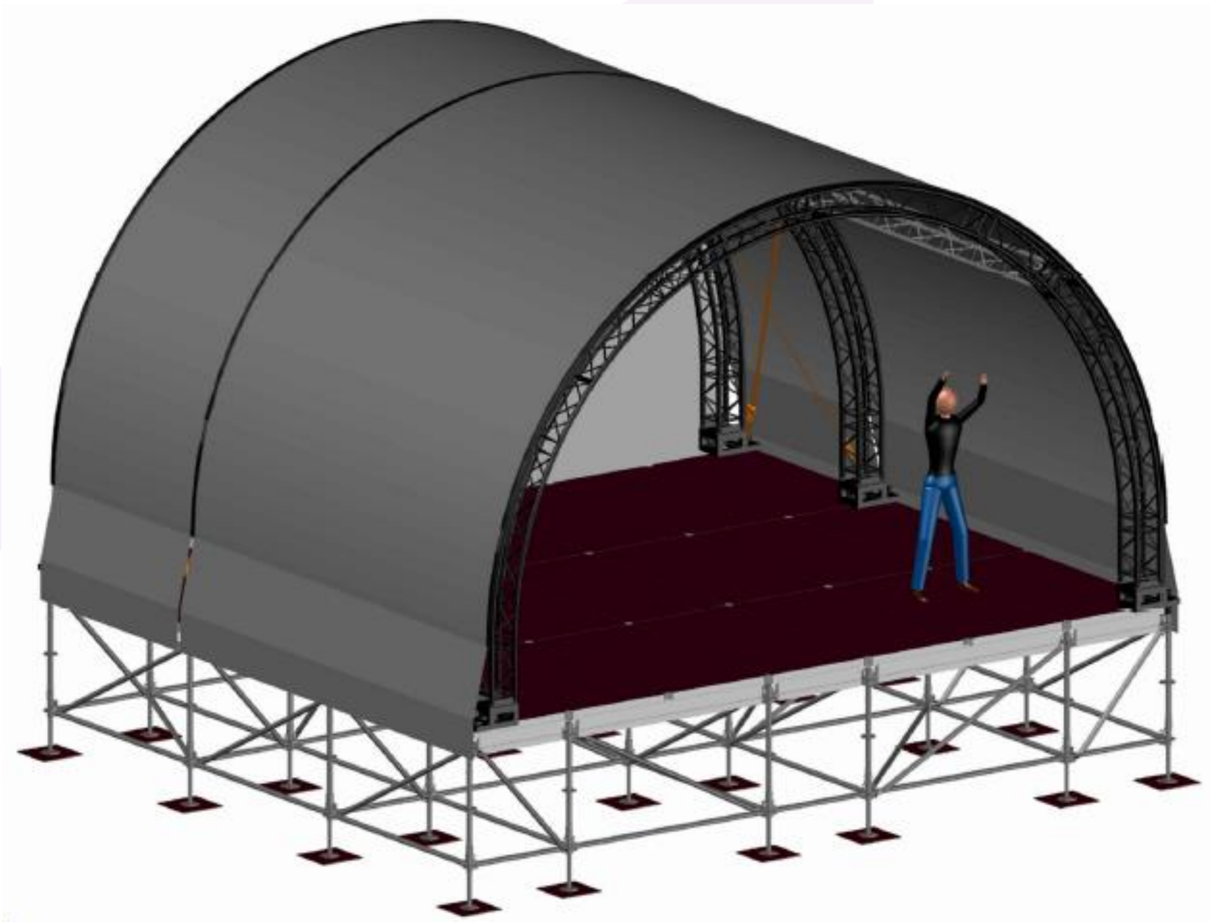
PODIUM – BOEK

ARES

Eekels Verhuur 112023-05



Inhoudsopgave

Voorwoord

Opdrachtgevers en organisatoren, alsmede gemeentelijke diensten hebben behoefte aan handvatten voor de beoordeling van kwaliteit en specificaties van overdekte podia die tijdelijk geplaatst worden. Met als doel het inzichtelijk krijgen van waar gehuurde overdekte podia aan moeten voldoen op gebied van onder meer brandveiligheid- en constructieve veiligheid. Een van de is om een podium-boek op te stellen waarin deze zaken overzichtelijk en begrijpelijk worden weergeven, dit op een vergelijkbare manier hoe een tentboek wordt samengesteld.

In het veld worden diverse termen gebruikt voor het overdekken van een podium; kap, dak, stage, overkapping. In essentie betreft het in dit bouwboek een podium wat voorzien is van een constructie welke zorgdraagt voor (gedeeltelijke) beschutting van de elementen.

In de bijlagen komen zaken aan de orde als tekeningen, kwaliteitsverklaringen, constructieve berekenen en andere informatie welke verder relevant is.
In de normen welke gaan over de overdekte podia worden kwaliteitsverklaringen, constructieve berekeningen en andere relevante stukken genoemd. Hierin staat gesteld dat deze stukken niet in de Nederlandse taal opgesteld hoeven te zijn, eventuele aanvullende toelichtingen en handleidingen wel. Het voorwoord en handleidingen die minimaal in het podium-boek moeten staan worden gezien als toelichting. Andere zaken dan de toelichting(en) in het podium-boek mogen in het Duits, Frans of Engels aangeleverd worden.

Het gebruik van het overdekte podium is geen onderwerp van het podium-boek.

Binnen het NEN lopen nog een aantal andere trajecten die te maken hebben met evenementen, allemaal beginnende met: 8020-

Een aantal, al dan niet Europese, algemeen gehanteerde normen en richtlijnen die te maken hebben met overdekte podia welke tijdelijk geplaatst worden zijn o.a.:

NPR 8020-50	Evenementen – Podiumconstructies – Verantwoordelijkheden
NPR 8020-51	Evenementen – Podiumconstructies – Belastingen en constructieve uitgangspunten
NEN-EN 13814	Machines en constructies op kermisterreinen en amusementsparken – Veiligheid
NEN-EN 1990	Grondslagen van het constructief ontwerp
NEN-EN 1991	Belastingen op constructies
NEN-EN 1993	Staalconstructies

Bovenstaande normen- en richtlijnen refereren o.a. aan de Eurocodes NEN-EN 1991-1-4/NB;

Deel 1: Belastingen op constructies
Deel 1-4: Algemene belastingen – Windbelasting.

Een tijdelijk geplaatst overdekt podium is in beginsel geen bouwwerk in de zin van het bouwbesluit. Hieruit voortvloeiende kan er daarom niet automatisch naar het bouwbesluit of andere zaken worden gekeken als het gaat om beoordeling van een tijdelijk geplaatst overdekt podium. Hier moeten dus ook de eerder genoemde normen- en richtlijnen naast gehouden worden.

Keuringsrapporten voor zeil, bijvoorbeeld bepaald volgens B1 of M1, zijn doorgaans voorzien van een geldigheidsdatum. Deze datum heeft alleen betrekking op het productieproces van het zeil en niet op het product. Het zegt niets over het (brand)verloop van de kwaliteit van het materiaal. Zeil dat voldoet aan de gestelde eisen blijft zelfdovend. Dit gegeven is mede onderschreven door het LNB, cluster brandveilig gebruik.

Overdekte podia zijn onder te verdelen in:
- (gedeeltelijk) met zijwanden van harde panelen of zeil
- zonder zijwanden
- voorzien van meer bouwlagen

Het gebruik van dit podium-boek is slechts voorbehouden aan Eekels Verhuur B.V..
Hallenstraat 20
P.O. Box 175
5530 AB Bladel
T: +31 0 73 6136867
E: info@eekelsverhuur.nl
I: www.eekelsverhuur.nl

NOODNUMMER: +31 0 467 870 112

1. Algemene informatie

In dit hoofdstuk worden alle gegevens van de fabrikant en algemene gegevens overdekte podia indien deze buiten Europa is geproduceerd, tevens naam van importeur.

1.1 Algemene gegevens fabrikant(en);

Zeil	**POLYMAR – FR COLOR 700**
Constructie	Interal Protruss S31 en Protruss T31
Type zeil	PVC; artikel 8509 5240

1.2 Algemene gegevens;

Naam	**ARES**
Type	Mini Tunnel Roof
Configuratie(s)	7.25x4.14 – 7.25x6.21 meter

2 Gegevens verhuurder of leverancier

Hieronder wordt alle huidige en relevante informatie weergegeven van de verhuurder/leverancier.

Rechtsvorm	Besloten Vennootschap
Handelsnaam	Eekels Verhuur B.V.
Bezoekadres	Hallenstraat 20 5531 AB BLADEL
Postadres	P.O. Box 175 5530 AD BLADEL
Telefoonnummer	0031 73 6136867
Website	www.eekelsverhuur.nl
Mailadres	info@eekelsverhuur.nl
K.v.K. nummer	84151722
Omzetbelasting nummer	NL863114192B01
Bank	Rabobank de Kempen
IBAN Rekening nummer	NL43RABO0374476608
BIC	RABONL2U

3 Algemene technische gegevens van de overdekte podia

Waar dient de huurder ten alle tijden rekening mee te houden bij de ingebruikname van het overdekte podium.

3.1 Algemeen

- Geen sneeuw- en/of hagelbelasting gerekend
- Podiumvloer is geschikt voor een belasting tot 750 kg/m2
- Obstakels moeten ten minste 0,5 meter van het doek verwijderd zijn (zowel binnen als buiten).

3.2 Bijzonderheden

Voor de berekeningen is aangehouden:

- Onbebouwde omgeving;
- Tekeningen volgens het bouwboek;
- Toetsing volgens NEN-EN 13814;
- Afmeting van de constructie: 7.25x4.14 – 7.25x6.21 meter

4 Basis instandhouding- en ontruimingsprotocol

Er zijn zaken welke in basis ten alle tijden van toepassing zijn bij een overdekt podium.

- De constructie van de overdekte podia mogen na oplevering nooit zo worden aangetast dat de constructieve veiligheid in het geding komt.
- Organisator moet grondankers, ballast, windverbanden, spanbanden, palen, wandpanelen, zeilen of andere zaken na losmaken voor welk doel dan ook direct weer terugplaatsen/vastmaken.
- Bij het verlaten van het terrein en/of afsluiten van dagelijkse werkzaamheden en/of na afloop van het evenement moet organisator waar mogelijk de toegang tot het overdekte podia sluiten of niet toegankelijk maken.
- Het overdekte podia moet(en) te allen tijde door organisator sneeuw- en of hagelvrij gehouden worden.
- Cumulatie van water, z.g. waterzakken, moeten door organisator direct verwijderd worden, indien dit niet lukt moet verhuurder meteen verwittigd worden.
- Eventuele loskomende grondverankering of verschuivende ballast moet door organisator direct gemeld worden aan verhuurder.
- Voor opgave gemiddelde wind in Bft. en windstoten. (piekwind) in relatie tot de grenswaarden, het sluiten of buiten gebruik stellen van het overdekte podium zie windtabel(len) elders in dit stuk. Daarbij dienen de beheersmaatregelen uit bijlage 4 in acht genomen te worden.
- Equipotentiaalverbinding. Al het blootliggende metaalwerk binnen een structuur dat in contact zou kunnen komen met een bron van elektrische stroom moet op adequate wijze geaard zijn. Er moet rekening worden gehouden met de mate van blootstelling en het risico op blikseminslag en, waar van toepassing, moet de constructie voldoende worden beschermd. Advies over verlichtingsniveaus voor normaal en noodgebruik valt buiten het toepassingsgebied van deze norm en is elders beschikbaar.
- Blikseminslag in de constructie die voldoet aan gestelde (brandveiligheidseisen levert geen schade op aan de overdekte podia).
- Bij acute dreiging van zwaar onweer gepaard gaande met z.g. valwind en/of hagel moet het overdekte podium en directe omgeving ontruimd-, en indien mogelijk gesloten worden. Het overdekte podium is hierin van ondergeschikt belang.
- Organisator moet het lokale weer tijdens het evenement adequaat bewaken en actie ondernemen waar eigen organisatieprotocollen of overdekte podiumspecificaties dit aangeven.

5 Verklaring weeromstandigheden

Met welke weersomstandigheden dient de huurder rekening te houden.

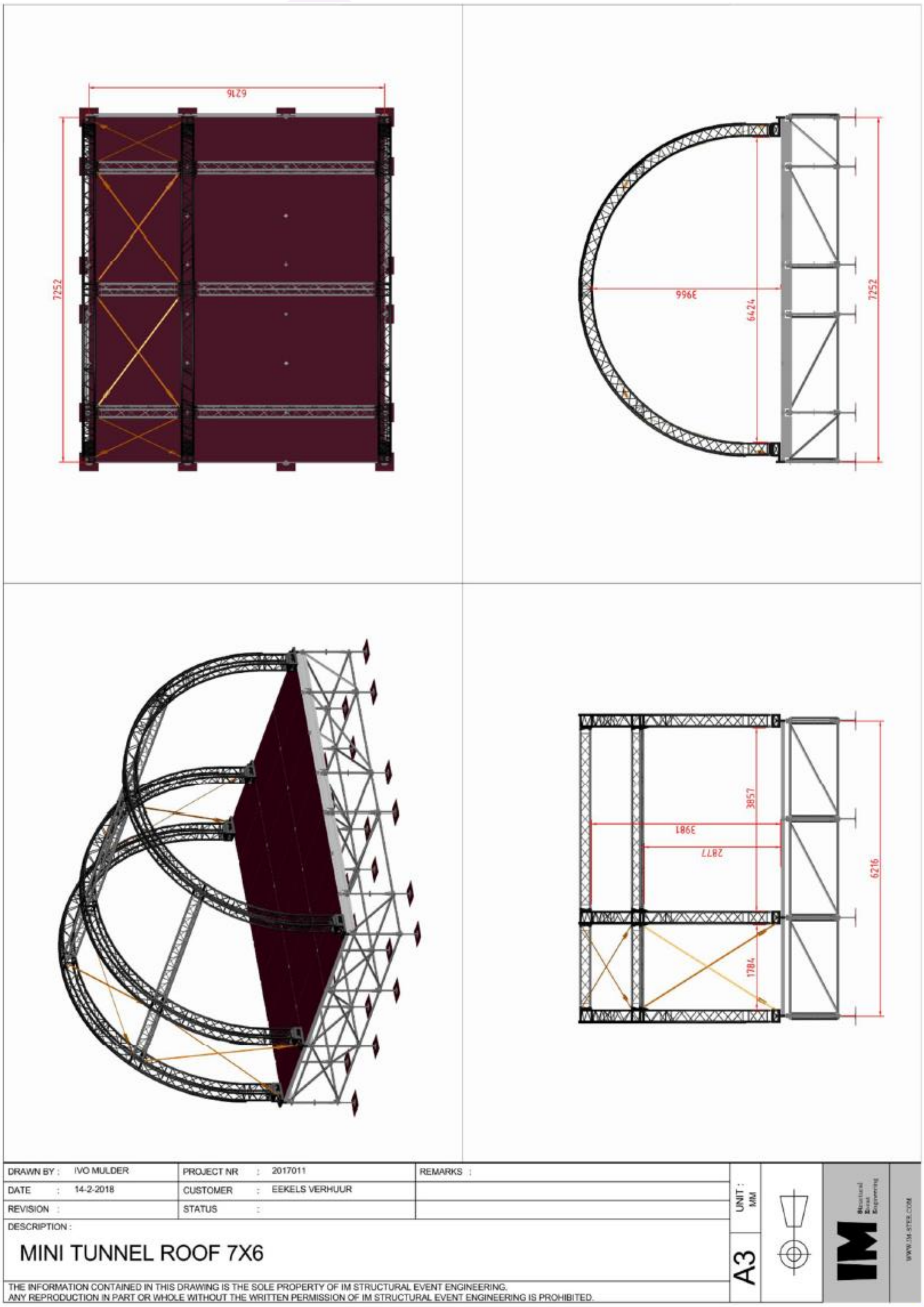
- Een constructie wordt berekend op een stuwdruk (de windbelasting per m2). De stuwdruk ontstaat door de windsnelheid. De windsnelheid is opgebouwd uit een stationair deel en een turbulent deel. Hierdoor ontstaan er pieken in de windsnelheid.
- Windsnelheid wordt standaard gemeten op 10 meter hoogte in het vrije veld, zonder obstakels. Er kan gesproken worden over een piekwindsnelheid, een 10-minuten gemiddelde windsnelheid of een uurgemiddelde windsnelheid. Hoe langer de tijd is, hoe lager het gemiddelde.
- De in de berekeningen gehanteerde beaufort-windschaal wordt in Nederland weergegeven in een 10-minuten **gemiddelde windsnelheid** op 10 meter hoogte in het vrije veld.
- **De stuwdruk waarop een overkapping berekend is, is bepalend voor de sterkte van de overkapping. Het gaat er dus om dat op de juiste manier wordt vastgesteld welke windsnelheid moet worden aangehouden om te kunnen bepalen of de stuwdruk overschreden wordt.**
- Als er niet op locatie gemeten wordt, moet gebruik worden gemaakt van de dichtstbijzijnde meteostation en moet de 10-minuten-gemiddelde windsnelheid op 10 meter hoogte worden opgevraagd. Als de grens-10 minutengemiddelde snelheid wordt bereikt, is de grens-stuwdruk bereikt. De opgegeven waarden gelden voor onbebouwd terrein (buiten de bebouwde kom) en niet voor het strand.
- Onderscheid tussen gemiddelde- en piekwindsnelheid in acht nemen.

De windkracht volgens de Schaal van Beaufort (bron: KNMI). De schaal van Beaufort wordt gebruikt voor de gemiddelde windsnelheid, over minstens 10 minuten gemeten, níet voor de snelheid van rukwinden/windstoten(piekwind).

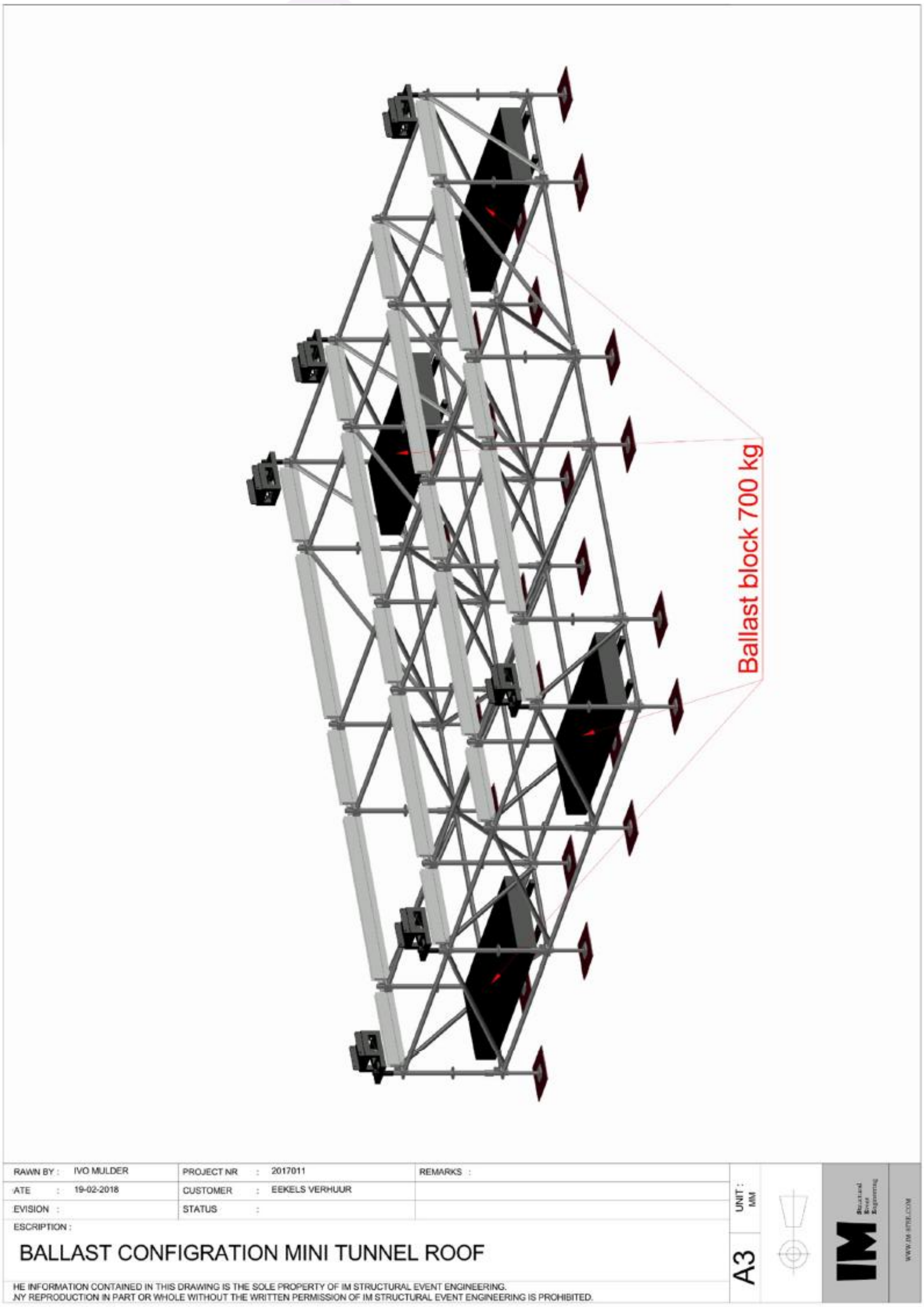
Kracht	**Benaming van KNMI**	**Benaming in Zeevaart**	**Snelheid in km/h***	**Snelheid in m/s***	**Snelheid in knopen**
0	Stil	Windstil	0-1	0-0,2	0-1
1	Zwak	Flauw en stil	1-5	0,3-1,5	1-3
2	Zwak	Flauwe koelte	6-11	1,6-3,3	4-6
3	Matig	Lichte koelte	12-19	3,4-5,4	7-10
4	Matig	Matige koelte	20-28	5,5-7,9	11-16
5	Vrij krachtig	Frisse bries	29-38	8,0-10,7	17-21
6	Vrij krachtig	Stijve bries	39-49	10,8-13,8	22-27
7	Hard	Harde wind	50-61	13,9-17,1	28-33
8	Stormachtig		62-74	17,2-20,7	34-40
9	Storm		75-88	20,8-24,4	41-47
10	Zware storm		89-102	24,5-28,4	48-55
11	Zeer zware storm / orkaanachtig		103-117	28,5-32,6	56-63
12	Orkaan		>117	>32,7	>63

De Nederlandse weerstations onder andere vinden op: www.meteovista.nl, www.knmi.nl, www.meteoconsult.nl en www.meteostation.nl.
Organisator kan ook bij onder andere Meteovista en Meteoconsult gedurende de duur van het evenement een weerbewakingscontract aangaan om nog beter op de hoogte te zijn van de lokale weersomstandigheden.

6 Bijlage I: Tekening(en)



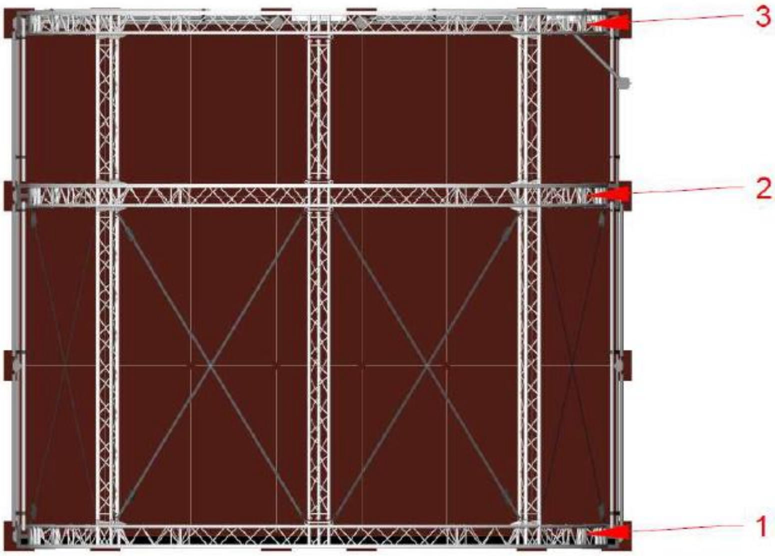
7 Bijlage II: Ballastplan



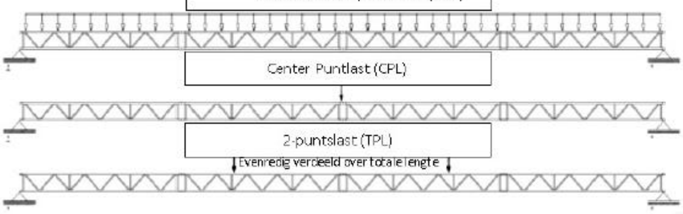
8 Bijlage III: Riggingscapaciteit

Riggingscapaciteit Ares 42/28

Bij uitvoering in opstelling Ares 28 vervalt truss 2



Naam	Waarde	Maximale Gebruiksbelasting per punt		
		1	2	3
A. Verdeelde last per meter (UDL)	kg/m	150	150	150
B. Center puntlast (CPL)	kg	1000	1000	1000
C. 2-puntslast (TPL)	kg	850	850	850
D. 4-puntslast (FPL)	kg	700	700	700



Figuur 1

Let op:
Bij Dynamische lasten dient een extra veiligheidsfactor gehanteerd te worden in overleg met constructeur Eekels verhuur!

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Hallenstraat 20
5531 AB Bladel

9 Bijlage IV: Beheersmaatregelen (WMP; Wind Management Plan)

In dit Beheersplan wordt kort omschreven welke stappen bij welke windsnelheid gezet dienen te worden. De waarde waarbij deze stappen gezet dienen te worden verschillen per windgebied.

Hieronder een opsomming van de 10-minuten gemiddelde windsnelheid per locatie (omschreven in de NEN-EN 1991-1-4:2005)

In de bovenstaande hoofdstukken is uitgelegd hoe de berekening is opgebouwd. Conform de Geldende normen dient dan het onderstaande Beheersingsplan toegepast te worden.

1. Zij- en achterzeilen dienen verwijderd te zijn bij het bereiken van onderstaande waarde;

Gebied	10 minuten gemiddelde windsnelheid (m/s)	Beaufort (Bft)	Piekwindsnelheid (m/s)	Stuwdruk (kN/m²)
Kust	10.58	5	17.89	0.20 kN/m²
Onbebouwd	12.03	6	17.89	0.20 kN/m²
Bebouwd	17.57	8	17.89	0.20 kN/m²

2. Het podium dient UIT-SERVICE (out-service) gesteld te zijn bij het bereiken van onderstaande waarde;
   - Tevens dient de directe omgeving ontruimd te zijn

Gebied	10 minuten gemiddelde windsnelheid (m/s)	Beaufort (Bft)	Piekwindsnelheid (m/s)	Stuwdruk (kN/m²)
Kust	15.65	7	26.46	0.4375kN/m²
Onbebouwd	17.79	8	26.46	0.4375kN/m²
Bebouwd	25.99	10	26.46	0.4375kN/m²

3. Bij acute dreiging van zwaar onweer gepaard gaande met z.g. valwind en/of hagel moet de constructie en directe omgeving ontruimd-, en indien mogelijk, gesloten worden. De overkapping is hierin van ondergeschikt belang.

NOTE; de 10-minuten gemiddelde windsnelheid wordt alleen weergegeven als referentie windsnelheid. Acties omtrent de constructie dienen ondernomen te worden aan de hand van de piekwindsnelheid.

Bij vragen of twijfel over dit plan kunt u altijd contact opnemen met Eekels Verhuur B.V.

10 Bijlage V: Zeilcertificaat

Technisches Datenblatt Nr.: **1017.14**

Produkt: POLYMAR® FR COLOR 700

Artikel Nr.: 8509 5240

Beschichtung und Ausrüstung				
Beschichtungsart	**PVC**			
Ausrüstung	**beidseitig mit Acryllack, mikrobiozid, UV-geschützt**			
Brennverhalten	**BS 7837, D.M. 26.06.84 (UNI 9177): CL. 2, DIN 4102: B1, NFP 92507: M2, GOST: G1, NFPA 701 Test 2, EN 13501-1: B-s2-d0**			
zu Brennverhalten	**stets die Aktualität der FR-Zulassung, sowie länderspezifische Gültigkeit prüfen**			
Gesamtgewicht		**680**	g/m²	DIN EN ISO 2286-2
Reißkraft Kette/Schuss		**3000 / 3000**	N/50 mm	DIN EN ISO 1421/V1
Weiterreißfestigkeit Kette/Schuss		**300 / 300**	N	DIN 53363
Haftfestigkeit		**20**	N/cm	PA 09.03 (intern)
Kältebeständigkeit.		**-40**	°C	DIN EN 1876-1
Wärmebeständigkeit		**+70**	°C	PA 07.04 (intern)
Lichtechtheit		**>6**	Note, Value	DIN EN ISO 105 B02
Knickfestigkeit	keine Risse	**100000 x**		DIN 53359 A
Trägergewebe				
Material		**PES**		DIN EN ISO 2076
Fadenstärke		**1100**	dtex	DIN EN ISO 2060
Bindung		**L 1/1**		ISO 3572

Bei den technischen Daten handelt es sich um ca. Werte, die auf Basis von ermittelten Durchschnittswerten erstellt wurden. Aus fertigungstechnischen Gründen sind Abweichungen bis zu -5% möglich. Diese technischen Angaben entsprechen dem heutigen Stand der Kenntnisse und sollen über unsere Produkte ohne Rechtsverbindlichkeit informieren. Diese Daten gelten für neue Ware. Einsatzvorschläge entbinden den Käufer nicht, selbst zu prüfen, ob das Material für den von ihm gewünschten Einsatz geeignet ist.

VL/LB:

QM-071/3-08/00 EA/007-06/98 Datum 17.05.2019

11 Bijlage VI: Berekening

Structural
Event
Engineering

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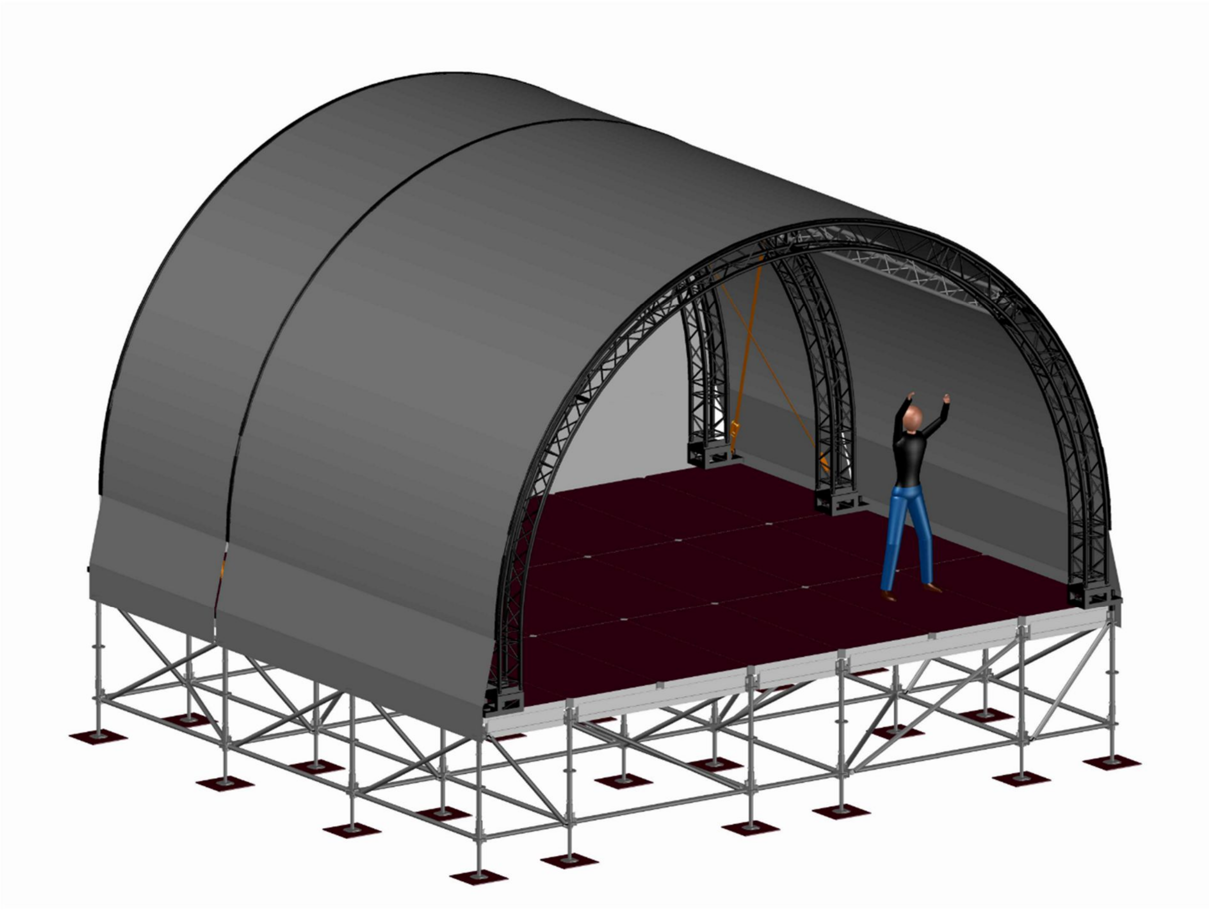

Project number: 2017011
Structural calculation Report
Mini Tunnel Roof 7x6
Eekels verhuur

Date: 5-3-2018

Ivo Mulder BCs

IM Structural Event Engineering
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8603 DK, Sneek
The Netherlands
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imulder@im-stee.com

Index

1 General Preliminary notes.

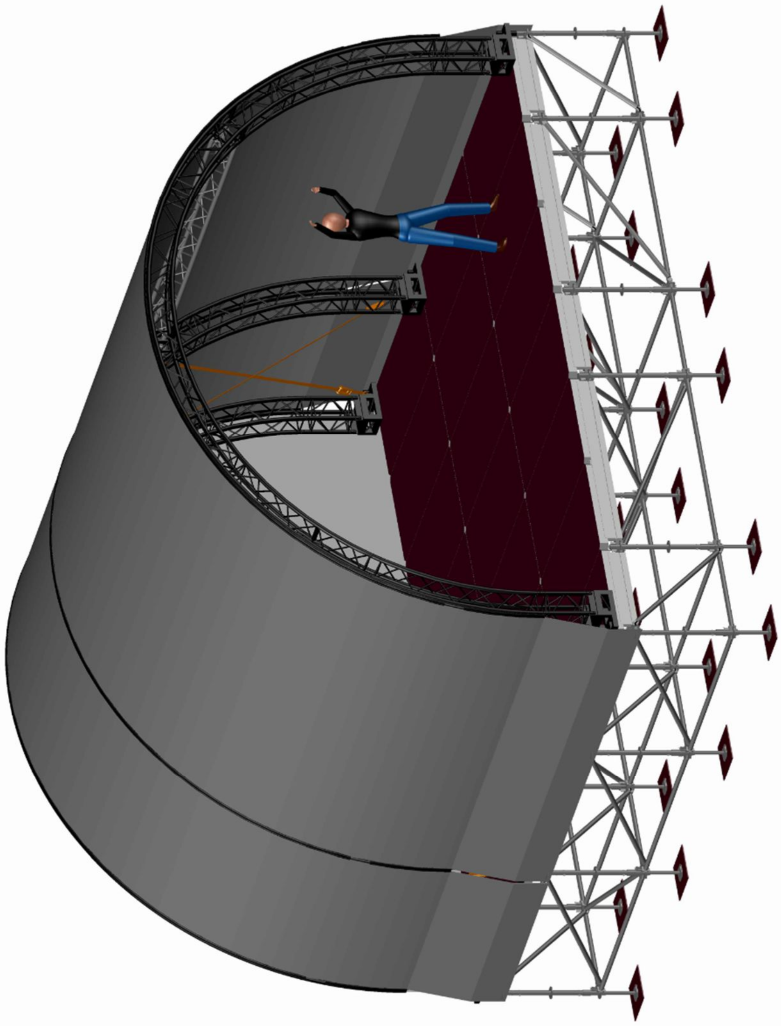
1.1 Project description.

This project concerns the calculation of a Mini Tunnel Roof dimensions 7 x 6 m with an maximum overall height of 6 meter.

The Mini Tunnel Roof is constructed from Interal Protruss. The main arches are square Protruss S31 with dimensions 0.29 x 0.29m and the truss between the main arches is Protruss T31 with dimensions 0.29 x 0.257m. The main chords of the main arches are produced from the material EN-AW 6060-T6 which differs from the structural calculation of the specific truss type. This has been taken into account in this calculation. The main chords of the trusses in between the main arches are made from the material EN-AW 6082 T6 which is according to the structural report.

The Mini Tunnel Roof is constructed on top of a Layher stage which is connected with special adapters. The height of the Layher stage which is taken into account in this calculation is 1.3 m. The Layher stage could be built with different heights.

1.2 Construction drawing of the mini Tunnel Roof 7x6



DRAWN BY : IVO MULDER	PROJECT NR : 2017011	REMARKS :
DATE : 14-2-2018	CUSTOMER : EEKELS VERHUUR	
REVISION :	STATUS :	

DESCRIPTION :

MINI TUNNEL ROOF 7X6

UNIT : MM

A3

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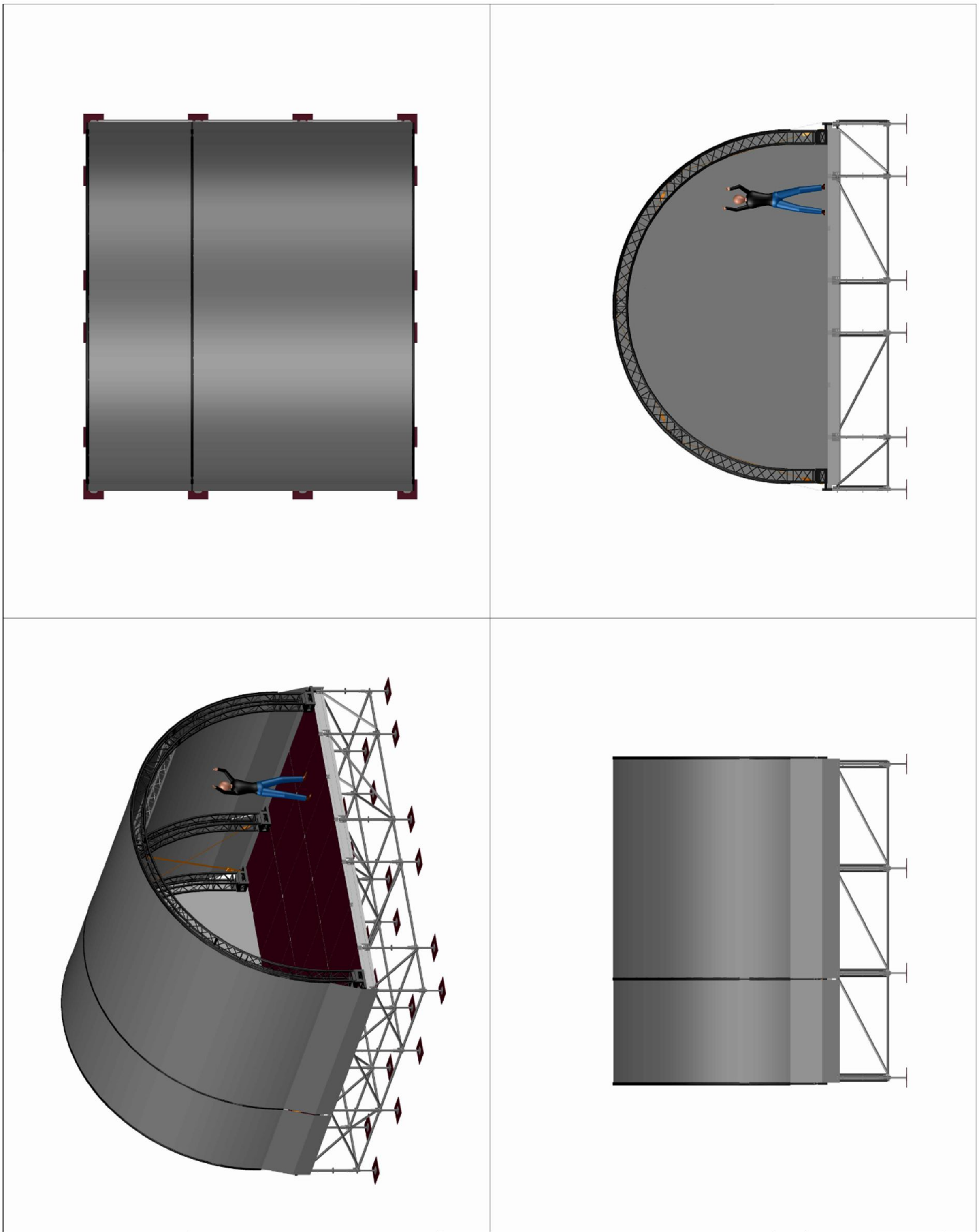

DRAWN BY : IVO MULDER	PROJECT NR : 2017011	REMARKS :
DATE : 14-2-2018	CUSTOMER : EEKELS VERHUUR	
REVISION :	STATUS :	

DESCRIPTION :

MINI TUNNEL ROOF 7X6

UNIT : MM

A3

Structural Event Engineering

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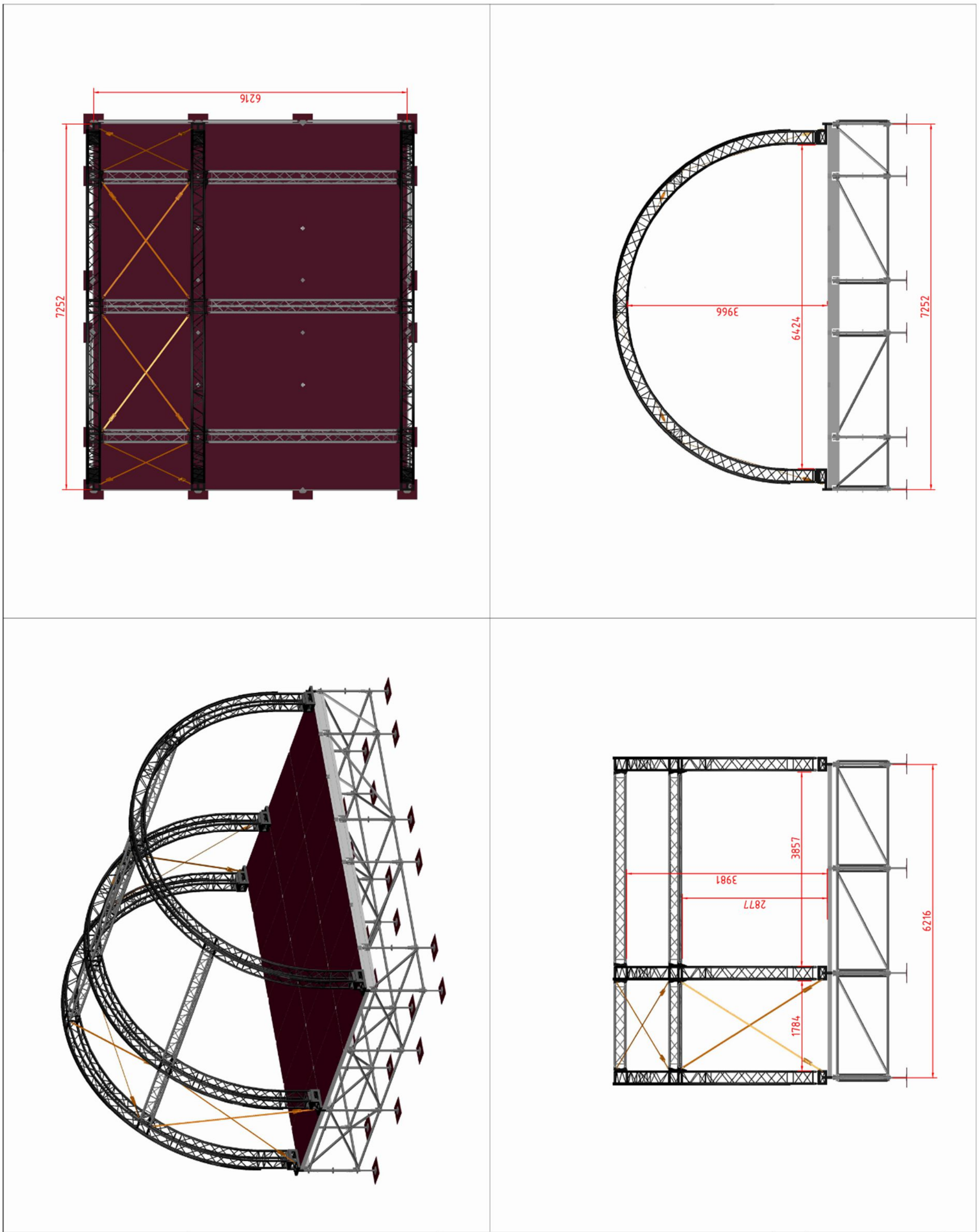

DRAWN BY : IVO MULDER	PROJECT NR : 2017011	REMARKS :
DATE : 14-2-2018	CUSTOMER : EEKELS VERHUUR	
REVISION :	STATUS :	

DESCRIPTION :

MINI TUNNEL ROOF 7X6

UNIT : MM

A3

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1.3 Used normalisation.

This calculation is based on the next parts of the Eurocodes.

NEN-EN 1990	(Eurocode 0) Basis of structural design.
NEN-EN 1991	(Eurocode 1) Action on structures.
NEN-EN 1993	(Eurocode 3) Design of steel structures.
NEN-EN 1999	(Eurocode 9) Design of Aluminium structures.
NEN-EN 13814	Fair ground and amusement park machinery and structures
NEN-EN 13782	Temporary Structures-Tents-Safety.
NEN-EN 12385	Steel wire ropes.

1.4 General load assumption explanation.

The loads which are taken into account in this calculation are based on the information gattered from the different parts of the Eurocodes. Some of the loading information's from the Eurocode are based on permanent building constructions which makes it not feasible to use these information for a temporary demountable construction. In these specific cases there will be an explanation of a well weighted decision why the calculation deviates from the information presented in the Eurocode.

1.5 Used materials.

Truss	Interal Protruss S31 and Protruss T31
Stage	Layher Event system

Connection between roof and stage is made by special steel adapters.

The cross wires are made from ratchet straps with a breaking strength of 25 Kn.

1.6 Load assumptions

1.6.1 Wind loading

According to the Eurocode 13814, two wind situation calculations have to be made for a temporary demountable structure. The first situation has a wind speed from 0 to 21 m/s and is called the In-service situation and the second situation has a wind speed from 21 m/s to 28 m/s and is called the Out-service situation. These maximum wind speeds are the maximum wind gust measured at 10 meters high in a free environment. The In-service situation is the situation where the construction can be used for events. In this situation the back wall is mounted. There is no danger concerning the structural integrity of the temporary demountable structure. Before the wind gust exceeds the maximum In-service wind speed of 21 m/s the back wall and big scenery objects need to be removed, so the wind can pass underneath the roof. All these actions, and how they are executed need to be written in a method statement. When all the actions are finished the Out-service situation is in place. In the Out-service situation the only people who can be in the neighbourhood of the stage are professionals who know and understand the risk involved in temporary demountable structures and are well aware of the method statement. When there are wind gusts higher than the 28 m/s the construction site need to be completely cleared from all people.

The values of the extreme thrust are based on area's which have a reference wind speed of $V_{b,o}$, less or equal to 28 m/s with a return period of 5 years according to the NEN-EN 13814. If the construction will be used in an area which requires a higher extreme thrust, the user need to be aware that using the same extreme thrust value the return period will be less than 5 years.

In the NEN-EN 1991 there are 5 different terrain categories determined. In the tables on the next pages the maximum wind gust is presented which the construction can withstand in the In-service and the Out-service situations, in conjunction with the height and the terrain category. The figure in the column with the head V_b in m/s is the mean wind velocity measured on 10m height in the concerning terrain category, it is recommended to use a professional weather station near to the place where the construction is build. The column with the head Max. wind gust is the maximum peak wind which is determined from the peak wind velocity by the law of Bernoulli.

Because the maximum height of the construction with a stage of 2-meter floor level is just below 8 meters, only the table from 0 < 8 m is presented on the next page.

1.6.2 In-service situation.

The 21 m/s which is mentioned as the maximum wind gust for the In-service situation is based on an average between the wind gust of 17.89 m/s for 0 < 8 m and the wind gust 21.91 m/s for 8 < 20 m.

0 < 8 meter   0.20 kN/m²

Terrain category	V_b in m/s (1)	Max. wind gust (2)
Sea or coastal area exposed to open sea	10.58	17.89
Lakes or flat and horizontal area with negligible vegetation and without obstacles	11.02	17.89
Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	12.03	17.89
Area with regular cover of vegetation or buildings with isolated obstacles with separations of maximum 20 obstacles heights (such as villages, suburban terrain permanent forest)	14.29	17.89
Area in which at least 15% of the surface is covered with buildings and their average heights exceeds 15 m.	17.57	17.89

1.6.3 Out-service situation.

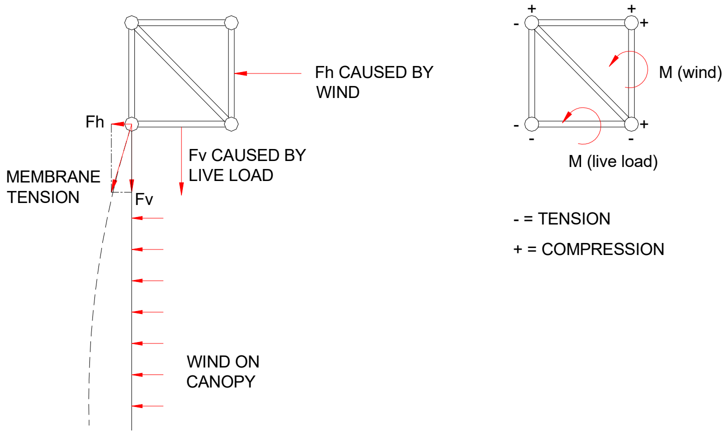
The 28m m/s which is mentioned as the maximum wind gust for the Out-service situation is based on an average between the wind gust 26.46 m/s for 0 < 8 m and the wind gust 31.62 m/s for 8 < 20 m.
The wind pressure which is mentioned in the table below is increased with 20 % in comparison to the Eurocode 13814. This because the factor C_{tem}, which is 0.80 is taken out of the wind pressure values. Intentionally the factor C_{tem} is applied due to the fact that protection, reinforcement and sheltering is possible. In the case of these kind of structure's this is not possible to do.

