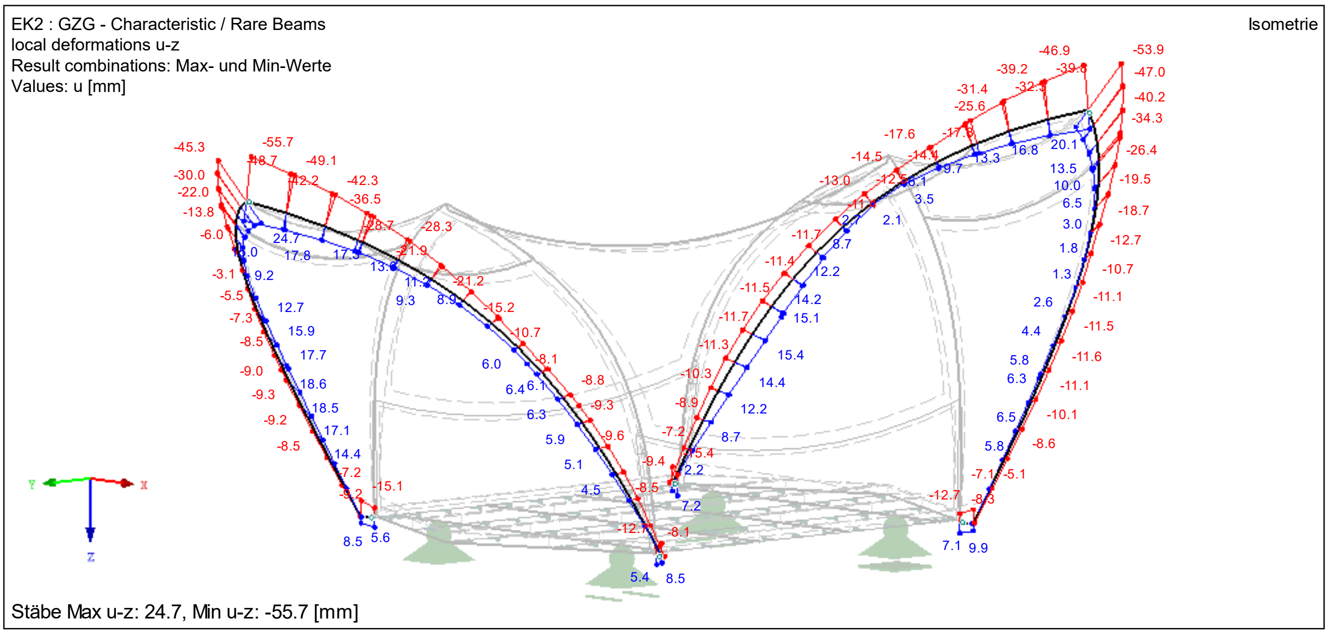
Stäbe Max M-y: 3.24, Min M-y: -1.51 [kNm]