0 < 8 meter   0,4375 kN/m²

Terrain category	V_b in m/s (1)	Max. wind gust (2)
Sea or coastal area exposed to open sea	15.65	26.46
Lakes or flat and horizontal area with negligible vegetation and without obstacles	16.3	26.46
Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	17.79	26.46
Area with regular cover of vegetation or buildings with isolated obstacles with separations of maximum 20 obstacles heights (such as villages, suburban terrain permanent forest)	21.14	26.46
Area in which at least 15% of the surface is covered with buildings and their average heights exceeds 15 m.	25.99	26.46

1.6.4 Membrane tension of the canopy due to wind influences.

If there is a wind pressure applied to a membrane this membrane will have reaction forces in two directions on the connection to the construction. This phenomenon is called membrane tension. And in some cases, this extra loading need to be applied.



With a dynamic loading q=0.50 kN/m^2 applying an aerodynamic coefficient C_f =0.40 and a span of l=5.00 m a resulting membrane tension of Z=0.80 kN/m is derived.

$Z=(Zy^2+Zz^2)^{1/2}$ =0.80 kN/m with Zz =0.5*0.4*5.0/2=0.50 kN/m
$Zy=(Z^2-Zz^2)^{1/2}=(0.80^2-0.50^2)^{1/2}$ =0.624
Zy/Zz=0.624/0.50=1.25 = 1 / 0.8

1.6.5 Snow Loads.

Snow loads are not taken into account in this calculation. Erection of the construction is initially intended to be in appropriate weather conditions. If the construction should be built in winter season, the construction need to be reinforced or kept free from snow, the method how the structure will be kept free from snow need to be written in the method statement.

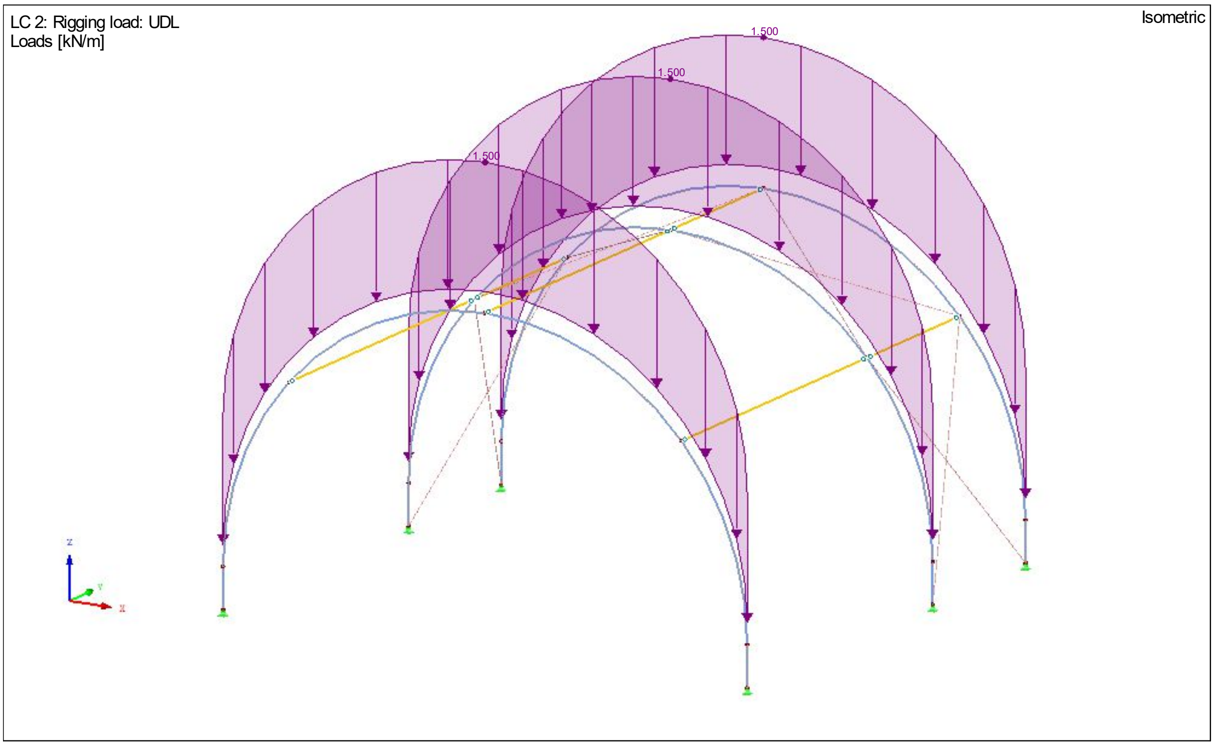
1.6.6 Live load.

In this structural report there are Live load configurations presented. These are intended to give an indication of the Rigging possibilities in the construction. If the actual loading of the construction deviates from these Rigging plots an additional calculation need to be made.
The shifting of Rigging point can influence the maximum loading of the construction.
Each Rigging point need to be attached to the node point of the truss.

1.7 Loading Configurations.

In the next 4 chapters the different live load configurations are presented.

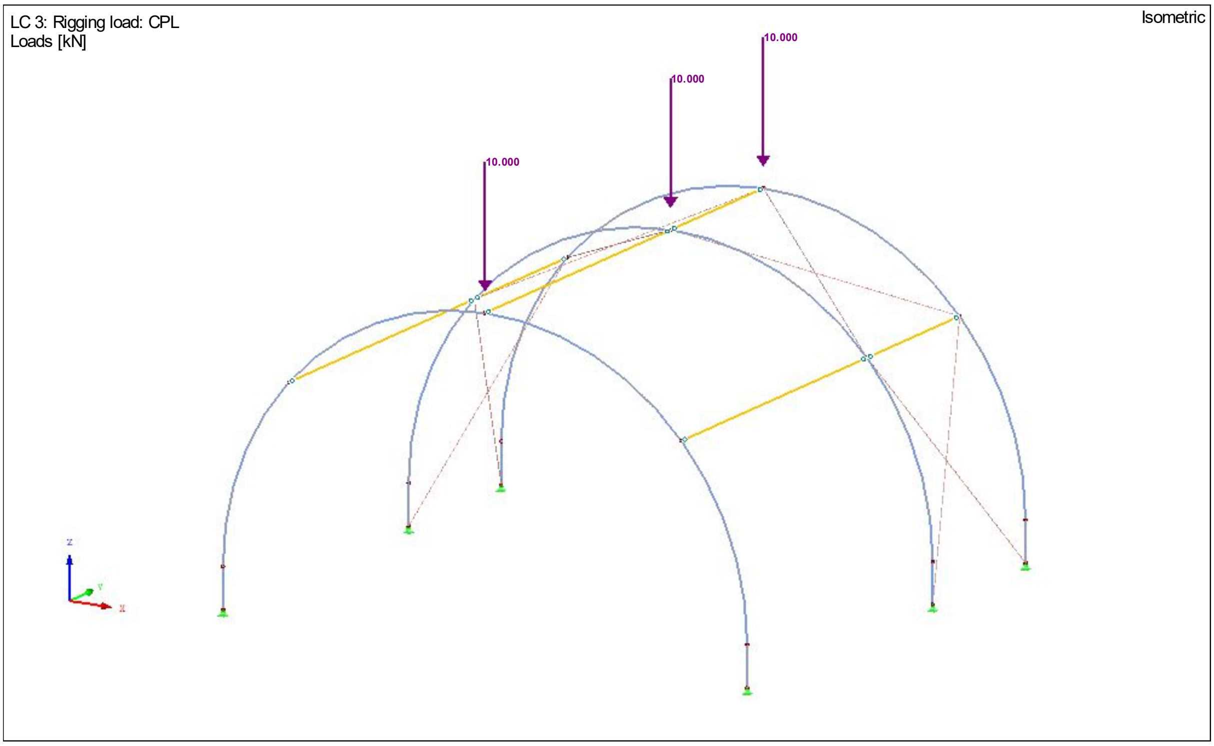
1.7.1 UDL Loading setup



The loading which is taken into account in the UDL Loading setup are:
Truss 1 = 150 kg/m
Truss 2 = 150 kg/m
Truss 3 = 150 kg/m

The total load on the main system is ~ 4750 Kg

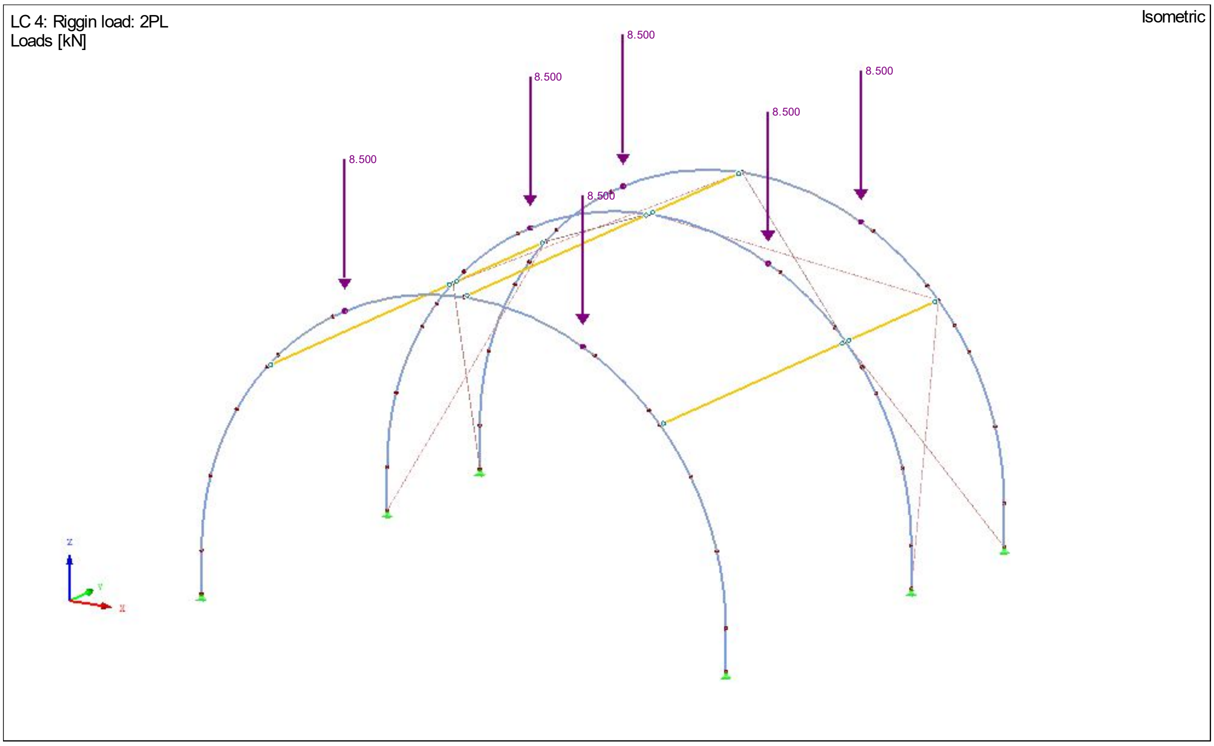
1.7.2 Center point load per truss arch.



The loading which is taken into account in the Centre point Load setup are:
Truss 1 = 1000 kg
Truss 2 = 1000 kg
Truss 3 = 1000 kg

The total load on the main system is ~ 3000 Kg

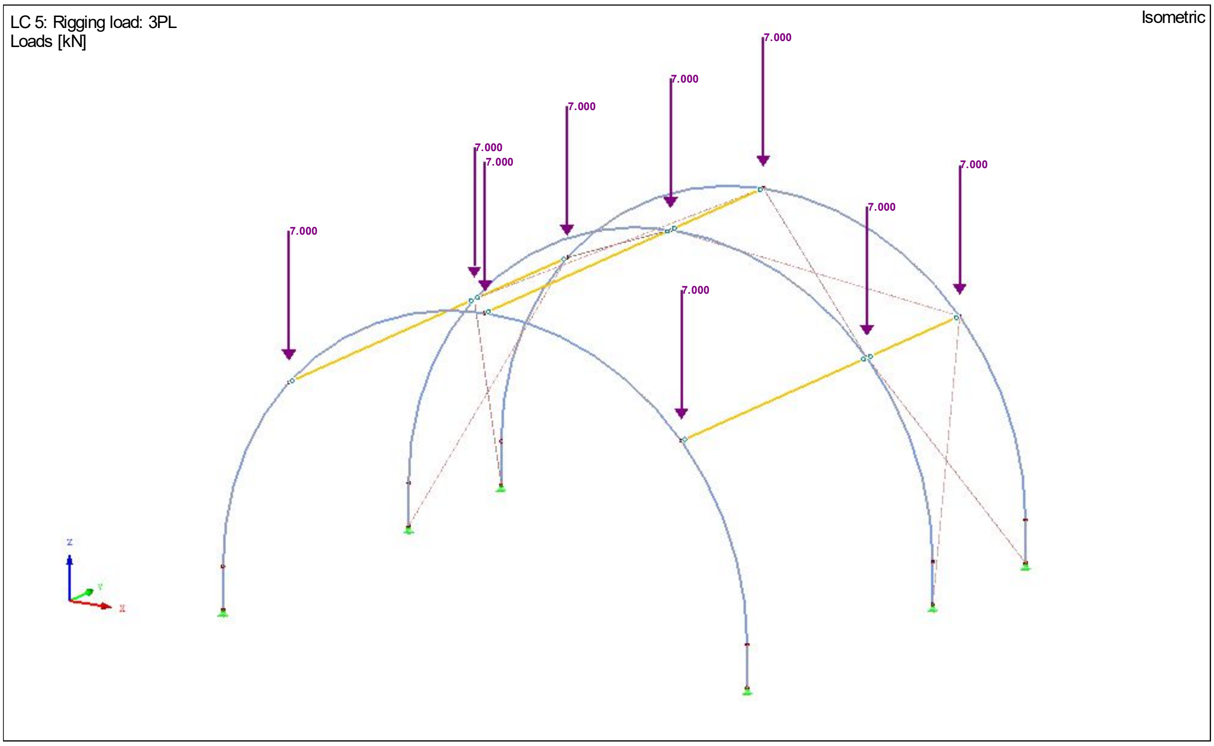
1.7.3 2x Point loads per truss arch.



The loading which is taken into account in the fourth point Loading setup are:
Truss 1 = 2 x 850 kg
Truss 2 = 2 x 850 kg
Truss 3 = 2 x 850 kg

The total load on the main system is ~ 5100 Kg

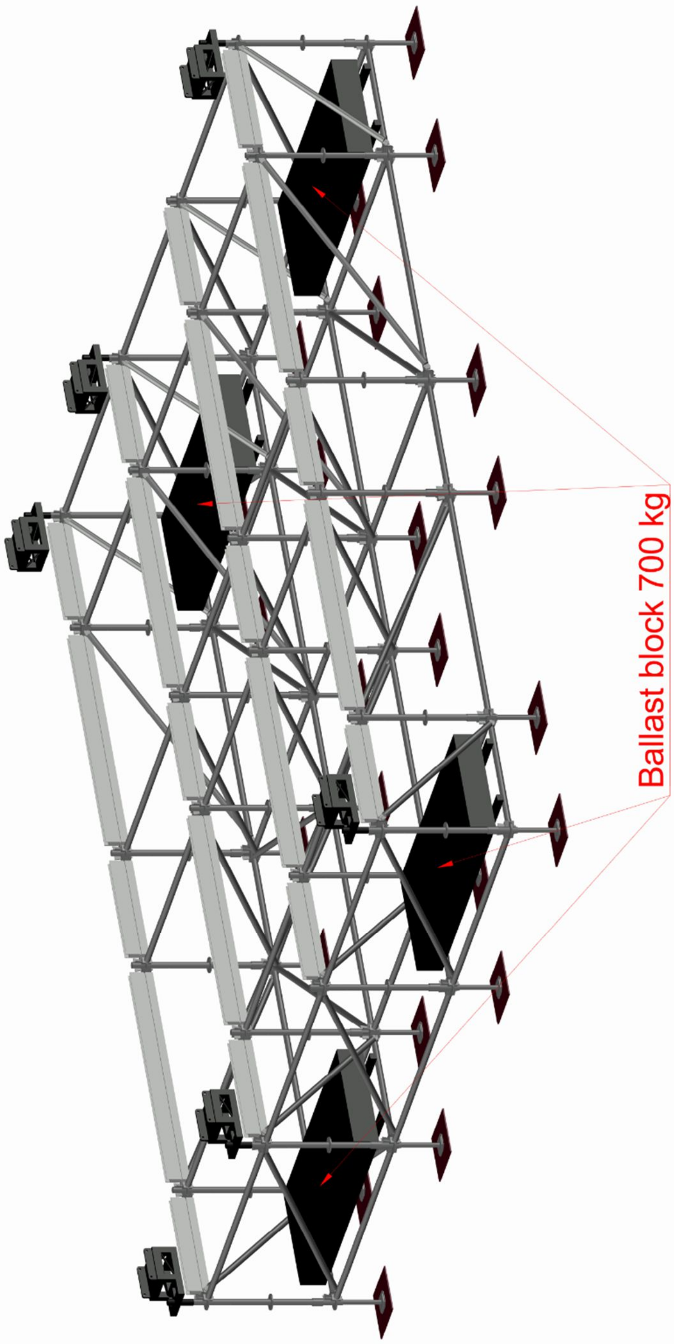
1.7.4 3x Point loads per truss arch.



The loading which is taken into account in the fourth point Loading setup are:
Truss 1 = 3 x 700 kg
Truss 2 = 3 x 700 kg
Truss 3 = 3 x 700 kg

The total load on the main system is ~ 6300 Kg

1.8 Necessary Ballast loading.



RAWN BY : IVO MULDER	PROJECT NR : 2017011	REMARKS :
ATE : 19-02-2018	CUSTOMER : EEKELS VERHUUR	
EVISION :	STATUS :	

ESCRIPTION :

BALLAST CONFIGRATION MINI TUNNEL ROOF

UNIT : MM

A3

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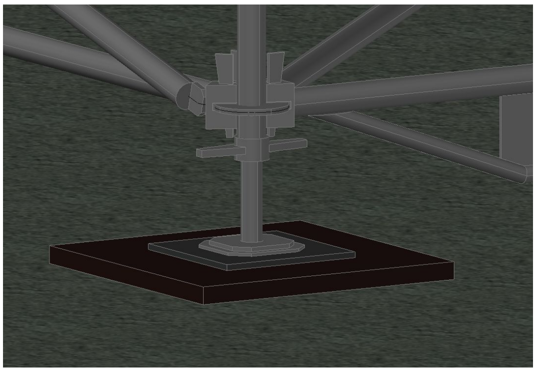
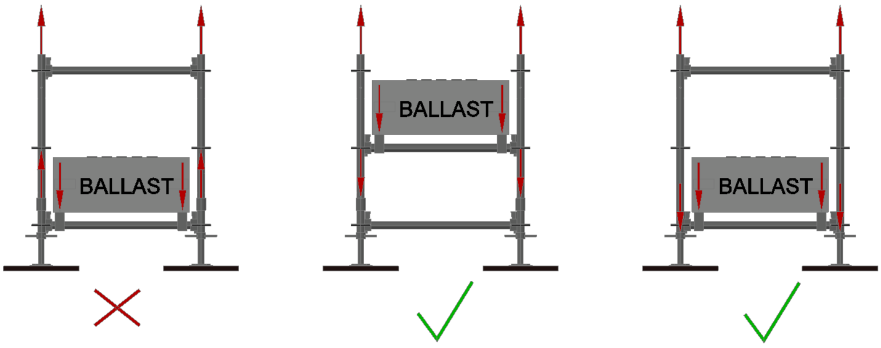
The ballast will be checked for uplift, overturning and sliding. The Layher stage which is designed as a ridged stage will be taken into account.

The safety factor for the ballast calculation against slipping is set to 1.2 according to the NEN-EN 13814. This is based on a horizontal load which is relying on friction.
For the friction coefficient the factor of 0.6 has been taken into account.
The Ballast calculation with factor 0.6 can be justified because rubber underlayment plates are used.

Ballast requirement with μ = 0.6 Steel-rubber-wood-concrete/sand/gravel 750 kg per point



The ballast need to be placed in such a way that it will be activated when lifting forces are applied. If the ballast is placed on the bottom level the use of Layher uprights with connected base collar is necessary.



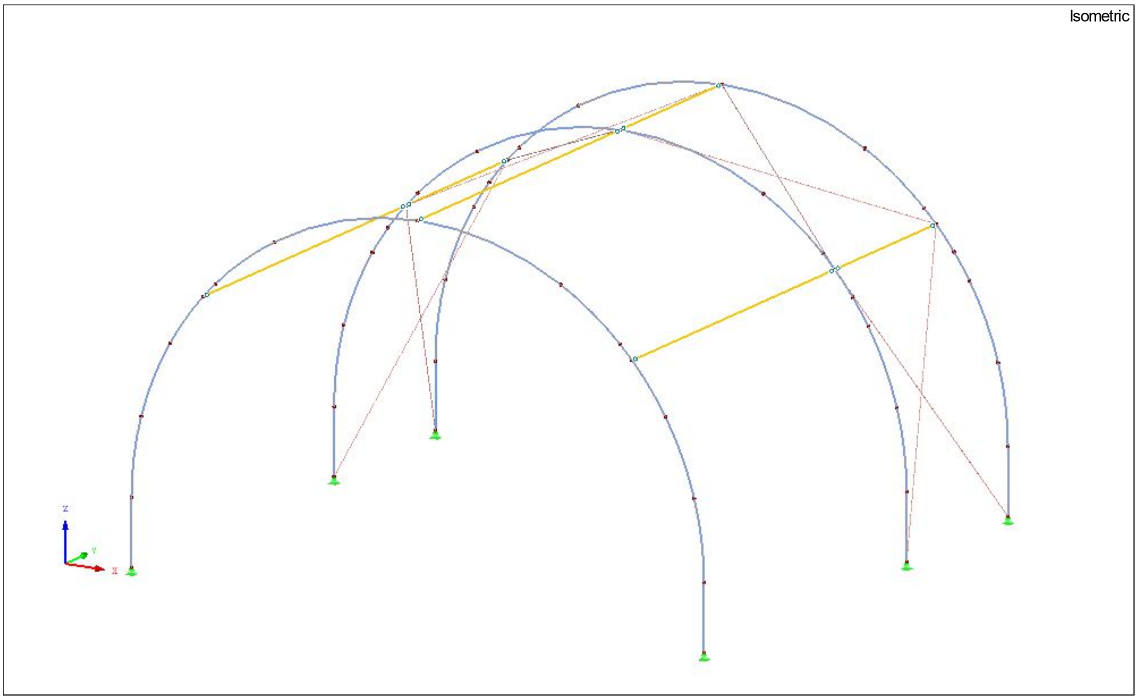
Ballast requirement with μ = 0.6 Steel-rubber-wood-concrete/sand/gravel 750 kg per point

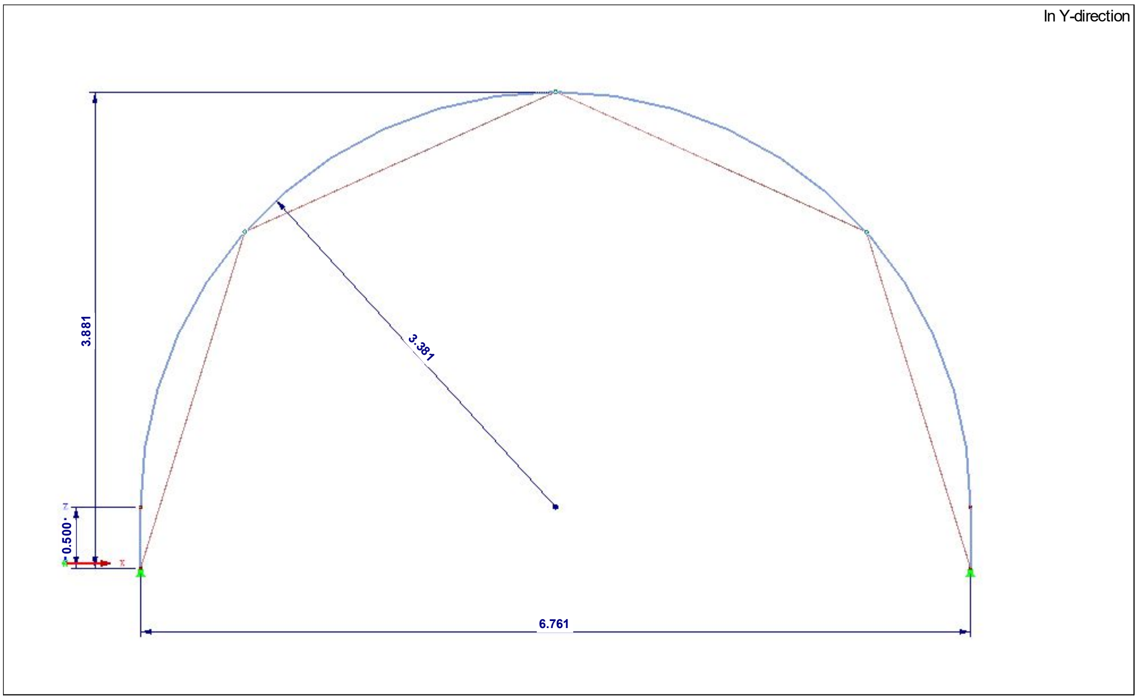
2.0 General calculation input.

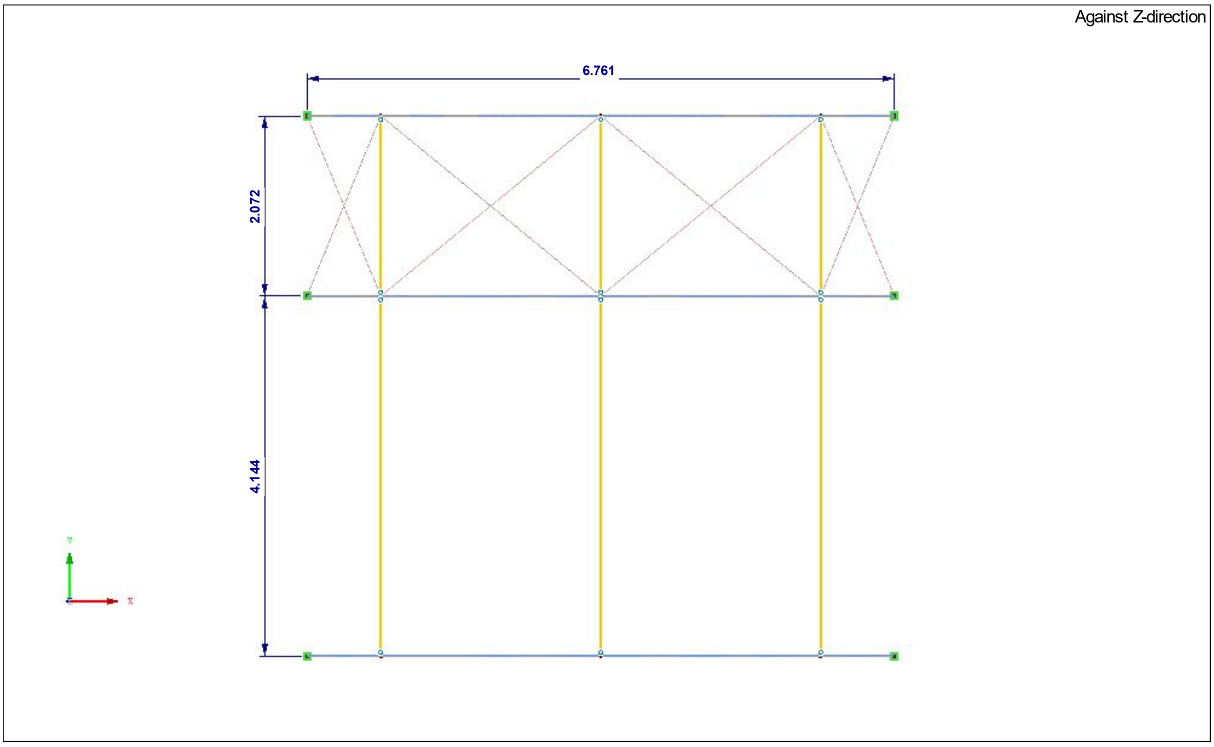
2.1 Information About the calculation program.

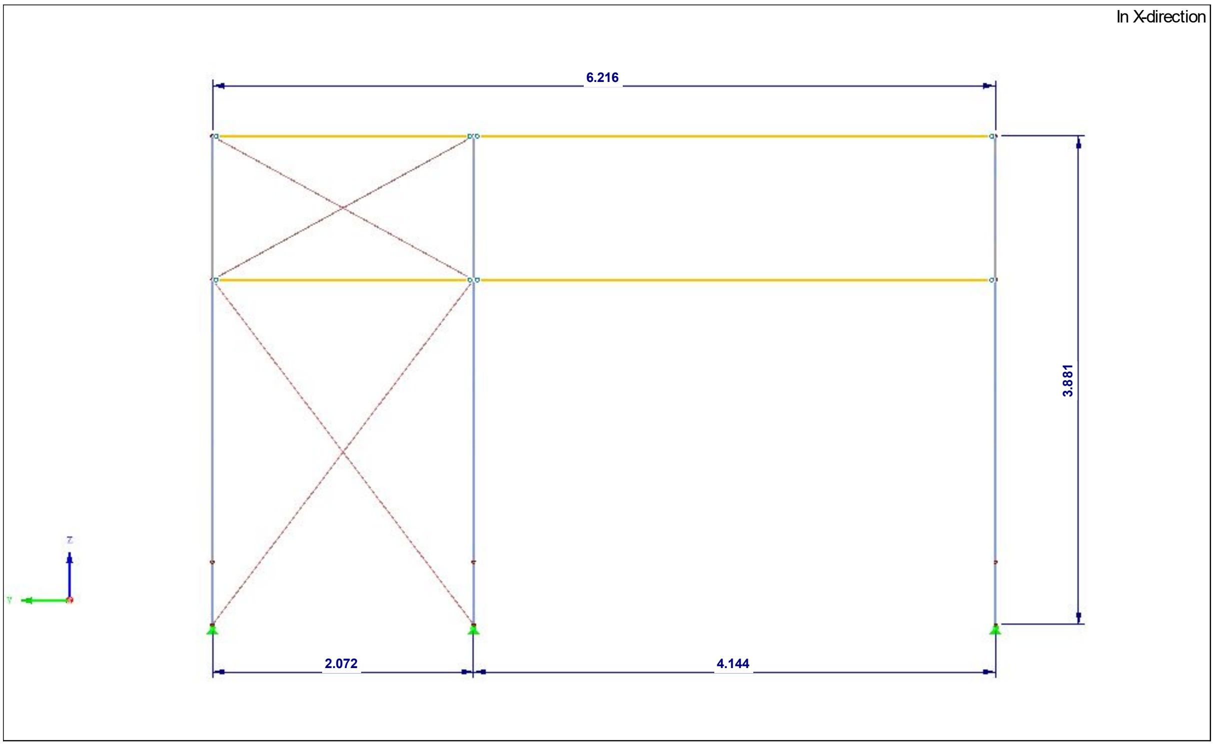
For the calculation of the construction the program RFem from Dlubal software GmbH has been used. The calculation of the Load cases has been made according to the Geometrically Linear analyses principle. The calculation of the Load combinations has been made according to the second order analysis (nonlinear) principle.

2.2 Construction model of the Mini Tunnel Roof 7x6






Against Z-direction
6.761
2.072
4.144
Y
X

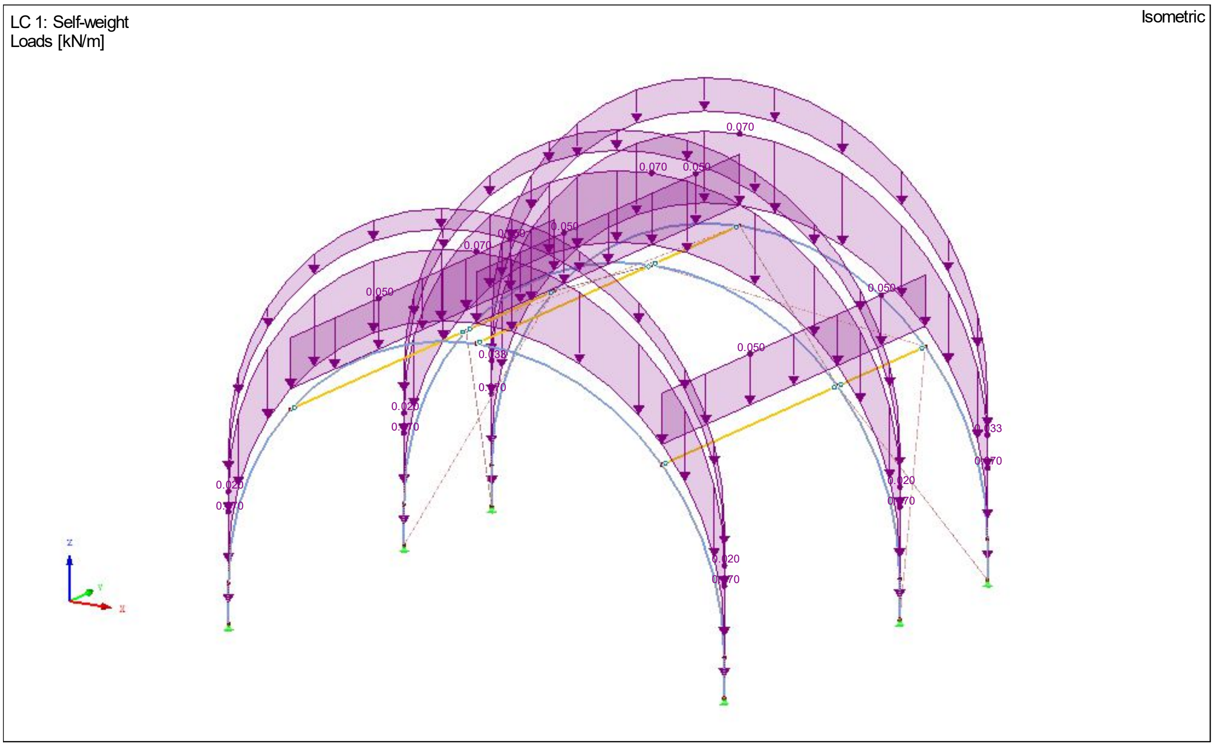

In X-direction
6.216
3.881
2.072
4.144
Z
Y

2.3 Different load cases.

For the calculation different load cases have been constructed in the program.

Load Case	Load Case Description	To Solve	EN 1990 | CEN Action Category	Self-Weight - Factor in Direction Active	X	Y	Z
LC1	Self-weight	+	Permanent	-	0,000	0,000	-1,000
LC2	Rigging load: UDL	+	Permanent/Imposed	-	0,000	0,000	0,000
LC3	Rigging load: CPL	+	Permanent/Imposed	-	0,000	0,000	0,000
LC4	Rigging load: 2PL	+	Permanent/Imposed	-	0,000	0,000	0,000
LC5	Rigging load: 3PL	+	Permanent/Imposed	-	0,000	0,000	0,000
LC10	In service wind 0°	+	Wind	-	0,000	0,000	0,000
LC11	In service wind 90°	+	Wind	-	0,000	0,000	0,000
LC12	In service wind 180°	+	Wind	-	0,000	0,000	0,000
LC20	Out service wind 0°	+	Wind	-	0,000	0,000	0,000
LC21	Out service wind 90°	+	Wind	-	0,000	0,000	0,000

2.4 load case input
2.4.1 LC1 Self-Weight

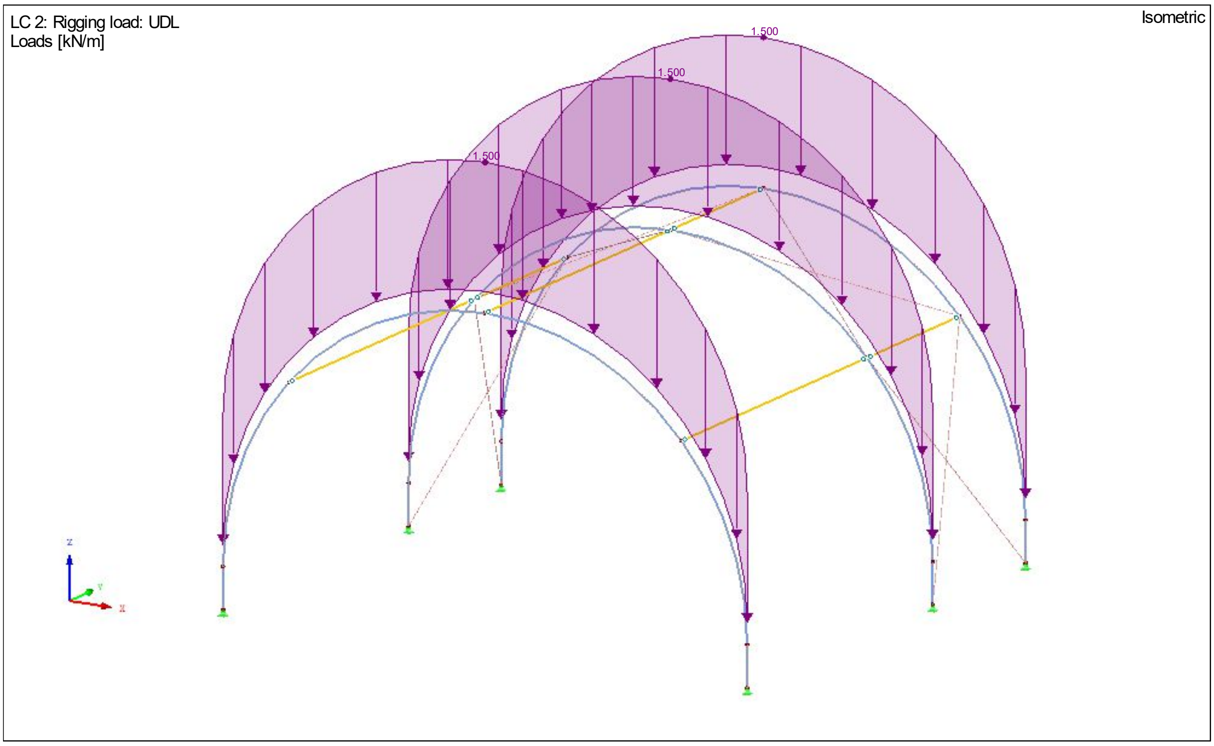


Interal Protruss S31 = 7 kg/m^{-1}
Interal Protruss T31 = 5 kg/m^{-1}

Canopy truss1 = 3.3 kg/m^{-1}
Canopy truss2 = 2 kg/m^{-1}
Canopy truss3 = 2 kg/m^{-1}

The total weight of the system is 421 kg

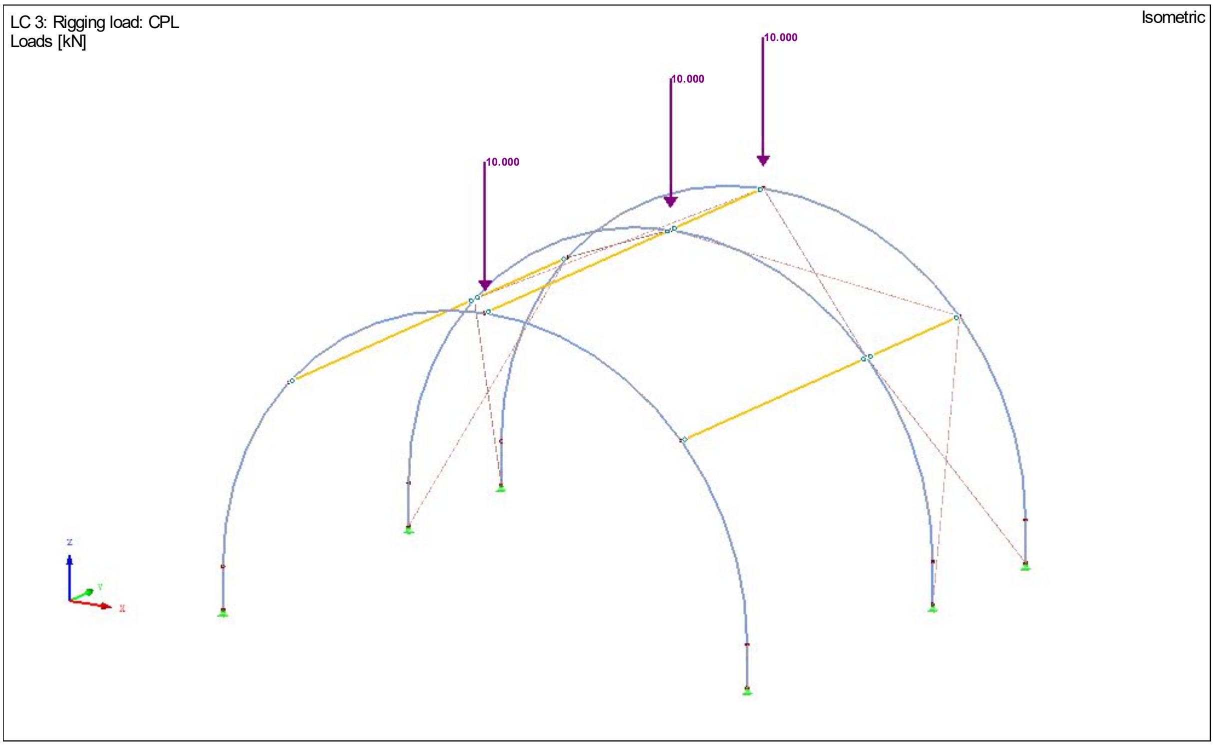
2.4.2 LC2 UDL Loading setup



The loading which is taken into account in the UDL Loading setup are:
Truss 1 = 150 kg/m
Truss 2 = 150 kg/m
Truss 3 = 150 kg/m

The total load on the main system is ~ 4750 Kg

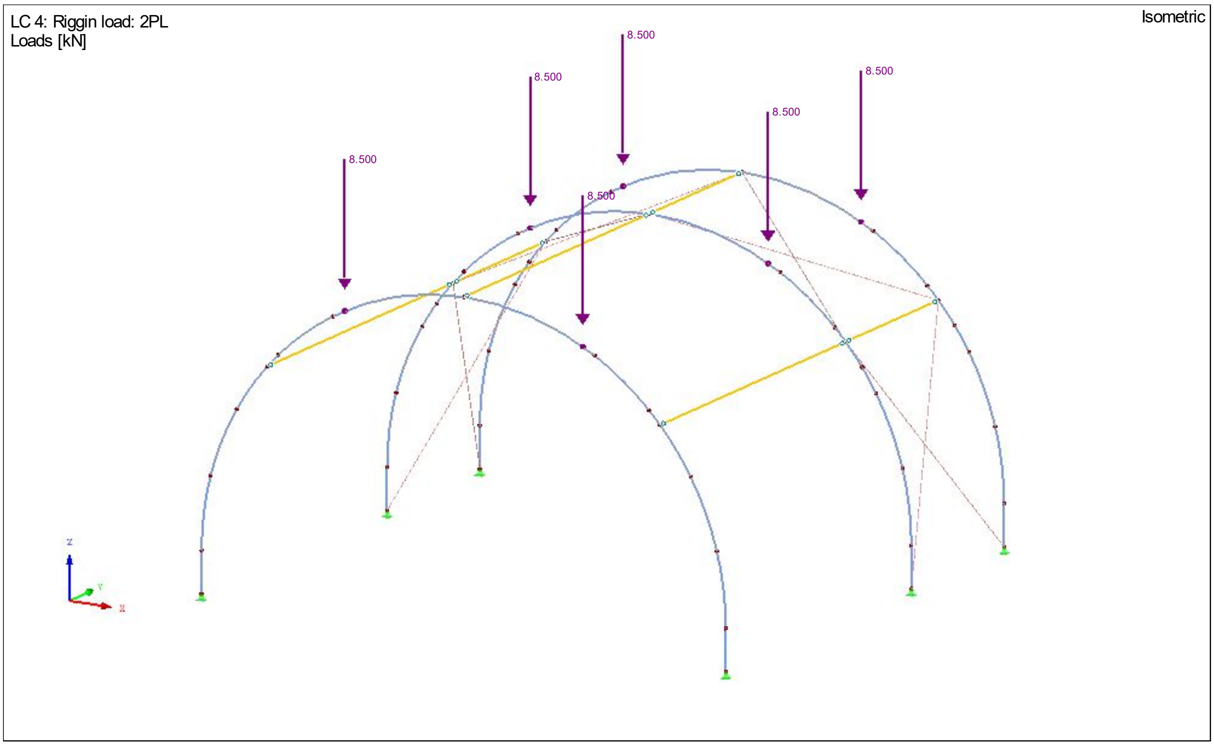
2.4.3 Center point load per truss arch.



The loading which is taken into account in the Centre point Load setup are:
Truss 1 = 1000 kg
Truss 2 = 1000 kg
Truss 3 = 1000 kg

The total load on the main system is ~ 3000 Kg

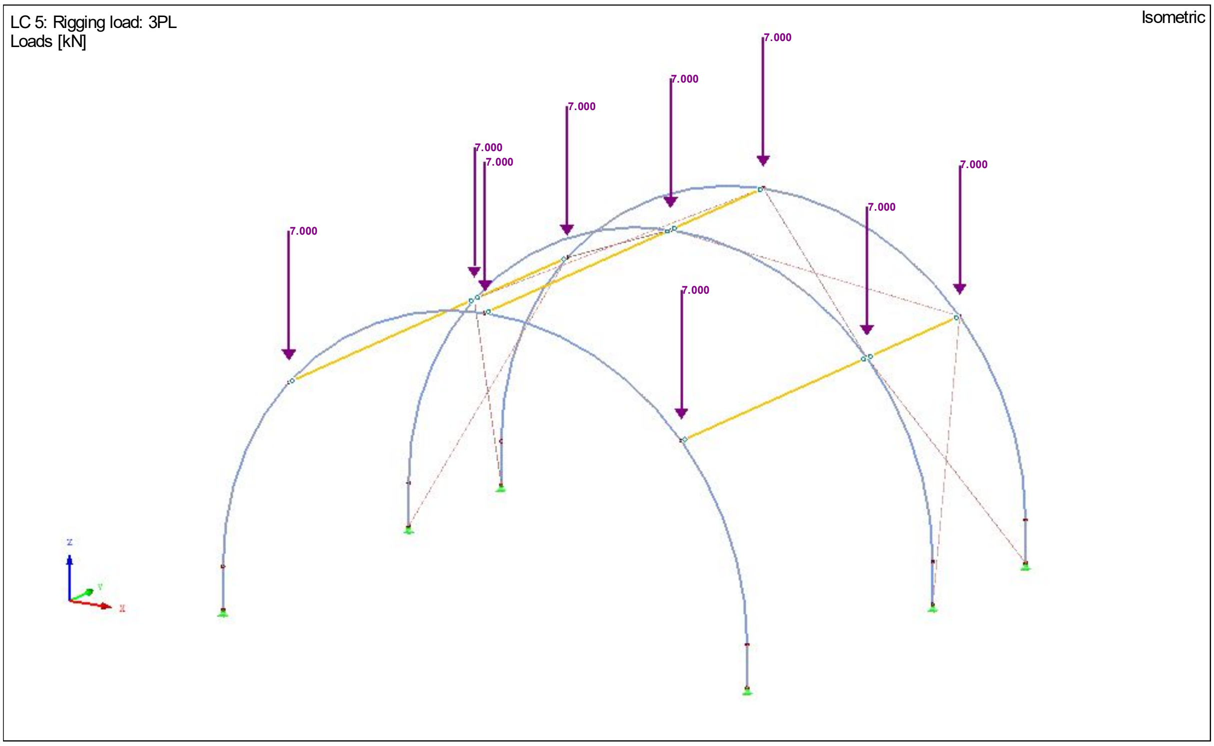
2.4.4 2x Point loads per truss arch.



The loading which is taken into account in the fourth point Loading setup are:
Truss 1 = 2 x 850 kg
Truss 2 = 2 x 850 kg
Truss 3 = 2 x 850 kg

The total load on the main system is ~ 5100 Kg

2.4.5 3x Point loads per truss arch.

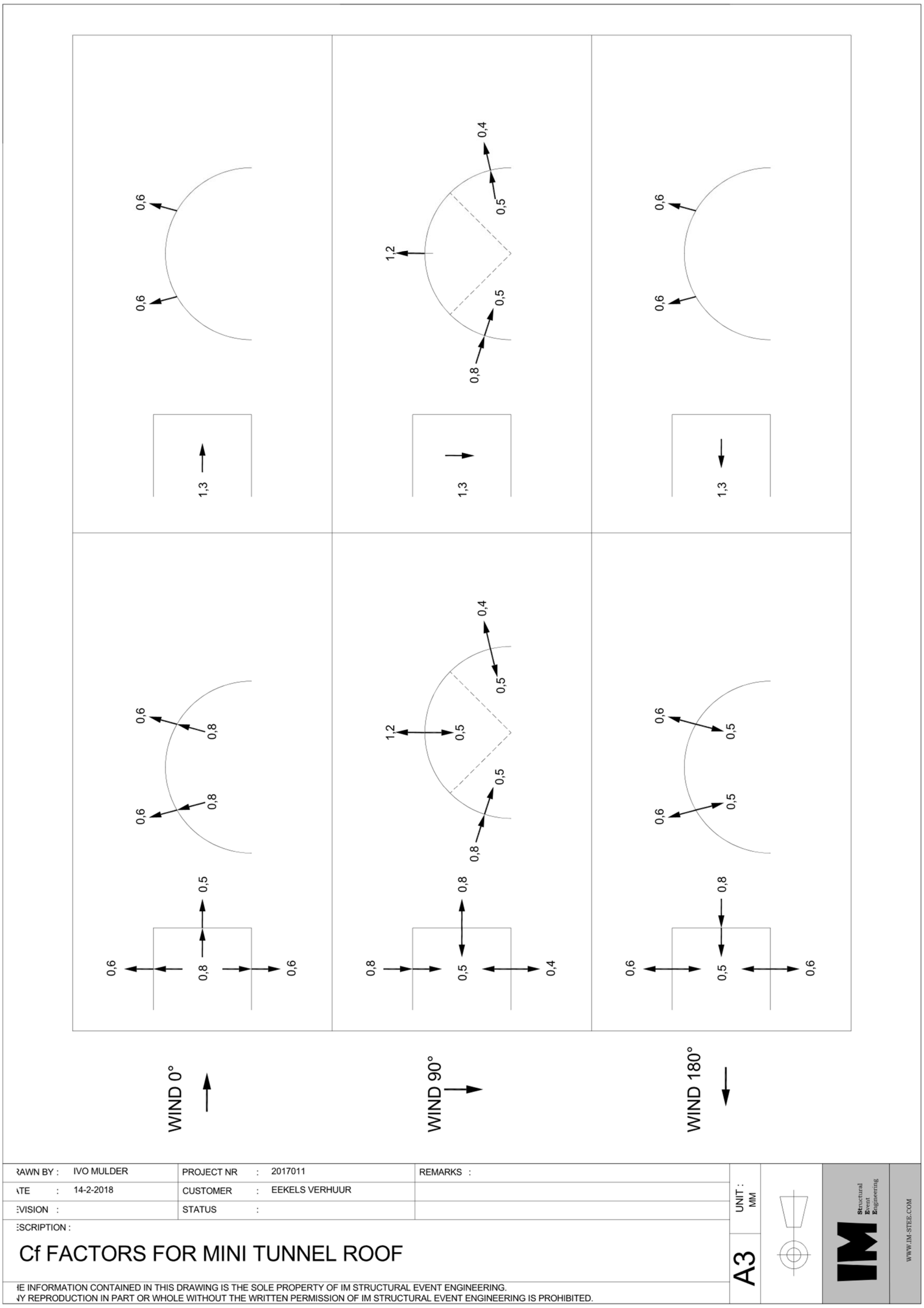


The loading which is taken into account in the fourth point Loading setup are:
Truss 1 = 3 x 700 kg
Truss 2 = 3 x 700 kg
Truss 3 = 3 x 700 kg

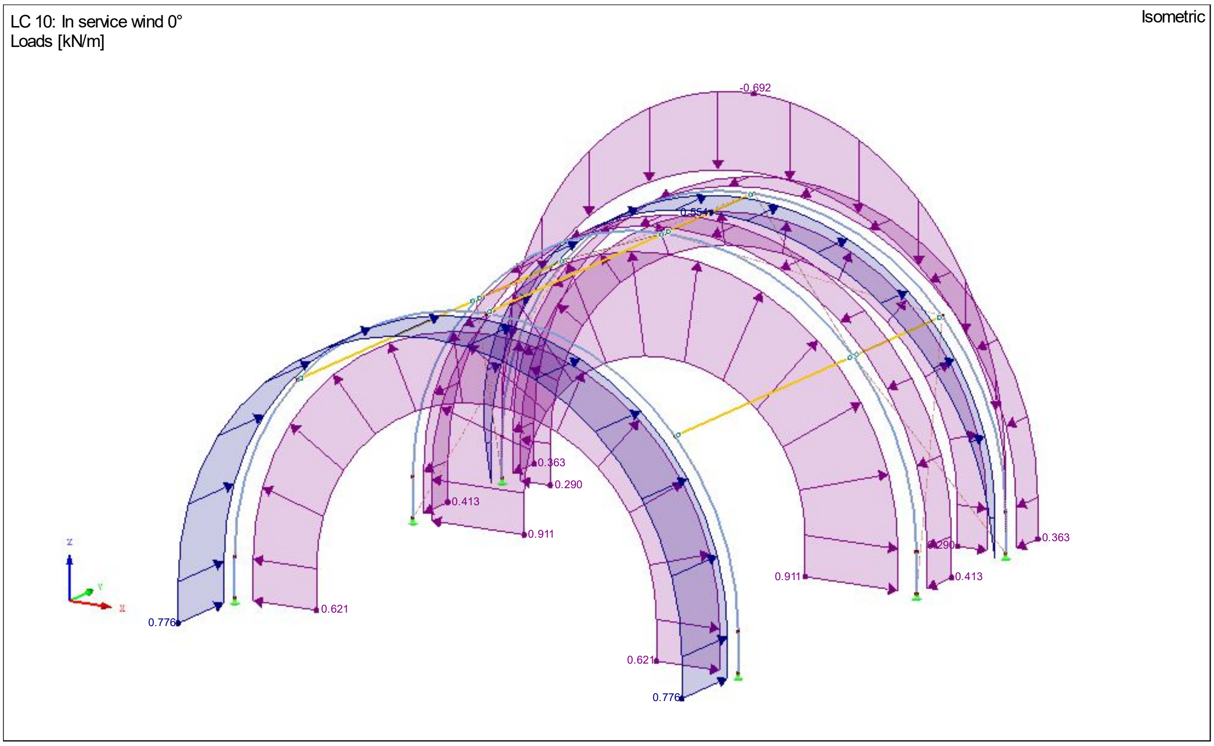
The total load on the main system is ~ 6300 Kg

2.5 Load cases concerning wing loading.

For the calculation of the wind loading the next wind coefficient are used. These factors are subtracted from the Eurocode NEN-EN 1991-1 1-4: general actions – wind actions and NEN-EN 13814 : Fairground and amusement park machinery and structures safety.



2.5.1 load case 10 In-service wind 0°.



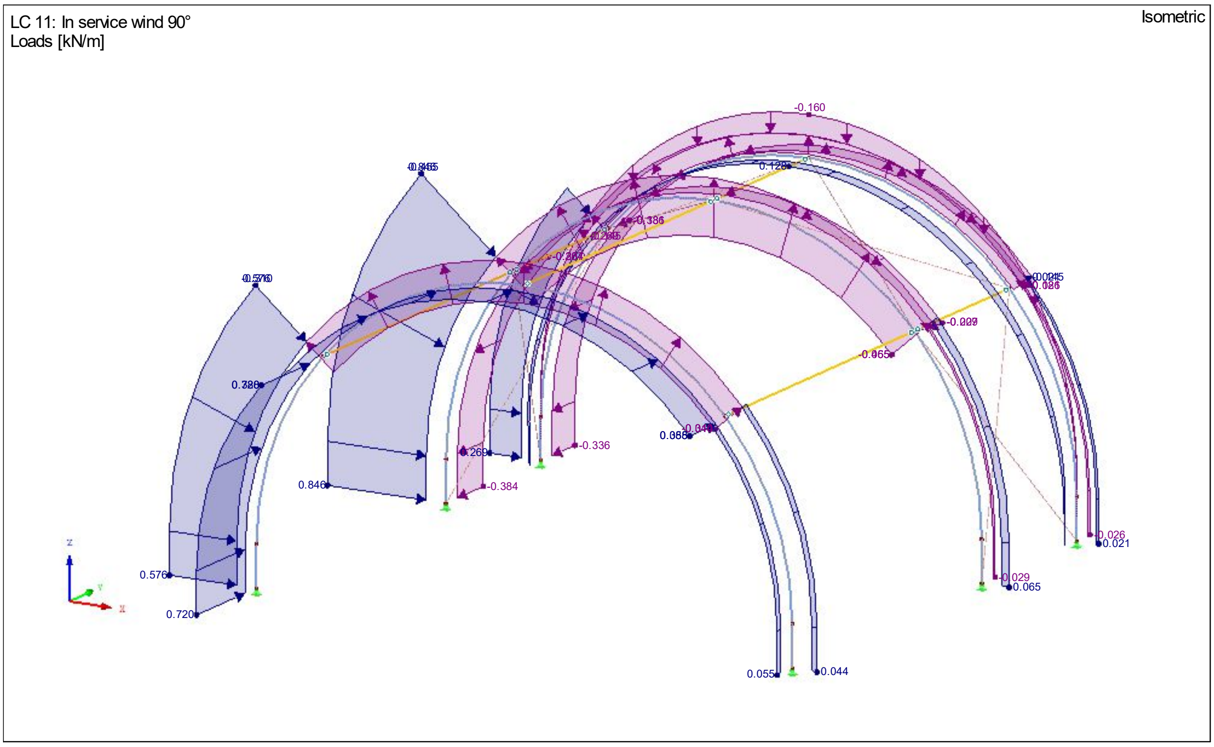
Wind calculations Roof spans
$q_{w,\ roof\ truss\ 1} = 1.4 * 0.2 * 1.036 = 0.290$ kN/m
$q_{w,\ roof\ truss\ 2} = 1.4 * 0.2 * 3.253 = 0.911$kN/m
$q_{w,\ roof\ truss\ 3} = 1.4 * 0.2 * 2.217 = 0.621$ kN/m

Membrane tension of the top canopy
$q_{mt,\ roof\ truss\ 1} = 0.290 / 0.8 = 0.363$ kN/m
$q_{mt,\ roof\ truss\ 2} = (0.621/0.8) - (0.290 / 0.8) = 0.413$ kN/m
$q_{mt,\ roof\ truss\ 3} = 0.621 / 0.8 = 0.776$ kN/m

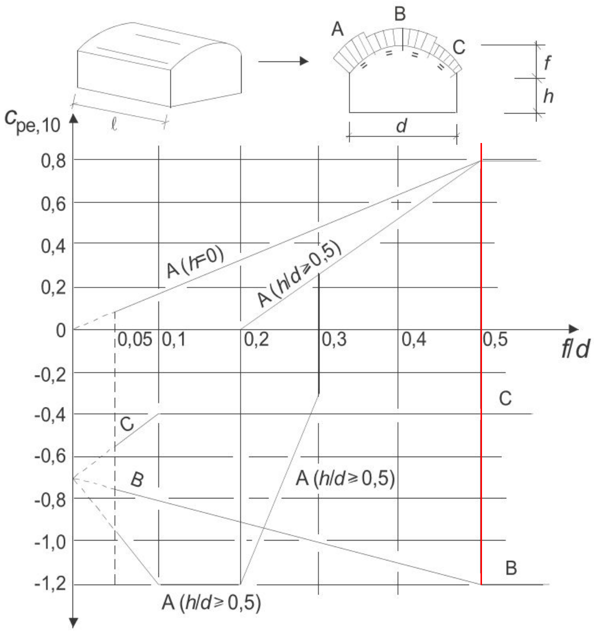
Wind on the back-wall canopy.
The round back wall canopy is attached to Truss 1 and the Layher stage. The load will be divided as a parabolic load on Truss 1 and the Layher stage. The height in the center of the roof is 6.25m
$q_{w,\ back\ wall\ mid} = 1.3 * 0.2 * 4.26 * 0.5 = 0.554$ kN/m
$q_{w,\ back\ wall\ side} = 1.3 * 0.2 * 0 = 0$ kN/m

Membrane tension of the back-wall canopy.
The membrane tension of the round back wall canopy will be divided as a parabolic load on Truss 1 and the Layher stage.
$q_{mt,\ back\ wall\ mid} = 0.554 / 0.8 = 0.692$ kN/m
$q_{mt,\ back\ wall\ side} = 0 / 0.8 = 0$ kN/m

2.5.2 load case 11 In-service situation wind direction 90°.



To determine the wind loading on the walls the next diagram of the Eurocode NEN-EN 1991-1 1-4: General actions – wind actions has been used.



In which
f = 3.52 Meter
h = 0.74 meter
d = 7.04 meter
f / d = 3.52 / 7.04 = 0.105
h / d = 3.52 / 7.04 = 0.5

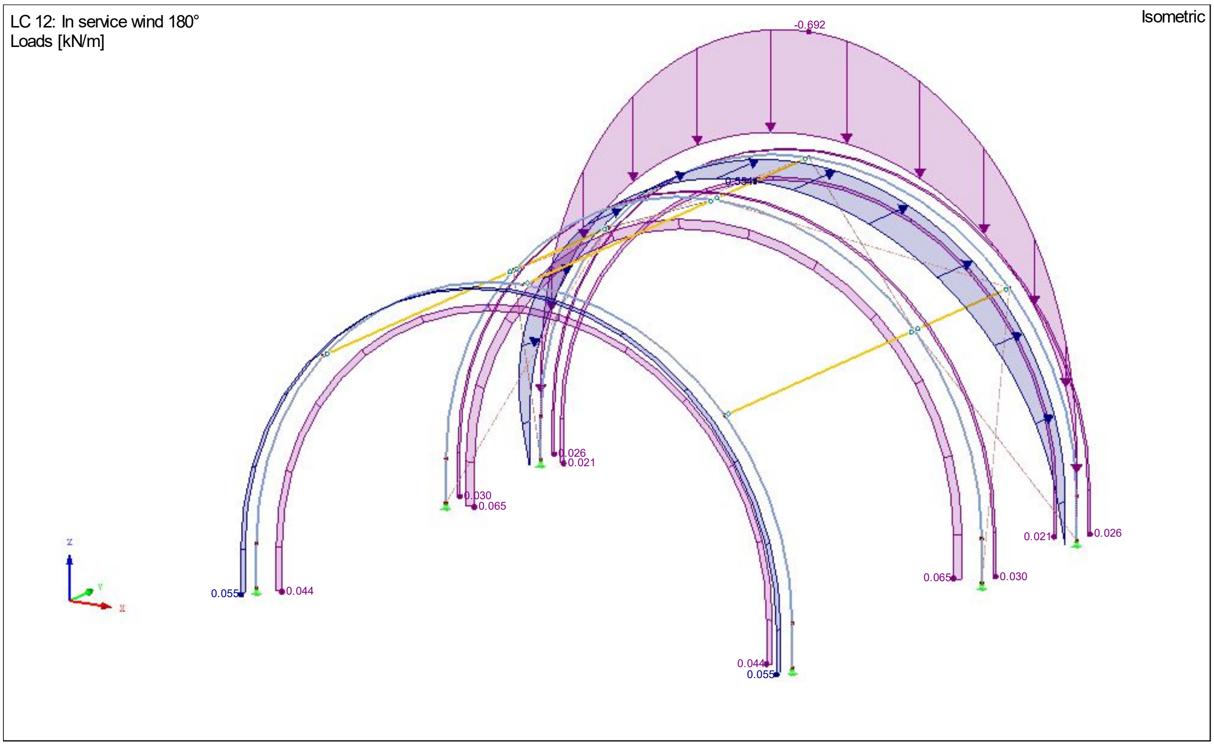
Extracting from the diagram the different C_{pe10} are,
A = -0.8 B = 1.2 C = 0.4
On the same time there is a Cf 0.5 working on the inside pulling the structure down.
The result of these two forces are
A = -1.3 B = 0.7 C = -0.1
Wind calculations for the Roof spans
$q_{w, \text{roof truss 1 section A}}$ = 1.3 * 0.2 * 1.036 = 0.269 kN/m
$q_{w, \text{roof truss 1 section B}}$ = 0.7 * 0.2 * 1.036 = 0.145 kN/m
$q_{w, \text{roof truss 1 section C}}$ = 0.1 * 0.2 * 1.036 = 0.021 kN/m
$q_{w, \text{roof truss 2 section A}}$ = 1.3 * 0.2 * 3.253 = 0.846 kN/m
$q_{w, \text{roof truss 2 section B}}$ = 0.7 * 0.2 * 3.253 = 0.455 kN/m
$q_{w, \text{roof truss 2 section C}}$ = 0.1 * 0.2 * 3.253 = 0.065 kN/m
$q_{w, \text{roof truss 3 section A}}$ = 1.3 * 0.2 * 2.217 = 0.576 kN/m
$q_{w, \text{roof truss 3 section B}}$ = 0.7 * 0.2 * 2.217 = 0.310 kN/m
$q_{w, \text{roof truss 3 section C}}$ = 0.1 * 0.2 * 2.217 = 0.044 kN/m

membrane tension calculations for the Roof spans
$q_{mt, \text{roof truss 1 section A}}$ = 0.269 / 0,8 = 0.336 kN/m
$q_{mt, \text{roof truss 1 section B}}$ = 0.145 / 0.8 = 0.181 kN/m
$q_{mt, \text{roof truss 1 section C}}$ = 0.020 / 0.8 = 0.026 kN/m
$q_{mt, \text{roof truss 2 section A}}$ = (0.721 / 0.8) - (0.269 / 0.8) = 0.384 kN/m
$q_{mt, \text{roof truss 2 section B}}$ = (0.388 / 0.8) – (0.145 / 0.8) = 0.207 kN/m
$q_{mt, \text{roof truss 2 section C}}$ = (0.055 / 0.8) – (0.020 / 0.8) = 0.029 kN/m
$q_{mt, \text{roof truss 3 section A}}$ = 0.721 / 0.8 = 0.337 kN/m
$q_{mt, \text{roof truss 3 section B}}$ = 0.388 / 0.8 = 0.181 kN/m
$q_{mt, \text{roof truss 3 section C}}$ = 0.055 / 0.8 = 0.026 kN/m

Wind on the back-wall canopy.
The round back wall canopy is attached to Truss 1 and the Layher stage. The load will be divided as a parabolic load on Truss 1 and the Layher stage. The height in the center of the roof is 6.25m
$q_{w, \text{back wall mid}}$ = 0.3 * 0.2 * 4.26 * 0.5 = 0.128 kN/m
$q_{w, \text{back wall side}}$ = 0.3 * 0.2 * 0 = 0 kN/m

Membrane tension of the back-wall canopy.
The membrane tension of the round back wall canopy will be divided as a parabolic load on Truss 1 and the Layher stage.
$q_{mt, \text{back wall mid}}$ = 0.128 / 0.8 = 0.160 kN/m
$q_{mt, \text{back wall side}}$ = 0 / 0.8 = 0 kN/m

2.5.3 load case 12 In-service wind 180°.



Wind calculations Roof spans

$q_{w, \text{roof truss 1}} = 0.1 * 0.2 * 1.036 = 0.021$ kN/m

$q_{w, \text{roof truss 2}} = 0.1 * 0.2 * 3.253 = 0.065$ kN/m

$q_{w, \text{roof truss 3}} = 0.1 * 0.2 * 2.217 = 0.044$ kN/m

Membrane tension of the top canopy

$q_{mt, \text{roof truss 1}} = 0.021 / 0.8 = 0.026$ kN/m

$q_{mt, \text{roof truss 2}} = (0.044 / 0.8) – (0.026 / 0.8) = 0.030$ kN/m

$q_{mt, \text{roof truss 3}} = 0.044 / 0.8 = 0.055$ kN/m

Wind on the back-wall canopy.

The round back wall canopy is attached to Truss 1 and the Layher stage. The load will be divided as a parabolic load on Truss 1 and the Layher stage. The height in the center of the roof is 6.25m

$q_{w, \text{back wall mid}} = 1.3 * 0.2 * 4.26 * 0.5 = 0.554$ kN/m

$q_{w, \text{back wall side}} = 1.3 * 0.2 * 0 = 0$ kN/m

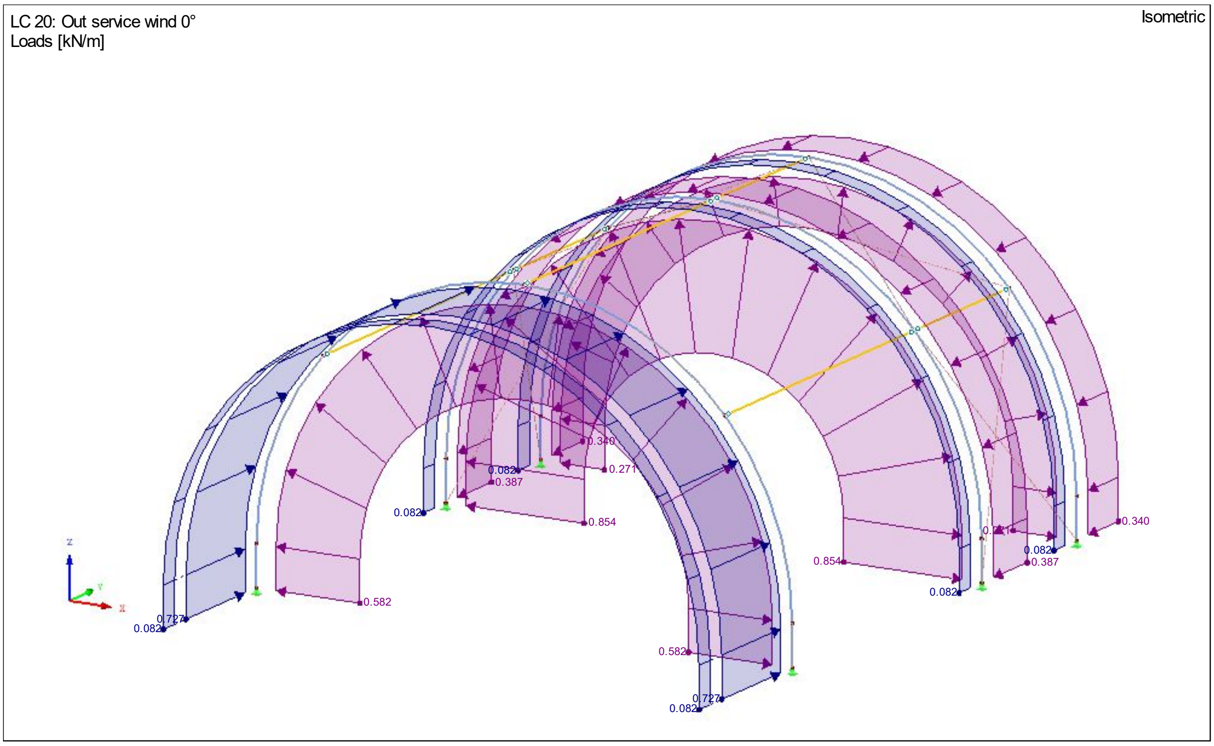
Membrane tension of the back-wall canopy.

The membrane tension of the round back wall canopy will be divided as a parabolic load on Truss 1 and the Layher stage.

$q_{mt, \text{back wall mid}} = 0.554 / 0.8 = 0.692$ kN/m

$q_{mt, \text{back wall side}} = 0 / 0.8 = 0$ kN/m

2.5.4 load case 20 Out-service wind 0°.



Wind calculations Roof spans

$q_{w,\text{ roof truss 1}} = 0.6 * 0.4375 * 1.036 = 0.272$ kN/m

$q_{w,\text{ roof truss 2}} = 0.6 * 0.4375 * 3.253 = 0.854$ kN/m

$q_{w,\text{ roof truss 3}} = 0.6 * 0.4375 * 2.217 = 0.582$ kN/m

Membrane tension of the top canopy

$q_{mt,\text{ roof truss 1}} = 0.272 / 0.8 = 0.339$ kN/m

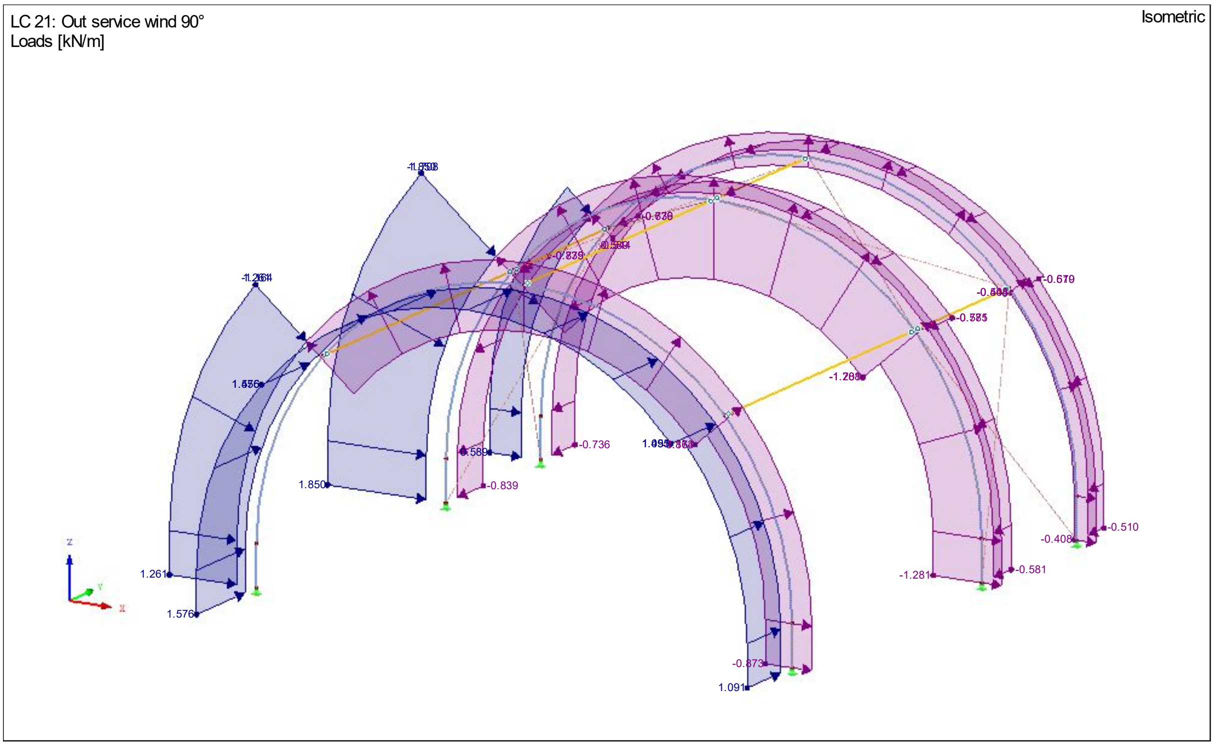
$q_{mt,\text{ roof truss 2}} = (0.582 / 0.8) – (0.272 / 0.8) = 0.387$ kN/m

$q_{mt,\text{ roof truss 3}} = 0.582 / 0.8 = 0.727$ kN/m

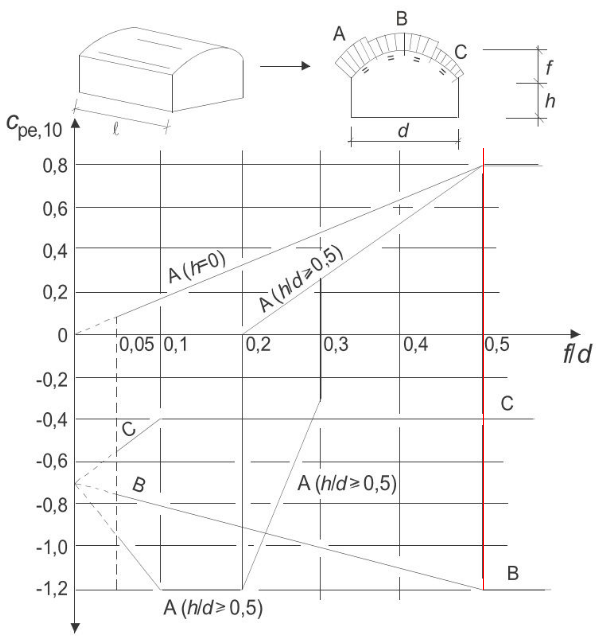
wind truss

$q_{w,\text{ Protruss S31}} = 1.3 * 0.4375 * 0.29 = 0.082$ kN/m

2.5.5 load case 21 Out-service wind 90°



To determine the wind loading on the walls the next diagram of the Eurocode NEN-EN 1991-1 1-4: General actions – wind actions has been used.



In which
f = 3.52 Meter
h = 0.74 meter
d = 7.04 meter
f / d = 3.52 / 7.04 = 0.105
h / d = 3.52 / 7.04 = 0.5

Extracting from the diagram the different C_{pe10} are,
A = -0.8 B = 1.2 C = 0.4
On the same time there is a Cf 0.5 working on the inside
A = -1.3 B = 1.2 C = -0.9
Wind calculations for the Roof spans
$q_{w, \text{roof truss 1 section A}}$ = 1.3 * 0.4375 * 1.036 = 0.589 kN/m
$q_{w, \text{roof truss 1 section B}}$ = 1.2 * 0.4375 * 1.036 = 0.544 kN/m
$q_{w, \text{roof truss 1 section C}}$ = 0.9 * 0.4375 * 1.036 = 0.408 kN/m
$q_{w, \text{roof truss 2 section A}}$ = 1.3 * 0.4375 * 3.253 = 1.850 kN/m
$q_{w, \text{roof truss 2 section B}}$ = 1.2 * 0.4375 * 3.253 = 1.708 kN/m
$q_{w, \text{roof truss 2 section C}}$ = 0.9 * 0.4375 * 3.253 = 1.281 kN/m
$q_{w, \text{roof truss 3 section A}}$ = 1.3 * 0.4375 * 2.217 = 1.261 kN/m
$q_{w, \text{roof truss 3 section B}}$ = 1.2 * 0.4375 * 2.217 = 1.164 kN/m
$q_{w, \text{roof truss 3 section C}}$ = 0.9 * 0.4375 * 2.217 = 0.873 kN/m

membrane tension calculations for the Roof spans
$q_{mt, \text{roof truss 1 section A}}$ = 0.589 / 0,8 = 0.736 kN/m
$q_{mt, \text{roof truss 1 section B}}$ = 0.544 / 0.8 = 0.679 kN/m
$q_{mt, \text{roof truss 1 section C}}$ = 0.408 / 0.8 = 0.510 kN/m
$q_{mt, \text{roof truss 2 section A}}$ = (1.576 / 0.8) - (0.737 / 0.8) = 0.839 kN/m
$q_{mt, \text{roof truss 2 section B}}$ = (1.455 / 0.8) – (0.680 / 0.8) = 0.775 kN/m
$q_{mt, \text{roof truss 2 section C}}$ = (1.091 / 0.8) – (0.510 / 0.8) = 0.581 kN/m
$q_{mt, \text{roof truss 3 section A}}$ = 1.261 / 0.8 = 1.576 kN/m
$q_{mt, \text{roof truss 3 section B}}$ = 1.164 / 0.8 = 1.455 kN/m
$q_{mt, \text{roof truss 3 section C}}$ = 0.873 / 0.8 = 1.091 kN/m

2.6 load combinations and result combinations
Different load combinations have been generated in the program.
The calculation has been done according to the stress capacity calculation.
The partial safety factors are According to the EN 13814:2004 chapter 5.3.6.1

$\gamma_G = 1.1$ or 1.35	Partial safety factor for permanent actions
$\gamma_{k,i} = 1.35$	Partial safety factor for variable actions

The fundamental combinations are

$\Sigma\ \gamma_G\ G_k$	$(= \Sigma\ 1.35 * G_k)$
$\Sigma\ \gamma_G\ G_k + \Sigma\ \gamma_{k,i}\ Q_{k,I}$	$(= \Sigma\ 1.1 * G_k + \Sigma\ 1.35 * Q_{k,i})$
G_k	Characteristic value of permanent actions
$Q_{k,i}$	Characteristic value of one of the variable actions

The γ_G is set to 1.15 as an extra safety for all the small extra material which are used in the construction and which are not specific inserted in the Self-weight load case. These extra materials are for example retched straps, steel wire's, clamps….

2.6.1 load combinations.

CO1-CO4 Live load without wind
CO10-CO34 Design Values In-service situation
CO50-CO74 Characteristic Values In-service situation
CO100-CO114 Design Values Out-service situation
CO150-CO164 Characteristic Values Out-service situation

Load	Load Combination		To	LC.1		LC.2		LC.3	
Combin.	DS	Description	Solve	Factor	No.	Factor	No.	Factor	No.
CO1	0	1.35*LC1 + 1.35*LC2	+	1,350	LC1	1,350	LC2		
CO2	0	1.35*LC1 + 1.35*LC3	+	1,350	LC1	1,350	LC3		
CO3	0	1.35*LC1 + 1.35*LC4	+	1,350	LC1	1,350	LC4		
CO4	0	1.35*LC1 + 1.35*LC5	+	1,350	LC1	1,350	LC5		
CO10	0	1.15*LC1 + 1.35*LC10	+	1,150	LC1	1,350	LC10		
CO11	0	1.15*LC1 + 1.35*LC2 + 1.35*LC10	+	1,150	LC1	1,350	LC2	1,350	LC10
CO12	0	1.15*LC1 + 1.35*LC3 + 1.35*LC10	+	1,150	LC1	1,350	LC3	1,350	LC10
CO13	0	1.15*LC1 + 1.35*LC4 + 1.35*LC10	+	1,150	LC1	1,350	LC4	1,350	LC10
CO14	0	1.15*LC1 + 1.35*LC5 + 1.35*LC10	+	1,150	LC1	1,350	LC5	1,350	LC10
CO20	0	1.15*LC1 + 1.35*LC11	+	1,150	LC1	1,350	LC11		
CO21	0	1.15*LC1 + 1.35*LC2 + 1.35*LC11	+	1,150	LC1	1,350	LC2	1,350	LC11
CO22	0	1.15*LC1 + 1.35*LC3 + 1.35*LC11	+	1,150	LC1	1,350	LC3	1,350	LC11
CO23	0	1.15*LC1 + 1.35*LC4 + 1.35*LC11	+	1,150	LC1	1,350	LC4	1,350	LC11
CO24	0	1.15*LC1 + 1.35*LC5 + 1.35*LC11	+	1,150	LC1	1,350	LC5	1,350	LC11
CO30	0	1.15*LC1 + 1.35*LC12	+	1,150	LC1	1,350	LC12		
CO31	0	1.15*LC1 + 1.35*LC2 + 1.35*LC12	+	1,150	LC1	1,350	LC2	1,350	LC12
CO32	0	1.15*LC1 + 1.35*LC3 + 1.35*LC12	+	1,150	LC1	1,350	LC3	1,350	LC12
CO33	0	1.15*LC1 + 1.35*LC4 + 1.35*LC12	+	1,150	LC1	1,350	LC4	1,350	LC12
CO34	0	1.15*LC1 + 1.35*LC5 + 1.35*LC12	+	1,150	LC1	1,350	LC5	1,350	LC12
CO50	0	LC1 + LC10	+	1,000	LC1	1,000	LC10		
CO51	0	LC1 + LC2 + LC10	+	1,000	LC1	1,000	LC2	1,000	LC10
CO52	0	LC1 + LC3 + LC10	+	1,000	LC1	1,000	LC3	1,000	LC10
CO53	0	LC1 + LC4 + LC10	+	1,000	LC1	1,000	LC4	1,000	LC10
CO54	0	LC1 + LC5 + LC10	+	1,000	LC1	1,000	LC5	1,000	LC10
CO60	0	LC1 + LC11	+	1,000	LC1	1,000	LC11		
CO61	0	LC1 + LC2 + LC11	+	1,000	LC1	1,000	LC2	1,000	LC11
CO62	0	LC1 + LC3 + LC11	+	1,000	LC1	1,000	LC3	1,000	LC11
CO63	0	LC1 + LC4 + LC11	+	1,000	LC1	1,000	LC4	1,000	LC11
CO64	0	LC1 + LC5 + LC11	+	1,000	LC1	1,000	LC5	1,000	LC11
CO70	0	LC1 + LC12	+	1,000	LC1	1,000	LC12		
CO71	0	LC1 + LC2 + LC12	+	1,000	LC1	1,000	LC2	1,000	LC12
CO72	0	LC1 + LC3 + LC12	+	1,000	LC1	1,000	LC3	1,000	LC12
CO73	0	LC1 + LC4 + LC12	+	1,000	LC1	1,000	LC4	1,000	LC12

CO74	0	LC1 + LC5 + LC12	+	1,000	LC1	1,000	LC5	1,000	LC12
CO100	0	1.15*LC1 + 1.35*LC20	+	1,150	LC1	1,350	LC20		
CO101	0	1.15*LC1 + 1.35*LC2 + 1.35*LC20	+	1,150	LC1	1,350	LC2	1,350	LC20
CO102	0	1.15*LC1 + 1.35*LC3 + 1.35*LC20	+	1,150	LC1	1,350	LC3	1,350	LC20
CO103	0	1.15*LC1 + 1.35*LC4 + 1.35*LC20	+	1,150	LC1	1,350	LC4	1,350	LC20
CO104	0	1.15*LC1 + 1.35*LC5 + 1.35*LC20	+	1,150	LC1	1,350	LC5	1,350	LC20
CO110	0	1.15*LC1 + 1.35*LC21	+	1,150	LC1	1,350	LC21		
CO111	0	1.15*LC1 + 1.35*LC2 + 1.35*LC21	+	1,150	LC1	1,350	LC2	1,350	LC21
CO112	0	1.15*LC1 + 1.35*LC3 + 1.35*LC21	+	1,150	LC1	1,350	LC3	1,350	LC21
CO113	0	1.15*LC1 + 1.35*LC4 + 1.35*LC21	+	1,150	LC1	1,350	LC4	1,350	LC21
CO114	0	1.15*LC1 + 1.35*LC5 + 1.35*LC21	+	1,150	LC1	1,350	LC5	1,350	LC21
CO150	0	LC1 + LC20	+	1,000	LC1	1,000	LC20		
CO151	0	LC1 + LC2 + LC20	+	1,000	LC1	1,000	LC2	1,000	LC20
CO152	0	LC1 + LC3 + LC20	+	1,000	LC1	1,000	LC3	1,000	LC20
CO153	0	LC1 + LC4 + LC20	+	1,000	LC1	1,000	LC4	1,000	LC20
CO154	0	LC1 + LC5 + LC20	+	1,000	LC1	1,000	LC5	1,000	LC20
CO160	0	LC1 + LC21	+	1,000	LC1	1,000	LC21		
CO161	0	LC1 + LC2 + LC21	+	1,000	LC1	1,000	LC2	1,000	LC21
CO162	0	LC1 + LC3 + LC21	+	1,000	LC1	1,000	LC3	1,000	LC21
CO163	0	LC1 + LC4 + LC21	+	1,000	LC1	1,000	LC4	1,000	LC21
CO164	0	LC1 + LC5 + LC21	+	1,000	LC1	1,000	LC5	1,000	LC21

2.6.2 result combinations

Different Result calculation have been generated in the program.

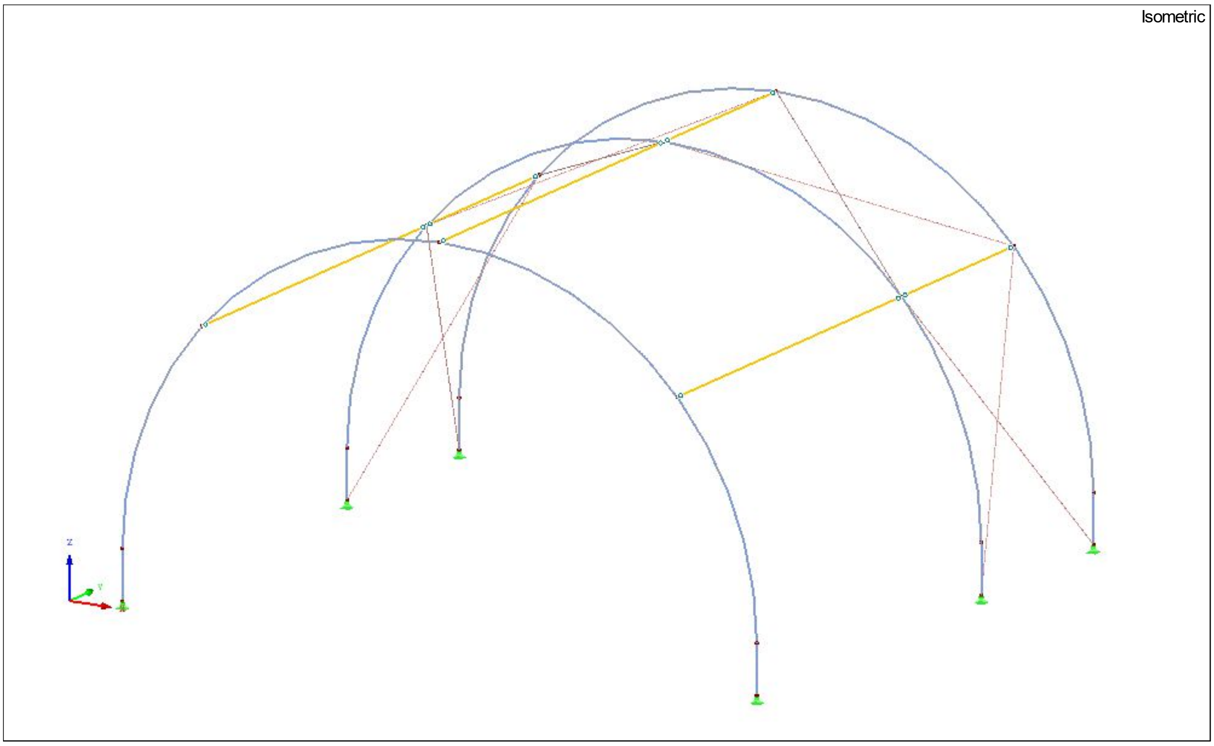
RC1 - Live loading without wind	: 1 * (CO1 - CO4)
RC2 - Design Values In-service	: 1 * (CO10 – CO34)
RC3 - Characteristic Values In-service	: 1 * (CO50 – CO74)
RC4 - Design Values Out-service	: 1 * (CO100 – CO114)
RC5 - Characteristic Values Out-service	: 1 * (CO150 – CO164)

3 Calculation results for different Load Cases and Load Combinations.

In this chapter the results of the different load cases and load combinations are. The design calculations will be used to check the structural integrity of separate parts of the structure. The results for the characteristic calculations will be used to determine the deflection of the system and the steel wires which need to be used. These results will not be presented for each load combination. If the use of these results is necessary, the particular information will be given.

3.1 General calculation of the Mini Tunnel Roof 7x6

3.1.1 construction scheme



Cross-Sections
1: Interal truss Protruss S31; Aluminum EN AW-6060 (ET,EP,ER/B) T6
2: Interal Truss Protruss T31; Aluminum EN-AW 6082 (EP,ET) T6
3: RD 10; steel 8.8 kw aliteit

3.1.2 Used Materials

Material No.	Material Description	Modulus of Elasticity E [kN/cm²]	Shear Modulus G [kN/cm²]	Poisson's Ratio • [-]	Specific Weight • [kN/m³]	Coeff. of Th. Exp. • [1/°C]	Partial Factor • $_M$ [-]	Material Model
1	Aluminum EN AW-6060 (ET,EP,ER/B) T6 | ENV 1999-1-1:1998	7000,00	2700,00	0,296	27,00	2,30E-05	1,100	Isotropic Linear Elastic
2	Aluminum EN-AW 6082 (EP,ET) T6 | EN 1999-1-1:2007	7000,00	2700,00	0,296	27,00	2,30E-05	1,000	Isotropic Linear Elastic
3	steel 8.8 kwaliteit | EN 10346:2009-03	21000,00	8076,92	0,300	78,50	1,20E-05	1,000	Isotropic Linear Elastic

3.1.3 Used cross sections

Section	Cross-Section	Material	Moments of inertia [cm⁴]			Cross-Sectional Areas [cm²]			Principal Axes	Rotation	Overall Dimensions [mm]	
No.	Description [mm]	No.	Torsion J	Bending I_y	Bending I_z	Axial A	Shear A_y	Shear A_z	• [°]	• ' [°]	Width b	Depth h
1	Interal truss Protruss S31	1	500,00	2096,00	2096,00	16,97	16,97	16,97	0,00	0,00	290,0	290,0
2	Interal Truss Protruss T31	2	150,00	1057,40	1057,40	12,72	12,72	12,72	0,00	0,00	289,0	257,0
3	RD 10	3	0,10	0,05	0,05	0,79	0,66	0,66	0,00	0,00	10,0	10,0

3.2 Calculation summary

	Description	Value	Unit	Comment
	Summary			
	Calculation Status	OK		
	Maximum displacement in X-direction	22,0	mm	CO112, Member No. 33, x: 1.091 m
	Maximum displacement in Y-direction	10,1	mm	CO13, Member No. 30, x: 1.769 m
	Maximum displacement in Z-direction	-14,7	mm	CO32, Member No. 32, x: 1.769 m
	Maximum vectorial displacement	22,9	mm	CO112, Member No. 33, x: 1.091 m
	Maximum rotation about X-axis	-3,2	mrad	CO13, Member No. 7, x: 0.500 m
	Maximum rotation about Y-axis	13,1	mrad	CO113, Member No. 7, x: 0.500 m
	Maximum rotation about Z-axis	2,6	mrad	CO114, Member No. 2, x: 1.327 m
	Number of 1D finite elements (member elements)	104		
	Number of 2D finite elements (surface elements)	0		
	Number of 3D finite elements (solid elements)	0		
	Number of FE mesh nodes	93		
	Number of equations	558		
	Matrix solver method	Direct		
	Maximum number of iterations	100		
	Number of divisions for member results	10		
	Number of divisions of members with cable, elastic foundation, taper, or plastic characteristic	10		
	Activate shear stiffness of members (A-y, A-z)	+		
	Plate bending theory	Mindlin		
	Allow failing members	+		
	Precision of convergence criteria of nonlinear calculation	1,0		

3.3 Calculation result of the separate load cases.

	Description	Value	Unit	Comment
	LC1 - Self-weight			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	0,00	kN	
	Sum of support forces in Y	0,00	kN	
	Sum of loads in Z	-4,22	kN	
	Sum of support forces in Z	-4,22	kN	Deviation: 0.00 %
	Resultant of reactions about X	0,040	kNm	At center of gravity of model (X: 0.000, Y: 3.485, Z: 2.624 m)
	Resultant of reactions about Y	0,000	kNm	At center of gravity of model
	Resultant of reactions about Z	0,000	kNm	At center of gravity of model
	Maximum displacement in X-direction	0,2	mm	Member No. 28, x: 0.442 m
	Maximum displacement in Y-direction	-0,1	mm	Member No. 32, x: 1.769 m
	Maximum displacement in Z-direction	-0,5	mm	Member No. 12, x: 2.072 m
	Maximum vectorial displacement	0,6	mm	Member No. 12, x: 2.072 m
	Maximum rotation about X-axis	-0,2	mrad	Member No. 12, x: 0.000 m
	Maximum rotation about Y-axis	0,2	mrad	Member No. 8, x: 0.500 m
	Maximum rotation about Z-axis	0,0	mrad	Member No. 15, x: 0.000 m
	Method of analysis	Linear		Geometrically Linear Analysis
	LC2 - Rigging load: UDL			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	0,00	kN	
	Sum of support forces in Y	0,00	kN	
	Sum of loads in Z	-47,74	kN	
	Sum of support forces in Z	-47,74	kN	Deviation: 0.00 %
	Resultant of reactions about X	1,528	kNm	At center of gravity of model (X: 0.000, Y: 3.485, Z: 2.624 m)
	Resultant of reactions about Y	0,000	kNm	At center of gravity of model
	Resultant of reactions about Z	0,000	kNm	At center of gravity of model
	Maximum displacement in X-direction	2,1	mm	Member No. 27, x: 0.442 m
	Maximum displacement in Y-direction	0,0	mm	Member No. 31, x: 1.769 m
	Maximum displacement in Z-direction	-3,2	mm	Member No. 30, x: 1.769 m
	Maximum vectorial displacement	3,2	mm	Member No. 30, x: 1.769 m
	Maximum rotation about X-axis	0,0	mrad	Member No. 32, x: 1.769 m
	Maximum rotation about Y-axis	1,8	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Z-axis	0,0	mrad	Member No. 14, x: 0.000 m
	Method of analysis	Linear		Geometrically Linear Analysis
	LC3 - Rigging load: CPL			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	0,00	kN	
	Sum of support forces in Y	0,00	kN	
	Sum of loads in Z	-30,00	kN	
	Sum of support forces in Z	-30,00	kN	Deviation: 0.00 %
	Resultant of reactions about X	0,953	kNm	At center of gravity of model (X: 0.000, Y: 3.485, Z: 2.624 m)
	Resultant of reactions about Y	0,000	kNm	At center of gravity of model
	Resultant of reactions about Z	0,000	kNm	At center of gravity of model
	Maximum displacement in X-direction	4,0	mm	Member No. 27, x: 0.295 m
	Maximum displacement in Y-direction	0,0	mm	Member No. 31, x: 1.769 m
	Maximum displacement in Z-direction	-7,0	mm	Member No. 30, x: 1.769 m
	Maximum vectorial displacement	7,0	mm	Member No. 30, x: 1.769 m
	Maximum rotation about X-axis	0,0	mrad	Member No. 12, x: 0.000 m
	Maximum rotation about Y-axis	-3,4	mrad	Member No. 30, x: 3.361 m
	Maximum rotation about Z-axis	0,0	mrad	Member No. 14, x: 0.000 m
	Method of analysis	Linear		Geometrically Linear Analysis
	LC4 - Riggin load: 2PL			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	0,00	kN	
	Sum of support forces in Y	0,00	kN	
	Sum of loads in Z	-51,00	kN	
	Sum of support forces in Z	-51,00	kN	Deviation: 0.00 %
	Resultant of reactions about X	1,621	kNm	At center of gravity of model (X: 0.000, Y: 3.485, Z: 2.624 m)
	Resultant of reactions about Y	0,000	kNm	At center of gravity of model
	Resultant of reactions about Z	0,000	kNm	At center of gravity of model
	Maximum displacement in X-direction	4,1	mm	Member No. 27, x: 0.442 m
	Maximum displacement in Y-direction	0,0	mm	Member No. 31, x: 1.769 m
	Maximum displacement in Z-direction	-5,6	mm	Member No. 30, x: 1.769 m
	Maximum vectorial displacement	5,6	mm	Member No. 30, x: 1.769 m
	Maximum rotation about X-axis	0,0	mrad	Member No. 12, x: 0.000 m
	Maximum rotation about Y-axis	3,4	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Z-axis	0,0	mrad	Member No. 14, x: 0.000 m
	Method of analysis	Linear		Geometrically Linear Analysis
	LC5 - Rigging load: 3PL			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	