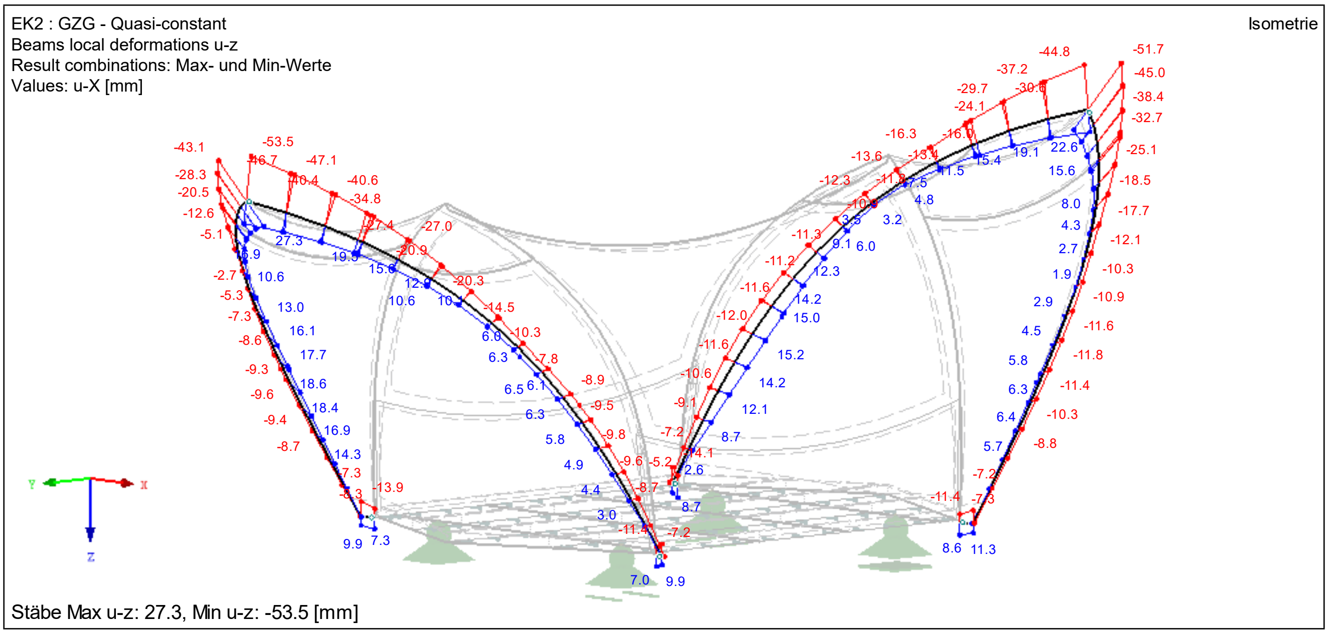


3.6.3 Proof of structural safety



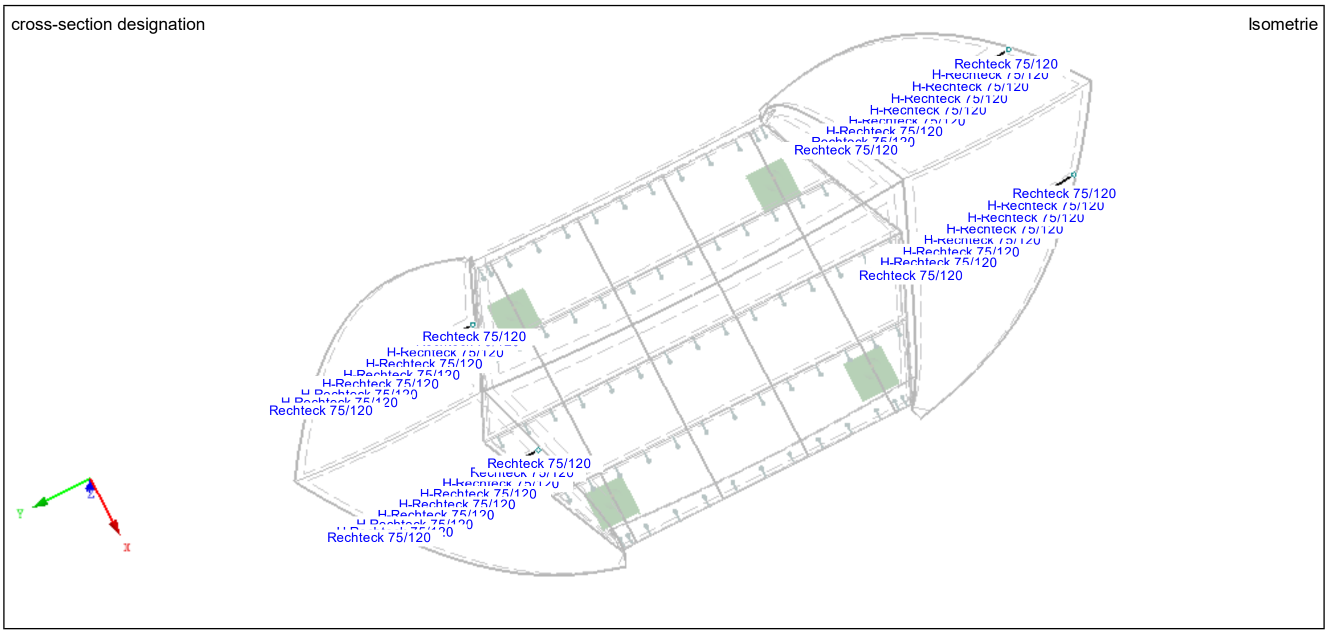
3.6.4 Deformations





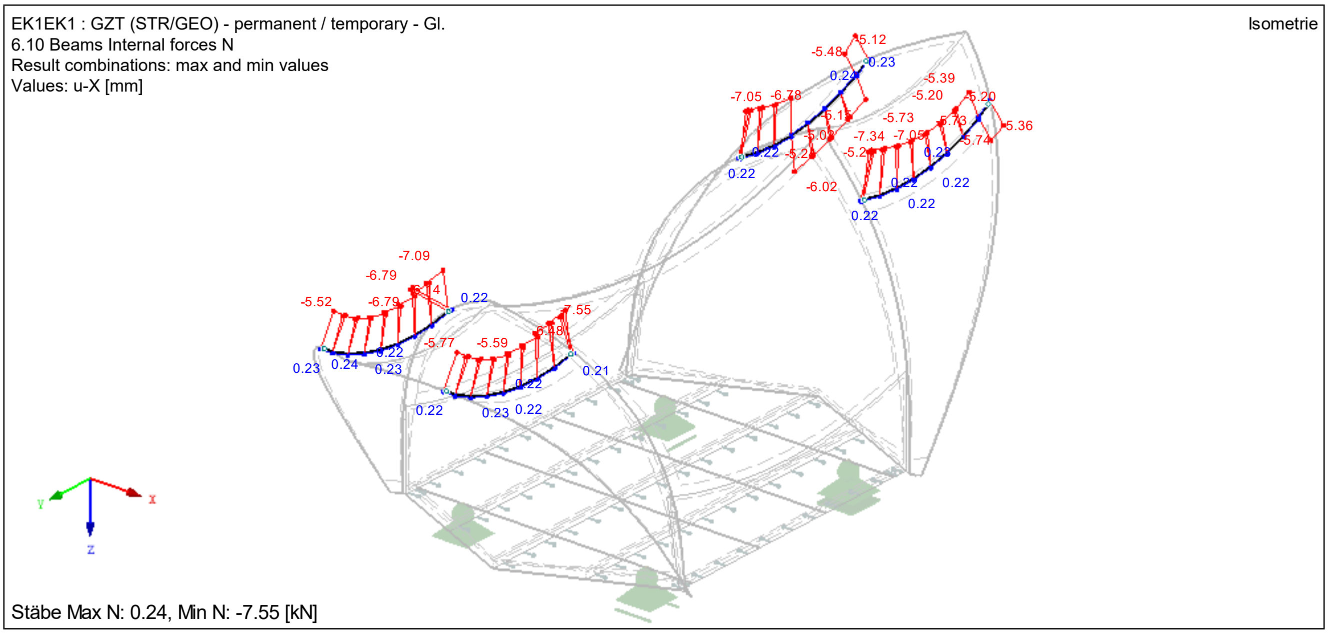