	Sum of loads in Y	0,00	kN	
	Sum of support forces in Y	0,00	kN	
	Sum of loads in Z	-63,00	kN	
	Sum of support forces in Z	-63,00	kN	Deviation: 0.00 %
	Resultant of reactions about X	2,002	kNm	At center of gravity of model (X: 0.000, Y: 3.485, Z: 2.624 m)
	Resultant of reactions about Y	0,000	kNm	At center of gravity of model
	Resultant of reactions about Z	0,000	kNm	At center of gravity of model
	Maximum displacement in X-direction	3,3	mm	Member No. 27, x: 0.442 m
	Maximum displacement in Y-direction	0,0	mm	Member No. 31, x: 1.769 m
	Maximum displacement in Z-direction	-5,3	mm	Member No. 30, x: 1.769 m
	Maximum vectorial displacement	5,3	mm	Member No. 30, x: 1.769 m
	Maximum rotation about X-axis	0,0	mrad	Member No. 31, x: 1.769 m
	Maximum rotation about Y-axis	2,9	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Z-axis	0,0	mrad	Member No. 14, x: 0.000 m
	Method of analysis	Linear		Geometrically Linear Analysis
	LC10 - In service wind 0°			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	4,29	kN	
	Sum of support forces in Y	4,29	kN	Deviation: 0.00 %
	Sum of loads in Z	6,96	kN	
	Sum of support forces in Z	6,96	kN	Deviation: 0.00 %
	Resultant of reactions about X	-21,410	kNm	At center of gravity of model (X: 0.000, Y: 3.485, Z: 2.624 m)
	Resultant of reactions about Y	0,000	kNm	At center of gravity of model
	Resultant of reactions about Z	0,000	kNm	At center of gravity of model
	Maximum displacement in X-direction	1,8	mm	Member No. 29, x: 0.442 m
	Maximum displacement in Y-direction	4,3	mm	Member No. 30, x: 1.769 m
	Maximum displacement in Z-direction	-2,5	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	4,9	mm	Member No. 13, x: 2.072 m
	Maximum rotation about X-axis	-1,7	mrad	Member No. 31, x: 1.769 m
	Maximum rotation about Y-axis	1,5	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	-0,7	mrad	Member No. 28, x: 0.590 m
	Method of analysis	Linear		Geometrically Linear Analysis
	LC11 - In service wind 90°			
	Sum of loads in X	4,22	kN	
	Sum of support forces in X	4,22	kN	Deviation: 0.00 %
	Sum of loads in Y	-1,41	kN	
	Sum of support forces in Y	-1,41	kN	Deviation: 0.00 %
	Sum of loads in Z	1,92	kN	
	Sum of support forces in Z	1,92	kN	Deviation: 0.00 %
	Resultant of reactions about X	-5,481	kNm	At center of gravity of model (X: 0.000, Y: 3.485, Z: 2.624 m)
	Resultant of reactions about Y	-9,136	kNm	At center of gravity of model
	Resultant of reactions about Z	5,026	kNm	At center of gravity of model
	Maximum displacement in X-direction	3,6	mm	Member No. 24, x: 0.589 m
	Maximum displacement in Y-direction	0,5	mm	Member No. 30, x: 3.095 m
	Maximum displacement in Z-direction	1,4	mm	Member No. 31, x: 2.653 m
	Maximum vectorial displacement	3,6	mm	Member No. 24, x: 0.589 m
	Maximum rotation about X-axis	0,4	mrad	Member No. 5, x: 0.000 m
	Maximum rotation about Y-axis	2,2	mrad	Member No. 6, x: 0.000 m
	Maximum rotation about Z-axis	0,6	mrad	Member No. 2, x: 0.884 m
	Method of analysis	Linear		Geometrically Linear Analysis
	LC12 - In service wind 180°			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	4,28	kN	
	Sum of support forces in Y	4,28	kN	Deviation: 0.00 %
	Sum of loads in Z	-4,48	kN	
	Sum of support forces in Z	-4,48	kN	Deviation: 0.00 %
	Resultant of reactions about X	-16,539	kNm	At center of gravity of model (X: 0.000, Y: 3.485, Z: 2.624 m)
	Resultant of reactions about Y	0,000	kNm	At center of gravity of model
	Resultant of reactions about Z	0,000	kNm	At center of gravity of model
	Maximum displacement in X-direction	1,7	mm	Member No. 29, x: 0.527 m
	Maximum displacement in Y-direction	4,2	mm	Member No. 32, x: 1.769 m
	Maximum displacement in Z-direction	-2,5	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	4,9	mm	Member No. 32, x: 1.769 m
	Maximum rotation about X-axis	-1,6	mrad	Member No. 31, x: 1.769 m
	Maximum rotation about Y-axis	1,5	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	-0,6	mrad	Member No. 15, x: 0.000 m
	Method of analysis	Linear		Geometrically Linear Analysis
	LC20 - Out service wind 0°			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	2,87	kN	
	Sum of support forces in Y	2,87	kN	Deviation: 0.00 %
	Sum of loads in Z	11,54	kN	
	Sum of support forces in Z	11,54	kN	Deviation: 0.00 %
	Resultant of reactions about X	-4,422	kNm	At center of gravity of model (X: 0.000, Y: 3.485, Z: 2.624 m)
	Resultant of reactions about Y	0,000	kNm	At center of gravity of model
	Resultant of reactions about Z	0,000	kNm	At center of gravity of model

	Maximum displacement in X-direction	0,5	mm	Member No. 29, x: 0.527 m
	Maximum displacement in Y-direction	1,7	mm	Member No. 30, x: 1.327 m
	Maximum displacement in Z-direction	-0,6	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	1,7	mm	Member No. 30, x: 1.327 m
	Maximum rotation about X-axis	-0,9	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Y-axis	0,4	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	0,7	mrad	Member No. 27, x: 0.884 m
	Method of analysis	Linear		Geometrically Linear Analysis
	LC21 - Out service wind 90°			
	Sum of loads in X	16,94	kN	
	Sum of support forces in X	16,94	kN	Deviation: 0.00 %
	Sum of loads in Y	0,01	kN	
	Sum of support forces in Y	0,01	kN	Deviation: 0.00 %
	Sum of loads in Z	16,54	kN	
	Sum of support forces in Z	16,54	kN	Deviation: 0.00 %
	Resultant of reactions about X	-7,009	kNm	At center of gravity of model (X: 0.000, Y: 3.485, Z: 2.624 m)
	Resultant of reactions about Y	-36,652	kNm	At center of gravity of model
	Resultant of reactions about Z	7,162	kNm	At center of gravity of model
	Maximum displacement in X-direction	13,4	mm	Member No. 24, x: 0.884 m
	Maximum displacement in Y-direction	2,8	mm	Member No. 30, x: 2.653 m
	Maximum displacement in Z-direction	4,0	mm	Member No. 30, x: 3.361 m
	Maximum vectorial displacement	13,6	mm	Member No. 24, x: 0.884 m
	Maximum rotation about X-axis	-1,4	mrad	Member No. 32, x: 1.769 m
	Maximum rotation about Y-axis	7,6	mrad	Member No. 6, x: 0.000 m
	Maximum rotation about Z-axis	1,5	mrad	Member No. 2, x: 1.179 m
	Method of analysis	Linear		Geometrically Linear Analysis

3.4 Calculation result of RC1 - General loading without wind 1 * (CO1 – CO4)

	Description	Value	Unit	Comment
	CO1 - 1.35*LC1 + 1.35*LC2			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	0,00	kN	
	Sum of support forces in Y	0,00	kN	
	Sum of loads in Z	-70,15	kN	
	Sum of support forces in Z	-70,15	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	3,4	mm	Member No. 27, x: 0.442 m
	Maximum displacement in Y-direction	-0,2	mm	Member No. 32, x: 1.769 m
	Maximum displacement in Z-direction	-5,5	mm	Member No. 12, x: 2.072 m
	Maximum vectorial displacement	5,5	mm	Member No. 12, x: 2.072 m
	Maximum rotation about X-axis	-0,3	mrad	Member No. 12, x: 0.000 m
	Maximum rotation about Y-axis	2,9	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Z-axis	0,0	mrad	Member No. 15, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		$N, V_y, V_z, M_y, M_z, M_T$
	CO2 - 1.35*LC1 + 1.35*LC3			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	0,00	kN	
	Sum of support forces in Y	0,00	kN	
	Sum of loads in Z	-46,19	kN	
	Sum of support forces in Z	-46,19	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	6,2	mm	Member No. 27, x: 0.295 m
	Maximum displacement in Y-direction	-0,2	mm	Member No. 32, x: 1.769 m
	Maximum displacement in Z-direction	-11,2	mm	Member No. 12, x: 2.072 m
	Maximum vectorial displacement	11,2	mm	Member No. 12, x: 2.072 m
	Maximum rotation about X-axis	-0,3	mrad	Member No. 14, x: 0.000 m
	Maximum rotation about Y-axis	-5,3	mrad	Member No. 30, x: 3.361 m
	Maximum rotation about Z-axis	0,0	mrad	Member No. 15, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		$N, V_y, V_z, M_y, M_z, M_T$
	CO3 - 1.35*LC1 + 1.35*LC4			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	0,00	kN	
	Sum of support forces in Y	0,00	kN	
	Sum of loads in Z	-74,54	kN	
	Sum of support forces in Z	-74,54	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	-6,4	mm	Member No. 1, x: 1.327 m
	Maximum displacement in Y-direction	-0,2	mm	Member No. 32, x: 1.769 m
	Maximum displacement in Z-direction	-9,2	mm	Member No. 12, x: 2.072 m
	Maximum vectorial displacement	9,2	mm	Member No. 12, x: 2.072 m
	Maximum rotation about X-axis	-0,3	mrad	Member No. 14, x: 0.000 m
	Maximum rotation about Y-axis	5,4	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Z-axis	0,0	mrad	Member No. 14, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		$N, V_y, V_z, M_y, M_z, M_T$
	CO4 - 1.35*LC1 + 1.35*LC5			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	0,00	kN	
	Sum of support forces in Y	0,00	kN	
	Sum of loads in Z	-90,74	kN	
	Sum of support forces in Z	-90,74	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	5,3	mm	Member No. 27, x: 0.442 m
	Maximum displacement in Y-direction	-0,2	mm	Member No. 32, x: 1.769 m
	Maximum displacement in Z-direction	-8,7	mm	Member No. 12, x: 2.072 m
	Maximum vectorial displacement	8,7	mm	Member No. 12, x: 2.072 m
	Maximum rotation about X-axis	-0,3	mrad	Member No. 12, x: 0.000 m
	Maximum rotation about Y-axis	4,6	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Z-axis	0,0	mrad	Member No. 15, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		$N, V_y, V_z, M_y, M_z, M_T$

3.5 Calculation result of RC2 – Design Values In-service: 1 * (CO10 – CO34)

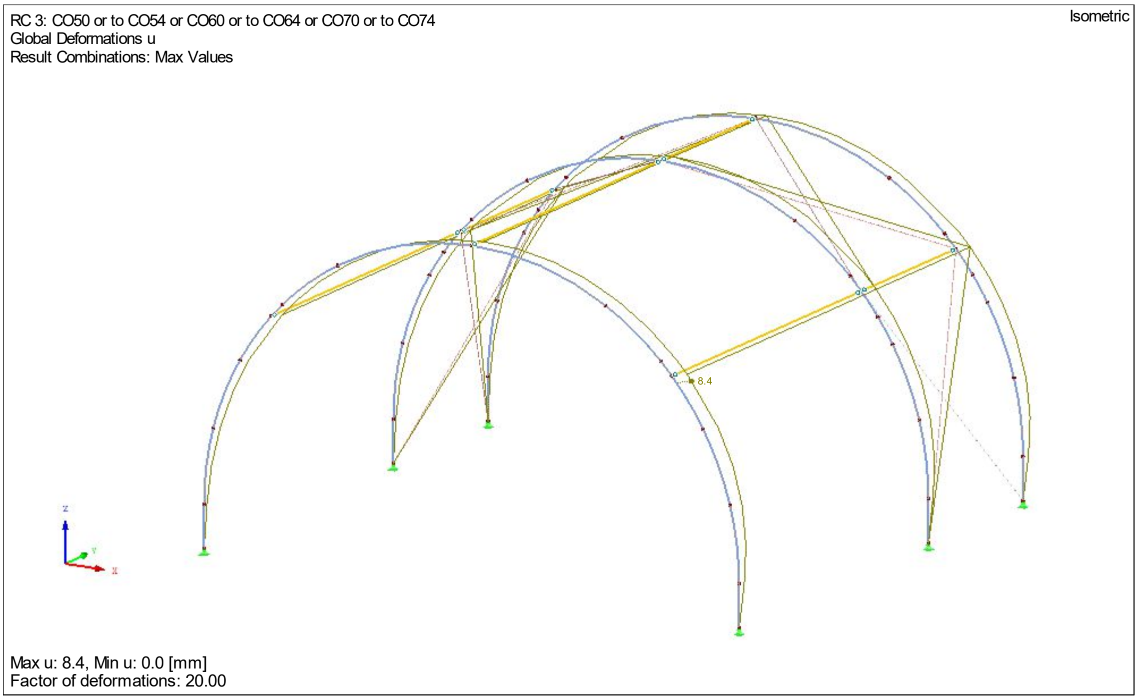
	Description	Value	Unit	Comment
	CO10 - 1.15*LC1 + 1.35*LC10			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	5,79	kN	
	Sum of support forces in Y	5,79	kN	Deviation: 0.00 %
	Sum of loads in Z	4,55	kN	
	Sum of support forces in Z	4,55	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	2,8	mm	Member No. 29, x: 0.442 m
	Maximum displacement in Y-direction	6,2	mm	Member No. 30, x: 1.769 m
	Maximum displacement in Z-direction	-4,0	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	7,3	mm	Member No. 13, x: 2.072 m
	Maximum rotation about X-axis	-2,5	mrad	Member No. 31, x: 1.769 m
	Maximum rotation about Y-axis	2,5	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	-1,1	mrad	Member No. 28, x: 0.590 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO11 - 1.15*LC1 + 1.35*LC2 + 1.35*LC10			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	5,79	kN	
	Sum of support forces in Y	5,79	kN	Deviation: 0.00 %
	Sum of loads in Z	-59,91	kN	
	Sum of support forces in Z	-59,91	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	6,0	mm	Member No. 29, x: 0.442 m
	Maximum displacement in Y-direction	8,3	mm	Member No. 30, x: 1.769 m
	Maximum displacement in Z-direction	-8,9	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	12,1	mm	Member No. 13, x: 2.072 m
	Maximum rotation about X-axis	-2,7	mrad	Member No. 31, x: 1.769 m
	Maximum rotation about Y-axis	5,2	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	-1,0	mrad	Member No. 15, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO12 - 1.15*LC1 + 1.35*LC3 + 1.35*LC10			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	5,79	kN	
	Sum of support forces in Y	5,79	kN	Deviation: 0.00 %
	Sum of loads in Z	-35,95	kN	
	Sum of support forces in Z	-35,95	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	8,8	mm	Member No. 29, x: 0.442 m
	Maximum displacement in Y-direction	9,2	mm	Member No. 30, x: 1.769 m
	Maximum displacement in Z-direction	-14,7	mm	Member No. 13, x: 2.072 m
	Maximum vectorial displacement	17,2	mm	Member No. 13, x: 2.072 m
	Maximum rotation about X-axis	-2,9	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Y-axis	7,1	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	-1,0	mrad	Member No. 15, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO13 - 1.15*LC1 + 1.35*LC4 + 1.35*LC10			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	5,79	kN	
	Sum of support forces in Y	5,79	kN	Deviation: 0.00 %
	Sum of loads in Z	-64,30	kN	
	Sum of support forces in Z	-64,30	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	9,0	mm	Member No. 29, x: 0.442 m
	Maximum displacement in Y-direction	10,1	mm	Member No. 30, x: 1.769 m
	Maximum displacement in Z-direction	-12,7	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	16,1	mm	Member No. 13, x: 2.072 m
	Maximum rotation about X-axis	-3,2	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Y-axis	7,6	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	-1,1	mrad	Member No. 15, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO14 - 1.15*LC1 + 1.35*LC5 + 1.35*LC10			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	5,79	kN	
	Sum of support forces in Y	5,79	kN	Deviation: 0.00 %
	Sum of loads in Z	-80,50	kN	
	Sum of support forces in Z	-80,50	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	8,0	mm	Member No. 29, x: 0.442 m
	Maximum displacement in Y-direction	9,7	mm	Member No. 30, x: 1.769 m
	Maximum displacement in Z-direction	-12,2	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	15,5	mm	Member No. 13, x: 2.072 m

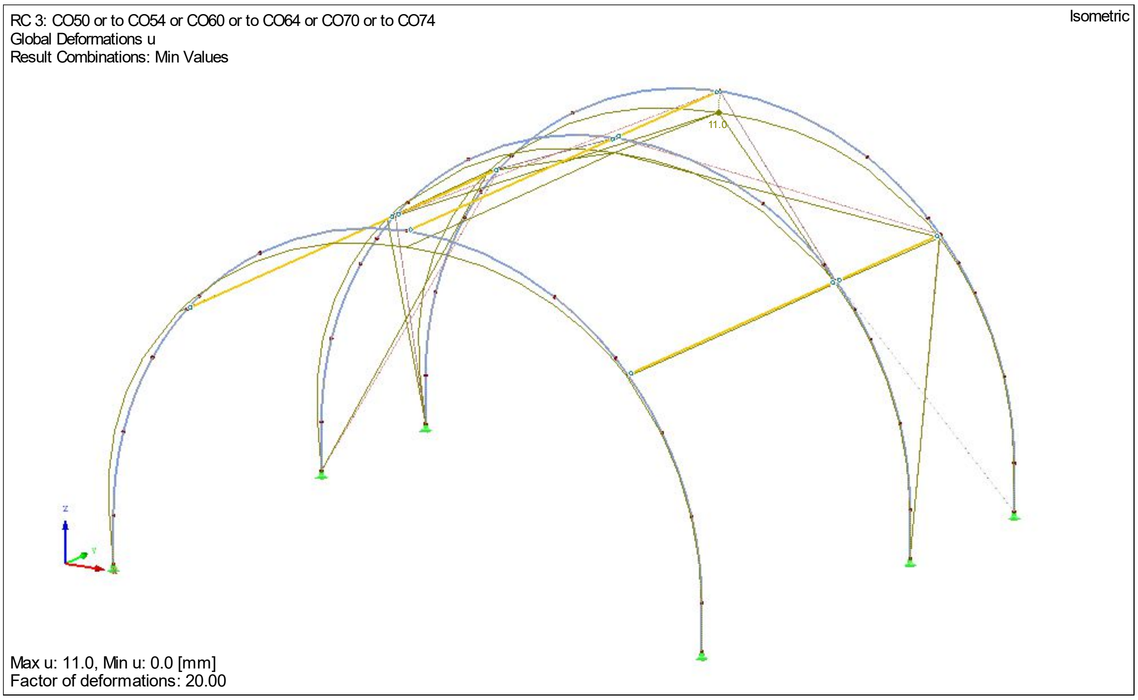
Maximum rotation about X-axis	-3,1	mrad	Member No. 7, x: 0.500 m
Maximum rotation about Y-axis	7,0	mrad	Member No. 9, x: 0.500 m
Maximum rotation about Z-axis	-1,1	mrad	Member No. 15, x: 0.000 m
Method of analysis	2nd Order		Second order analysis (Nonlinear)
Internal forces referred to deformed system for...	+		$N, V_y, V_z, M_y, M_z, M_T$
CO20 - 1.15*LC1 + 1.35*LC11			
Sum of loads in X	5,70	kN	
Sum of support forces in X	5,70	kN	Deviation: 0.00 %
Sum of loads in Y	-1,90	kN	
Sum of support forces in Y	-1,90	kN	Deviation: 0.00 %
Sum of loads in Z	-2,26	kN	
Sum of support forces in Z	-2,26	kN	Deviation: 0.00 %
Maximum displacement in X-direction	5,1	mm	Member No. 24, x: 0.634 m
Maximum displacement in Y-direction	0,8	mm	Member No. 30, x: 3.095 m
Maximum displacement in Z-direction	1,7	mm	Member No. 31, x: 3.095 m
Maximum vectorial displacement	5,2	mm	Member No. 24, x: 0.634 m
Maximum rotation about X-axis	-0,6	mrad	Member No. 13, x: 0.000 m
Maximum rotation about Y-axis	3,1	mrad	Member No. 6, x: 0.000 m
Maximum rotation about Z-axis	1,0	mrad	Member No. 2, x: 0.884 m
Method of analysis	2nd Order		Second order analysis (Nonlinear)
Internal forces referred to deformed system for...	+		$N, V_y, V_z, M_y, M_z, M_T$
CO21 - 1.15*LC1 + 1.35*LC2 + 1.35*LC11			
Sum of loads in X	5,70	kN	
Sum of support forces in X	5,70	kN	Deviation: 0.00 %
Sum of loads in Y	-1,90	kN	
Sum of support forces in Y	-1,90	kN	Deviation: 0.00 %
Sum of loads in Z	-66,71	kN	
Sum of support forces in Z	-66,71	kN	Deviation: 0.00 %
Maximum displacement in X-direction	6,4	mm	Member No. 33, x: 1.473 m
Maximum displacement in Y-direction	-1,7	mm	Member No. 25, x: 0.000 m
Maximum displacement in Z-direction	-4,6	mm	Member No. 32, x: 1.327 m
Maximum vectorial displacement	6,5	mm	Member No. 33, x: 1.473 m
Maximum rotation about X-axis	1,2	mrad	Member No. 5, x: 0.000 m
Maximum rotation about Y-axis	4,4	mrad	Member No. 9, x: 0.500 m
Maximum rotation about Z-axis	1,4	mrad	Member No. 2, x: 1.327 m
Method of analysis	2nd Order		Second order analysis (Nonlinear)
Internal forces referred to deformed system for...	+		$N, V_y, V_z, M_y, M_z, M_T$
CO22 - 1.15*LC1 + 1.35*LC3 + 1.35*LC11			
Sum of loads in X	5,70	kN	
Sum of support forces in X	5,70	kN	Deviation: 0.00 %
Sum of loads in Y	-1,90	kN	
Sum of support forces in Y	-1,90	kN	Deviation: 0.00 %
Sum of loads in Z	-42,76	kN	
Sum of support forces in Z	-42,76	kN	Deviation: 0.00 %
Maximum displacement in X-direction	9,4	mm	Member No. 33, x: 1.768 m
Maximum displacement in Y-direction	-2,3	mm	Member No. 26, x: 0.339 m
Maximum displacement in Z-direction	-10,1	mm	Member No. 32, x: 1.769 m
Maximum vectorial displacement	10,8	mm	Member No. 32, x: 1.769 m
Maximum rotation about X-axis	1,6	mrad	Member No. 5, x: 0.000 m
Maximum rotation about Y-axis	6,2	mrad	Member No. 7, x: 0.500 m
Maximum rotation about Z-axis	1,5	mrad	Member No. 2, x: 1.327 m
Method of analysis	2nd Order		Second order analysis (Nonlinear)
Internal forces referred to deformed system for...	+		$N, V_y, V_z, M_y, M_z, M_T$
CO23 - 1.15*LC1 + 1.35*LC4 + 1.35*LC11			
Sum of loads in X	5,70	kN	
Sum of support forces in X	5,70	kN	Deviation: 0.00 %
Sum of loads in Y	-1,90	kN	
Sum of support forces in Y	-1,90	kN	Deviation: 0.00 %
Sum of loads in Z	-71,11	kN	
Sum of support forces in Z	-71,11	kN	Deviation: 0.00 %
Maximum displacement in X-direction	9,4	mm	Member No. 27, x: 0.000 m
Maximum displacement in Y-direction	-3,0	mm	Member No. 26, x: 0.509 m
Maximum displacement in Z-direction	-8,1	mm	Member No. 32, x: 1.327 m
Maximum vectorial displacement	9,4	mm	Member No. 27, x: 0.000 m
Maximum rotation about X-axis	1,9	mrad	Member No. 5, x: 0.000 m
Maximum rotation about Y-axis	6,8	mrad	Member No. 7, x: 0.500 m
Maximum rotation about Z-axis	1,7	mrad	Member No. 2, x: 1.327 m
Method of analysis	2nd Order		Second order analysis (Nonlinear)
Internal forces referred to deformed system for...	+		$N, V_y, V_z, M_y, M_z, M_T$
CO24 - 1.15*LC1 + 1.35*LC5 + 1.35*LC11			
Sum of loads in X	5,70	kN	
Sum of support forces in X	5,70	kN	Deviation: 0.00 %
Sum of loads in Y	-1,90	kN	
Sum of support forces in Y	-1,90	kN	Deviation: 0.00 %
Sum of loads in Z	-87,31	kN	
Sum of support forces in Z	-87,31	kN	Deviation: 0.00 %
Maximum displacement in X-direction	8,2	mm	Member No. 27, x: 0.000 m
Maximum displacement in Y-direction	-2,7	mm	Member No. 26, x: 0.339 m
Maximum displacement in Z-direction	-7,6	mm	Member No. 32, x: 1.769 m

	Maximum vectorial displacement	8,5	mm	Member No. 32, x: 1.769 m
	Maximum rotation about X-axis	1,7	mrad	Member No. 5, x: 0.000 m
	Maximum rotation about Y-axis	6,1	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Z-axis	1,6	mrad	Member No. 2, x: 1.327 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO30 - 1.15*LC1 + 1.35*LC12			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	5,78	kN	
	Sum of support forces in Y	5,78	kN	Deviation: 0.00 %
	Sum of loads in Z	-10,89	kN	
	Sum of support forces in Z	-10,89	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	2,8	mm	Member No. 29, x: 0.442 m
	Maximum displacement in Y-direction	6,2	mm	Member No. 32, x: 1.769 m
	Maximum displacement in Z-direction	-4,0	mm	Member No. 13, x: 2.072 m
	Maximum vectorial displacement	7,4	mm	Member No. 32, x: 1.769 m
	Maximum rotation about X-axis	-2,4	mrad	Member No. 31, x: 1.769 m
	Maximum rotation about Y-axis	2,4	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	-0,9	mrad	Member No. 15, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO31 - 1.15*LC1 + 1.35*LC2 + 1.35*LC12			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	5,78	kN	
	Sum of support forces in Y	5,78	kN	Deviation: 0.00 %
	Sum of loads in Z	-75,35	kN	
	Sum of support forces in Z	-75,35	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	6,0	mm	Member No. 29, x: 0.442 m
	Maximum displacement in Y-direction	8,2	mm	Member No. 30, x: 1.769 m
	Maximum displacement in Z-direction	-8,9	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	12,1	mm	Member No. 13, x: 2.072 m
	Maximum rotation about X-axis	-2,6	mrad	Member No. 31, x: 1.769 m
	Maximum rotation about Y-axis	5,2	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	-1,0	mrad	Member No. 15, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO32 - 1.15*LC1 + 1.35*LC3 + 1.35*LC12			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	5,78	kN	
	Sum of support forces in Y	5,78	kN	Deviation: 0.00 %
	Sum of loads in Z	-51,39	kN	
	Sum of support forces in Z	-51,39	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	8,8	mm	Member No. 29, x: 0.442 m
	Maximum displacement in Y-direction	9,1	mm	Member No. 30, x: 1.769 m
	Maximum displacement in Z-direction	-14,7	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	17,3	mm	Member No. 13, x: 2.072 m
	Maximum rotation about X-axis	-2,7	mrad	Member No. 31, x: 1.769 m
	Maximum rotation about Y-axis	7,1	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	-1,1	mrad	Member No. 15, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO33 - 1.15*LC1 + 1.35*LC4 + 1.35*LC12			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	5,78	kN	
	Sum of support forces in Y	5,78	kN	Deviation: 0.00 %
	Sum of loads in Z	-79,74	kN	
	Sum of support forces in Z	-79,74	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	9,0	mm	Member No. 29, x: 0.442 m
	Maximum displacement in Y-direction	10,0	mm	Member No. 30, x: 1.769 m
	Maximum displacement in Z-direction	-12,8	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	16,2	mm	Member No. 13, x: 2.072 m
	Maximum rotation about X-axis	-2,8	mrad	Member No. 32, x: 0.442 m
	Maximum rotation about Y-axis	7,6	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	-1,1	mrad	Member No. 15, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO34 - 1.15*LC1 + 1.35*LC5 + 1.35*LC12			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	5,78	kN	
	Sum of support forces in Y	5,78	kN	Deviation: 0.00 %
	Sum of loads in Z	-95,94	kN	
	Sum of support forces in Z	-95,94	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	8,0	mm	Member No. 29, x: 0.442 m
	Maximum displacement in Y-direction	9,6	mm	Member No. 30, x: 1.769 m

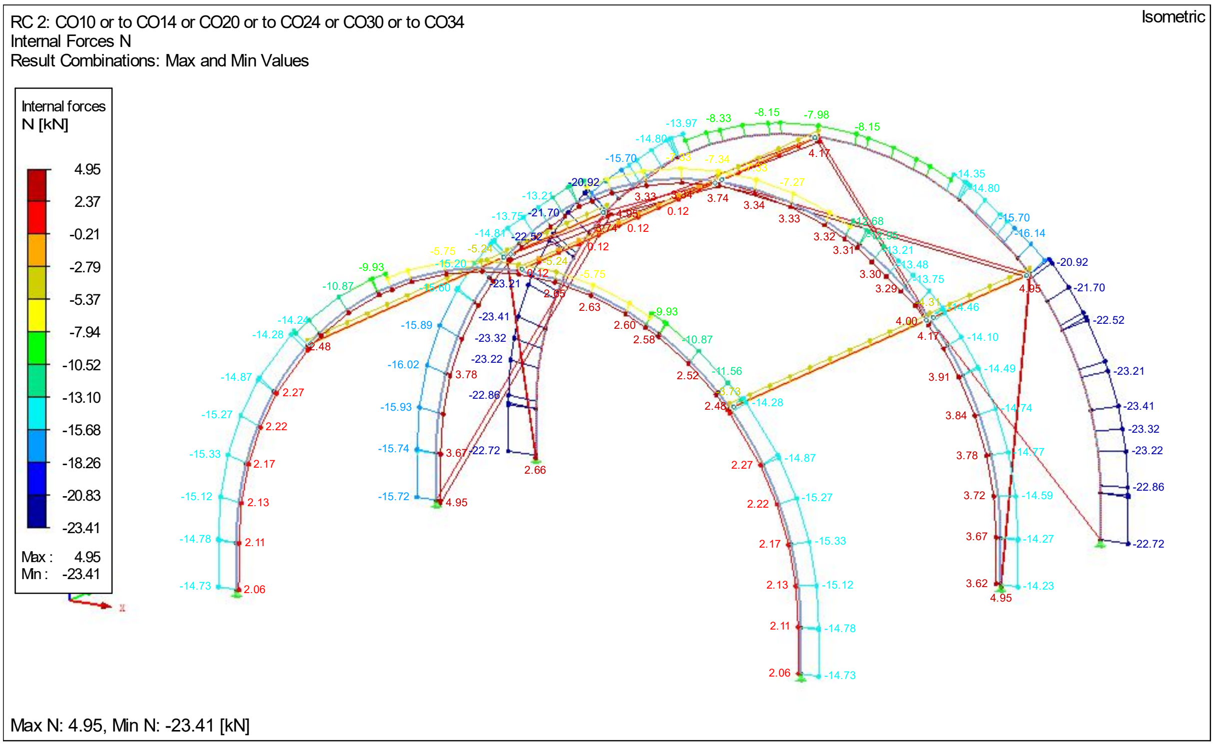
	Maximum displacement in Z-direction	-12,2	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	15,6	mm	Member No. 13, x: 2.072 m
	Maximum rotation about X-axis	-2,8	mrad	Member No. 31, x: 1.769 m
	Maximum rotation about Y-axis	7,0	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	-1,1	mrad	Member No. 15, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T

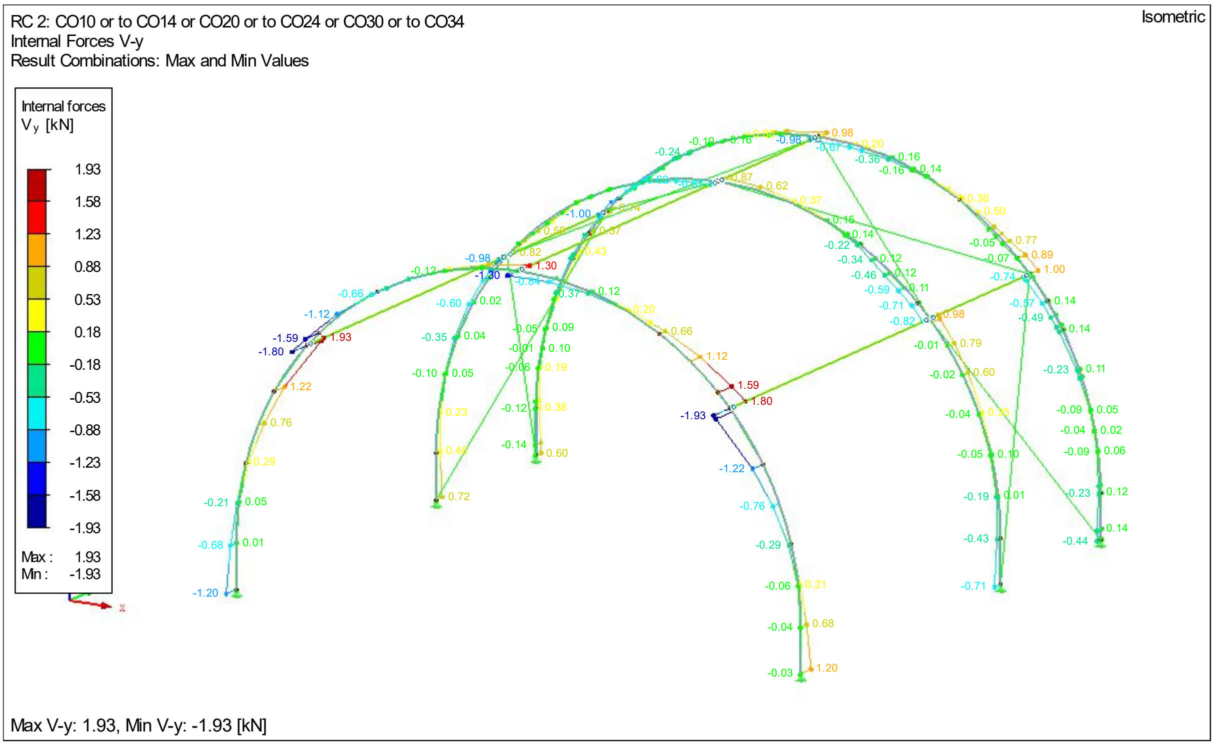
3.5.1 Deformation of the In-service situation characteristic max and min values.

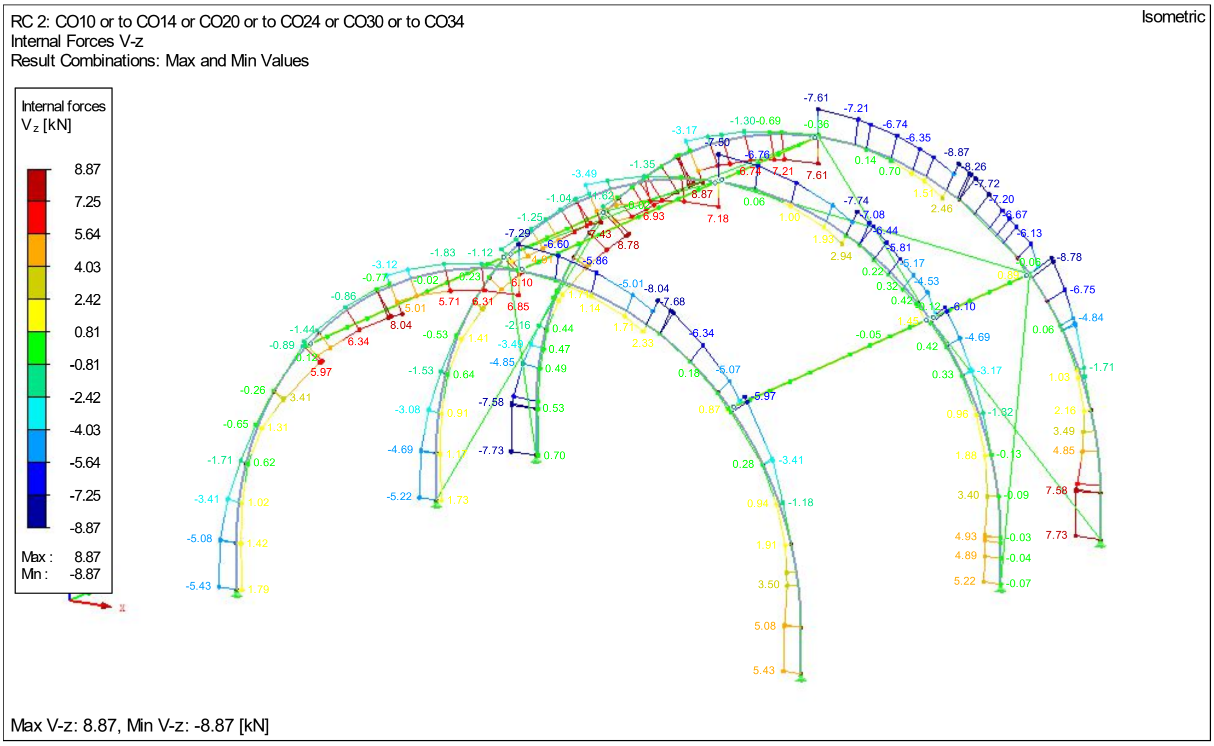


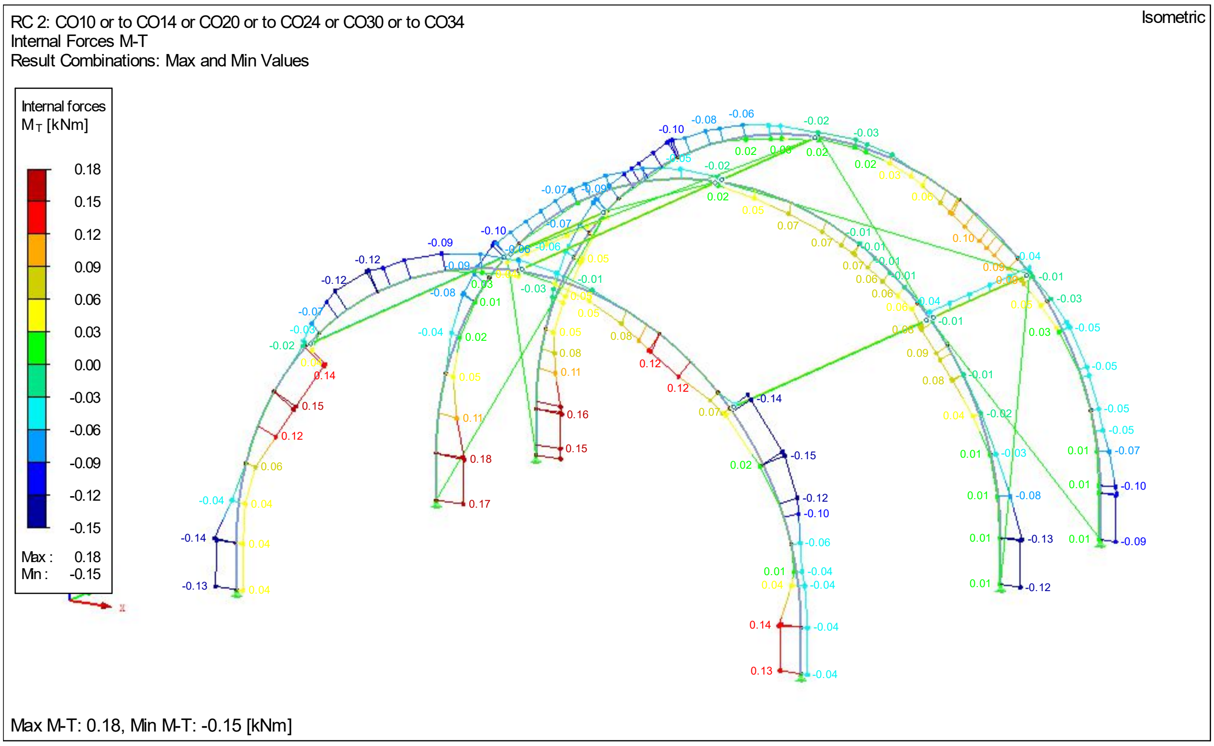


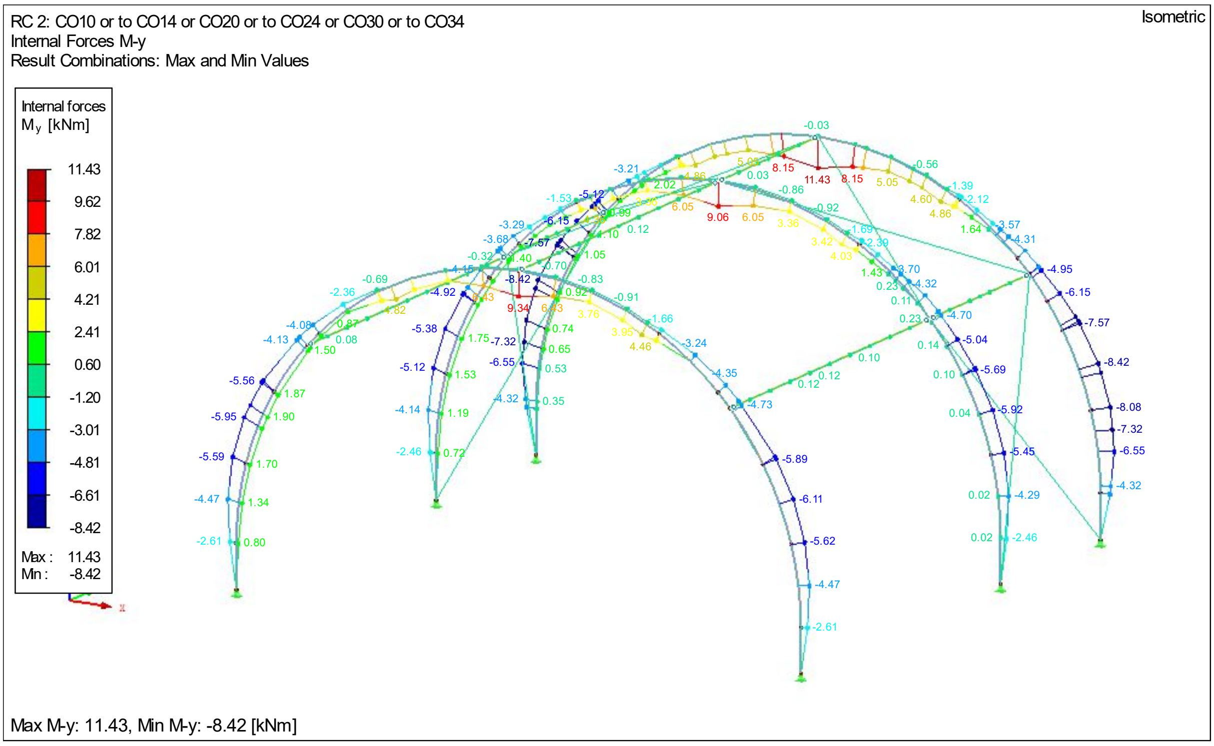
3.5.2 Internal force diagram RC2 Design values In-service.

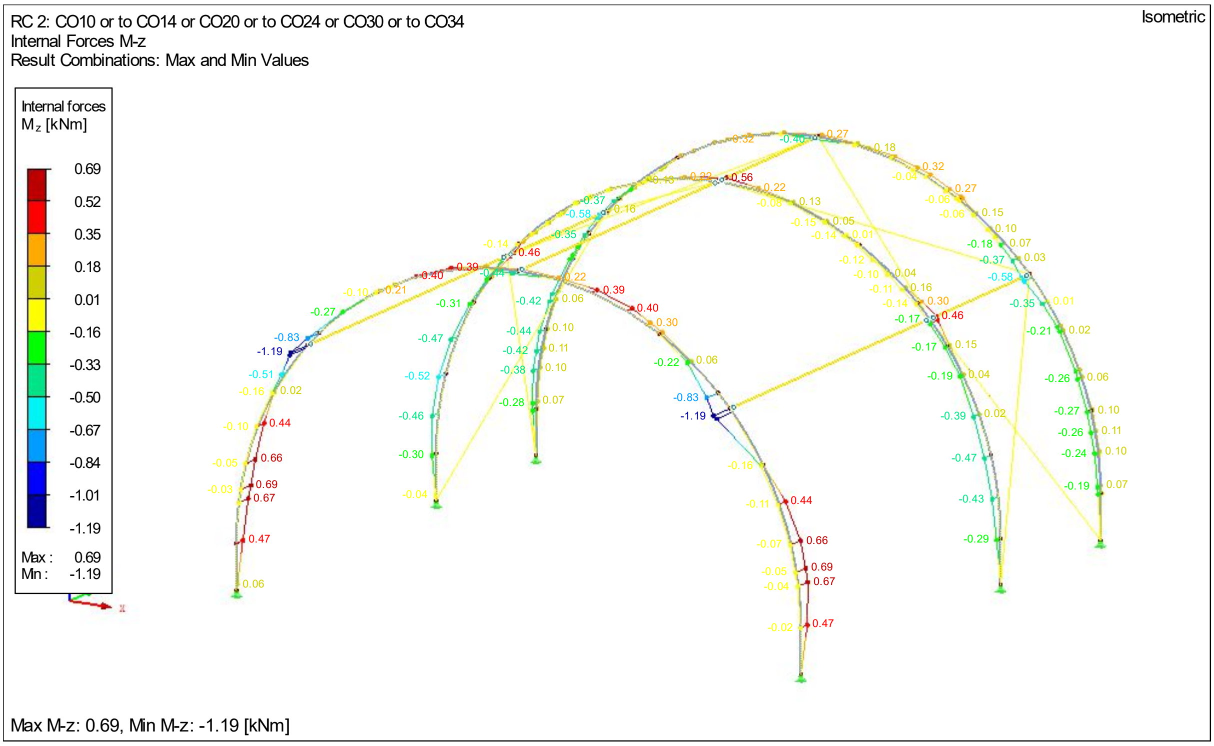





RC 2: CO10 or to CO14 or CO20 or to CO24 or CO30 or to CO34
Internal Forces V-z
Result Combinations: Max and Min Values
Isometric
Internal forces
V z [kN]
8.87
7.25
5.64
4.03
2.42
0.81
-0.81
-2.42
-4.03
-5.64
-7.25
-8.87
Max : 8.87
Min : -8.87
Max V-z: 8.87, Min V-z: -8.87 [kN]


RC 2: CO10 or to CO14 or CO20 or to CO24 or CO30 or to CO34
Internal Forces M-T
Result Combinations: Max and Min Values
Isometric
Internal forces
M T [kNm]
0.18
0.15
0.12
0.09
0.06
0.03
0.00
-0.03
-0.06
-0.09
-0.12
-0.15
Max : 0.18
Min : -0.15
Max M-T: 0.18, Min M-T: -0.15 [kNm]


RC 2: CO10 or to CO14 or CO20 or to CO24 or CO30 or to CO34
Internal Forces M-y
Result Combinations: Max and Min Values
Isometric
Internal forces
My [kNm]
11.43
9.62
7.82
6.01
4.21
2.41
0.60
-1.20
-3.01
-4.81
-6.61
-8.42
Max : 11.43
Min : -8.42
Max M-y: 11.43, Min M-y: -8.42 [kNm]


RC 2: CO10 or to CO14 or CO20 or to CO24 or CO30 or to CO34
Internal Forces M-z
Result Combinations: Max and Min Values
Isometric
Internal forces
Mz [kNm]
0.69
0.52
0.35
0.18
0.01
-0.16
-0.33
-0.50
-0.67
-0.84
-1.01
-1.19
Max : 0.69
Min : -1.19
Max M-z: 0.69, Min M-z: -1.19 [kNm]

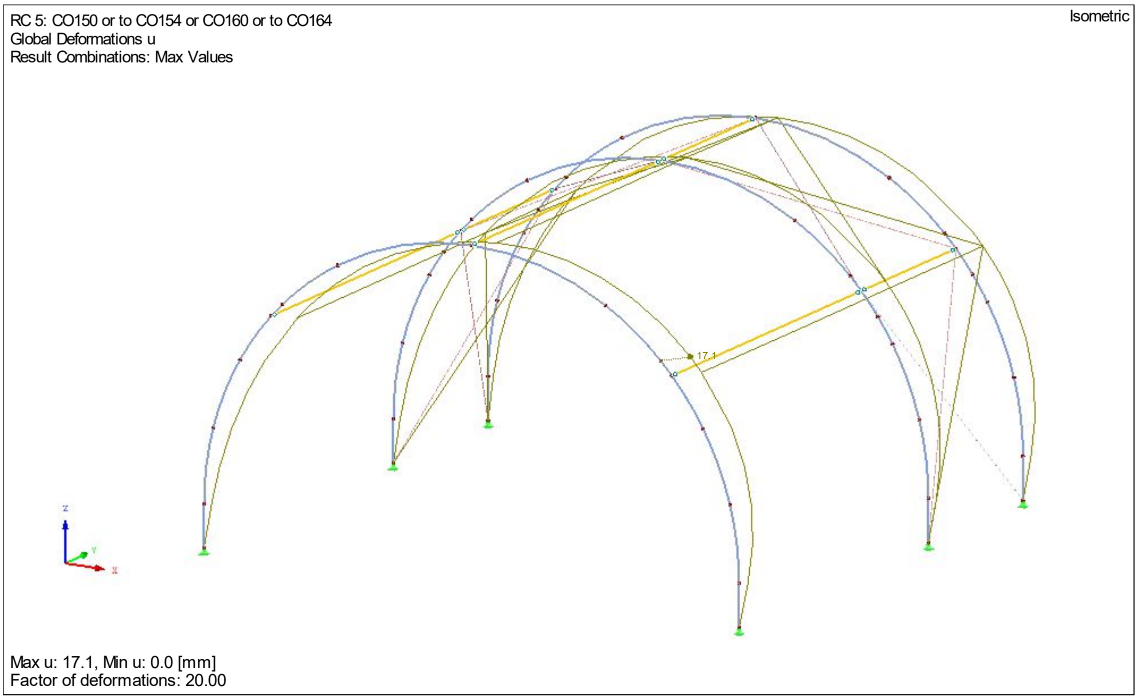
3.6 Calculation result of RC4 - Design Values Out-service: 1 * (CO100 – CO114)

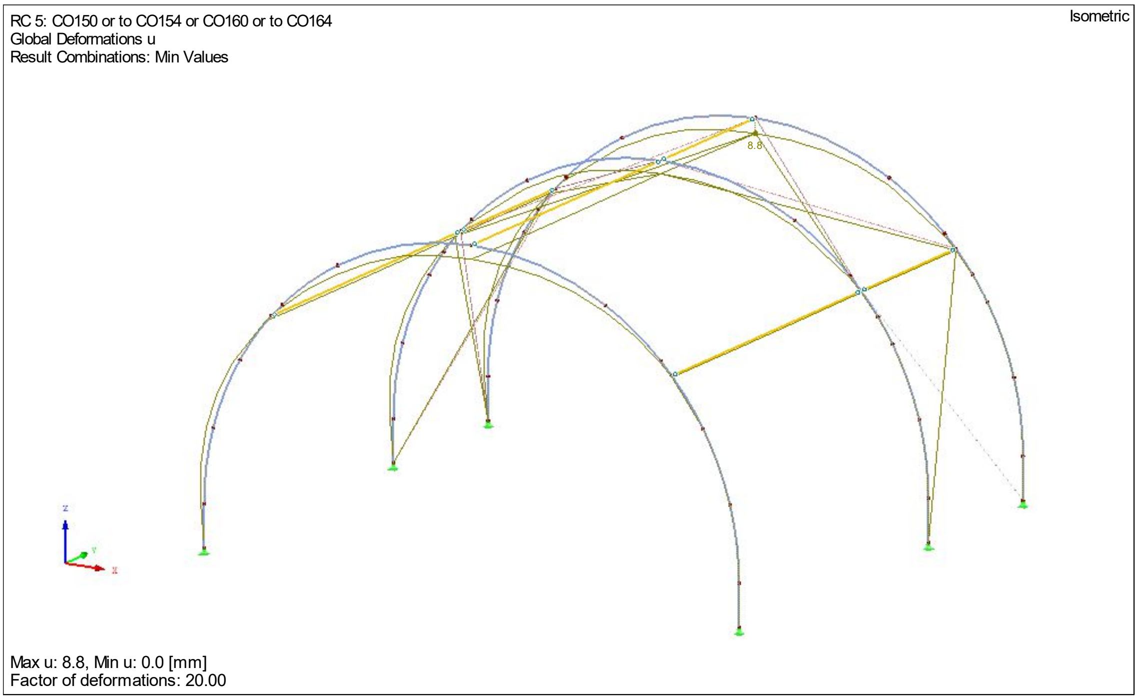
	Description	Value	Unit	Comment
	CO100 - 1.15*LC1 + 1.35*LC20			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	3,87	kN	
	Sum of support forces in Y	3,87	kN	Deviation: 0.00 %
	Sum of loads in Z	10,73	kN	
	Sum of support forces in Z	10,73	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	0,9	mm	Member No. 29, x: 0.527 m
	Maximum displacement in Y-direction	2,5	mm	Member No. 30, x: 1.327 m
	Maximum displacement in Z-direction	-1,2	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	2,6	mm	Member No. 13, x: 2.072 m
	Maximum rotation about X-axis	-1,4	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Y-axis	0,8	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	1,1	mrad	Member No. 27, x: 0.884 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO101 - 1.15*LC1 + 1.35*LC2 + 1.35*LC20			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	3,87	kN	
	Sum of support forces in Y	3,87	kN	Deviation: 0.00 %
	Sum of loads in Z	-53,73	kN	
	Sum of support forces in Z	-53,73	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	4,0	mm	Member No. 29, x: 0.442 m
	Maximum displacement in Y-direction	4,5	mm	Member No. 30, x: 1.327 m
	Maximum displacement in Z-direction	-6,0	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	7,4	mm	Member No. 13, x: 2.072 m
	Maximum rotation about X-axis	-2,1	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Y-axis	3,5	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	1,3	mrad	Member No. 27, x: 0.884 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO102 - 1.15*LC1 + 1.35*LC3 + 1.35*LC20			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	3,87	kN	
	Sum of support forces in Y	3,87	kN	Deviation: 0.00 %
	Sum of loads in Z	-29,77	kN	
	Sum of support forces in Z	-29,77	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	6,9	mm	Member No. 29, x: 0.442 m
	Maximum displacement in Y-direction	5,4	mm	Member No. 30, x: 1.327 m
	Maximum displacement in Z-direction	-11,8	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	12,9	mm	Member No. 13, x: 2.072 m
	Maximum rotation about X-axis	-2,4	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Y-axis	-5,7	mrad	Member No. 32, x: 3.361 m
	Maximum rotation about Z-axis	1,4	mrad	Member No. 27, x: 0.884 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO103 - 1.15*LC1 + 1.35*LC4 + 1.35*LC20			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	3,87	kN	
	Sum of support forces in Y	3,87	kN	Deviation: 0.00 %
	Sum of loads in Z	-58,12	kN	
	Sum of support forces in Z	-58,12	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	7,0	mm	Member No. 29, x: 0.442 m
	Maximum displacement in Y-direction	6,2	mm	Member No. 30, x: 1.327 m
	Maximum displacement in Z-direction	-9,9	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	11,5	mm	Member No. 13, x: 2.072 m
	Maximum rotation about X-axis	-2,7	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Y-axis	5,9	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	1,5	mrad	Member No. 27, x: 0.884 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO104 - 1.15*LC1 + 1.35*LC5 + 1.35*LC20			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	3,87	kN	
	Sum of support forces in Y	3,87	kN	Deviation: 0.00 %
	Sum of loads in Z	-74,32	kN	
	Sum of support forces in Z	-74,32	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	6,0	mm	Member No. 29, x: 0.527 m
	Maximum displacement in Y-direction	5,9	mm	Member No. 30, x: 1.327 m
	Maximum displacement in Z-direction	-9,3	mm	Member No. 32, x: 1.769 m
	Maximum vectorial displacement	10,9	mm	Member No. 13, x: 2.072 m

	Maximum rotation about X-axis	-2,6	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Y-axis	5,3	mrad	Member No. 9, x: 0.500 m
	Maximum rotation about Z-axis	1,5	mrad	Member No. 27, x: 0.884 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO110 - 1.15*LC1 + 1.35*LC21			
	Sum of loads in X	22,87	kN	
	Sum of support forces in X	22,87	kN	Deviation: 0.00 %
	Sum of loads in Y	0,02	kN	
	Sum of support forces in Y	0,02	kN	Deviation: 0.00 %
	Sum of loads in Z	17,48	kN	
	Sum of support forces in Z	17,48	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	19,5	mm	Member No. 24, x: 0.884 m
	Maximum displacement in Y-direction	4,1	mm	Member No. 30, x: 2.653 m
	Maximum displacement in Z-direction	5,7	mm	Member No. 30, x: 3.361 m
	Maximum vectorial displacement	19,9	mm	Member No. 24, x: 0.884 m
	Maximum rotation about X-axis	-2,1	mrad	Member No. 32, x: 1.769 m
	Maximum rotation about Y-axis	11,0	mrad	Member No. 6, x: 0.000 m
	Maximum rotation about Z-axis	2,2	mrad	Member No. 2, x: 1.179 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO111 - 1.15*LC1 + 1.35*LC2 + 1.35*LC21			
	Sum of loads in X	22,87	kN	
	Sum of support forces in X	22,87	kN	Deviation: 0.00 %
	Sum of loads in Y	0,02	kN	
	Sum of support forces in Y	0,02	kN	Deviation: 0.00 %
	Sum of loads in Z	-46,97	kN	
	Sum of support forces in Z	-46,97	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	19,6	mm	Member No. 33, x: 0.589 m
	Maximum displacement in Y-direction	5,5	mm	Member No. 30, x: 3.095 m
	Maximum displacement in Z-direction	-5,7	mm	Member No. 32, x: 0.177 m
	Maximum vectorial displacement	20,5	mm	Member No. 33, x: 0.589 m
	Maximum rotation about X-axis	-2,5	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Y-axis	10,6	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Z-axis	2,4	mrad	Member No. 2, x: 1.327 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO112 - 1.15*LC1 + 1.35*LC3 + 1.35*LC21			
	Sum of loads in X	22,87	kN	
	Sum of support forces in X	22,87	kN	Deviation: 0.00 %
	Sum of loads in Y	0,02	kN	
	Sum of support forces in Y	0,02	kN	Deviation: 0.00 %
	Sum of loads in Z	-23,02	kN	
	Sum of support forces in Z	-23,02	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	22,0	mm	Member No. 33, x: 1.091 m
	Maximum displacement in Y-direction	6,2	mm	Member No. 30, x: 3.095 m
	Maximum displacement in Z-direction	-9,6	mm	Member No. 32, x: 1.327 m
	Maximum vectorial displacement	22,9	mm	Member No. 33, x: 1.091 m
	Maximum rotation about X-axis	-2,8	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Y-axis	12,4	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Z-axis	2,5	mrad	Member No. 2, x: 1.327 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO113 - 1.15*LC1 + 1.35*LC4 + 1.35*LC21			
	Sum of loads in X	22,87	kN	
	Sum of support forces in X	22,87	kN	Deviation: 0.00 %
	Sum of loads in Y	0,02	kN	
	Sum of support forces in Y	0,02	kN	Deviation: 0.00 %
	Sum of loads in Z	-51,37	kN	
	Sum of support forces in Z	-51,37	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	21,7	mm	Member No. 33, x: 1.179 m
	Maximum displacement in Y-direction	6,6	mm	Member No. 30, x: 3.361 m
	Maximum displacement in Z-direction	-8,7	mm	Member No. 32, x: 0.608 m
	Maximum vectorial displacement	22,7	mm	Member No. 33, x: 1.179 m
	Maximum rotation about X-axis	-3,2	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Y-axis	13,1	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Z-axis	2,6	mrad	Member No. 2, x: 1.327 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO114 - 1.15*LC1 + 1.35*LC5 + 1.35*LC21			
	Sum of loads in X	22,87	kN	
	Sum of support forces in X	22,87	kN	Deviation: 0.00 %
	Sum of loads in Y	0,02	kN	
	Sum of support forces in Y	0,02	kN	Deviation: 0.00 %
	Sum of loads in Z	-67,57	kN	
	Sum of support forces in Z	-67,57	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	20,9	mm	Member No. 33, x: 0.884 m
	Maximum displacement in Y-direction	6,6	mm	Member No. 30, x: 3.095 m
	Maximum displacement in Z-direction	-7,5	mm	Member No. 32, x: 0.884 m

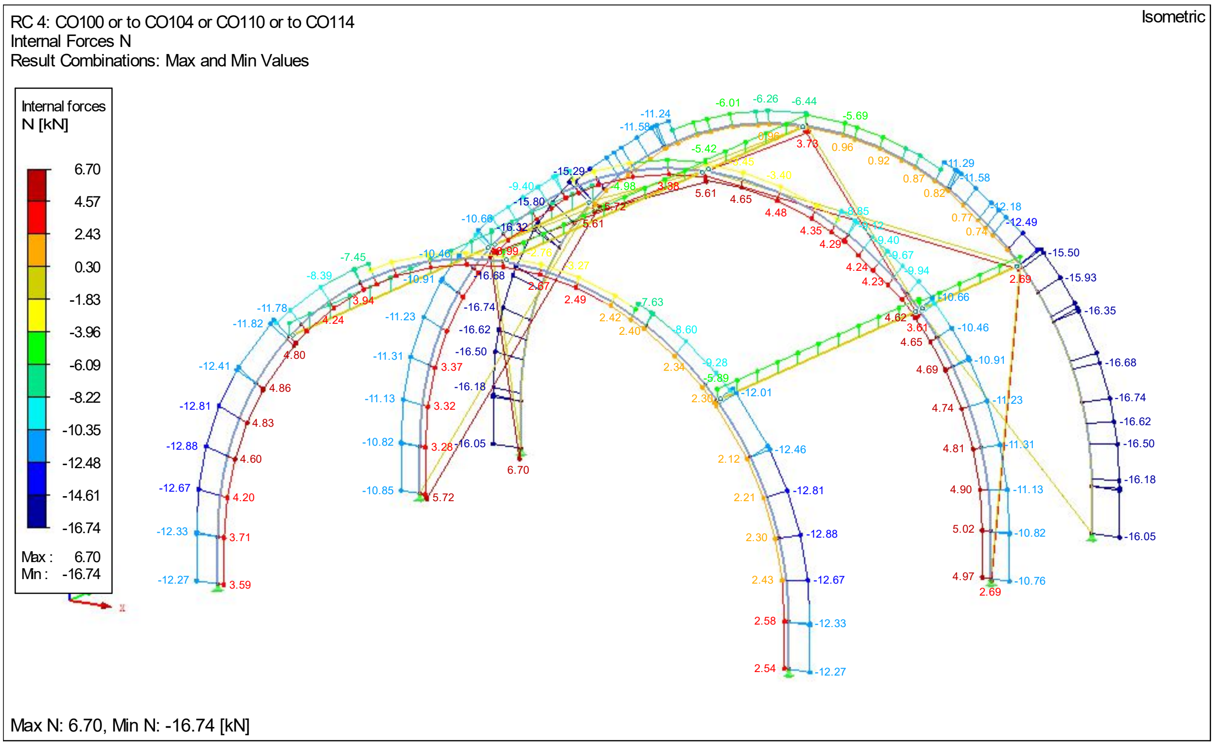
	Maximum vectorial displacement	21,9	mm	Member No. 33, x: 0.884 m
	Maximum rotation about X-axis	-3,0	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Y-axis	12,4	mrad	Member No. 7, x: 0.500 m
	Maximum rotation about Z-axis	2,6	mrad	Member No. 2, x: 1.327 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T

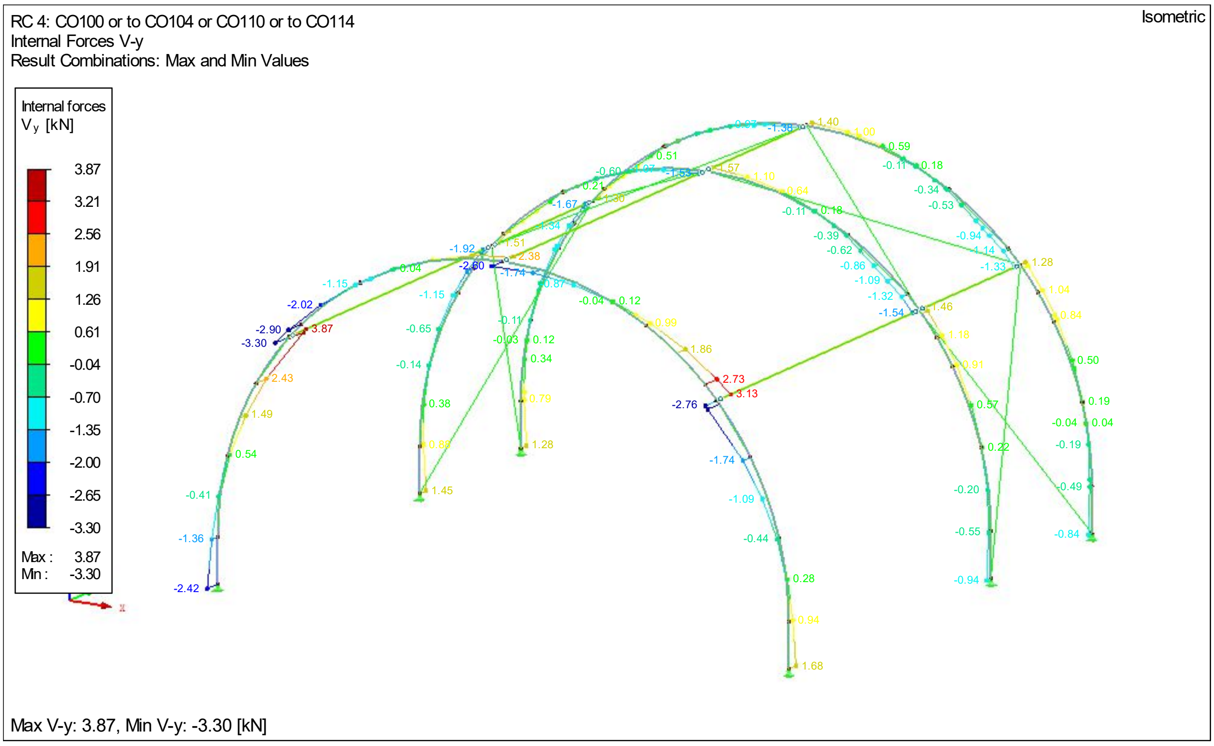
3.6.1 Deformation of the Out-service situation characteristic max and min values.

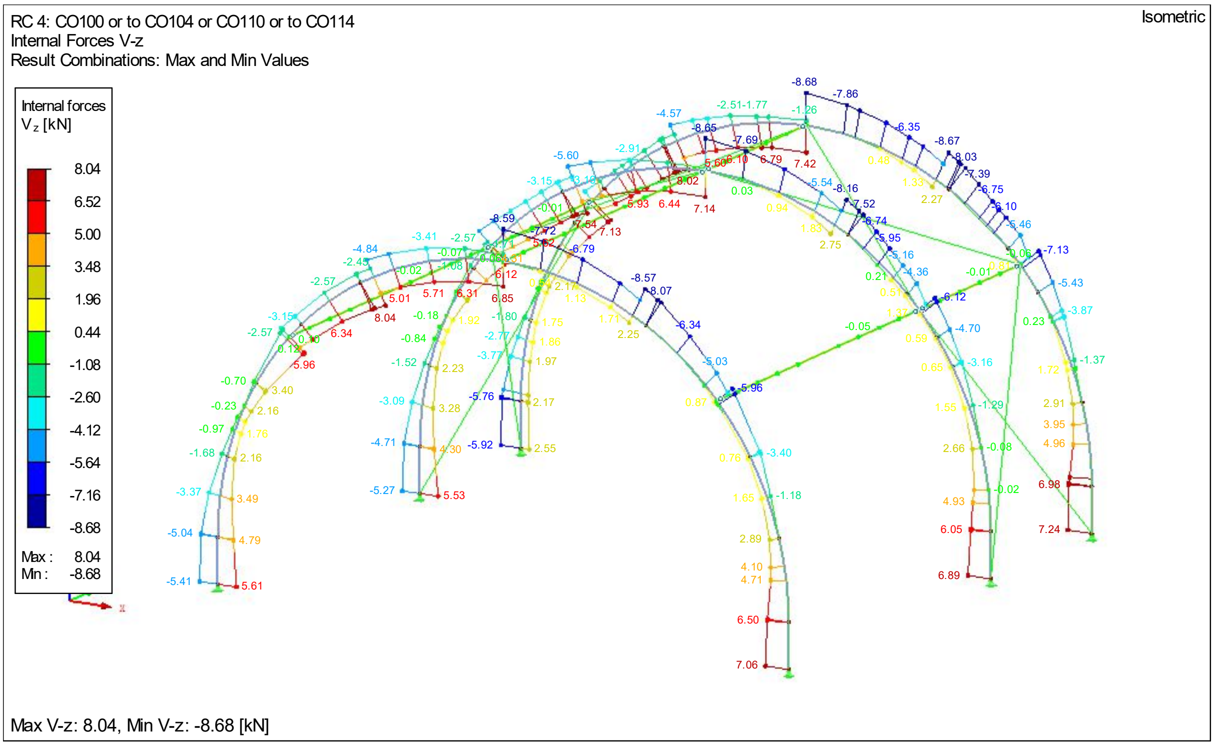


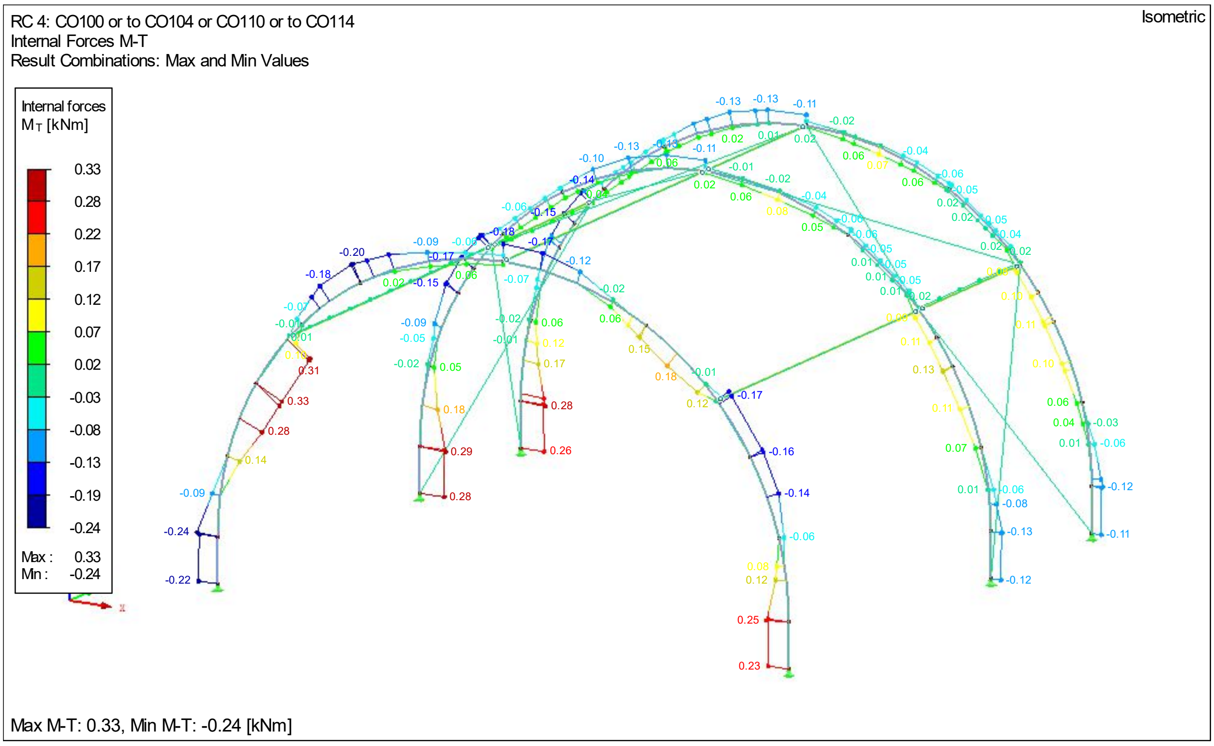


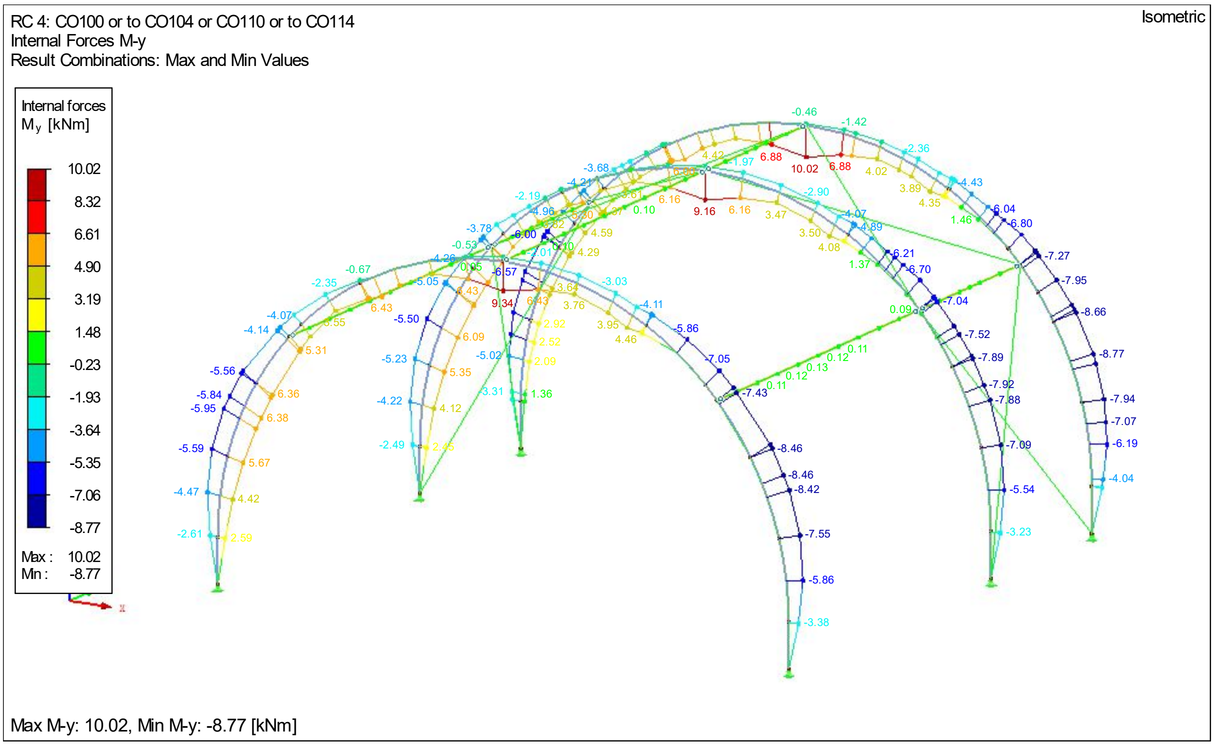
3.6.2 Internal force diagram RC4 Design Values Out-service.

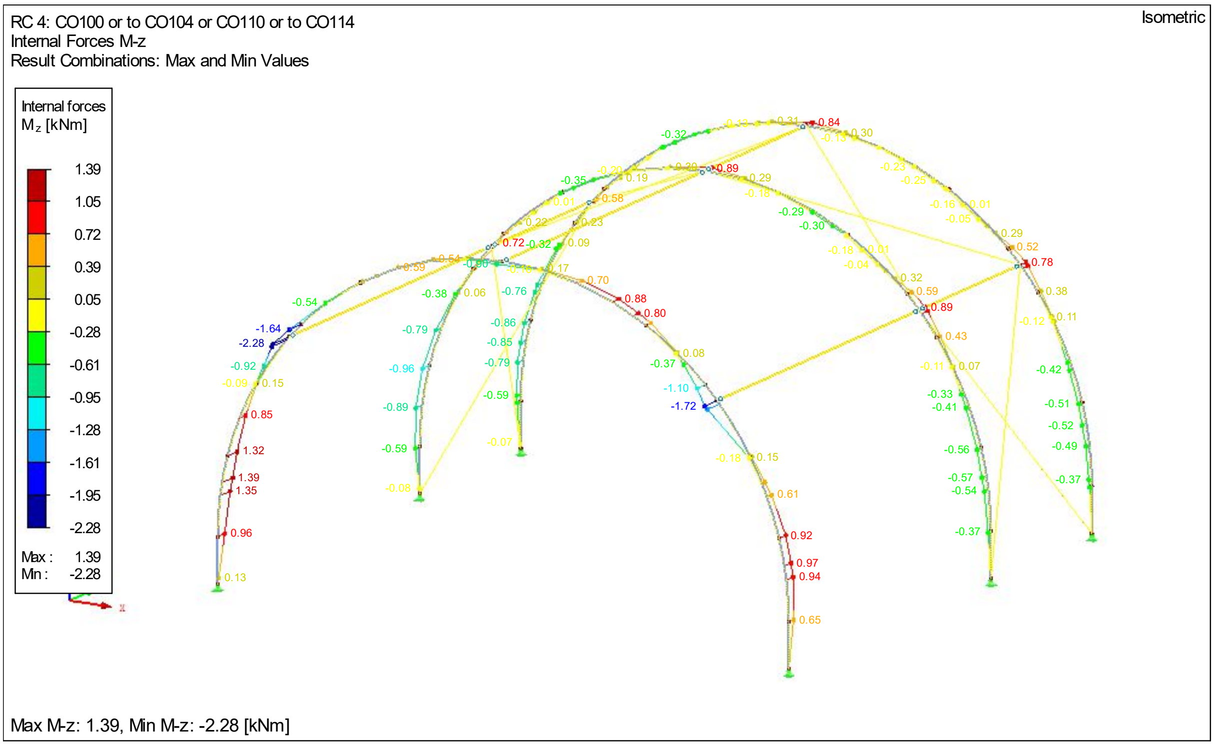





RC 4: CO100 or to CO104 or CO110 or to CO114
Internal Forces V-z
Result Combinations: Max and Min Values
Isometric
Internal forces
V_z [kN]
8.04
6.52
5.00
3.48
1.96
0.44
-1.08
-2.60
-4.12
-5.64
-7.16
-8.68
Max : 8.04
Min : -8.68
Max V-z: 8.04, Min V-z: -8.68 [kN]


RC 4: CO100 or to CO104 or CO110 or to CO114
Internal Forces M-T
Result Combinations: Max and Min Values
Isometric
Internal forces
M_T [kNm]
0.33
0.28
0.22
0.17
0.12
0.07
0.02
-0.03
-0.08
-0.13
-0.19
-0.24
Max : 0.33
Min : -0.24
Max M-T: 0.33, Min M-T: -0.24 [kNm]


RC 4: CO100 or to CO104 or CO110 or to CO114
Internal Forces M-y
Result Combinations: Max and Min Values
Isometric
Internal forces
M_y [kNm]
10.02
8.32
6.61
4.90
3.19
1.48
-0.23
-1.93
-3.64
-5.35
-7.06
-8.77
Max : 10.02
Min : -8.77
Max M-y: 10.02, Min M-y: -8.77 [kNm]


RC 4: CO100 or to CO104 or CO110 or to CO114
Internal Forces M-z
Result Combinations: Max and Min Values
Isometric
Internal forces
M_z [kNm]
1.39
1.05
0.72
0.39
0.05
-0.28
-0.61
-0.95
-1.28
-1.61
-1.95
-2.28
Max : 1.39
Min : -2.28
Max M-z: 1.39, Min M-z: -2.28 [kNm]

4.0 Detail calculations for different parts.

In this chapter, necessary detail calculations of different parts are made.

4.1 Detail Check of the Protruss S31 Main arches

The Main chord of the Protruss S31 has been produced from the material aluminium EN AW 6060 T6 instead of EN AW 6082 T6. This has been done because of the small radius of the arch trusses. This results in a lower maximum normal force in the main chord.

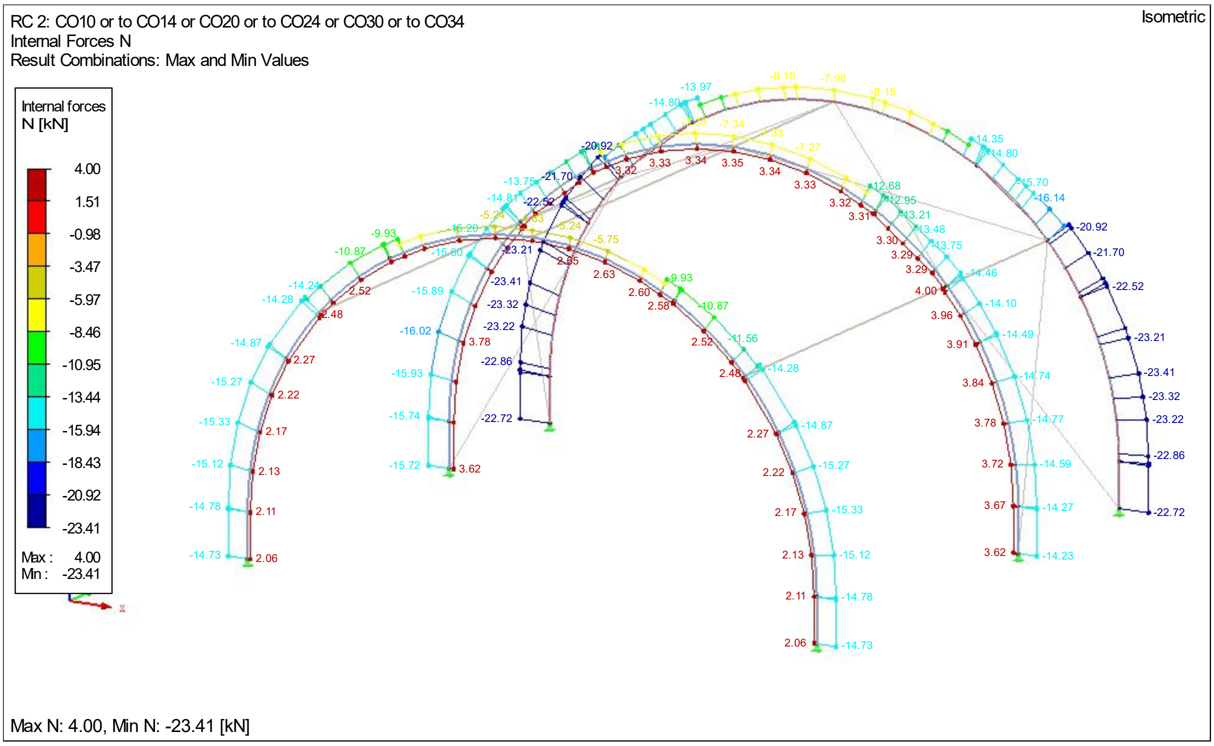
The lower Maximum normal force in the main chord is.
Limiting factor is the weld of the coupler to the main chord.
The coupling system and braces are the same and will have no influence.

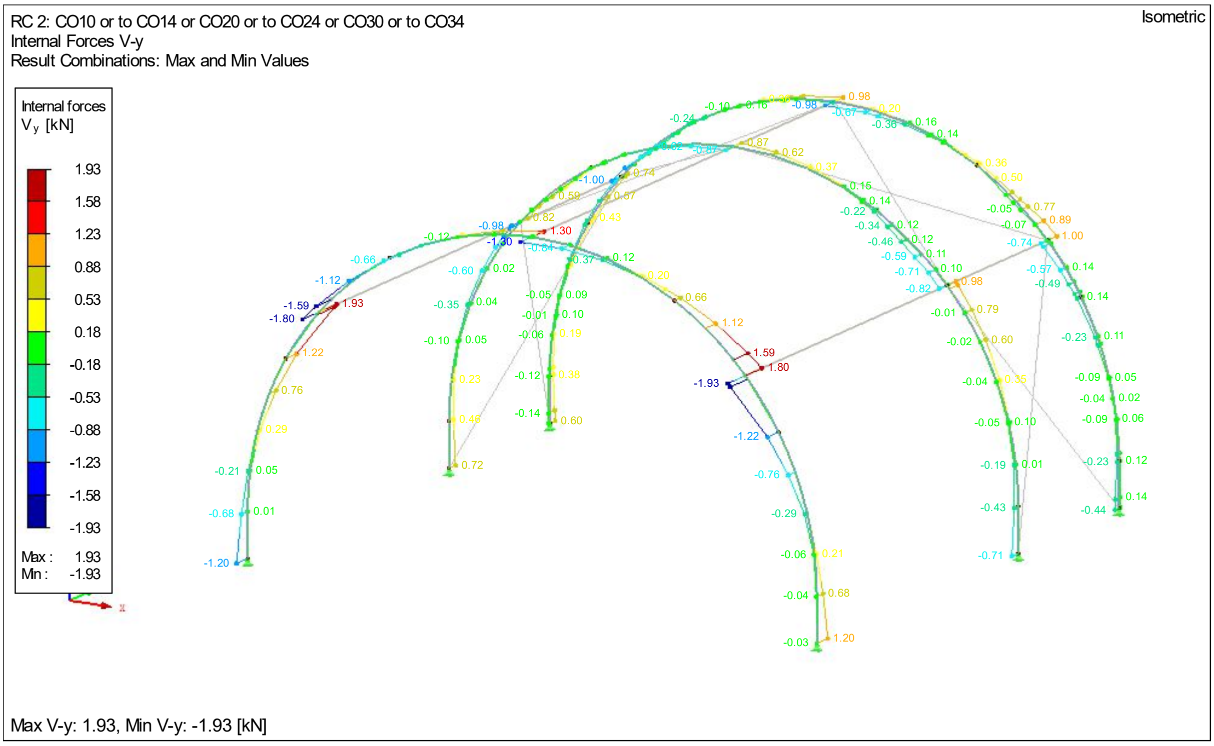
$N_{rd,Haz\ Chord} = A_{eff} * f_{uk,haz}*0.8 * 1 / \gamma m2 = 4.241 * 10 * 0.8 * 1/1.25 = 27.14$ kN
$M_{Rd,\ main\ chord} = W_{chord} * f_{uk,haz}*0.8 * 1 / \gamma m2 = 4.493 * 10 * 0.8 * 1/1.25 = 28.75$ kNcm

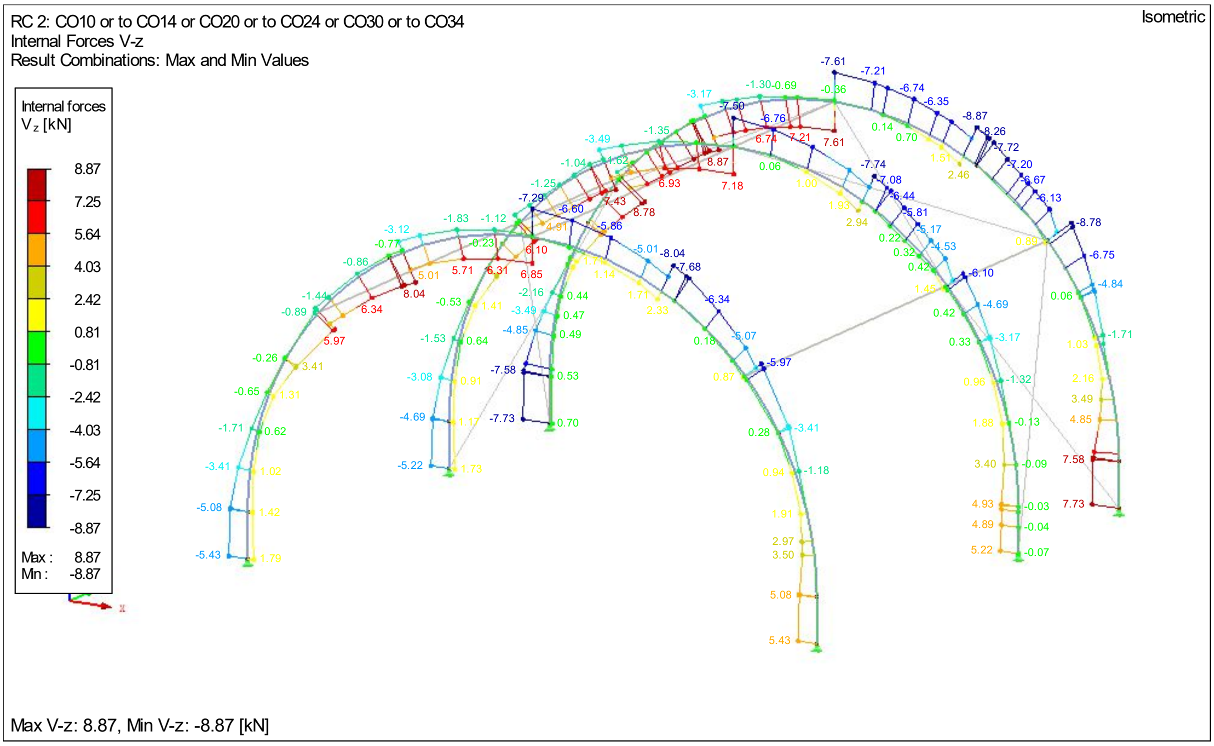
All the structural geometry such as sectional area and moment of inertia and of the truss will stay the same.
The truss data are printed in the annex of this document.

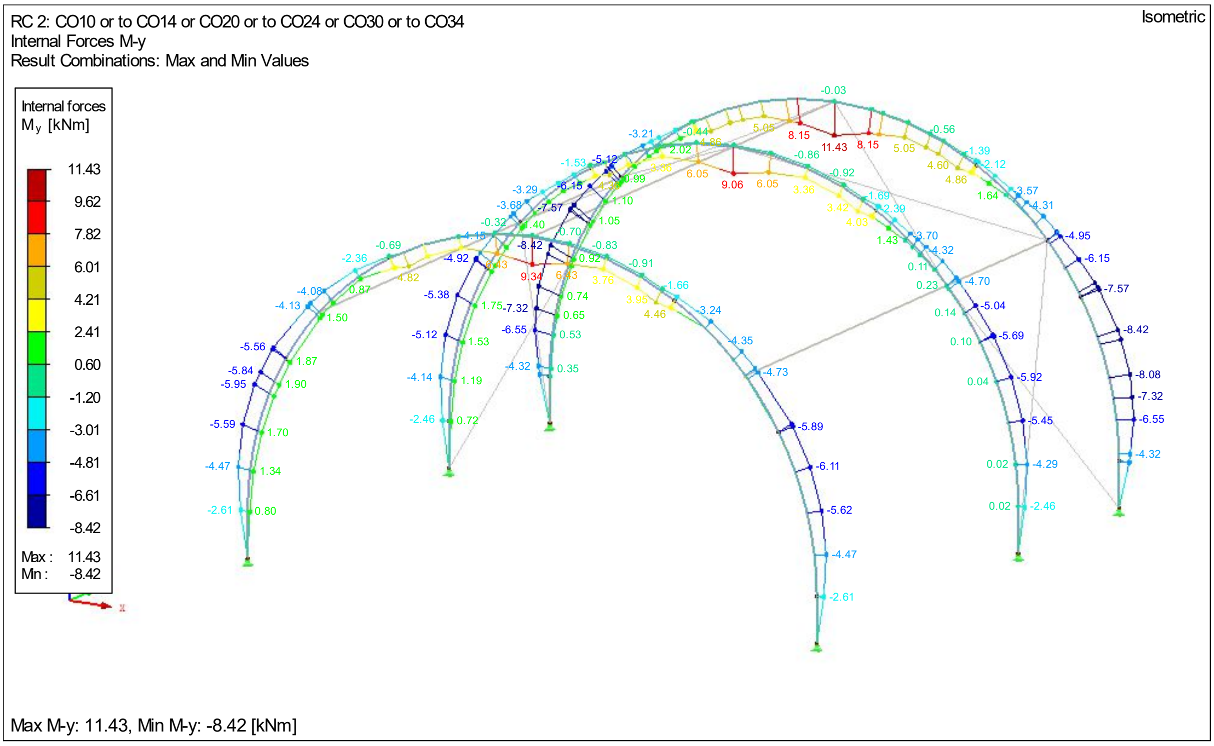
4.1.1 Internal forces RC2 Design Values In-service

Different internal forces for the Protruss S31 in RC2 Design values In-service

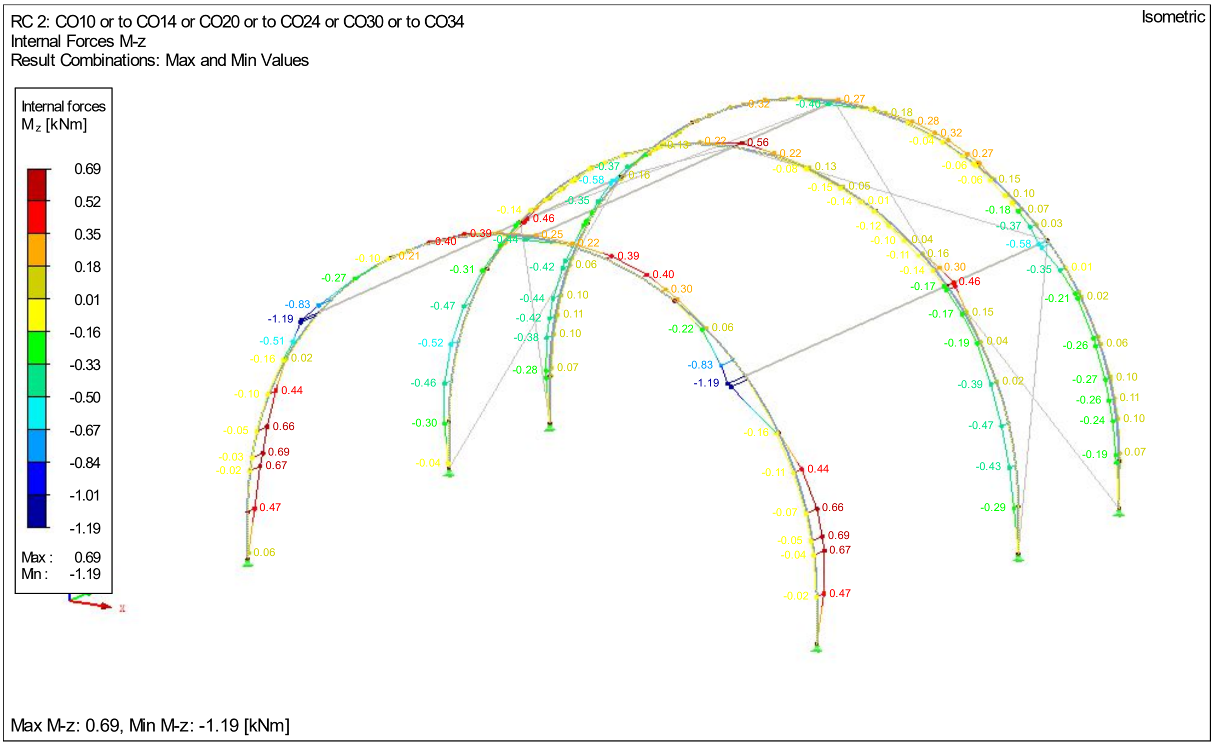



RC 2: CO10 or to CO14 or CO20 or to CO24 or CO30 or to CO34
Internal Forces V-y
Result Combinations: Max and Min Values
Isometric
Internal forces
V_y [kN]
1.93
1.58
1.23
0.88
0.53
0.18
-0.18
-0.53
-0.88
-1.23
-1.58
-1.93
Max : 1.93
Min : -1.93
Max V-y: 1.93, Min V-y: -1.93 [kN]


RC 2: CO10 or to CO14 or CO20 or to CO24 or CO30 or to CO34
Internal Forces V-z
Result Combinations: Max and Min Values
Isometric
Internal forces
V_z [kN]
8.87
7.25
5.64
4.03
2.42
0.81
-0.81
-2.42
-4.03
-5.64
-7.25
-8.87
Max : 8.87
Min : -8.87
Max V-z: 8.87, Min V-z: -8.87 [kN]



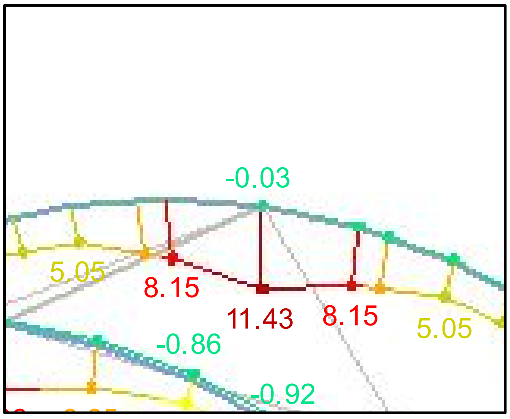
RC 2: CO10 or to CO14 or CO20 or to CO24 or CO30 or to CO34
Internal Forces M-y
Result Combinations: Max and Min Values
Isometric
Internal forces
M_y [kNm]
11.43
9.62
7.82
6.01
4.21
2.41
0.60
-1.20
-3.01
-4.81
-6.61
-8.42
Max : 11.43
Min : -8.42
Max M-y: 11.43, Min M-y: -8.42 [kNm]



RC 2: CO10 or to CO14 or CO20 or to CO24 or CO30 or to CO34
Internal Forces M-z
Result Combinations: Max and Min Values
Isometric
Internal forces
M_z [kNm]
0.69
0.52
0.35
0.18
0.01
-0.16
-0.33
-0.50
-0.67
-0.84
-1.01
-1.19
Max : 0.69
Min : -1.19
Max M-z: 0.69, Min M-z: -1.19 [kNm]

Check of the special Protruss S31 top center with the maximum values of RC2

Decisive truss is truss1 with the backwall.



N_d = 7.98 kN
M_{dy} = 11.43 kN
M_{dz} = 0.40 kN

$N_{d,\ main\ chord} = N_d/4 + M_{dy} / 2 / h + M_{dz} / 2 / h$
$N_{d,\ main\ chord}$ = 7.98 / 4 + 11.43 / 2 / 0.239 + 0.40 / 2 / 0.239
$N_{d,\ main\ chord}$ = 26.74 kN

Check
According to paragraph 4.1 this special Protruss S31 truss has a $N_{Rd,\ main\ chord}$ = 27.14 kN

$\eta = N_{d,\ main\ chord} / N_{Rd,\ main\ chord} < 1$
$\eta = 26.74 / 27.14 = 0.98 < 1$

Check of the special Protruss S31 truss connections with the values of RC2

Interaction between the different Internal forces has been checked in a separate File.