3.7 Canopy drop beam

3.7.1 Cross sections



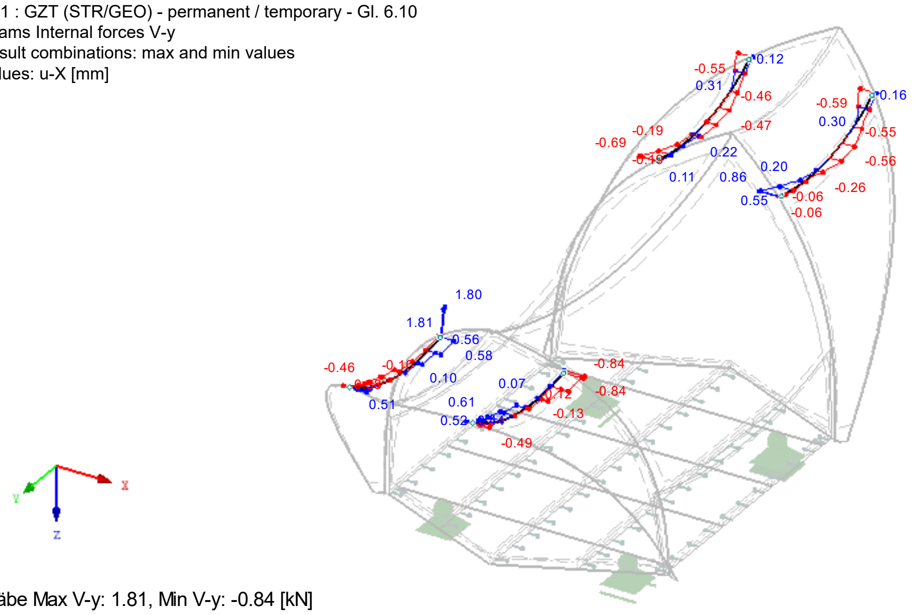
Material: LVL, KERTO-Q

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-X [mm]