Normative	Forces [kN]			Moments [kNm]		
Load Combination	N	V_y	V_z	M_T	M_y	M_z
CO 33	-20,81	-0,05	2,12	-0,04	-8,08	0,1

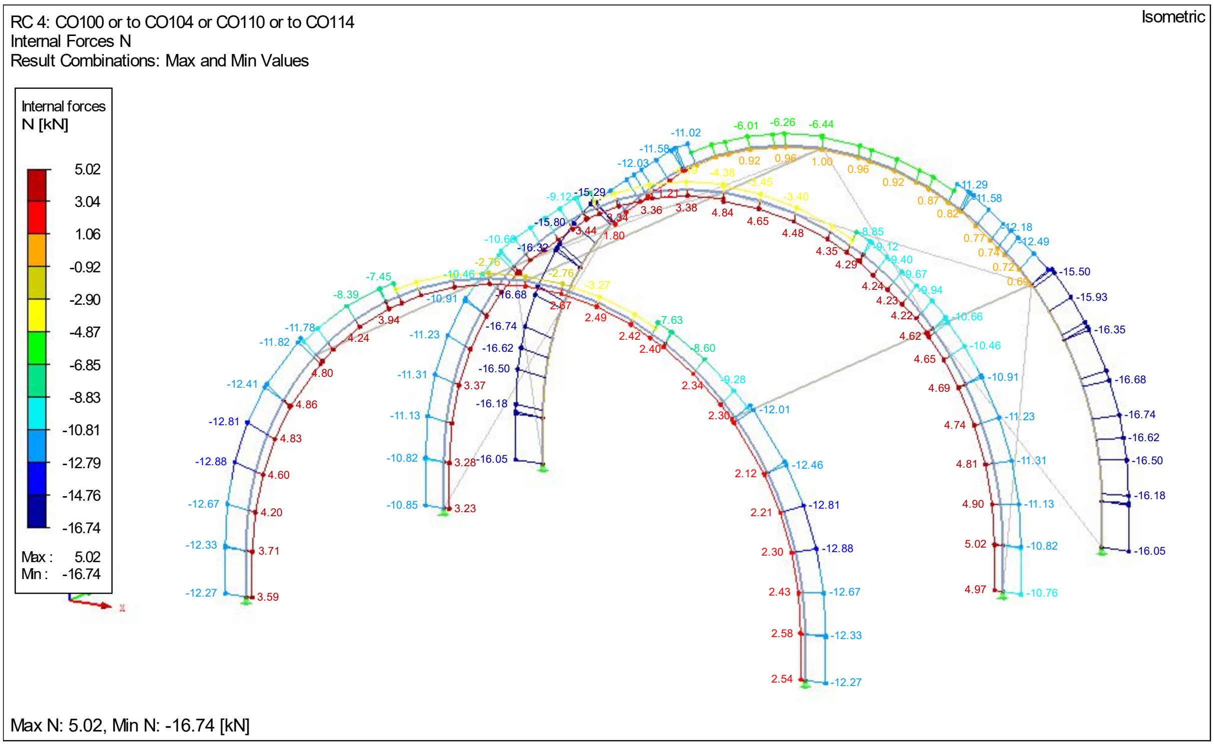
$V_{d, \text{main chord}} = 0.25 * \sqrt{(Vdy^2 + Vdz^2)} = 0.25 * \sqrt{(0.05^2 + 2.12^2)}$
$V_{d, \text{main chord}} = 0.53$ kN
$M_{d, \text{main chord}} = V_{d, \text{main chord}} * e = 0.53 * 5$
$M_{d, \text{main chord}} = 2.65$ kNcm
$N_{d, \text{main chord}} = Nd/4 + Mdy / 2 / h + Mdz / 2 / h$
$N_{d, \text{main chord}} = 20.81 / 4 + 8.08 / 2 / 0.239 + 0.1 / 2 / 0.239$
$N_{d, \text{main chord}} = 22.32$ kN

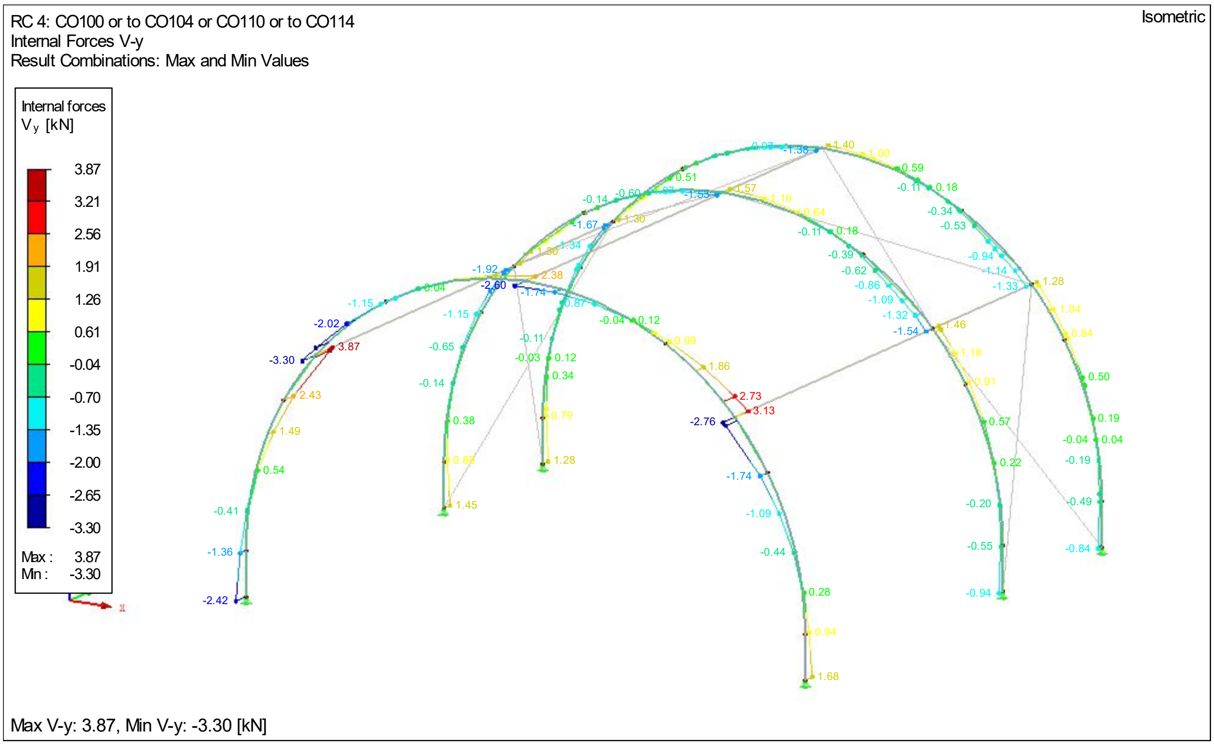
Check
According to paragraph 4.1 this special Protruss S31 truss has a $N_{Rd, \text{main chord}} = 27.14$ kN and the $M_{Rd, \text{main chord}} = 28.75$ kNcm.

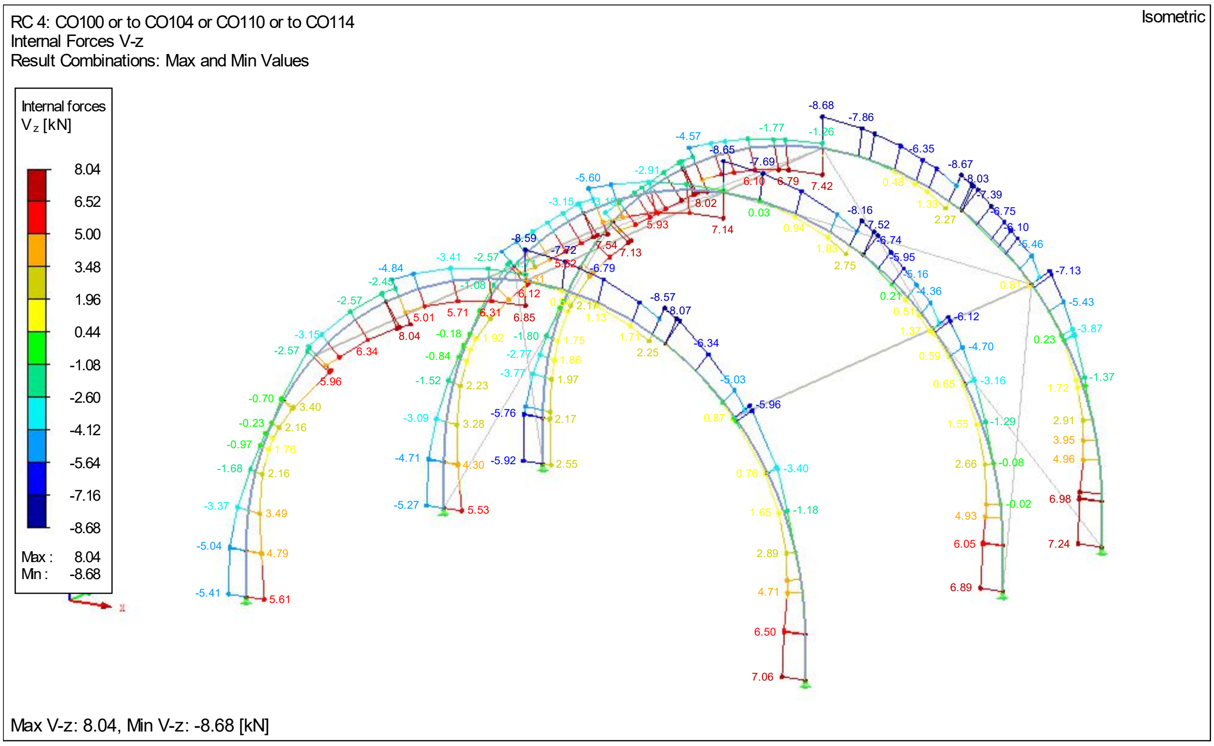
$\eta = (N_{d, \text{main chord}} / N_{Rd})^{1,3} + M_{d, \text{main chord}} / M_{Rd}$
$\eta = (22.32 / 27.14)^{1,3} + ((2.65 / 28.75)^{1.7})^{0.6} = 0.86 < 1$

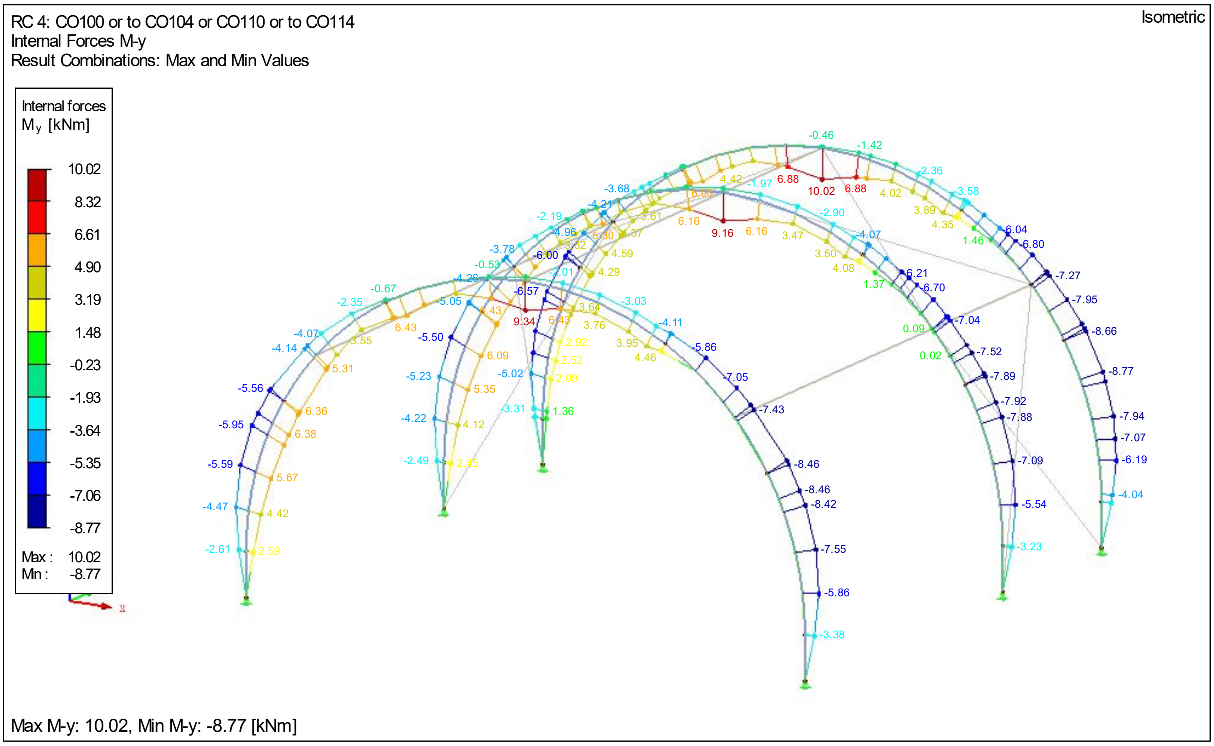
4.1.2 RC4 Design Values Out-service

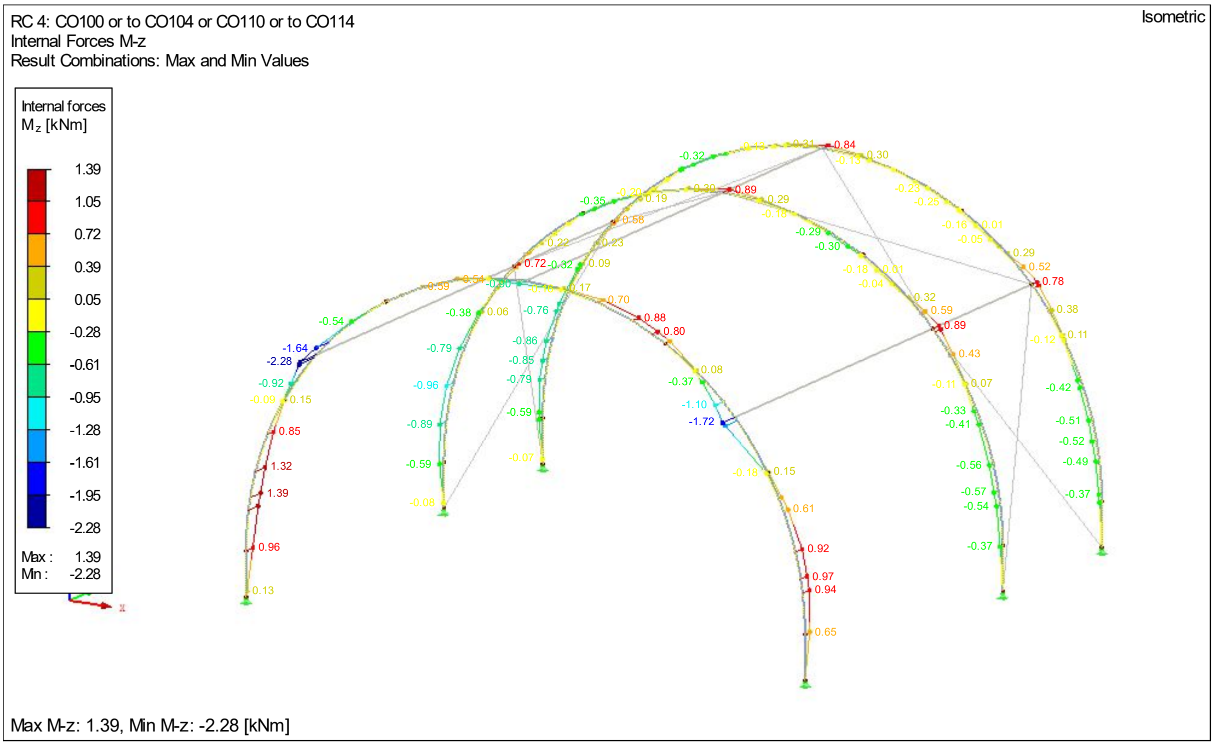
Different internal forces for the keder profile in RC4 Design Values Out-service





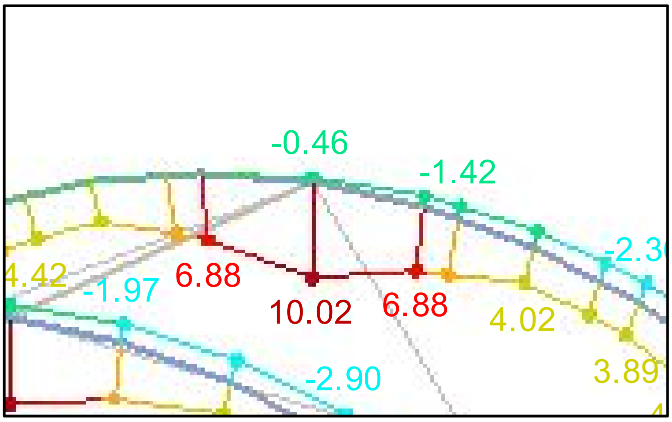

RC 4: CO100 or to CO104 or CO110 or to CO114
Internal Forces V-z
Result Combinations: Max and Min Values
Isometric
Internal forces
Vz [kN]
8.04
6.52
5.00
3.48
1.96
0.44
-1.08
-2.60
-4.12
-5.64
-7.16
-8.68
Max : 8.04
Min : -8.68
Max V-z: 8.04, Min V-z: -8.68 [kN]


RC 4: CO100 or to CO104 or CO110 or to CO114
Internal Forces M-y
Result Combinations: Max and Min Values
Isometric
Internal forces
My [kNm]
10.02
8.32
6.61
4.90
3.19
1.48
-0.23
-1.93
-3.64
-5.35
-7.06
-8.77
Max : 10.02
Min : -8.77
Max M-y: 10.02, Min M-y: -8.77 [kNm]


RC 4: CO100 or to CO104 or CO110 or to CO114
Internal Forces M-z
Result Combinations: Max and Min Values
Isometric
Internal forces
M-z [kNm]
1.39
1.05
0.72
0.39
0.05
-0.28
-0.61
-0.95
-1.28
-1.61
-1.95
-2.28
Max : 1.39
Min : -2.28
Max M-z: 1.39, Min M-z: -2.28 [kNm]

Check of the special Protruss S31 top center with the maximum values of RC4

Decisive truss is truss1 with the backwall.



N_d = 6.44 kN
M_{dy} = 10.02 kN
M_{dz} = 0.84 kN

$N_{d,\ main\ chord} = N_d/4 + M_{dy} / 2 / h + M_{dz} / 2 / h$
$N_{d,\ main\ chord} = 6.44 / 4 + 10.02 / 2 / 0.239 + 0.84 / 2 / 0.239$
$N_{d,\ main\ chord} = 24.33$ kN

Check
According to paragraph 4.1 this special Protruss S31 truss has a $N_{Rd,\ main\ chord} = 27.14$ kN

$\eta = N_{d,\ main\ chord} / N_{Rd,\ main\ chord} < 1$
$\eta = 24.33 / 27.14 = 0.89 < 1$

Check of the special Protruss S31 truss connections with the values of RC4

Interaction between the different Internal forces has been checked in a separate File.

Normative Load Combination	Forces [kN]			Moments [kNm]		
	N	V_y	V_z	M_T	M_y	M_z
CO 113	-9,75	3,03	-3,44	0	-6,92	-1,5

$V_{d,\ main\ chord} = 0.25 * \sqrt{(Vdy^2 + Vdz^2)} = 0.25 * \sqrt{(3.03^2 + 3.44^2)}$
$V_{d,\ main\ chord} = 1.14$ kN
$M_{d,\ main\ chord} = Vd,\ main\ chord * e = 1.14 * 5$
$M_{d,\ main\ chord} = 5.73$ kNcm
$N_{d,\ main\ chord} = Nd/4 + Mdy / 2 / h + Mdz / 2 / h$
$N_{d,\ main\ chord} = 9.75 / 4 + 6.92 / 2 / 0.239 + 1.5 / 2 / 0.239$
$N_{d,\ main\ chord} = 20.05$ kN

Check
According to paragraph 4.1 this special Protruss S31 truss has a $N_{Rd,\ main\ chord} = 27.14$ kN and the $M_{Rd,\ main\ chord} = 28.75$ kNcm.

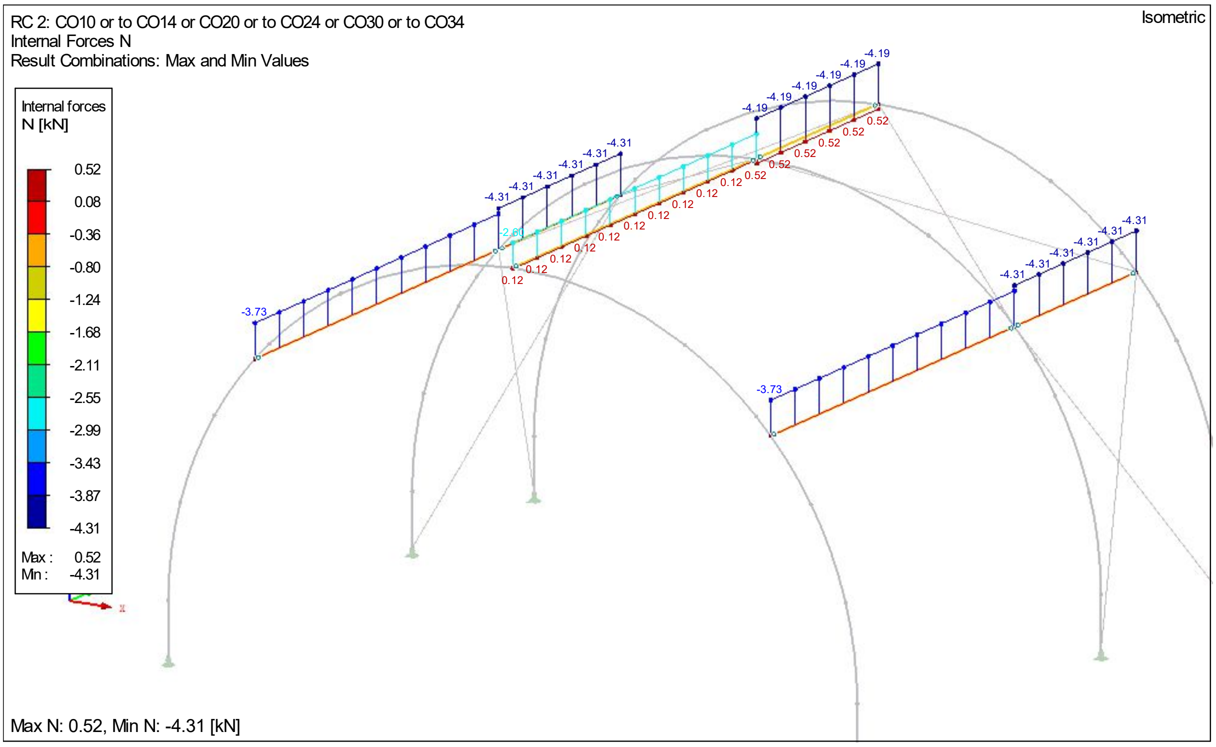
$\eta = (N_{d,\ main\ chord} / N_{Rd})^{1,3} + M_{d,\ main\ chord} / M_{Rd}$
$\eta = (20.05 / 27.14)^{1,3} + ((5.73 / 28.75)^{1.7})^{0.6} = 0.87 < 1$

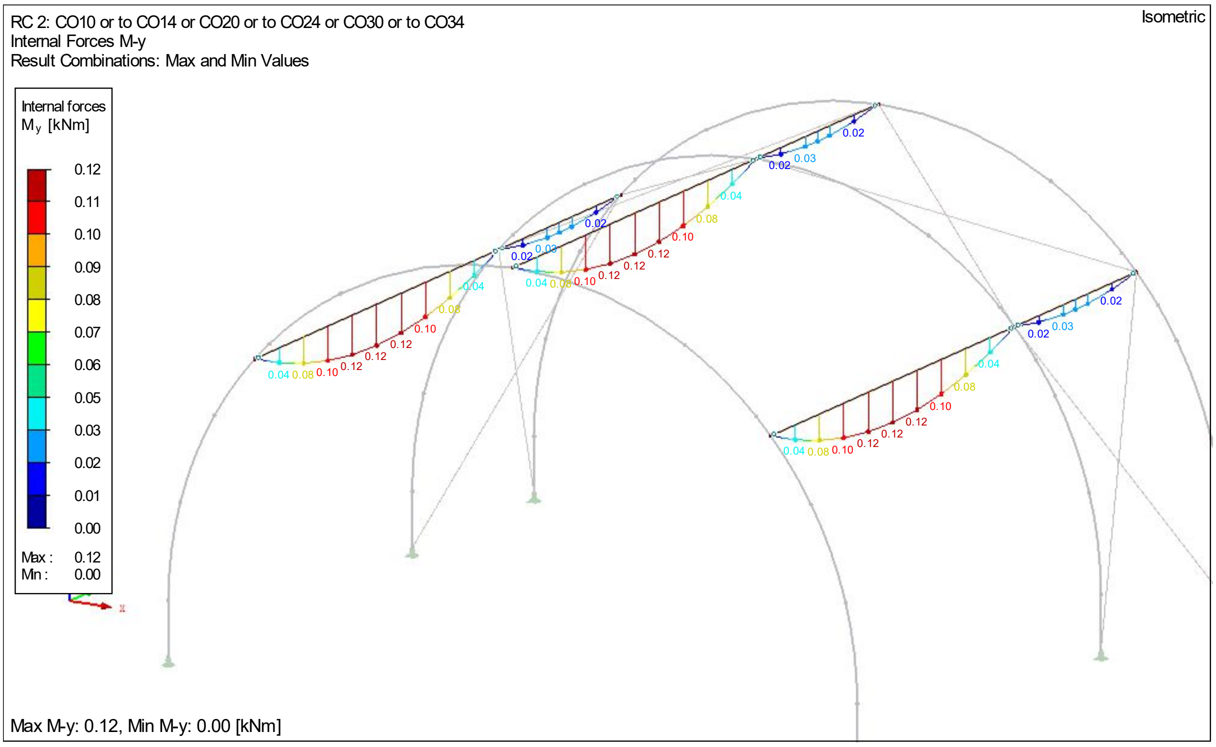
4.2 Detail check of the Protruss T31 Roof truss

The roof trusses are loaded on compression therefor these trusses will be checked on buckling
With the Internal forces of RC2 and RC4

4.2.1 Internal forces RC2 Design Values In-service

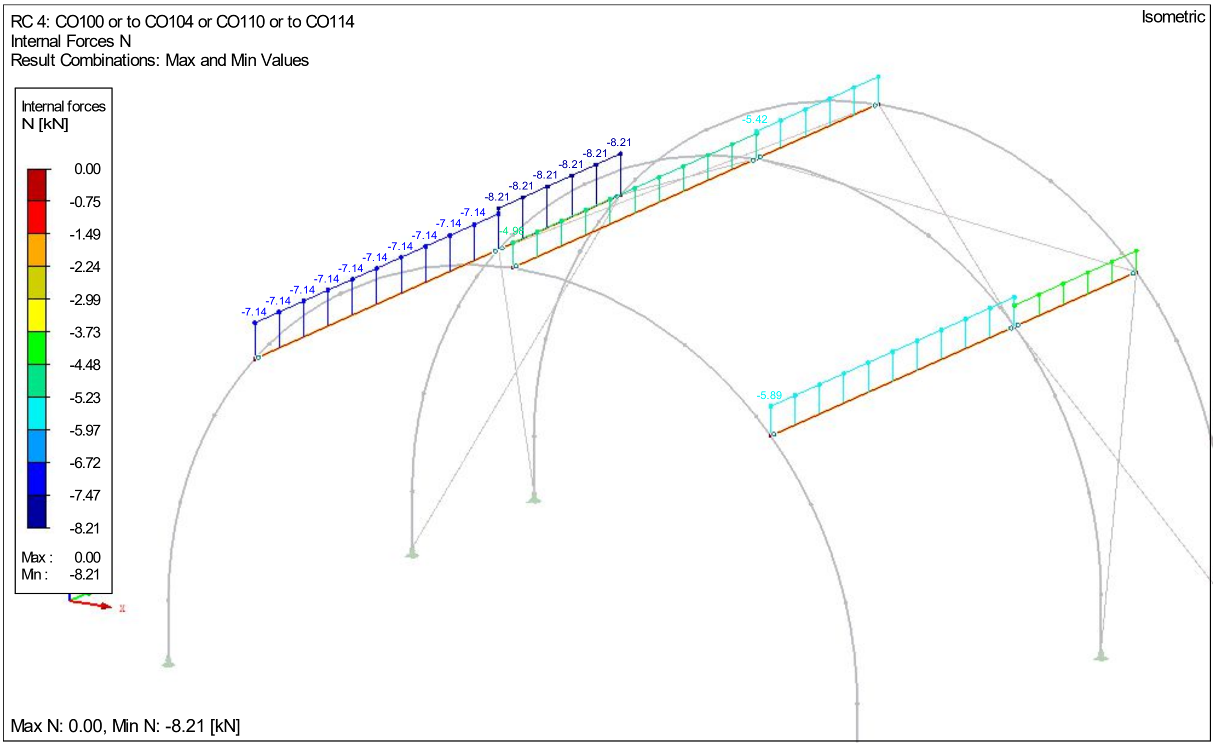
Different internal forces for the Protruss T31 in RC2 Design values In-service

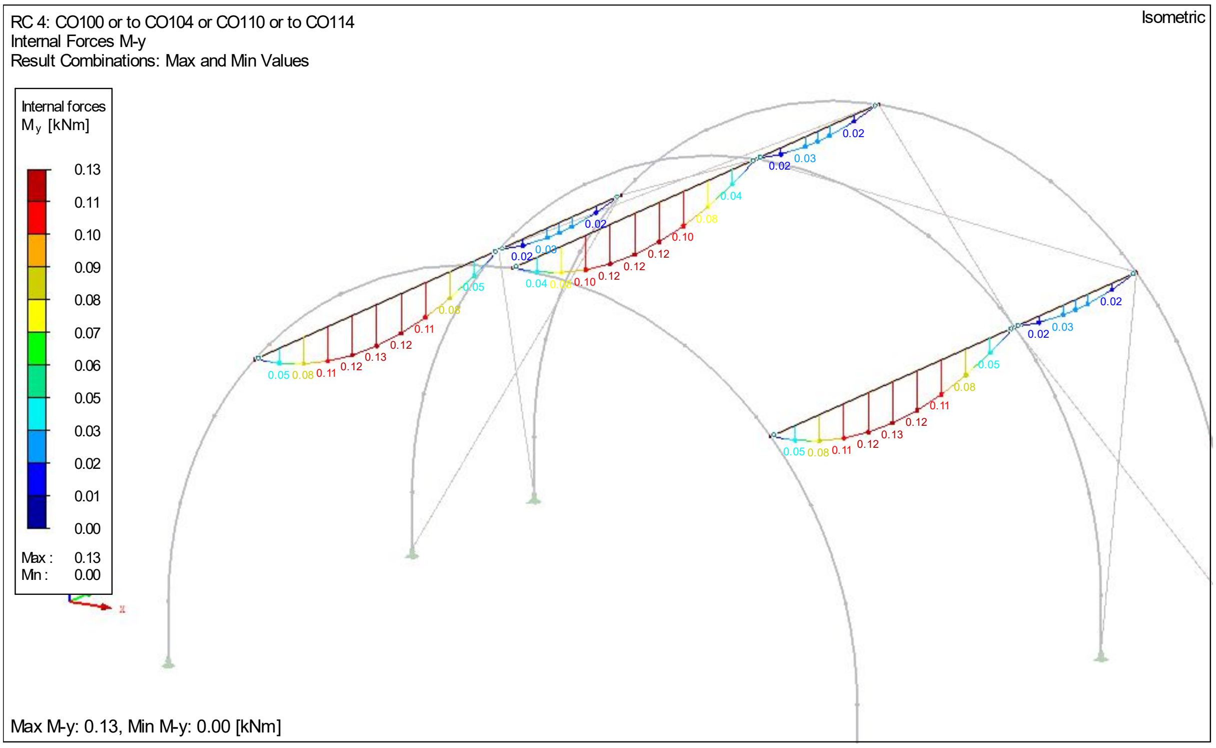




4.2.2 Internal forces RC4 Design Values Out-service

Different internal forces for the Protruss T31 in RC2 Design values In-service





Check of the Protruss S31 Roof truss on buckling in the Out-service situation.

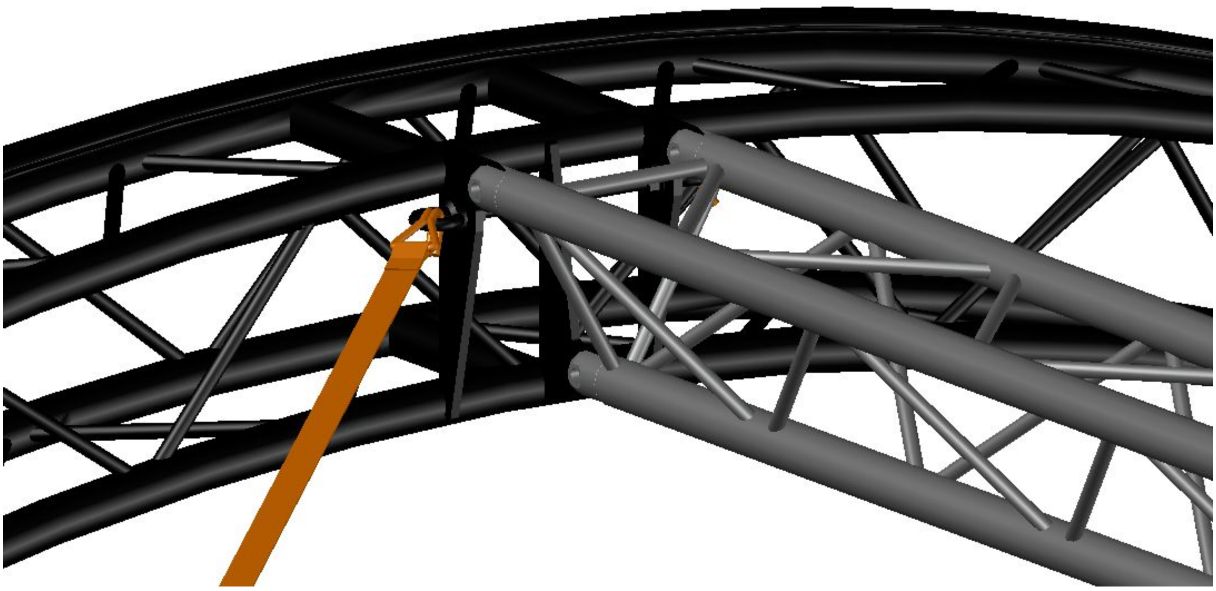
$N =$ 8.21 kN
$M_y =$ 0.13 kNm
$M_z =$ 0 kNm

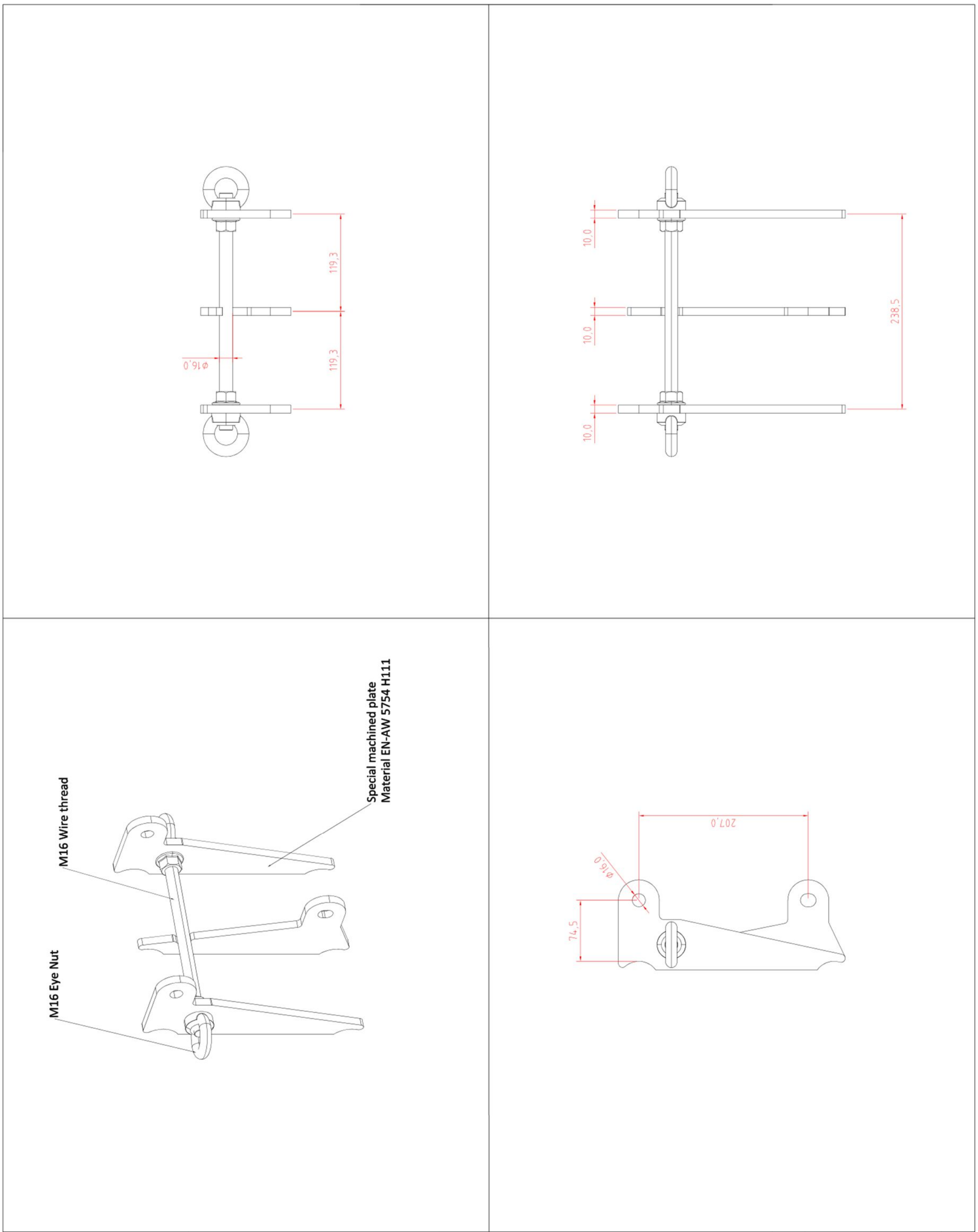
$N_{ED,\ main\ chord} = N / 4 + M_y / 2 / \text{height}_{(centre\ to\ centre)} + M_z / 2 / \text{width}_{(centre\ to\ centre)}$
$N_{ED,\ main\ chord} = 8.21 / 3 + 0.13 / 0.207 + 0 / 0.239 = 3.39\ kN < 50.22\ kN$

Buckling calculation:
Buckling Length factor K = 1 table 6,8 NEN-EN 1999-1-1
$L_{cr} = 1 * 414 = 414$
$\lambda_z = L_{cr} / (i_z * \pi) * (\sqrt{((A_{eff} * f_0) / A * E)})$
$\lambda_z = 414 / (9.89 * \pi) * \sqrt{((12.723 * 25) / (12.723 * 7000))} = 0.79$
$\Theta_z = 0.5 * (1 + \alpha * (\lambda_z - \lambda_0) + \lambda_z^2)$
$\Theta_z = 0.5 * (1 + 0.2 * (0.79 - 0.10) + 0.79^2) = 0.88$
$X_z = 1 / (\Theta_z + \sqrt{(\Theta_z^2 - \lambda_z^2)})$
$X_z = 1 / (0.88 + \sqrt{(0.88^2 - 0.79^2)}) = 0.79$

$(N / (X_z * N_{RD}))^{0.8} + ((M_y / M_{y,RD})^{1,7} + (M_z / M_{z,RD})^{1,7})^{0.6} < 1$
$(8.21 / (0.79 * 150.66))^{0.8} + ((0.13 / 9.48)^{1,7} + (0 / 10.95)^{1,7})^{0.6} = 0.13 < 1$

4.3 Check of T31 Roof truss to the S31 Main arch truss





RAWN BY : IVO MULDER	PROJECT NR : 2017011	REMARKS :	UNIT : MM
ATE : 16-02-2018	CUSTOMER : EEKELS VERHUUR		
EVISION :	STATUS :		

ESCRIPTION :

ROOF TRUSS AND STEEL WIRE ATTACHMENT

A3

Structural Event Engineering

WWW.IM-SEE.COM

Check of the bearing forces in the holes of plate

Plate information

Material	EN-AW 5754 H111
f_u	18 kN/cm²
$f_{u,haz}$	18 kN/cm²

T = 10 mm
D = 16 mm

Maximum normal force in the T31 Roof truss = 8.21 kN

$F_{b, Ed}$ = 8.21 kN / 3 = 2.73 kN
$F_{b, Rd}$ = 1.5 * f_u * D * T / γ_{m2} = 1.5 * 18 * 1.6 * 1 / 1.25 = 34.56 kN
$F_{b, Ed}$ / $F_{b, Rd}$ < 1
2.73 / 34.56 = 0.08 < 1.0

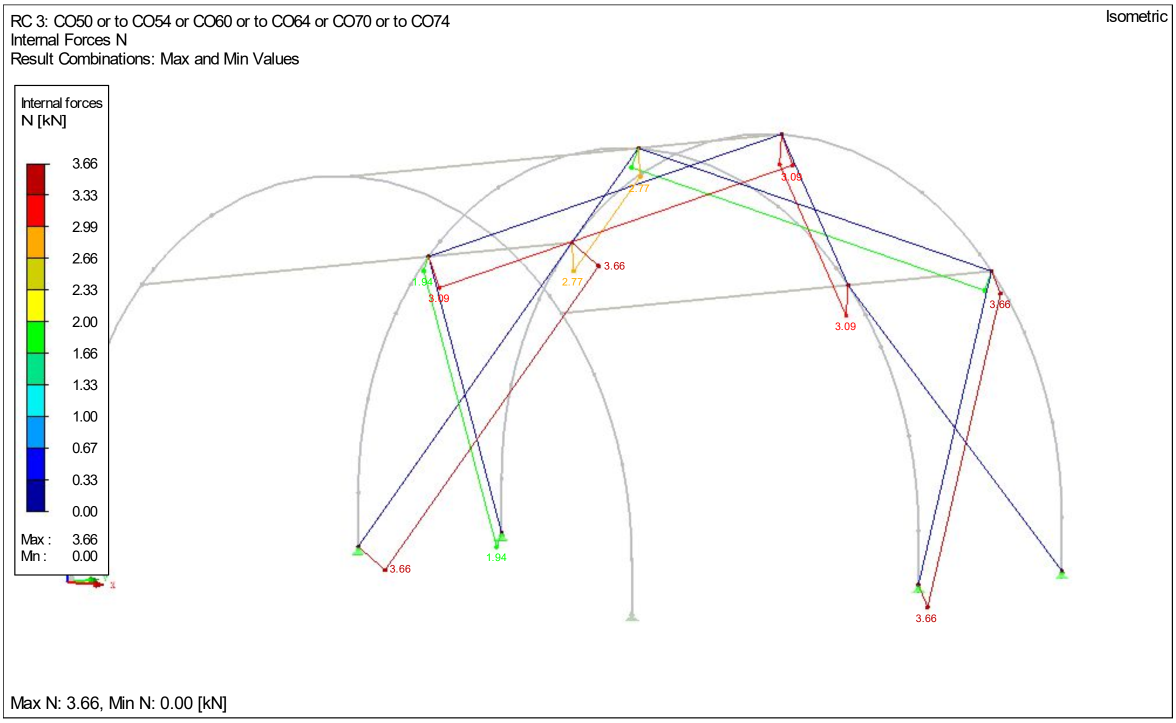
Due to the low maximum normal force the welding of the plate to the main tube and truss pin are not decisive.

4.3 Check of the steel wire’s.

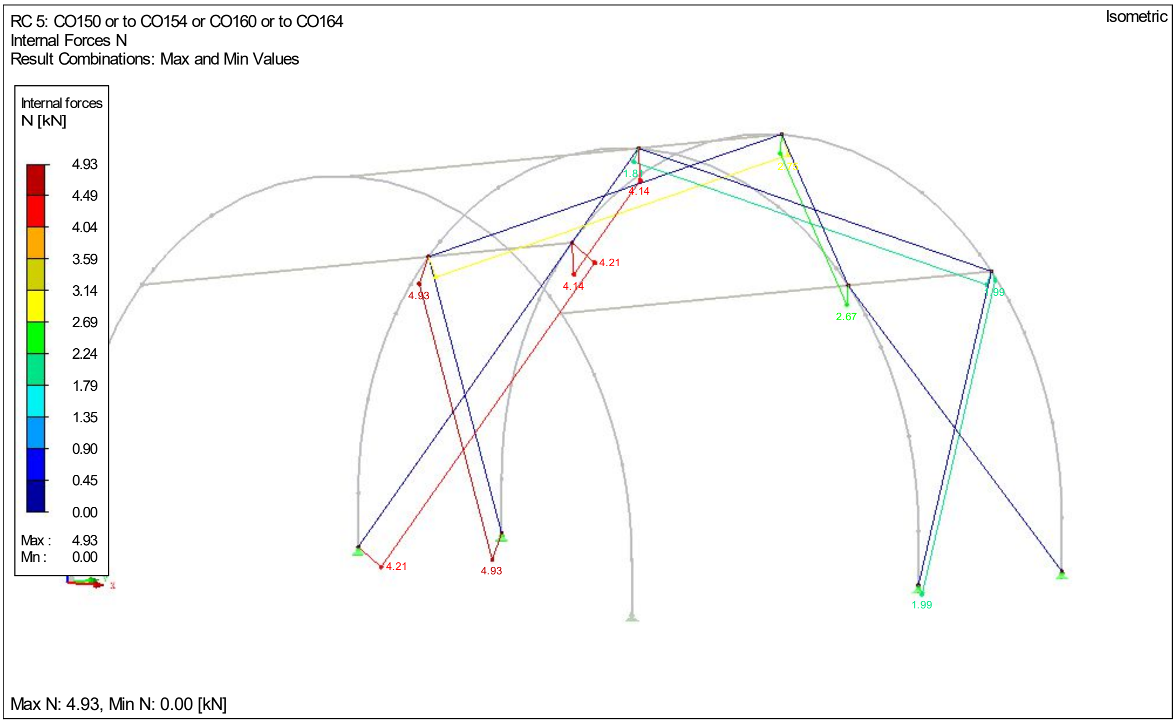
The check of the steel wire’s will be done against the characteristic values of RC3 and RC5. This because the steel wires require different safety factors against breaking strength. The use components for the cross wires are ratchet straps

4.3.1 Internal forces steel wire’s

Maximum normal forces in RC3: characteristic values In service



Maximum normal forces in RC5: characteristic Out service situation.



Maximum steel wire force is 4.93 kN.

For the cross wire is a safety factor required of 3.5.
The minimum breaking strength which is required is 4.93 x 3.5 = 17.25 kN

The used Ratchet strap is a 50mm ratchet strap with a breaking strength of 25 kN

Check 17.25 / 25 = 0.69 < 1

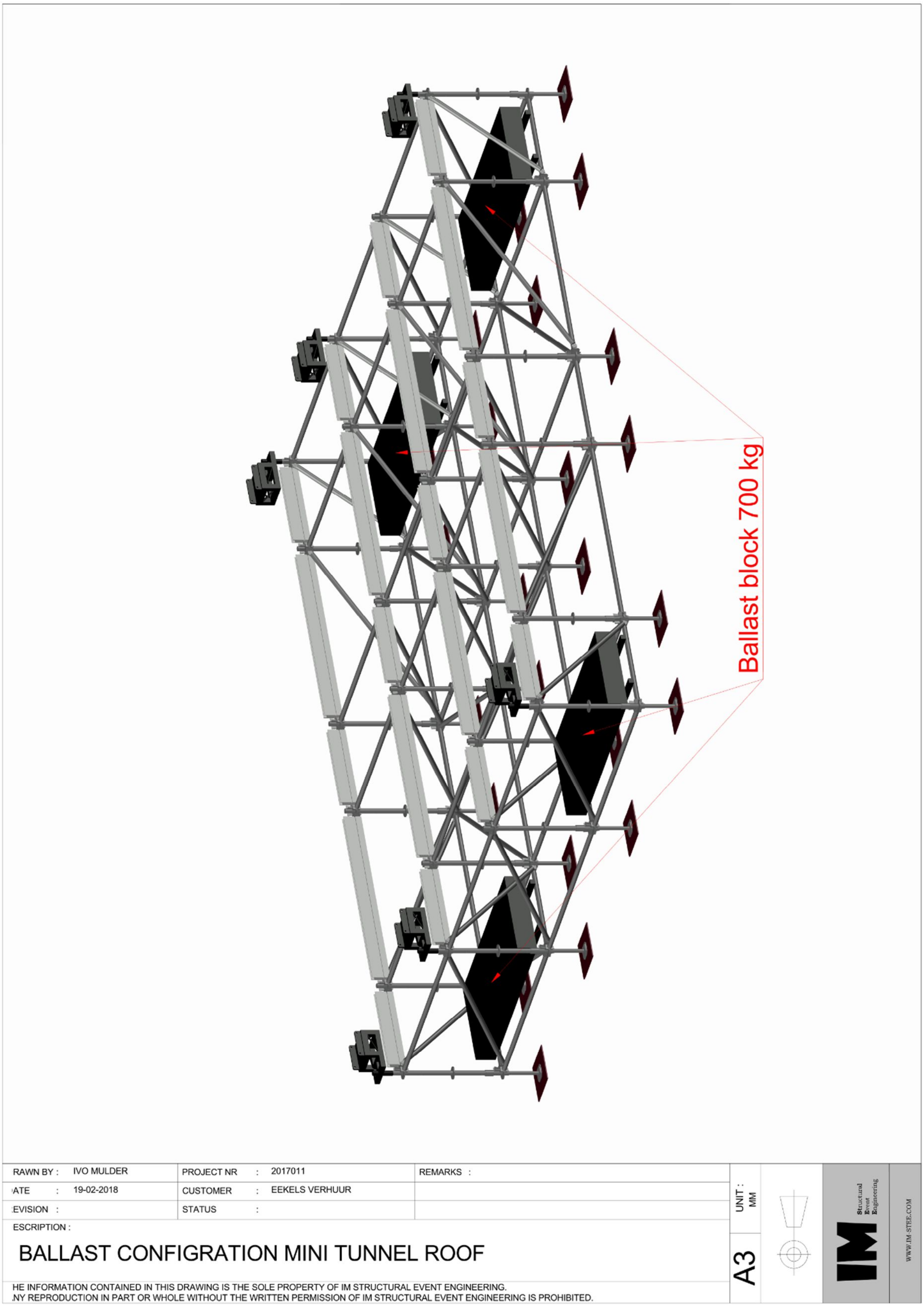
The Ratchet straps can be replaced by any system which is suitable for these purposes.
The minimum required safety factor against breaking strength for these systems is 3.5

The connection of the steel wire to the structure is done by an M16 eye nut which is Bolted to the welded plates.

The minimum required WLL of the M16 Eye nut is 5 kN.

5.0 Necessary Ballast.

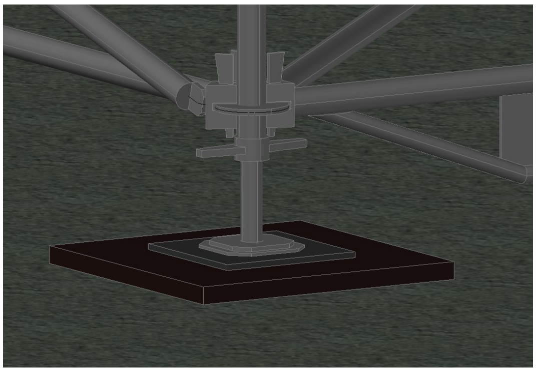
5.1 Ballast drawing.



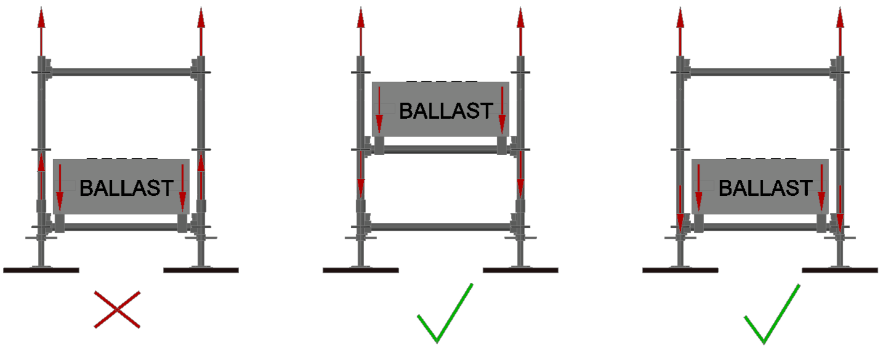
5.2 Ballast calculation.