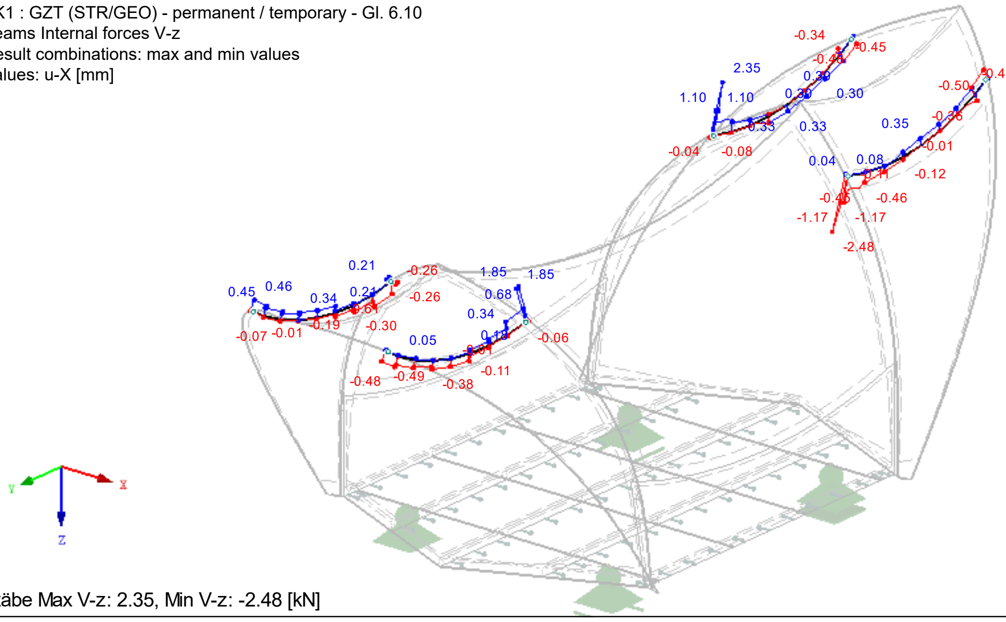
Isometrie



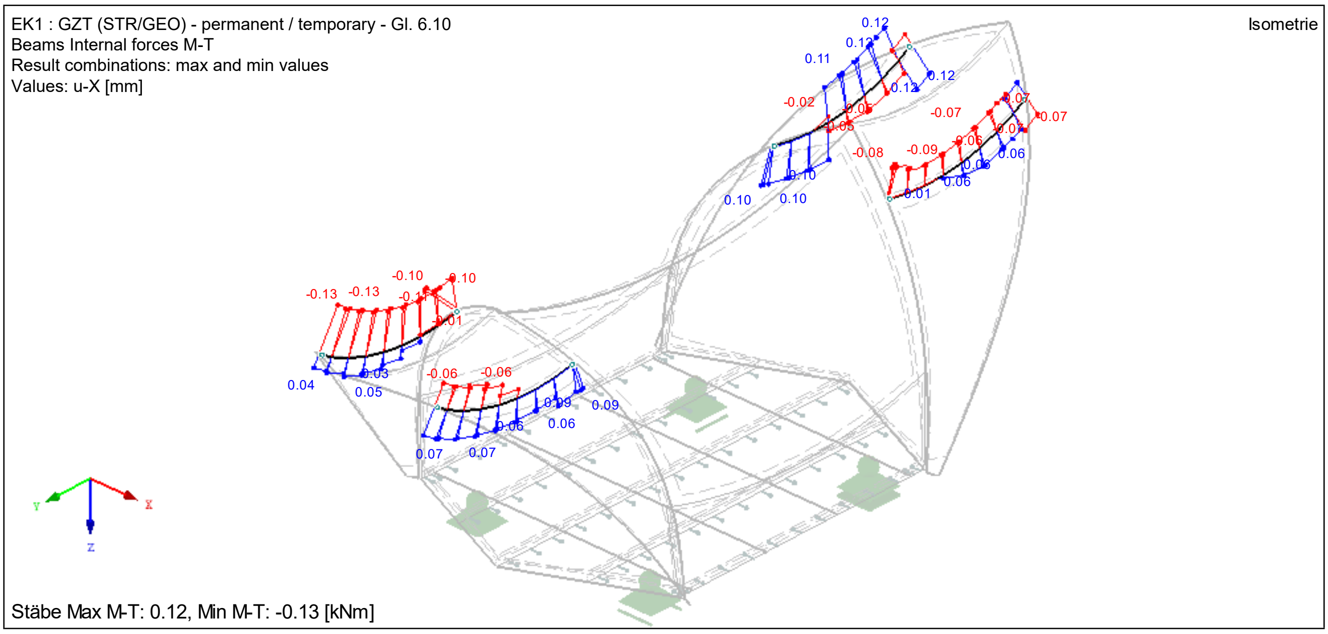
Stäbe Max V-y: 1.81, Min V-y: -0.84 [kN]

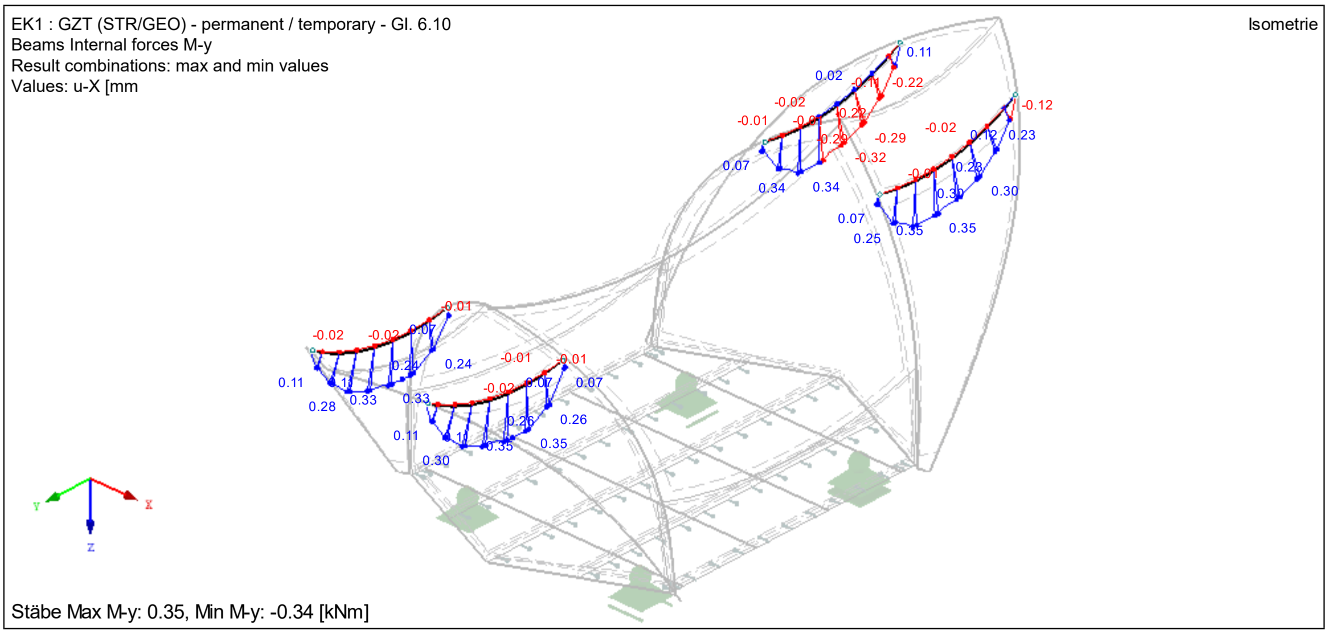
EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces V-z
Result combinations: max and min values
Values: u-X [mm]