The ballast will be checked for uplift, overturning and sliding. The Layher stage which is designed as a ridged stage will be taken into account.

The safety factor for the ballast calculation against slipping is set to 1.2 according to the NEN-EN 13814. This is based on a horizontal load which is relying on friction.
For the friction coefficient the factor of 0.6 has been taken into account.
The Ballast calculation with factor 0.6 can be justified because rubber underlayment plate is used.

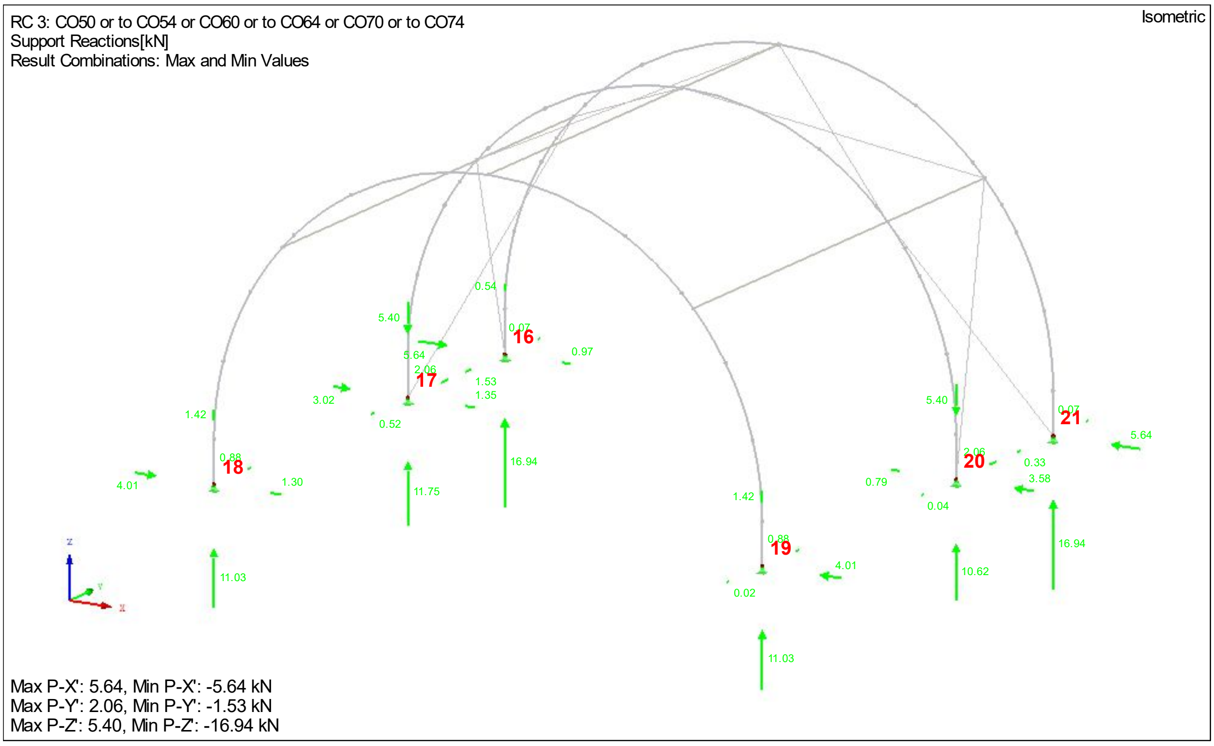


The ballast need to be placed in such a way that it will be activated when lifting forces are applied. If the ballast is placed on the bottom level the use of Layher uprights with connected base collar is necessary.

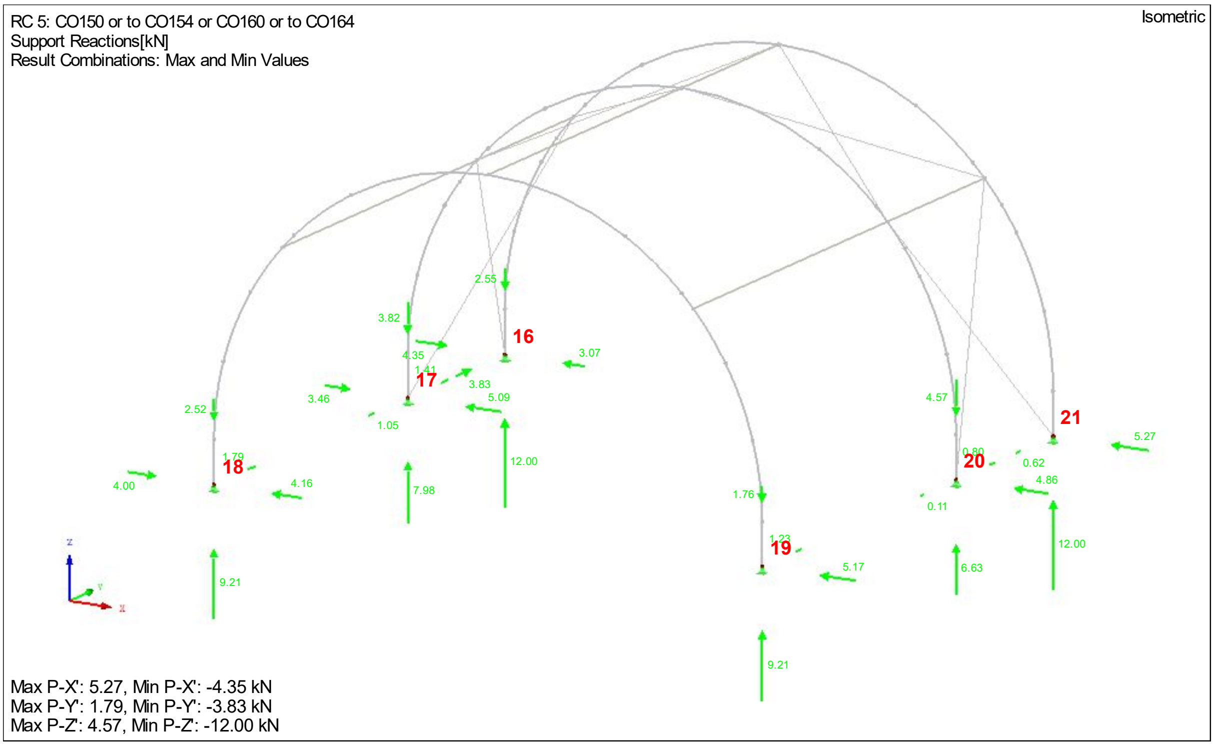


5.3 Ballast against uplift.

Reaction forces RC3 In-service situation



Reaction forces RC5 Out service situation



Maximum and minimum reaction forces in RC3 per support

Node No.		Support Forces [kN]			Support Moments [kNm]		
		$P_{X'}$	$P_{Y'}$	$P_{Z'}$	$M_{X'}$	$M_{Y'}$	$M_{Z'}$
16	Max	0,97	0,07	0,54	0,00	0,00	0,11
	Min	-5,64	-1,53	-16,94	0,00	0,00	0,00
17	Max	1,35	2,06	5,40	0,00	0,00	0,12
	Min	-3,02	-0,52	-11,75	0,00	0,00	0,00
18	Max	1,30	0,88	1,42	0,00	0,00	0,03
	Min	-4,01	0,00	-11,03	0,00	0,00	-0,10
19	Max	4,01	0,88	1,42	0,00	0,00	0,10
	Min	0,00	-0,02	-11,03	0,00	0,00	-0,03
20	Max	3,58	2,06	5,40	0,00	0,00	0,00
	Min	-0,79	-0,04	-10,62	0,00	0,00	-0,09
21	Max	5,64	0,07	0,00	0,00	0,00	0,01
	Min	0,00	-0,33	-16,94	0,00	0,00	-0,07

Maximum and minimum reaction forces in RC5 per support

Node No.		Support Forces [kN]			Support Moments [kNm]		
		$P_{X'}$	$P_{Y'}$	$P_{Z'}$	$M_{X'}$	$M_{Y'}$	$M_{Z'}$
16	Max	3,07	0,00	2,55	0,00	0,00	0,19
	Min	-4,35	-3,83	-12,00	0,00	0,00	0,00
17	Max	5,09	1,41	3,82	0,00	0,00	0,21
	Min	-3,46	-1,05	-7,98	0,00	0,00	0,00
18	Max	4,16	1,79	2,52	0,00	0,00	0,00
	Min	-4,00	0,00	-9,21	0,00	0,00	-0,16
19	Max	5,17	1,23	1,76	0,00	0,00	0,17
	Min	0,00	0,00	-9,21	0,00	0,00	0,00
20	Max	4,86	0,80	4,57	0,00	0,00	0,00
	Min	0,00	-0,11	-6,63	0,00	0,00	-0,09
21	Max	5,27	0,00	0,00	0,00	0,00	0,00
	Min	0,00	-0,62	-12,00	0,00	0,00	-0,08

For the calculation of the ballast against uplift per support point a part of the Layher stage self-weight is taken into account.
The total self-weight of the Layher system is approx. 1824 kg.
The center of the stage will not help against the uplift forces for the separate supports, therefor only 50% of the self-weight is taken into account, which is 912 Kg.
Layher weight per support point = 912 / 6 = 152 kg.

Ballast calculation support 16 and 21
(2.55 – 1.52) * 1.2 = 1.24 kn < 0 Ballast = 124 kg.

Ballast calculation support 17 and 20
(5.40 – 1.52) * 1.2 = 4.66 kn > 0 Ballast = 466 kg.

Ballast calculation support 18 and 19
(2.52 – 1.52) * 1.2 = 1.20 kn < 0 Ballast = 120 kg.

This means a ballast loading on each side of 710 Kg is necessary.

5.4 Calculation of ballast against overturning and slipping.

Description	Value	Unit
CO50 - LC1 + LC10		
Sum of loads in X	0,00	kN
Sum of loads in Y	4,29	kN
Sum of loads in Z	2,75	kN
CO51 - LC1 + LC2 + LC10		
Sum of loads in X	0,00	kN
Sum of loads in Y	4,29	kN
Sum of loads in Z	-45,00	kN
CO52 - LC1 + LC3 + LC10		
Sum of loads in X	0,00	kN
Sum of loads in Y	4,29	kN
Sum of loads in Z	-27,25	kN
CO53 - LC1 + LC4 + LC10		
Sum of loads in X	0,00	kN
Sum of loads in Y	4,29	kN
Sum of loads in Z	-48,25	kN
CO54 - LC1 + LC5 + LC10		
Sum of loads in X	0,00	kN
Sum of loads in Y	4,29	kN
Sum of loads in Z	-60,25	kN
CO60 - LC1 + LC11		
Sum of loads in X	4,22	kN
Sum of loads in Y	-1,41	kN
Sum of loads in Z	-2,30	kN
CO61 - LC1 + LC2 + LC11		
Sum of loads in X	4,22	kN
Sum of loads in Y	-1,41	kN
Sum of loads in Z	-50,04	kN
CO62 - LC1 + LC3 + LC11		
Sum of loads in X	4,22	kN
Sum of loads in Y	-1,41	kN
Sum of loads in Z	-32,30	kN
CO63 - LC1 + LC4 + LC11		
Sum of loads in X	4,22	kN
Sum of loads in Y	-1,41	kN
Sum of loads in Z	-53,30	kN
CO64 - LC1 + LC5 + LC11		
Sum of loads in X	4,22	kN
Sum of loads in Y	-1,41	kN
Sum of loads in Z	-65,30	kN
CO70 - LC1 + LC12		
Sum of loads in X	0,00	kN
Sum of loads in Y	4,28	kN
Sum of loads in Z	-8,69	kN
CO71 - LC1 + LC2 + LC12		
Sum of loads in X	0,00	kN
Sum of loads in Y	4,28	kN
Sum of loads in Z	-56,44	kN
CO72 - LC1 + LC3 + LC12		
Sum of loads in X	0,00	kN
Sum of loads in Y	4,28	kN
Sum of loads in Z	-38,69	kN
CO73 - LC1 + LC4 + LC12		
Sum of loads in X	0,00	kN
Sum of loads in Y	4,28	kN
Sum of loads in Z	-59,69	kN
CO74 - LC1 + LC5 + LC12		
Sum of loads in X	0,00	kN
Sum of loads in Y	4,28	kN
Sum of loads in Z	-71,69	kN

Description	Value	Unit
CO150 - LC1 + LC20		
Sum of loads in X	0,00	kN
Sum of loads in Y	2,87	kN
Sum of loads in Z	7,32	kN
CO151 - LC1 + LC2 + LC20		
Sum of loads in X	0,00	kN
Sum of loads in Y	2,87	kN
Sum of loads in Z	-40,42	kN
CO152 - LC1 + LC3 + LC20		
Sum of loads in X	0,00	kN
Sum of loads in Y	2,87	kN
Sum of loads in Z	-22,68	kN
CO153 - LC1 + LC4 + LC20		
Sum of loads in X	0,00	kN
Sum of loads in Y	2,87	kN
Sum of loads in Z	-43,68	kN
CO154 - LC1 + LC5 + LC20		
Sum of loads in X	0,00	kN
Sum of loads in Y	2,87	kN
Sum of loads in Z	-55,68	kN
CO160 - LC1 + LC21		
Sum of loads in X	16,94	kN
Sum of loads in Y	0,01	kN
Sum of loads in Z	12,32	kN
CO161 - LC1 + LC2 + LC21		
Sum of loads in X	16,94	kN
Sum of loads in Y	0,01	kN
Sum of loads in Z	-35,42	kN
CO162 - LC1 + LC3 + LC21		
Sum of loads in X	16,94	kN
Sum of loads in Y	0,01	kN
Sum of loads in Z	-17,68	kN
CO163 - LC1 + LC4 + LC21		
Sum of loads in X	16,94	kN
Sum of loads in Y	0,01	kN
Sum of loads in Z	-38,68	kN
CO164 - LC1 + LC5 + LC21		
Sum of loads in X	16,94	kN
Sum of loads in Y	0,01	kN
Sum of loads in Z	-50,68	kN

For the calculation of the ballast against overturning and sliding of the system the total self weight of the Layher stage can be taken into account.
The total self weight of the Layher system is approx. 1824 kg.

Decisive load combination CO 160.

5.4.1 Calculation of ballast against overturning.

Check: $M_{stab}/ M_{ov} > 1.2$

Used info for the stability calculation.
Sum of vertical forces = 12.32 kN
Sum of horizontal load = 16.94 kN
Self-weight of the Layher stage = 18.24 kN
(The self-weight of the stage is calculated in chapter 6.)

The center of gravity of the complete system lays on a height of 3.62 meter.

Overturning moment
M_{ov} = 16.94 * 3.62 = 61.32 kNm

Stabilization moment
M_{stab} = (Ballast + Layher self-weight + down force) * width / 2
M_{stab} = (ballast + 18.24 – 12.32) * 7 / 2

M_{stab}/ M_{ov} = ((ballast + 18.24 – 12.32) * 7 / 2) / 61.32 > 1.2
Ballast = ((61.32 *1.2) / 3.5) - 5.92
Ballast = 15.10 kN ~ 750 kg per side.

5.4.2 Calculation of ballast against slipping.

Sum of vertical forces = 12.32 kN
Sum of horizontal load = 16.94 kN
Self-weight of the Layher stage = 18.24 kN
(The self-weight of the stage is calculated in chapter 6.)

Ballast calculation with the friction coefficient 0.6
(ballast + Self-weight) * friction coefficient / wind loading > 1.2
(Ballast per side * 2 + 18.24 -12.32) * 0.6 / 16.94 > 1.2
(16.94 * 1.2) / 0.6 = B * 2 + 5.92
(33.88 – 5.92) / 2 = Ballast per side
Ballast = 13.98 kN ~ 1400 kg per side

6.0 Calculation of the Layher System.

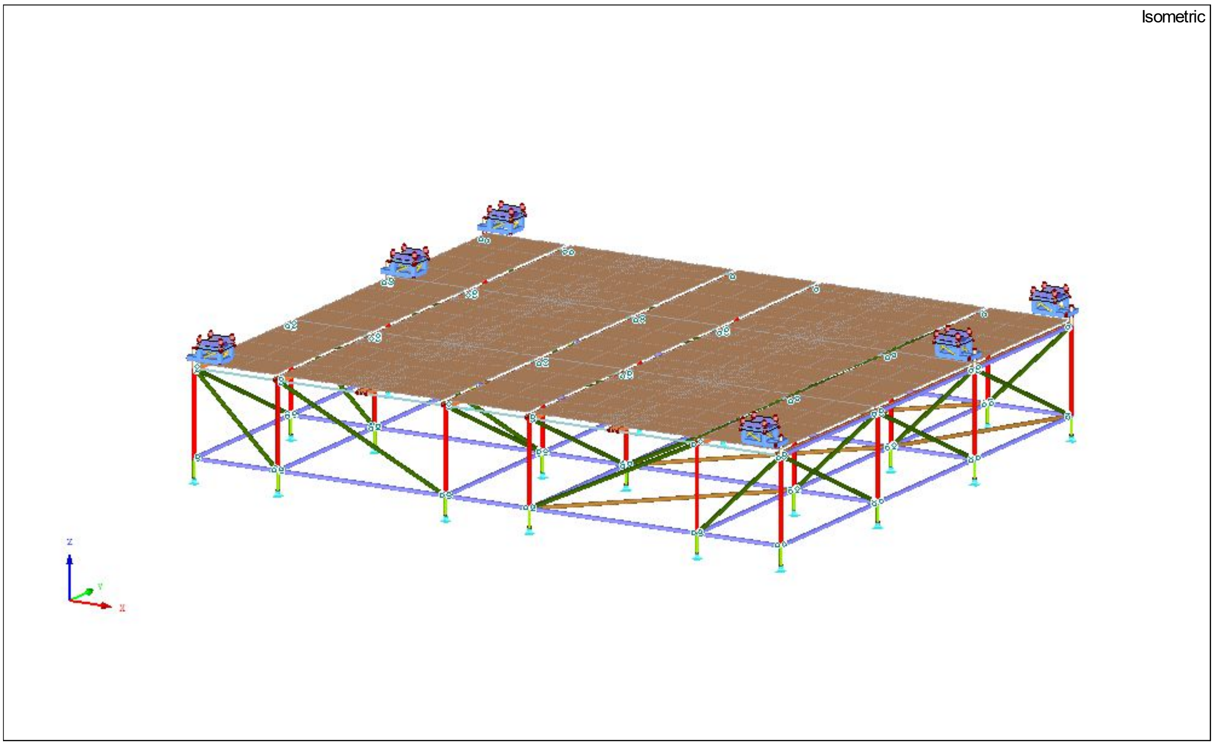
The staging system is built from the Layher scaffolding system. The type of Layher which is used in General is the K2000+ system. All the design figures which are taken into account in this calculation are taken for the K2000+.
For the calculation of the Layher system there are different load combinations calculated. The first 3 are from the In-service situation. The In-service load combinations will be combined with the floor loading. The other two are from the Out-service situation These load case will not be combined with the floor loading while there is nobody allowed on stage in the Out-service situation.
The different reaction forces are taken from the load combinations

- : CO50
- : CO60
- : CO70
- : CO150
- : CO160

6.1 RFem Layher stage Model.

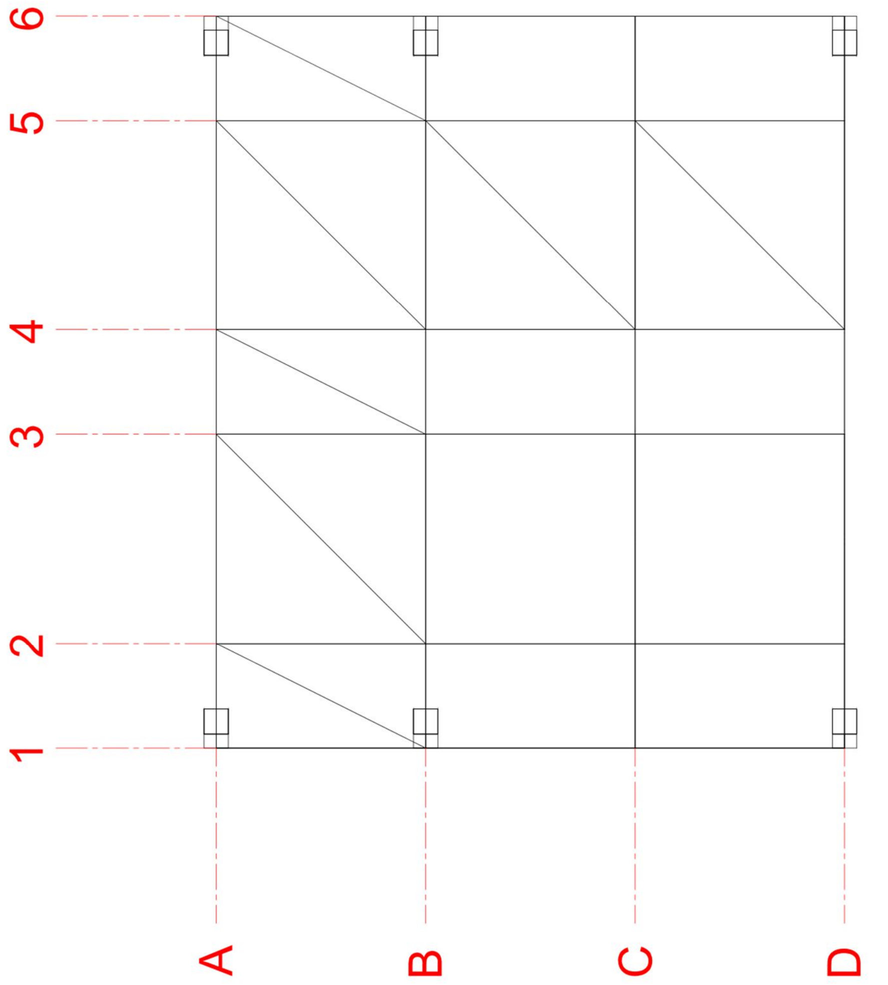
For the Layher stage a separate model is constructed in the RFem program.
In this model the forces of the different load combinations are set as forces on the different node positions. The result calculations will be compared with the Layher design forces as shown in chapter 6.5 Layher Design values.

6.1.1 The Layher construction scheme.

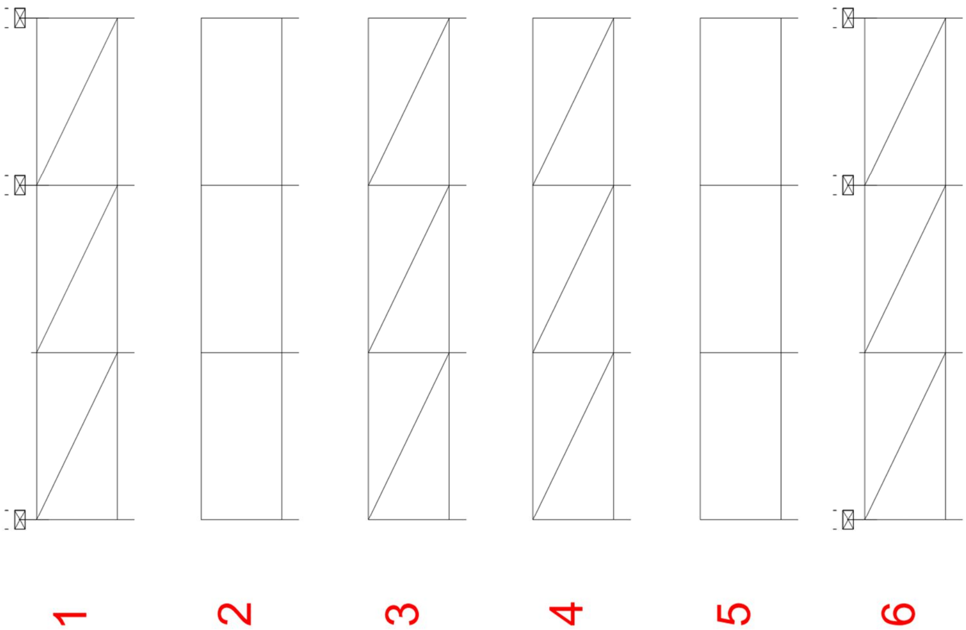


Cross-Sections
- 1: QRO 50x3.2 (Hot Formed); Steel S 235 JR
- 2: Ring 16/2; Steel S 235 JR
- 3: RO 48.3x4.0 (Hot Formed); Steel S 235 JR
- 4: RO 38x4.5 | DIN EN 10220; Steel S 355 JR
- 5: RO 48.3x3.2 (Hot Formed); S320GD 1.0250
- 6: RO 48.3x3.2 (Hot Formed); S320GD 1.0250
- 7: RO 48.3x3.2 (Hot Formed); S320GD 1.0250
- 8: RO 48.3x2.6 (Hot Formed); Steel S 235 JR
- 9: Circle 40; Steel S 355 JR
- 10: EV transom; Aluminum EN-AW 6005A (EP/O,ER/B) T6
- 11: HK 50/30/4/4/4/4; Aluminum EN-AW 6005A (EP/O,ER/B) T6

6.1.2 Layher setup.



DRAWN BY : IVO MULDER	PROJECT NR : 2017011	REMARKS :	UNIT : MM		
DATE : 19-02-2018	CUSTOMER : EEKELS VERHUUR				
REVISION :	STATUS :				
DESCRIPTION : LAYHER STAGE LAYOUT MINI TUNNEL ROOF			A3		WWW.IM-STEE.COM



DRAWN BY : IVO MULDER	PROJECT NR : 2017011	REMARKS :	UNIT : MM
DATE : 19-02-2018	CUSTOMER : EEKELS VERHUUR		
REVISION :	STATUS :		

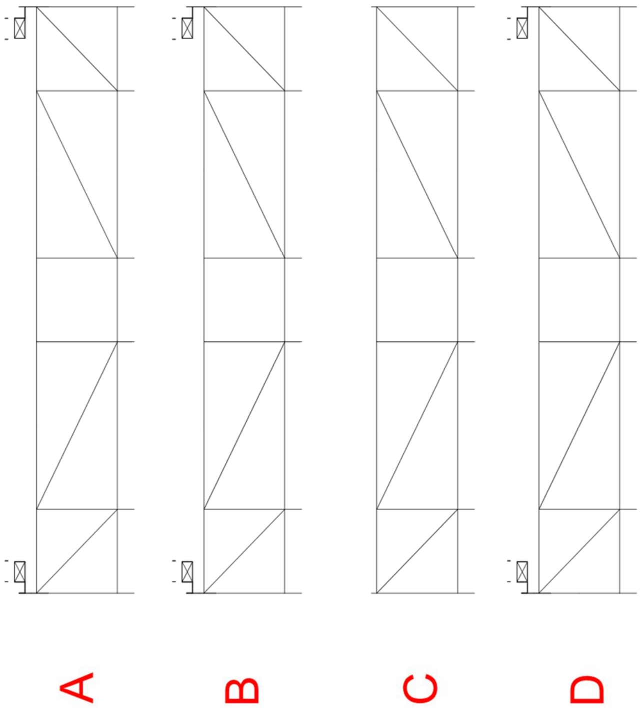
DESCRIPTION :

LAYHER STAGE LAYOUT MINI TUNNEL ROOF

A3

Structural Event Engineering

WWW.IM-STEE.COM



DRAWN BY :	IVO MULDER	PROJECT NR :	2017011	REMARKS :	
DATE :	19-02-2018	CUSTOMER :	EEKELS VERHUUR		
REVISION :		STATUS :			

DESCRIPTION :

LAYHER STAGE LAYOUT MINI TUNNEL ROOF

UNIT : MM

A3

Structural Event Engineering

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6.1.3 used materials.

Material No.	Material Description	Modulus of Elasticity E [kN/cm^2]	Shear Modulus G [kN/cm^2]	Poisson's Ratio • [-]	Specific Weight • [kN/m^3]	Coeff. of Th. Exp. • [1/°C]	Partial Factor • M [-]	Material Model
1	Steel S 235 JR | EN 10025-2:2004-11	21000,00	8076,92	0,300	78,50	1,20E-05	1,000	Isotropic Linear Elastic
2	Steel S 235 JR | EN 10025-2:2004-11	21000,00	8076,92	0,300	78,50	1,20E-05	1,000	Isotropic Linear Elastic
3	S320GD 1.0250 | EN 10346:2009-03	21000,00	8076,92	0,300	78,50	1,20E-05	1,000	Isotropic Linear Elastic
4	Steel S 355 JR | EN 10025-2:2004-11	21000,00	8076,92	0,300	78,50	1,20E-05	1,000	Isotropic Linear Elastic
5	Plywood, Class F20/10 E40/20, Plate Stress, Perpendicular | EN 12369-2:2011-06	200,00	3,50	3,286	5,00	5,00E-06	1,200	Orthotropic Elastic 2D...
6	Aluminum EN-AW 6005A (EP/O,ER/B) T6 | EN 1999-1-1:2007	7000,00	2700,00	0,296	27,00	2,30E-05	1,000	Isotropic Linear Elastic

6.1.4 Used cross sections.

Section No.	Cross-Section Description [mm]	Material No.	Moments of inertia [cm^4] Torsion J	 Bending I_y	 Bending I_z	Cross-Sectional Areas [cm^2] Axial A	 Shear A_y	 Shear A_z	Principal Axes • [°]	Rotation • ' [°]	Overall Dimensions [mm] Width b	 Depth h
1	QRO 50x3.2 (Hot Formed)	1	33,80	21,20	21,20	5,88	2,53	2,53	0,00	0,00	50,0	50,0
2	Ring 16/2	1	0,44	0,22	0,22	0,88	0,45	0,45	0,00	0,00	16,0	16,0
3	RO 48.3x4.0 (Hot Formed)	1	27,50	13,80	13,80	5,57	2,77	2,77	0,00	0,00	48,3	48,3
4	RO 38x4.5 | DIN EN 10220	4	13,53	6,76	6,76	4,74	2,38	2,38	0,00	0,00	38,0	38,0
5	RO 48.3x3.2 (Hot Formed)	3	23,20	11,60	11,60	4,53	2,26	2,26	0,00	0,00	48,3	48,3
6	RO 48.3x3.2 (Hot Formed)	3	23,20	11,60	11,60	4,53	2,26	2,26	0,00	0,00	48,3	48,3
7	RO 48.3x3.2 (Hot Formed)	3	23,20	11,60	11,60	4,53	2,26	2,26	0,00	0,00	48,3	48,3
8	RO 48.3x2.6 (Hot Formed)	2	19,60	9,78	9,78	3,73	1,85	1,85	0,00	0,00	48,3	48,3
9	RO 42.4x3.2 (Hot Formed)	4	15,20	7,62	7,62	3,94	1,96	1,96	0,00	0,00	42,4	42,4
10	EV transom	6	50,00	554,00	70,00	18,78	18,00	18,00	0,00	0,00	49,0	172,5
11	HK 50/30/4/4/4/4	6	16,87	17,67	7,52	5,76	1,62	3,48	0,00	0,00	30,0	50,0

6.1.5 Load cases, load combinations and result combinations.

Load Case	Load Case Description	To Solve	EN 1990 | CEN Action Category	Self-Weight - Factor in Direction Active	 X	 Y	 Z
LC1	Self-weight	+	Permanent	-	0,000	0,000	-1,000
LC2	ballast loading	+	Permanent	-	0,000	0,000	-1,000
LC3	floor loading 0°	+	Permanent/Imposed	-	0,000	0,000	0,000
LC4	floor loading 90°	+	Permanent/Imposed	-	0,000	0,000	0,000
LC5	floor loading 180°	+	Permanent/Imposed	-	0,000	0,000	0,000
LC6	Reaction forces CO50	-	Permanent/Imposed	-	0,000	0,000	0,000
LC7	Reaction forces CO60	-	Permanent/Imposed	-	0,000	0,000	0,000
LC8	Reaction forces CO70	-	Permanent/Imposed	-	0,000	0,000	0,000
LC9	Reaction forces CO150	-	Permanent/Imposed	-	0,000	0,000	0,000
LC10	Reaction forces CO160	-	Permanent/Imposed	-	0,000	0,000	0,000

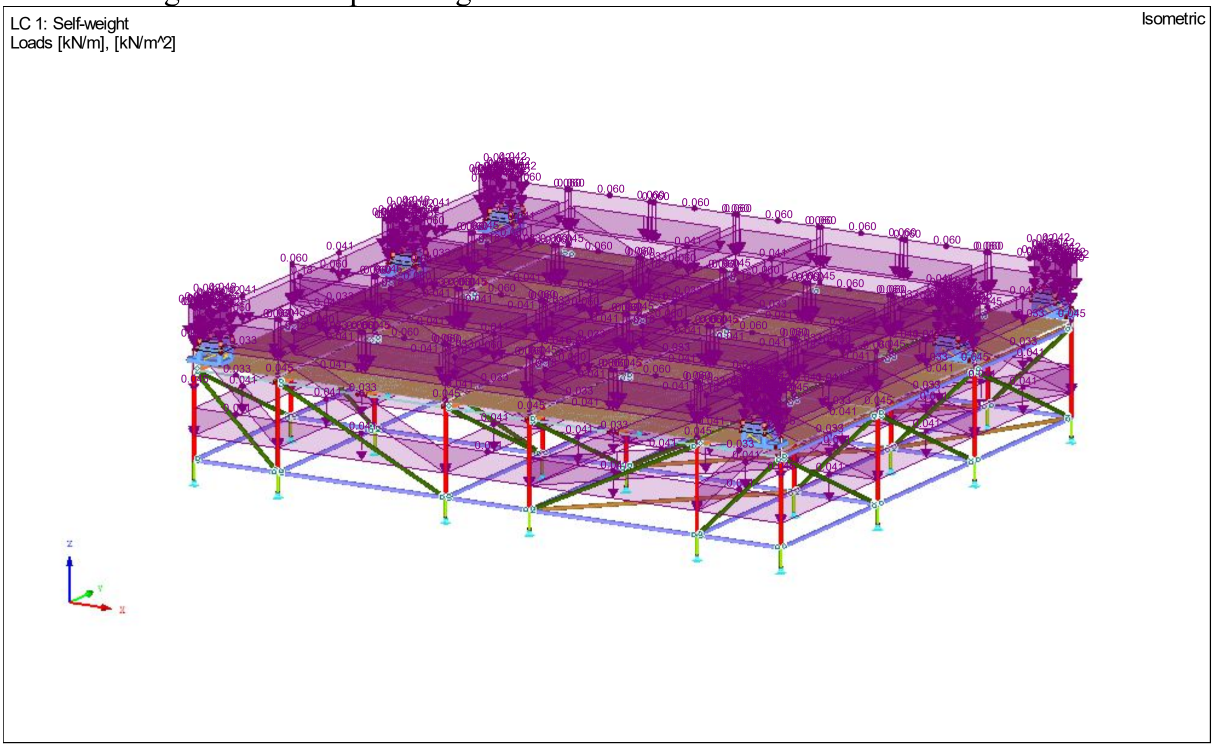
Load Combin.	Load Combination DS	 Description	To Solve	LC.1 Factor	 No.	LC.2 Factor	 No.	LC.3 Factor	 No.	LC.4 Factor	 No.
CO1	0	1.15*LC1 + 1.15*LC2 + 1.35*LC3 + 1.35*LC6	+	1,150	LC1	1,150	LC2	1,350	LC3	1,350	LC6
CO2	0	1.15*LC1 + 1.15*LC2 + 1.35*LC4 + 1.35*LC7	+	1,150	LC1	1,150	LC2	1,350	LC4	1,350	LC7
CO3	0	1.15*LC1 + 1.15*LC2 + 1.35*LC5 + 1.35*LC8	+	1,150	LC1	1,150	LC2	1,350	LC5	1,350	LC8
CO4	0	1.15*LC1 + 1.15*LC2 + 1.35*LC9	+	1,150	LC1	1,150	LC2	1,350	LC9		
CO5	0	1.15*LC1 + 1.15*LC2 + 1.35*LC10	+	1,150	LC1	1,150	LC2	1,350	LC10		
CO50	0	LC1 + LC2 + LC3 + LC6	+	1,000	LC1	1,000	LC2	1,000	LC3	1,000	LC6
CO51	0	LC1 + LC2 + LC4 + LC7	+	1,000	LC1	1,000	LC2	1,000	LC4	1,000	LC7
CO52	0	LC1 + LC2 + LC5 + LC8	+	1,000	LC1	1,000	LC2	1,000	LC5	1,000	LC8
CO53	0	LC1 + LC2 + LC9	+	1,000	LC1	1,000	LC2	1,000	LC9		
CO54	0	LC1 + LC2 + LC10	+	1,000	LC1	1,000	LC2	1,000	LC10		

RC1 –load combinations Design values : 1 * (CO1 or to CO5)
RC2 –load combinations Characteristic values : 1 * (CO50 or to CO54)

6.2 Loading Input.

6.2.1 LC1: Self-weight

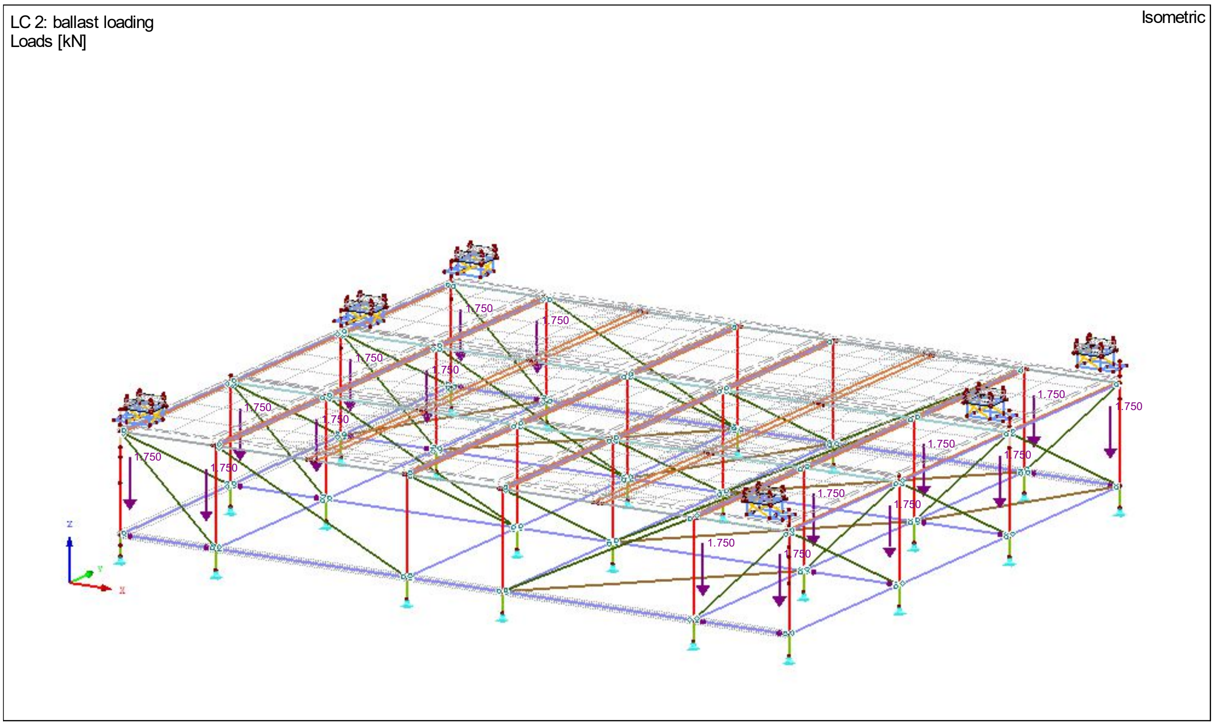
The self-weight of the complete stage



Layher pole = 0.045 kN/m^{-1}
Layher Ledger = 0.041 kN/m^{-1}
Layher Diagonal = 0.033 kN/m^{-1}
Layher Adapter main profile = 0.042 kN/m^{-1}

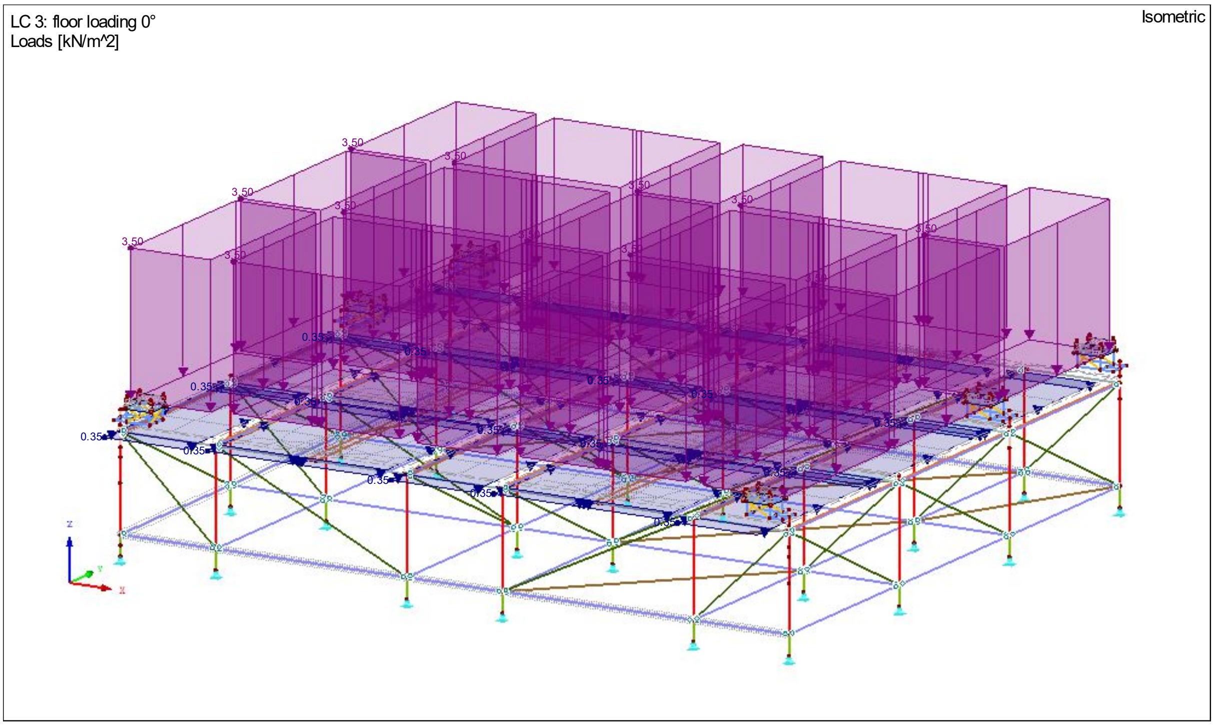
6.2.2 LC2: Ballast loading

The ballast has been set as a separate load case, for the check of the structural integrity of the system.



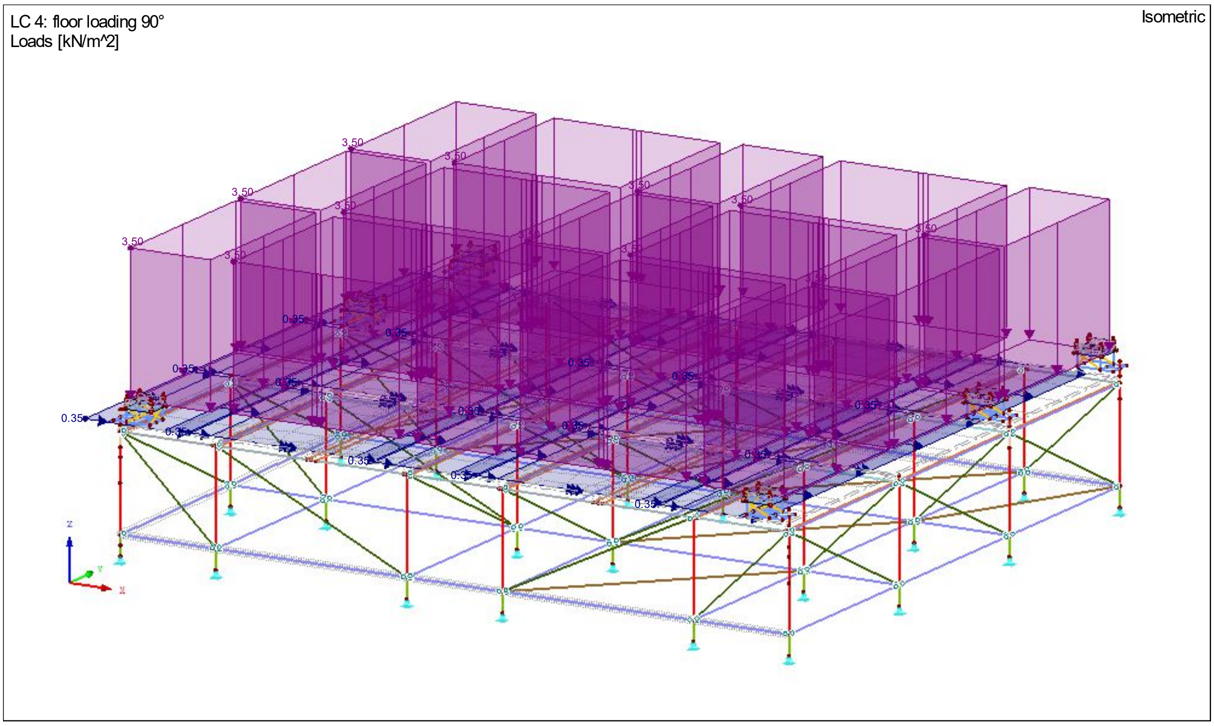
6.2.3 LC3: Floor loading 0°

The floor loading which is taken into account is 350 kg/m² which is according to the NEN-EN 13814.
For the horizontal stability check an extra loading of 10% of the vertical loading is set as an extra horizontal force. This horizontal force has been set in the direction of the wind.



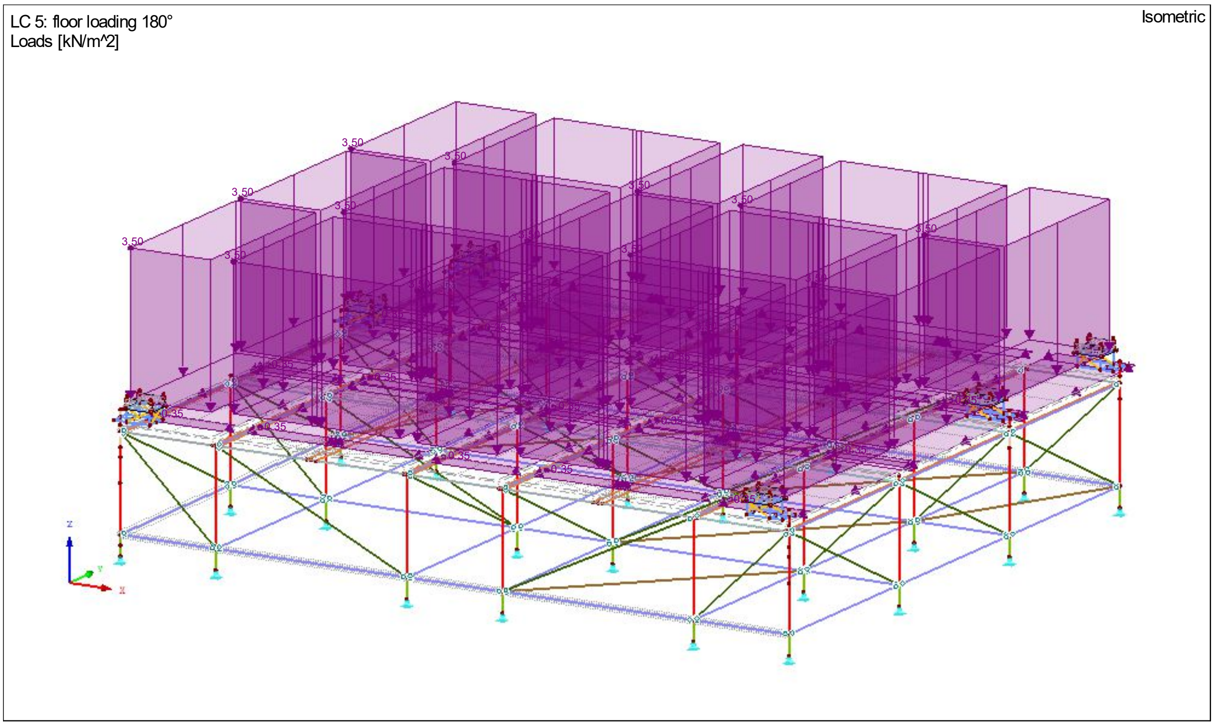
6.2.4 LC4: Floor loading 90°

The floor loading which is taken into account is 350 kg/m² which is according to the NEN-EN 13814.
For the horizontal stability check an extra loading of 10% of the vertical loading is set as an extra horizontal force. This horizontal force has been set in the direction of the wind.



6.2.5 LC5: Floor loading 180°

The floor loading which is taken into account is 350 kg/m² which is according to the NEN-EN 13814.
For the horizontal stability check an extra loading of 10% of the vertical loading is set as an extra horizontal force. This horizontal force has been set in the direction of the wind.