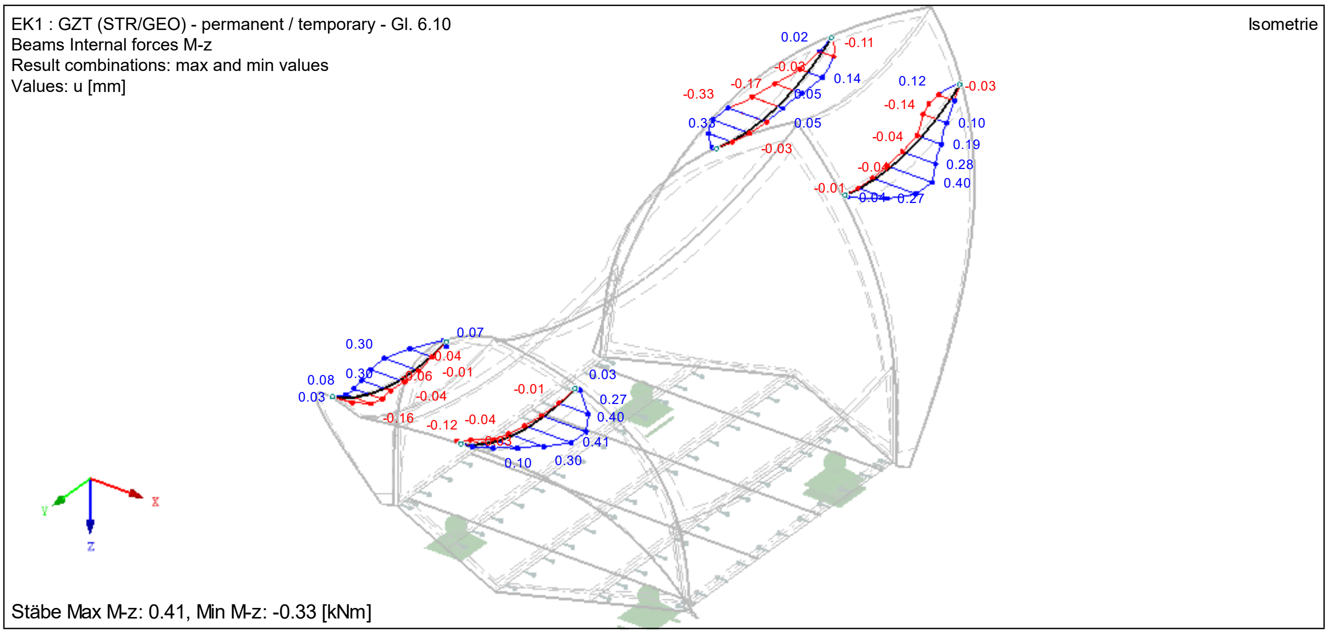
Isometrie



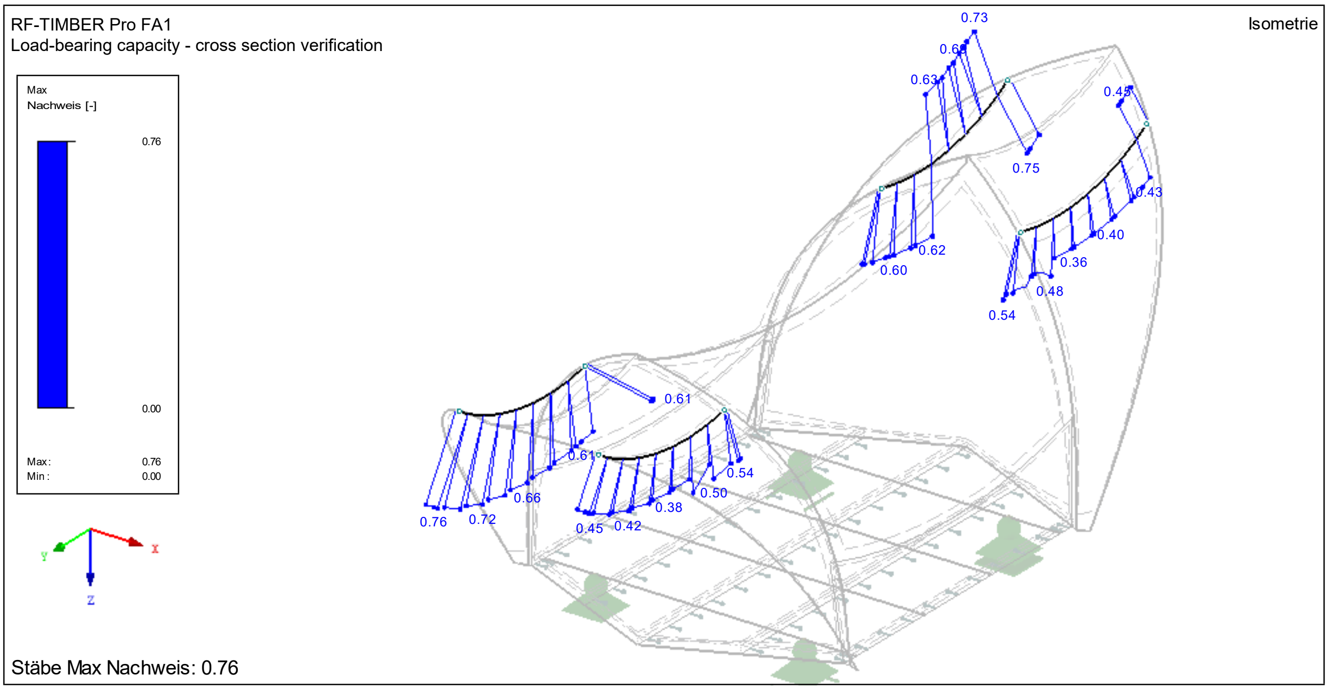
Stäbe Max V-z: 2.35, Min V-z: -2.48 [kN]


EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-T
Result combinations: max and min values
Values: u-X [mm]
Isometrie
Stäbe Max M-T: 0.12, Min M-T: -0.13 [kNm]

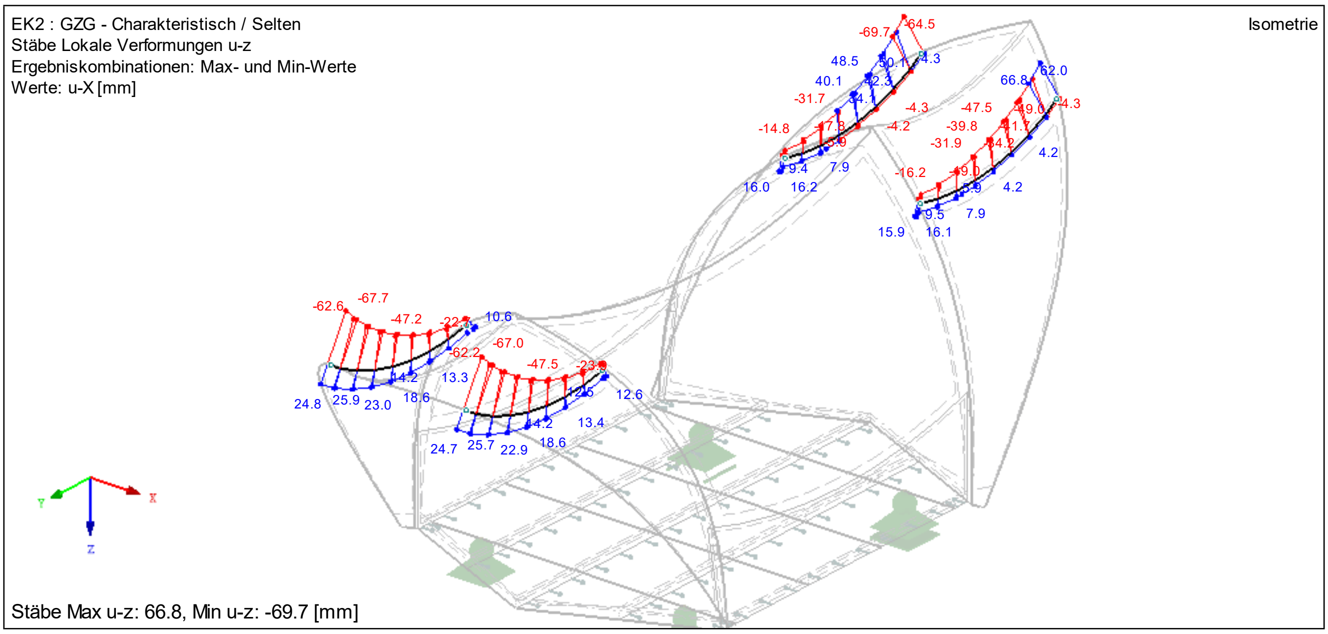

EK1 : GZT (STR/GEO) - permanent / temporary - Gl. 6.10
Beams Internal forces M-y
Result combinations: max and min values
Values: u-X [mm
Isometrie
Stäbe Max M-y: 0.35, Min M-y: -0.34 [kNm]

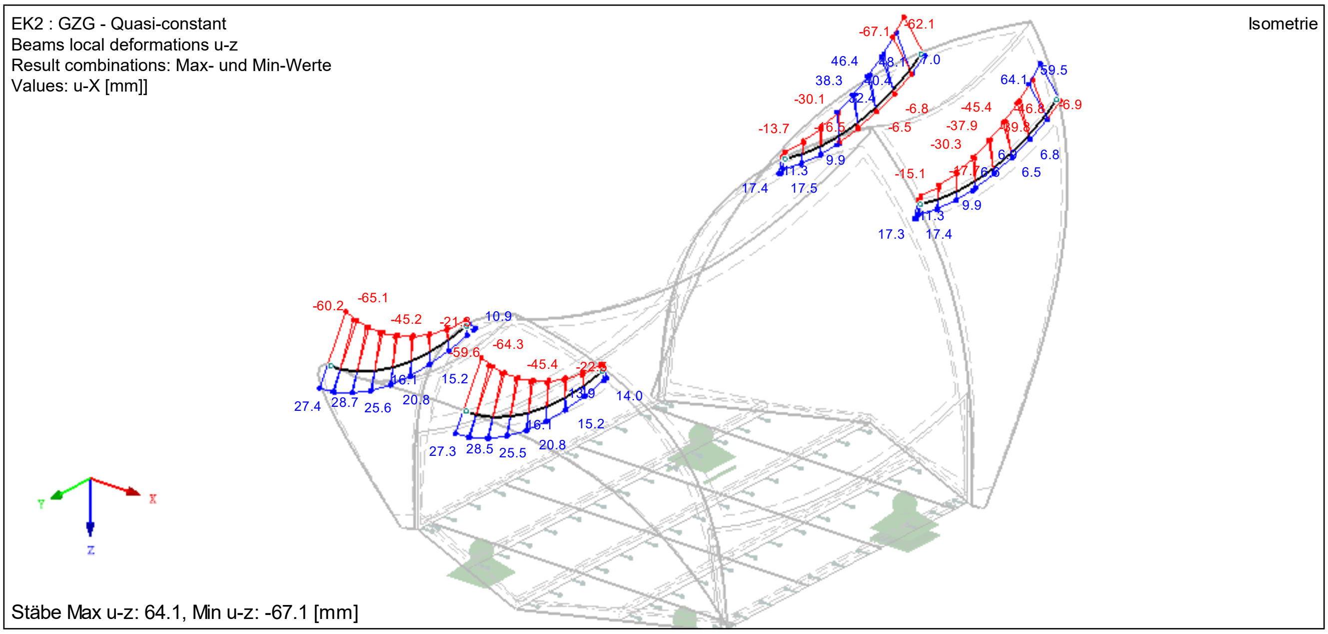


3.7.3 Proof of structural safety



3.7.4 Deformations





3.8 Fundierung

3.8.1 Uplift safety

characteristic uplift safety	$P_{w,z,k}$= 14,49 kN
design value uplif safety	$P_{w,z,d}$= 21,74 kN unfavourable effect γ_Q=1,50
characteristic self-weight	$G_{Konstr.,z,k}$= 2,55 kN
design value self-weight	$G_{Konstr.,z,d}$= 2,30 kN favourable effect γ_G=0,90
Self-weight foundation	$G_{Fund.,z,k}$= 23,04 kN concrete foundation 80x80x150 cm
design value foundation	$G_{Fund.,z,d}$= 20,74 kN faγ_G=0,90
Proof of uplift safety	$P_{w,z,d}$= 21,74 kN < $R_{z,d}$= 23,03 kN **94,37% proof filfilled**

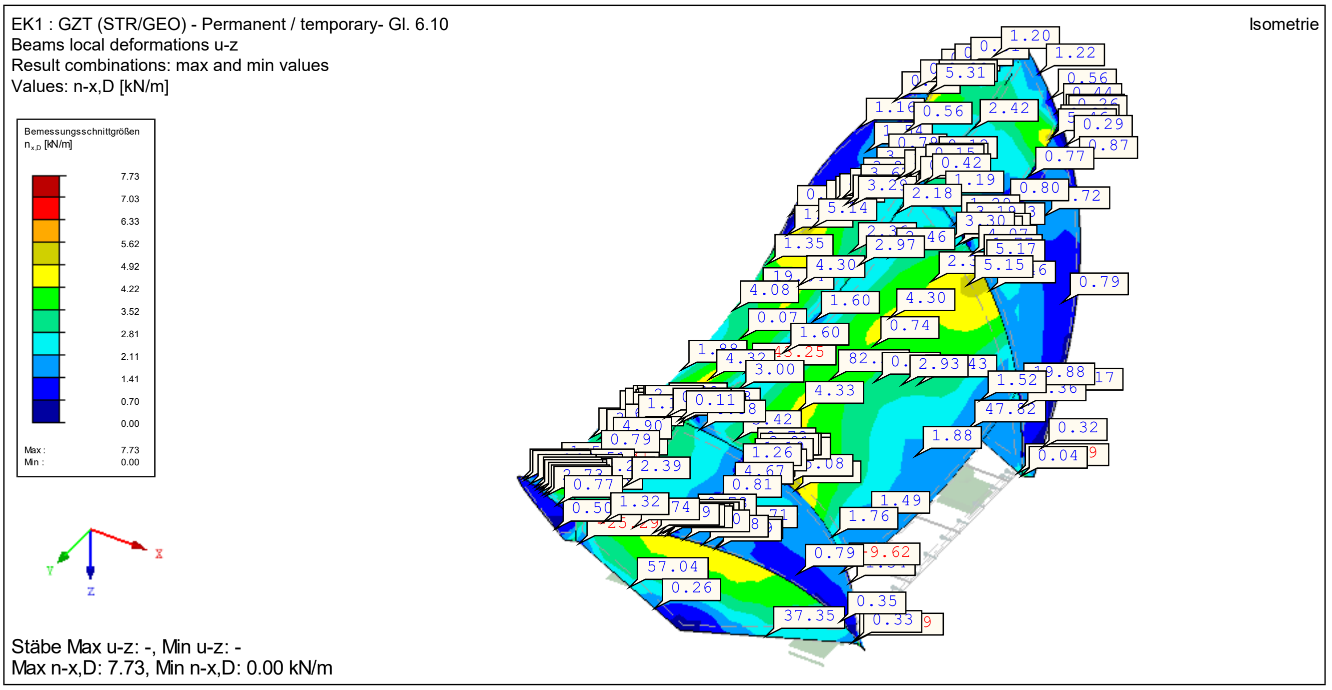
3.8.2 Anti-skid

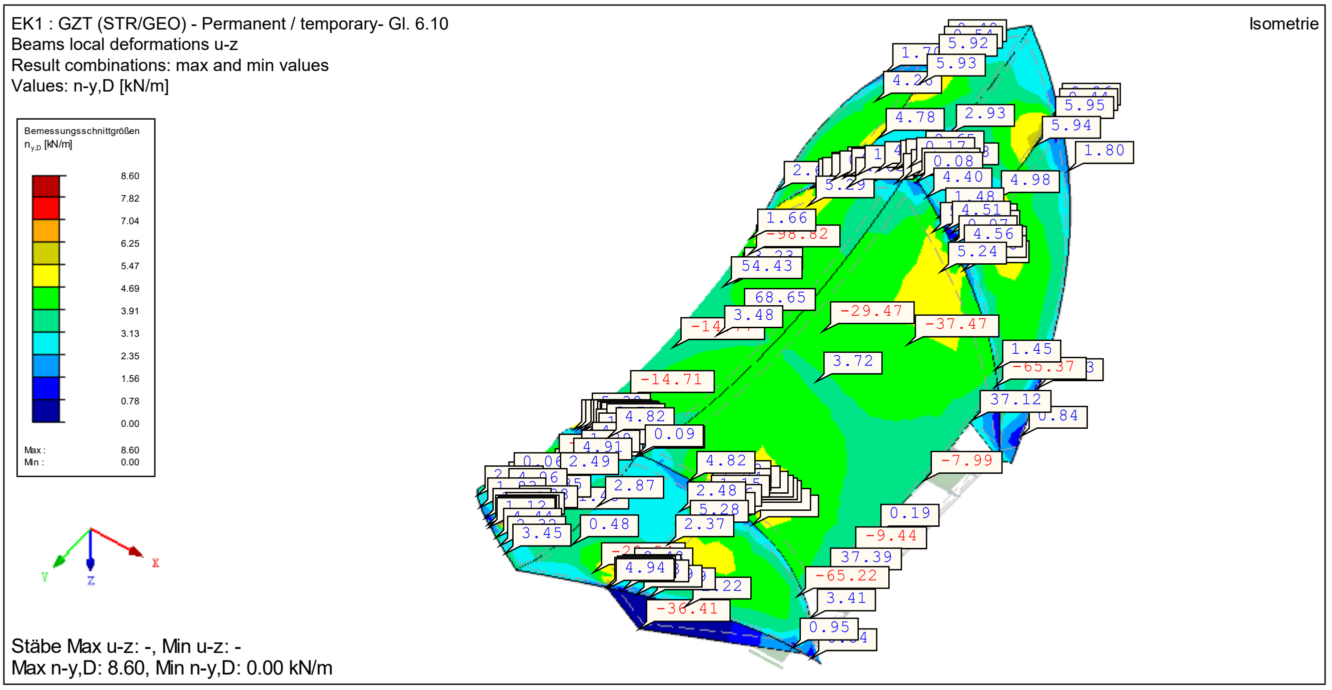
characteristic horizontal force	$P_{w,x,y,k}$= 3,75 kN
design value horizontal force	$P_{w,x,y,d}$= 5,63 kN unfavourable effect γ_Q=1,50
charactersitc self-weight	$G_{Konstr.,z,k}$= 2,55 kN
design value self-weight	$G_{Konstr.,z,k}$= 2,30 kN favourable effect γ_G=0,90
Self-weight foundation	$G_{Fund.,z,k}$= 23,04 kN concrete Foudnation 80x80x150
design value foundation	cm $G_{Fund.,z,d}$= 20,74 kN favourable effect γ_G=0,90
Coefficient of friction on concrete	μ= 0,50
Proof of uplift safety	$P_{w,x,y,d}$= 5,63 kN < $R_{x,y,d}$= 11,52 kN **48,85% 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





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