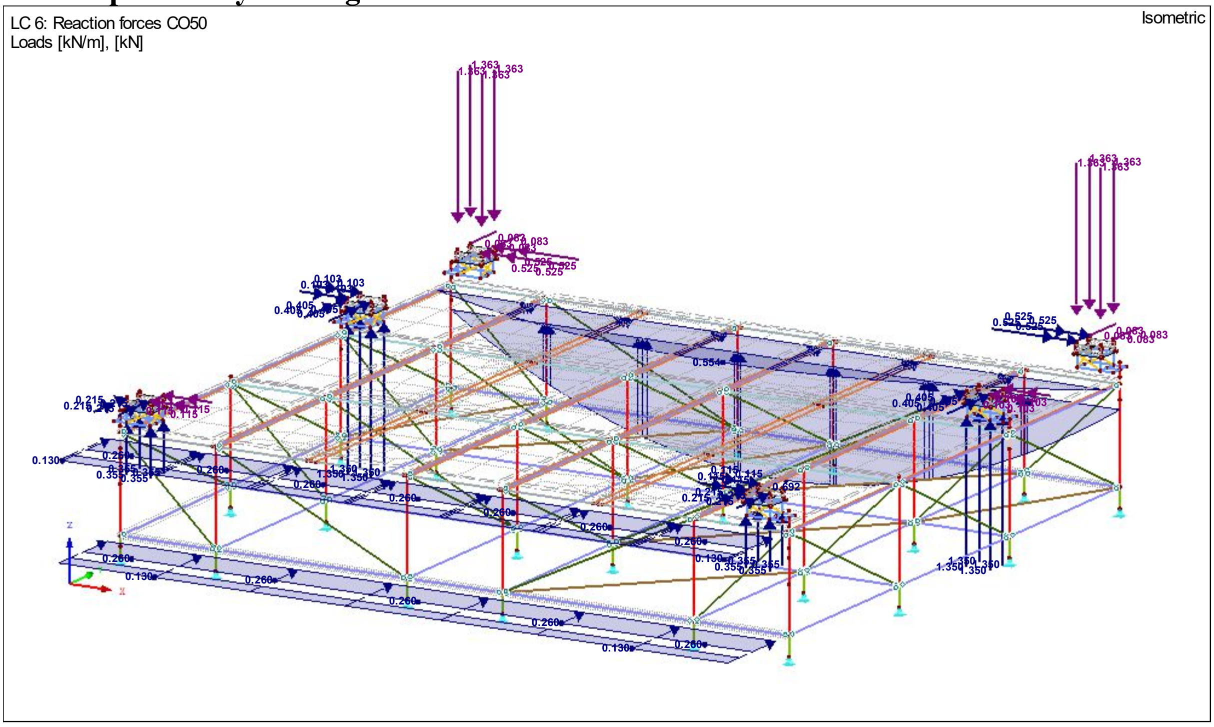


6.2.6 LC6: Reaction forces CO50.

Reaction forces Mini Tunnel roof construction

Node	Support Forces [kN]			Support Moments [kNm]		
No.	$P_{X'}$	$P_{Y'}$	$P_{Z'}$	$M_{X'}$	$M_{Y'}$	$M_{Z'}$
16	-2,10	-0,33	-5,45	0,00	0,00	0,07
17	0,41	1,62	5,40	0,00	0,00	0,09
18	-0,46	0,86	1,42	0,00	0,00	-0,07
19	0,46	0,86	1,42	0,00	0,00	0,07
20	-0,41	1,62	5,40	0,00	0,00	-0,09
21	2,10	-0,33	-5,45	0,00	0,00	-0,07
• Forces	0,00	4,29	2,75			
• Loads	0,00	4,29	2,75			

Load input in Layher stage model.



The loading of the wind on the stage and part of the loading of the wind on the back back wall are added as member loads on the model.

Wind on stage

$q_{w,\ stage} = 1.3 * 0.2 * 1 = 0.260$ kN/m

this is divided on the top and bottom ledger of the stage

Wind on the back-wall canopy.

The round back wall canopy is attached to truss1 and the Layher stage. The load will be divided as a parabolic load on truss1 and the Layher stage.

$q_{w,\ back\ wall\ mid} = 1.3 * 0.2 * 4.26 * 0.5 = 0.554$ kN/m

Membrane tension of the back-wall canopy.

The membrane tension of the round back wall canopy will be divided as a parabolic load on truss1 and the Layher stage.

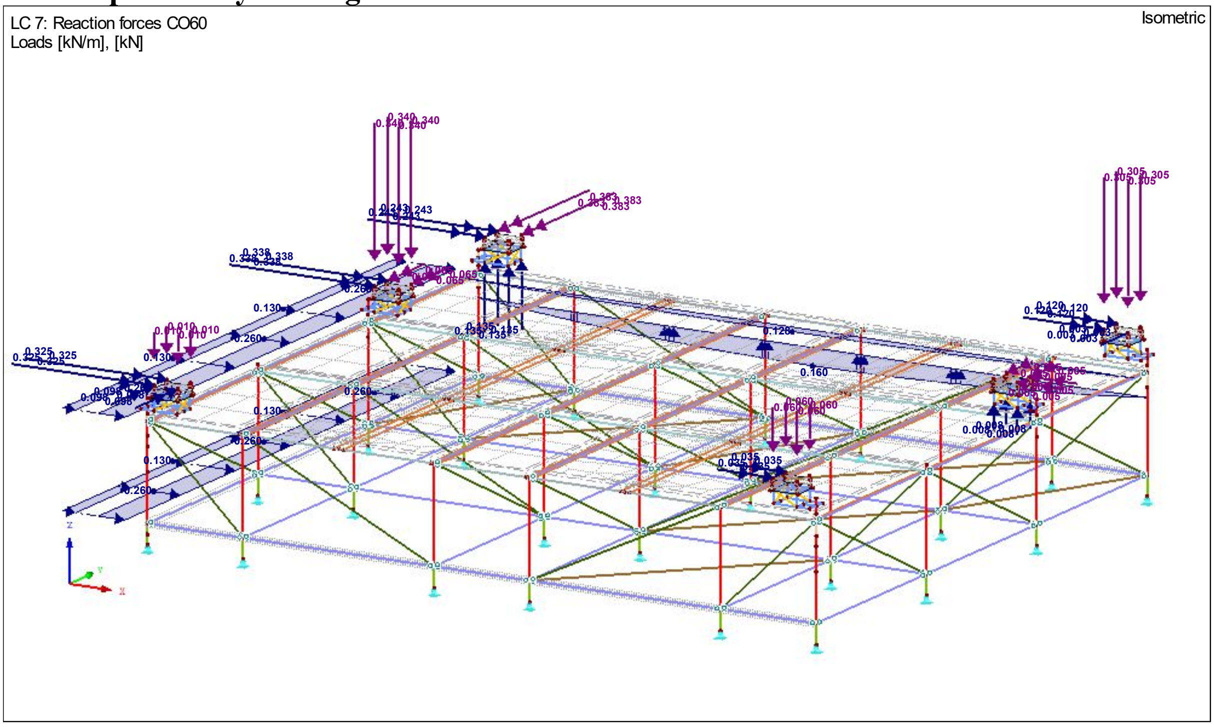
$q_{mt,\ back\ wall\ mid} = 0.554 / 0.8 = 0.692$ kN/m

6.2.7 LC7: Reaction forces CO60.

Reaction forces Mini Tunnel roof construction

Node No.	Support Forces [kN] $P_{X'}$	$P_{Y'}$	$P_{Z'}$	Support Moments [kNm] $M_{X'}$	$M_{Y'}$	$M_{Z'}$
16	0,97	-1,53	0,54	0,00	0,00	0,07
17	1,35	-0,26	-1,36	0,00	0,00	0,08
18	1,30	0,39	-0,04	0,00	0,00	-0,04
19	0,14	0,00	-0,24	0,00	0,00	-0,01
20	-0,02	-0,02	0,03	0,00	0,00	0,00
21	0,48	0,01	-1,22	0,00	0,00	0,01
• Forces	4,22	-1,41	-2,30			
• Loads	4,22	-1,41	-2,30			

Load input in Layher stage model.



The loading of the wind on the stage and part of the loading of the wind on the back back wall are added as member loads on the model.

Wind on stage
$q_{w,\ stage} = 1.3 * 0.2 * 1 = 0.260$ kN/m
this is divided on the top and bottom ledger of the stage

Wind on the back-wall canopy.
The round back wall canopy is attached to truss1 and the Layher stage. The load will be divided as a parabolic load on truss1 and the Layher stage.
$q_{w,\ back\ wall\ mid} = 0.3 * 0.2 * 4.26 * 0.5 = 0.128$ kN/m

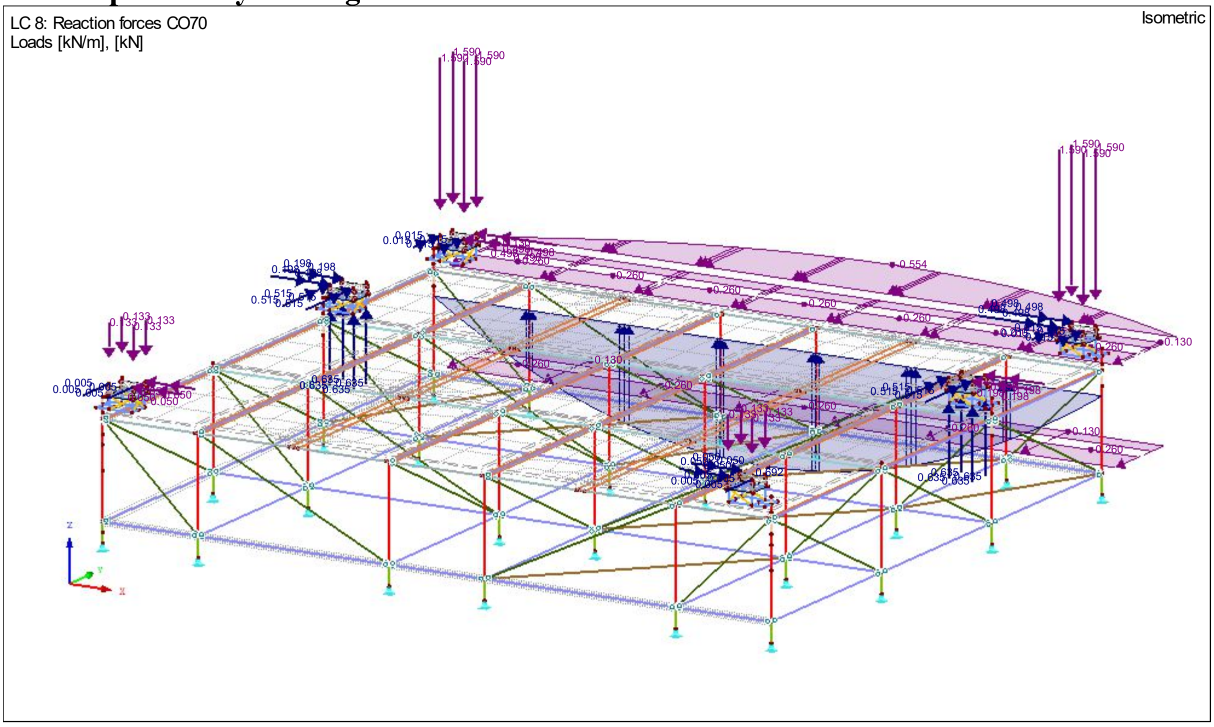
Membrane tension of the back-wall canopy.
The membrane tension of the round back wall canopy will be divided as a parabolic load on truss1 and the Layher stage.
$q_{mt,\ back\ wall\ mid} = 0.128 / 0.8 = 0.160$ kN/m

6.2.8 LC8: Reaction forces CO70.

Reaction forces Mini Tunnel roof construction

Node No.	Support Forces [kN] $P_{X'}$	$P_{Y'}$	$P_{Z'}$	Support Moments [kNm] $M_{X'}$	$M_{Y'}$	$M_{Z'}$
16	-1,99	0,06	-6,36	0,00	0,00	0,03
17	0,79	2,06	2,54	0,00	0,00	0,04
18	-0,20	0,02	-0,53	0,00	0,00	0,03
19	0,20	0,02	-0,53	0,00	0,00	-0,03
20	-0,79	2,06	2,54	0,00	0,00	-0,04
21	1,99	0,06	-6,36	0,00	0,00	-0,03
• Forces	0,00	4,28	-8,69			
• Loads	0,00	4,28	-8,69			

Load input in Layher stage model.



The loading of the wind on the stage and part of the loading of the wind on the back back wall are added as member loads on the model.

Wind on stage

$q_{w,\ stage} = 1.3 * 0.2 * 1 = 0.260$ kN/m

this is divided on the top and bottom ledger of the stage

Wind on the back-wall canopy.

The round back wall canopy is attached to truss1 and the Layher stage. The load will be divided as a parabolic load on truss1 and the Layher stage.

$q_{w,\ back\ wall\ mid} = 1.3 * 0.2 * 4.26 * 0.5 = 0.554$ kN/m

Membrane tension of the back-wall canopy.

The membrane tension of the round back wall canopy will be divided as a parabolic load on truss1 and the Layher stage.

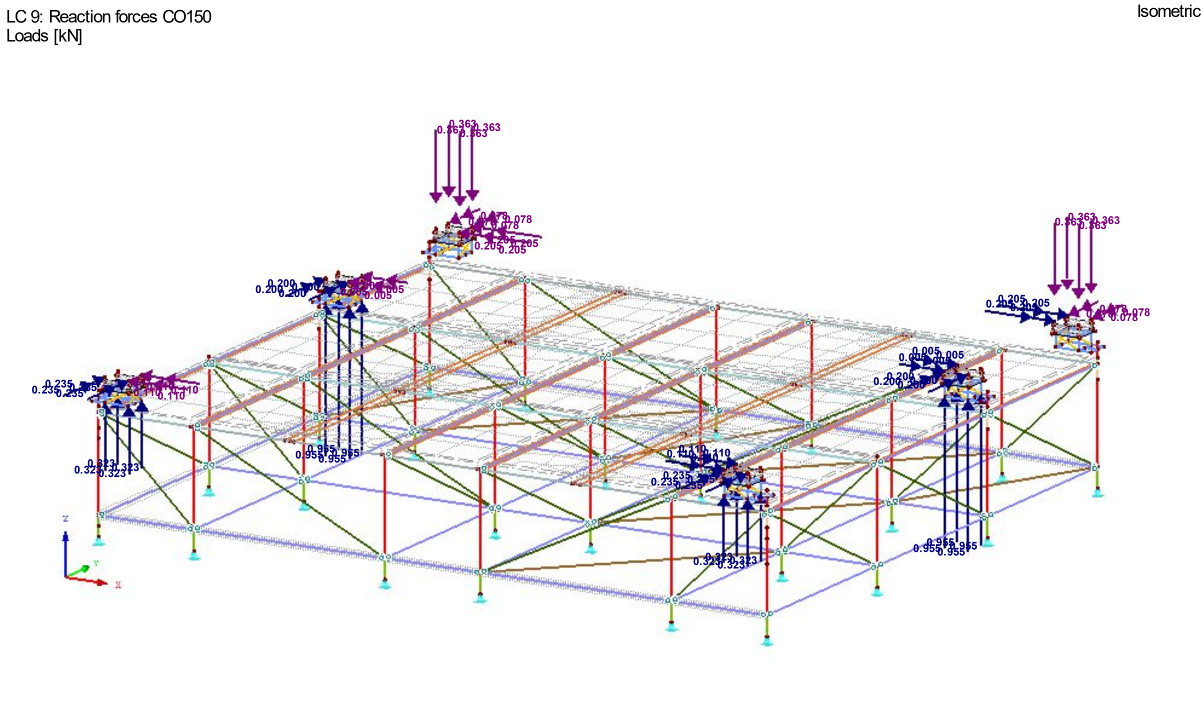
$q_{mt,\ back\ wall\ mid} = 0.554 / 0.8 = 0.692$ kN/m

6.2.9 LC9: Reaction forces CO150.

Reaction forces Mini Tunnel roof construction

Node	Support Forces [kN]			Support Moments [kNm]		
No.	$P_{X'}$	$P_{Y'}$	$P_{Z'}$	$M_{X'}$	$M_{Y'}$	$M_{Z'}$
16	-0,82	-0,31	-1,45	0,00	0,00	0,04
17	-0,02	0,80	3,82	0,00	0,00	0,04
18	-0,44	0,94	1,29	0,00	0,00	-0,11
19	0,44	0,94	1,29	0,00	0,00	0,11
20	0,02	0,80	3,82	0,00	0,00	-0,04
21	0,82	-0,31	-1,45	0,00	0,00	-0,04
• Forces	0,00	2,87	7,32			
• Loads	0,00	2,87	7,32			

Load input in Layher stage model.



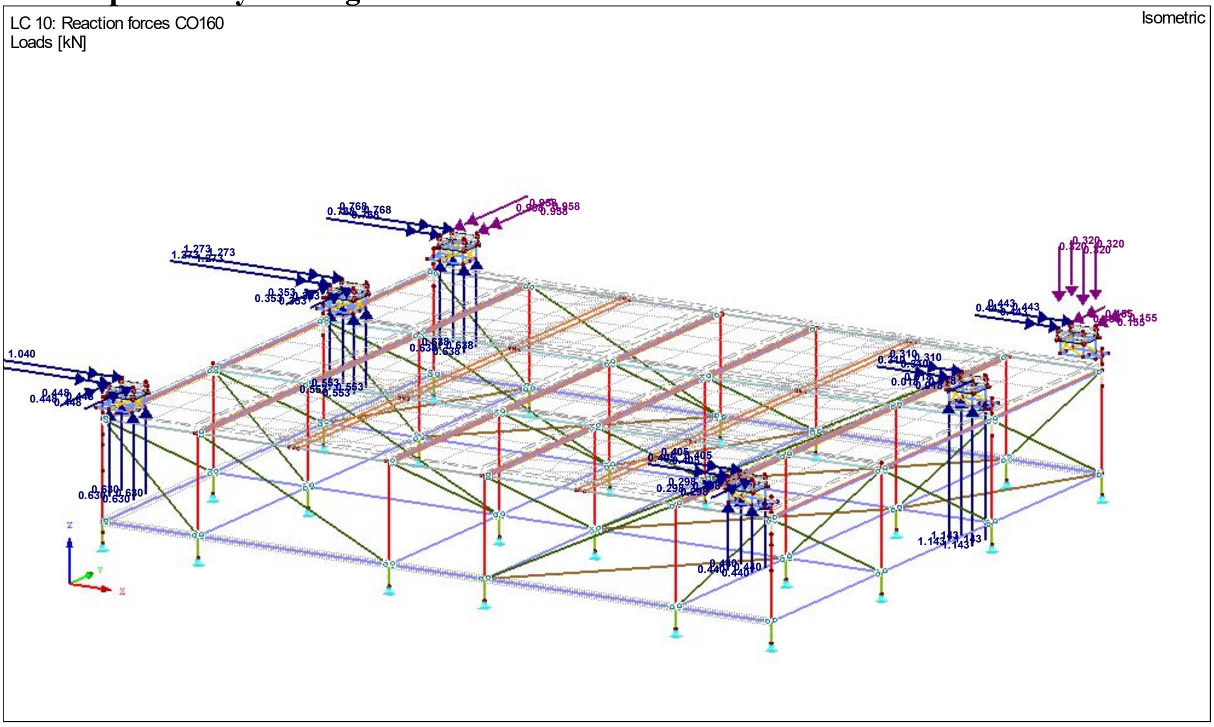
During the Out service situation, the back wall and the stage scrim need to be removed therefor no extra loading will be added to the model.

6.2.10 LC10: Reaction forces CO160.

Reaction forces Mini Tunnel roof construction

Node No.	Support Forces [kN]			Support Moments [kNm]		
	$P_{X'}$	$P_{Y'}$	$P_{Z'}$	$M_{X'}$	$M_{Y'}$	$M_{Z'}$
16	3,07	-3,83	2,55	0,00	0,00	0,17
17	5,09	1,41	2,21	0,00	0,00	0,18
18	4,16	1,79	2,52	0,00	0,00	-0,16
19	1,62	1,19	1,76	0,00	0,00	0,11
20	1,24	0,07	4,57	0,00	0,00	-0,09
21	1,77	-0,62	-1,28	0,00	0,00	-0,08
• Forces	16,94	0,01	12,32			
• Loads	16,94	0,01	12,32			

Load input in Layher stage model.



During the Out service situation, the back wall and the stage scrim need to be removed therefor no extra loading will be added to the model.

6.3 Results summary of the Layher stage Calculation.

	Description	Value	Unit	Comment
	Summary			
	Calculation Status	OK		
	Maximum displacement in X-direction	6,4	mm	CO2, Member No. 46, x: 1.036 m
	Maximum displacement in Y-direction	-10,1	mm	CO5, Member No. 25, x: 0.025 m
	Maximum displacement in Z-direction	-19,2	mm	CO3, FE Mesh Node No. 841 (X: 4.585, Y: -5.181, Z: 0.314 m)
	Maximum vectorial displacement	19,2	mm	CO3, FE Mesh Node No. 841 (X: 4.585, Y: -5.181, Z: 0.314 m)
	Maximum rotation about X-axis	30,9	mrad	CO1, FE Mesh Node No. 1345 (X: 4.689, Y: -0.271, Z: 0.314 m)
	Maximum rotation about Y-axis	-41,6	mrad	CO3, FE Mesh Node No. 843 (X: 4.949, Y: -5.187, Z: 0.314 m)
	Maximum rotation about Z-axis	-8,8	mrad	CO5, FE Mesh Node No. 1451 (X: 0.125, Y: 0.119, Z: 0.640 m)
	Number of 1D finite elements (member elements)	1080		
	Number of 2D finite elements (surface elements)	1290		
	Number of 3D finite elements (solid elements)	0		
	Number of FE mesh nodes	1740		
	Number of equations	10440		
	Matrix solver method	Direct		
	Maximum number of iterations	100		
	Number of divisions for member results	10		
	Number of divisions of members with cable, elastic foundation, taper, or plastic characteristic	10		
	Activate shear stiffness of members (A-y, A-z)	+		
	Plate bending theory	Mindlin		
	Activate ineffective supports	+		
	Precision of convergence criteria of nonlinear calculation	1,0		

6.3.1 Result for the single load cases LC1 to LC5.

	Description	Value	Unit	Comment
	LC1 - Self-weight			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	0,00	kN	
	Sum of support forces in Y	0,00	kN	
	Sum of loads in Z	-18,24	kN	
	Sum of support forces in Z	-18,24	kN	Deviation: 0.00 %
	Resultant of reactions about X	0,544	kNm	At center of gravity of model (X: 3.643, Y: -3.017, Z: 0.090 m)
	Resultant of reactions about Y	0,059	kNm	At center of gravity of model
	Resultant of reactions about Z	0,000	kNm	At center of gravity of model
	Maximum displacement in X-direction	0,2	mm	Member No. 709, x: 1.150 m
	Maximum displacement in Y-direction	-0,2	mm	Member No. 723, x: 1.150 m
	Maximum displacement in Z-direction	-1,6	mm	Member No. 699, x: 1.465 m
	Maximum vectorial displacement	1,6	mm	Member No. 699, x: 1.465 m
	Maximum rotation about X-axis	1,3	mrad	Member No. 699, x: 2.930 m
	Maximum rotation about Y-axis	-1,3	mrad	Member No. 690, x: 2.930 m
	Maximum rotation about Z-axis	-0,1	mrad	Member No. 705, x: 0.000 m
	Method of analysis	Linear		Geometrically Linear Analysis
	LC2 - ballast loading			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	0,00	kN	
	Sum of support forces in Y	0,00	kN	
	Sum of loads in Z	-28,00	kN	
	Sum of support forces in Z	-28,00	kN	Deviation: 0.00 %
	Resultant of reactions about X	2,558	kNm	At center of gravity of model (X: 3.643, Y: -3.017, Z: 0.090 m)
	Resultant of reactions about Y	-0,466	kNm	At center of gravity of model
	Resultant of reactions about Z	0,000	kNm	At center of gravity of model
	Maximum displacement in X-direction	0,0	mm	Member No. 719, x: 2.301 m
	Maximum displacement in Y-direction	0,0	mm	
	Maximum displacement in Z-direction	-1,0	mm	Member No. 580, x: 0.518 m
	Maximum vectorial displacement	1,0	mm	Member No. 580, x: 0.518 m
	Maximum rotation about X-axis	0,0	mrad	Member No. 684, x: 0.000 m
	Maximum rotation about Y-axis	3,5	mrad	Member No. 580, x: 1.036 m
	Maximum rotation about Z-axis	0,0	mrad	Member No. 720, x: 2.301 m
	Method of analysis	Linear		Geometrically Linear Analysis
	LC3 - floor loading 0°			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	14,99	kN	
	Sum of support forces in Y	14,99	kN	Deviation: 0.00 %
	Sum of loads in Z	-149,94	kN	
	Sum of support forces in Z	-149,94	kN	Deviation: 0.00 %
	Resultant of reactions about X	9,447	kNm	At center of gravity of model (X: 3.643, Y: -3.017, Z: 0.090 m)
	Resultant of reactions about Y	-2,493	kNm	At center of gravity of model
	Resultant of reactions about Z	-0,249	kNm	At center of gravity of model
	Maximum displacement in X-direction	1,2	mm	FE Mesh Node No. 1734 (X: 4.949, Y: -3.115, Z: 0.314 m)
	Maximum displacement in Y-direction	1,6	mm	FE Mesh Node No. 717 (X: 3.626, Y: -4.662, Z: 0.314 m)
	Maximum displacement in Z-direction	-9,9	mm	FE Mesh Node No. 1364 (X: 4.585, Y: -1.037, Z: 0.314 m)
	Maximum vectorial displacement	9,9	mm	FE Mesh Node No. 1364 (X: 4.585, Y: -1.037, Z: 0.314 m)
	Maximum rotation about X-axis	16,1	mrad	FE Mesh Node No. 1345 (X: 4.689, Y: -0.271, Z: 0.314 m)
	Maximum rotation about Y-axis	-20,0	mrad	FE Mesh Node No. 1734 (X: 4.949, Y: -3.115, Z: 0.314 m)
	Maximum rotation about Z-axis	-1,5	mrad	Member No. 719, x: 2.301 m
	Method of analysis	Linear		Geometrically Linear Analysis
	LC4 - floor loading 90°			
	Sum of loads in X	14,99	kN	
	Sum of support forces in X	14,99	kN	Deviation: 0.00 %
	Sum of loads in Y	0,00	kN	
	Sum of support forces in Y	0,00	kN	
	Sum of loads in Z	-149,94	kN	
	Sum of support forces in Z	-149,94	kN	Deviation: 0.00 %
	Resultant of reactions about X	13,698	kNm	At center of gravity of model (X: 3.643, Y: -3.017, Z: 0.090 m)
	Resultant of reactions about Y	1,758	kNm	At center of gravity of model
	Resultant of reactions about Z	1,370	kNm	At center of gravity of model
	Maximum displacement in X-direction	1,8	mm	FE Mesh Node No. 1734 (X: 4.949, Y: -3.115, Z: 0.314 m)
	Maximum displacement in Y-direction	-1,0	mm	FE Mesh Node No. 1249 (X: 3.626, Y: -1.554, Z: 0.314 m)
	Maximum displacement in Z-direction	-9,9	mm	FE Mesh Node No. 1364 (X: 4.585, Y: -1.037, Z: 0.314 m)
	Maximum vectorial displacement	9,9	mm	FE Mesh Node No. 1245 (X: 2.667, Y: -1.037, Z: 0.314 m)
	Maximum rotation about X-axis	-16,2	mrad	FE Mesh Node No. 678 (X: 1.580, Y: -5.944, Z: 0.314 m)
	Maximum rotation about Y-axis	-20,0	mrad	FE Mesh Node No. 1734 (X: 4.949, Y: -3.115, Z: 0.314 m)
	Maximum rotation about Z-axis	-1,4	mrad	Member No. 705, x: 0.000 m
	Method of analysis	Linear		Geometrically Linear Analysis
	LC5 - floor loading 180°			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	

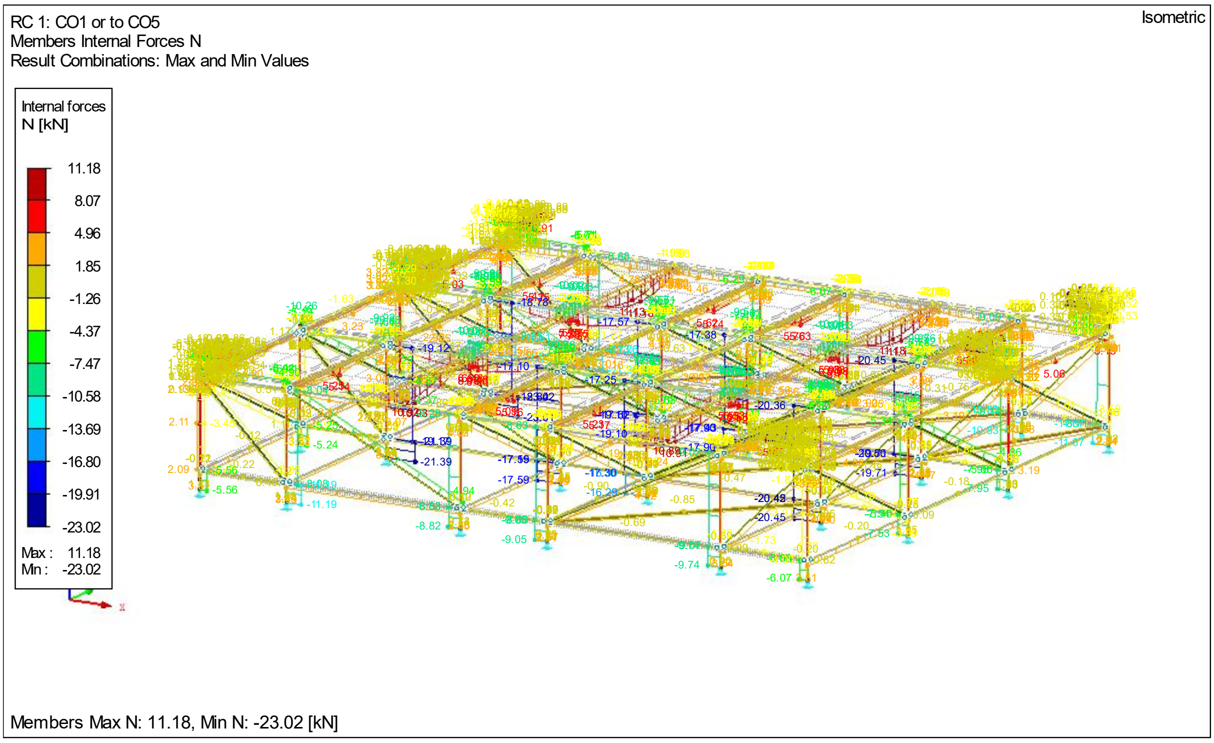
	Sum of loads in Y	-14,99	kN	
	Sum of support forces in Y	-14,99	kN	Deviation: 0.00 %
	Sum of loads in Z	-149,94	kN	
	Sum of support forces in Z	-149,94	kN	Deviation: 0.00 %
	Resultant of reactions about X	17,949	kNm	At center of gravity of model (X: 3.643, Y: -3.017, Z: 0.090 m)
	Resultant of reactions about Y	-2,493	kNm	At center of gravity of model
	Resultant of reactions about Z	0,249	kNm	At center of gravity of model
	Maximum displacement in X-direction	1,2	mm	FE Mesh Node No. 1734 (X: 4.949, Y: -3.115, Z: 0.314 m)
	Maximum displacement in Y-direction	-1,6	mm	FE Mesh Node No. 1249 (X: 3.626, Y: -1.554, Z: 0.314 m)
	Maximum displacement in Z-direction	-9,9	mm	FE Mesh Node No. 704 (X: 2.667, Y: -5.181, Z: 0.314 m)
	Maximum vectorial displacement	9,9	mm	FE Mesh Node No. 704 (X: 2.667, Y: -5.181, Z: 0.314 m)
	Maximum rotation about X-axis	-16,2	mrad	FE Mesh Node No. 679 (X: 2.564, Y: -5.944, Z: 0.314 m)
	Maximum rotation about Y-axis	20,0	mrad	FE Mesh Node No. 1621 (X: 2.303, Y: -3.115, Z: 0.314 m)
	Maximum rotation about Z-axis	-1,5	mrad	Member No. 705, x: 0.000 m
	Method of analysis	Linear		Geometrically Linear Analysis

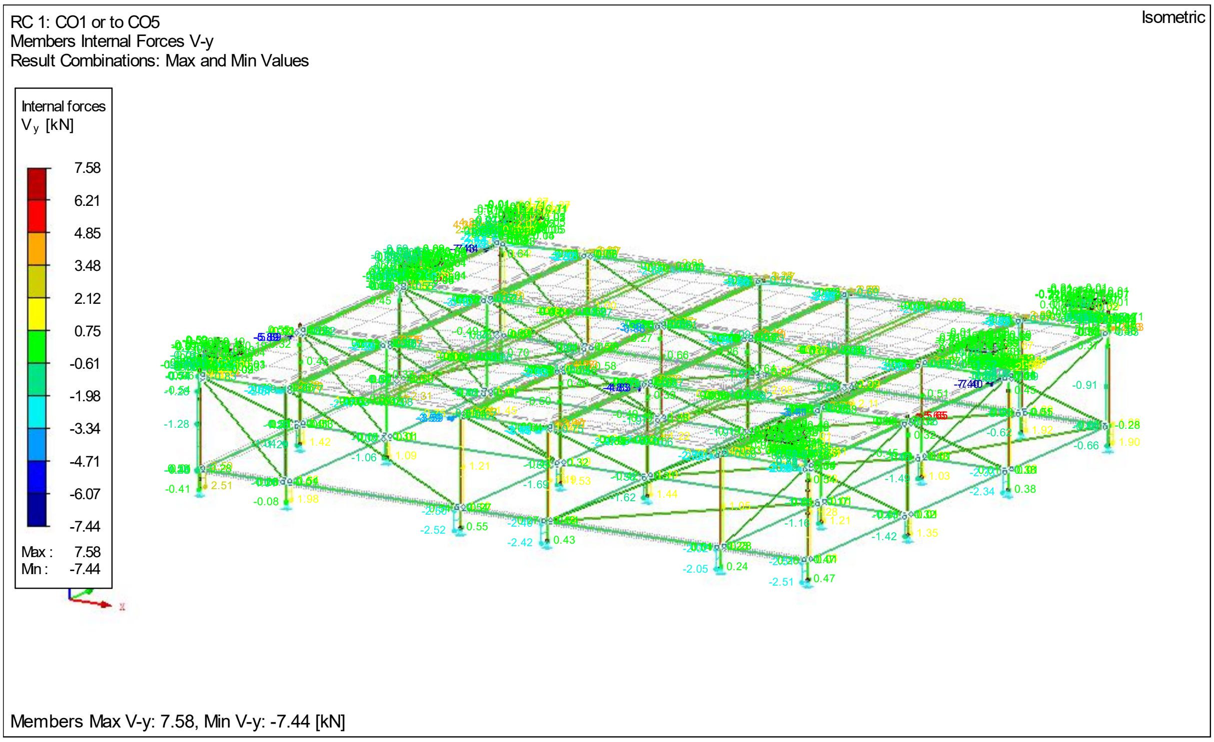
6.3.2 Result for the load combination CO1-CO5.

	Description	Value	Unit	Comment
	CO1 - 1.15*LC1 + 1.15*LC2 + 1.35*LC3 + 1.35*LC6			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	37,10	kN	
	Sum of support forces in Y	37,10	kN	Deviation: 0.00 %
	Sum of loads in Z	-247,38	kN	
	Sum of support forces in Z	-247,38	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	3,5	mm	Member No. 194, x: 0.000 m
	Maximum displacement in Y-direction	6,2	mm	Member No. 673, x: 1.036 m
	Maximum displacement in Z-direction	-19,1	mm	FE Mesh Node No. 1364 (X: 4.585, Y: -1.037, Z: 0.314 m)
	Maximum vectorial displacement	19,2	mm	FE Mesh Node No. 1364 (X: 4.585, Y: -1.037, Z: 0.314 m)
	Maximum rotation about X-axis	30,9	mrad	FE Mesh Node No. 1345 (X: 4.689, Y: -0.271, Z: 0.314 m)
	Maximum rotation about Y-axis	-41,4	mrad	FE Mesh Node No. 1366 (X: 4.949, Y: -1.043, Z: 0.314 m)
	Maximum rotation about Z-axis	8,0	mrad	Member No. 673, x: 2.072 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO2 - 1.15*LC1 + 1.15*LC2 + 1.35*LC4 + 1.35*LC7			
	Sum of loads in X	32,48	kN	
	Sum of support forces in X	32,48	kN	Deviation: 0.00 %
	Sum of loads in Y	-1,07	kN	
	Sum of support forces in Y	-1,07	kN	Deviation: 0.00 %
	Sum of loads in Z	-257,64	kN	
	Sum of support forces in Z	-257,64	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	6,4	mm	Member No. 46, x: 1.036 m
	Maximum displacement in Y-direction	-5,3	mm	Member No. 25, x: 0.025 m
	Maximum displacement in Z-direction	-19,1	mm	FE Mesh Node No. 841 (X: 4.585, Y: -5.181, Z: 0.314 m)
	Maximum vectorial displacement	19,2	mm	FE Mesh Node No. 704 (X: 2.667, Y: -5.181, Z: 0.314 m)
	Maximum rotation about X-axis	-30,7	mrad	FE Mesh Node No. 820 (X: 4.688, Y: -5.944, Z: 0.314 m)
	Maximum rotation about Y-axis	-41,4	mrad	FE Mesh Node No. 843 (X: 4.949, Y: -5.187, Z: 0.314 m)
	Maximum rotation about Z-axis	-8,1	mrad	Member No. 46, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO3 - 1.15*LC1 + 1.15*LC2 + 1.35*LC5 + 1.35*LC8			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	-25,52	kN	
	Sum of support forces in Y	-25,52	kN	Deviation: 0.00 %
	Sum of loads in Z	-262,82	kN	
	Sum of support forces in Z	-262,82	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	-2,6	mm	Member No. 124, x: 0.000 m
	Maximum displacement in Y-direction	-6,1	mm	Member No. 579, x: 1.036 m
	Maximum displacement in Z-direction	-19,2	mm	FE Mesh Node No. 841 (X: 4.585, Y: -5.181, Z: 0.314 m)
	Maximum vectorial displacement	19,2	mm	FE Mesh Node No. 841 (X: 4.585, Y: -5.181, Z: 0.314 m)
	Maximum rotation about X-axis	-30,8	mrad	FE Mesh Node No. 679 (X: 2.564, Y: -5.944, Z: 0.314 m)
	Maximum rotation about Y-axis	-41,6	mrad	FE Mesh Node No. 843 (X: 4.949, Y: -5.187, Z: 0.314 m)
	Maximum rotation about Z-axis	8,1	mrad	Member No. 579, x: 0.000 m
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO4 - 1.15*LC1 + 1.15*LC2 + 1.35*LC9			
	Sum of loads in X	0,00	kN	
	Sum of support forces in X	0,00	kN	
	Sum of loads in Y	3,86	kN	
	Sum of support forces in Y	3,86	kN	Deviation: 0.00 %
	Sum of loads in Z	-43,29	kN	
	Sum of support forces in Z	-43,29	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	-2,6	mm	Member No. 85, x: 0.025 m
	Maximum displacement in Y-direction	2,6	mm	Member No. 157, x: 0.025 m

	Maximum displacement in Z-direction	3,7	mm	FE Mesh Node No. 221 (X: 6.838, Y: -2.217, Z: 0.585 m)
	Maximum vectorial displacement	4,6	mm	Member No. 193, x: 0.000 m
	Maximum rotation about X-axis	-4,8	mrad	Member No. 157, x: 0.025 m
	Maximum rotation about Y-axis	-7,9	mrad	Member No. 78, x: 0.176 m
	Maximum rotation about Z-axis	2,2	mrad	FE Mesh Node No. 1537 (X: 0.125, Y: -6.335, Z: 0.640 m)
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T
	CO5 - 1.15*LC1 + 1.15*LC2 + 1.35*LC10			
	Sum of loads in X	22,88	kN	
	Sum of support forces in X	22,88	kN	Deviation: 0.00 %
	Sum of loads in Y	0,01	kN	
	Sum of support forces in Y	0,01	kN	Deviation: 0.03 %
	Sum of loads in Z	-36,53	kN	
	Sum of support forces in Z	-36,53	kN	Deviation: 0.00 %
	Maximum displacement in X-direction	4,7	mm	Member No. 194, x: 0.000 m
	Maximum displacement in Y-direction	-10,1	mm	Member No. 25, x: 0.025 m
	Maximum displacement in Z-direction	5,1	mm	FE Mesh Node No. 221 (X: 6.838, Y: -2.217, Z: 0.585 m)
	Maximum vectorial displacement	10,7	mm	Member No. 24, x: 0.025 m
	Maximum rotation about X-axis	19,3	mrad	Member No. 25, x: 0.025 m
	Maximum rotation about Y-axis	12,7	mrad	Member No. 187, x: 0.106 m
	Maximum rotation about Z-axis	-8,8	mrad	FE Mesh Node No. 1451 (X: 0.125, Y: 0.119, Z: 0.640 m)
	Method of analysis	2nd Order		Second order analysis (Nonlinear)
	Internal forces referred to deformed system for...	+		N, V_y, V_z, M_y, M_z, M_T

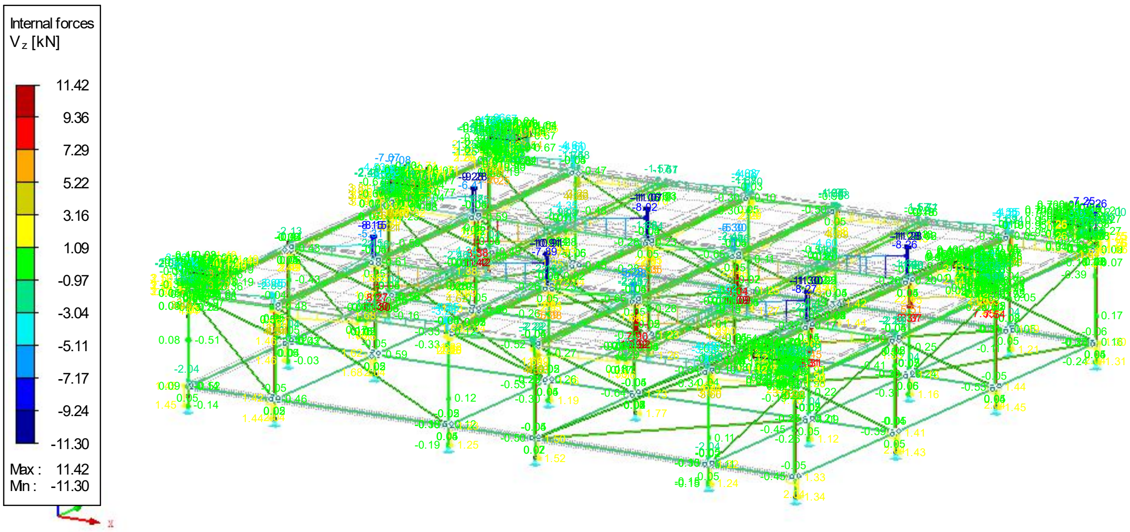
6.3.3 internal force diagrams –load combinations Design values: 1 * (CO1 or to CO5).





RC 1: CO1 or to CO5
Members Internal Forces V-z
Result Combinations: Max and Min Values

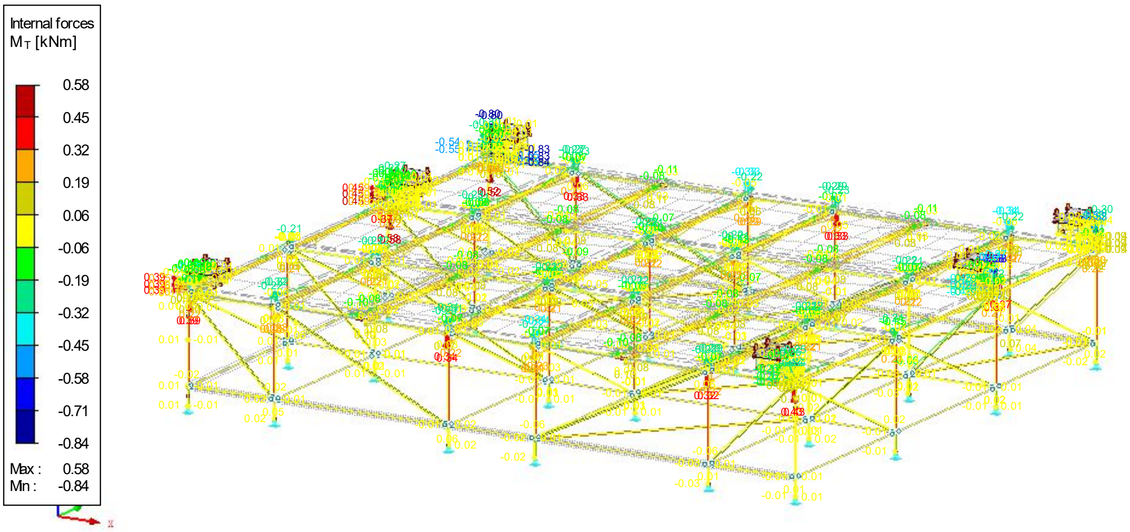
Isometric



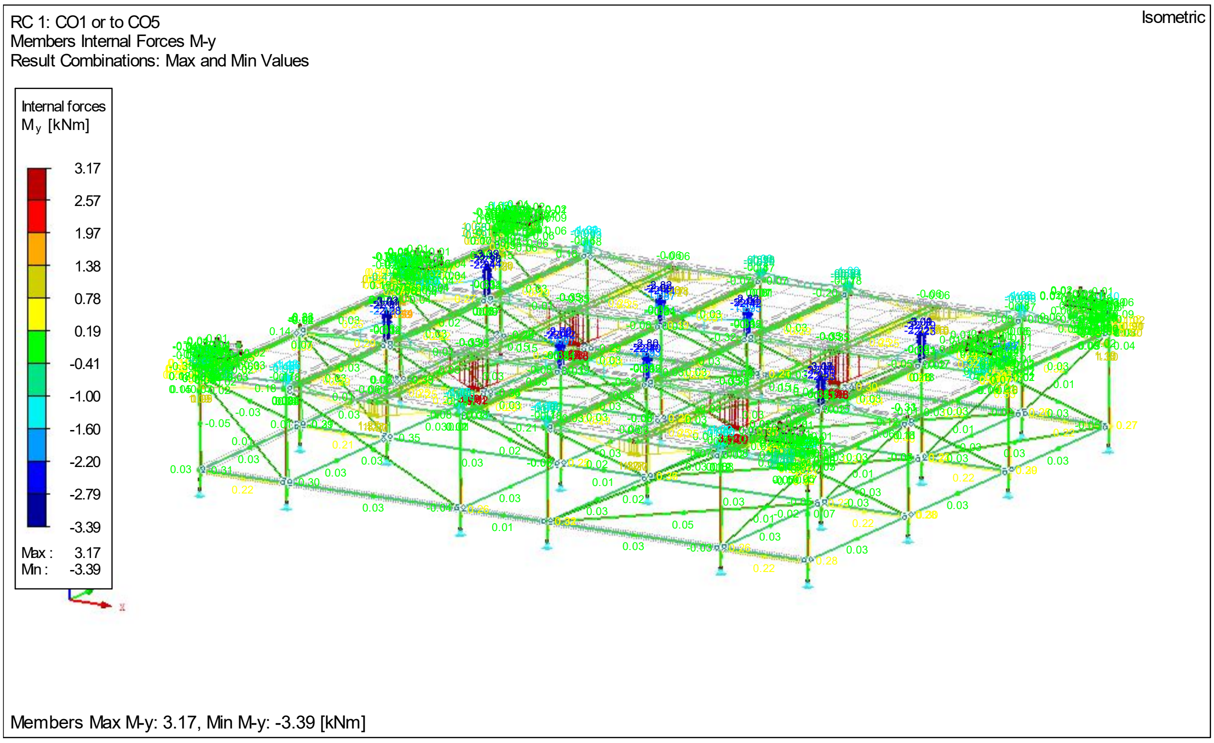
Members Max V-z: 11.42, Min V-z: -11.30 [kN]

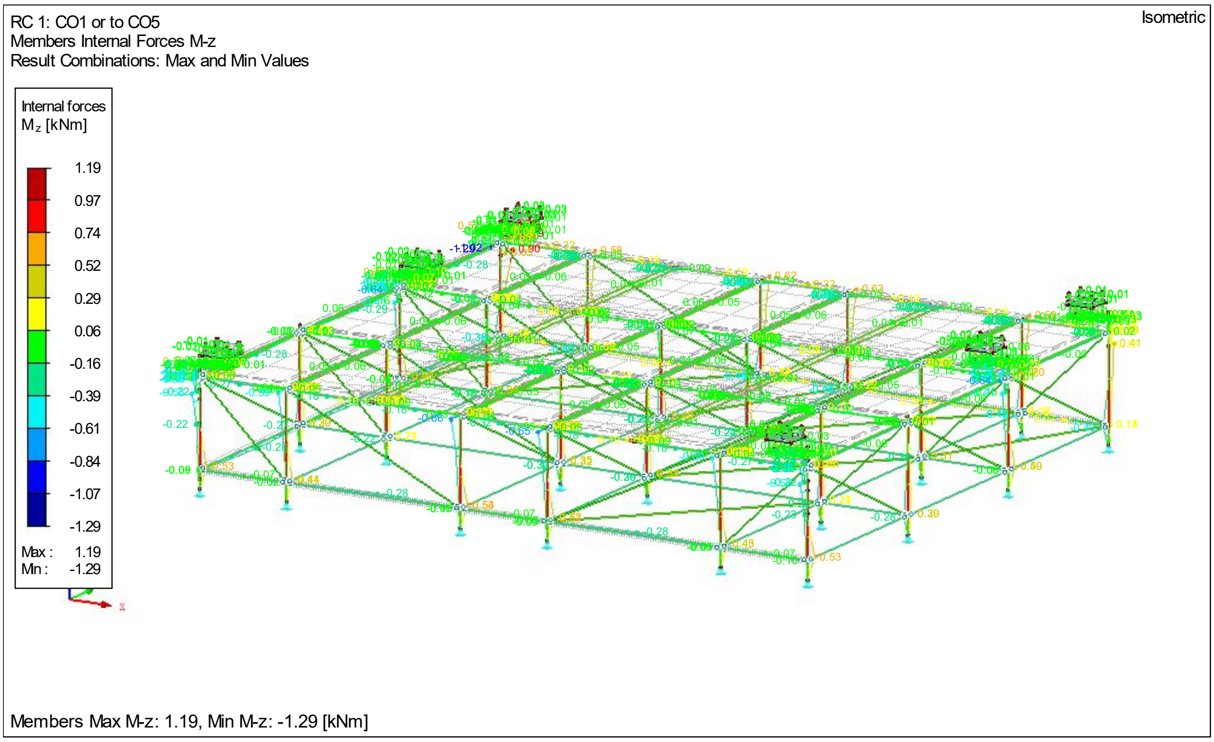
RC 1: CO1 or to CO5
Members Internal Forces M-T
Result Combinations: Max and Min Values

Isometric



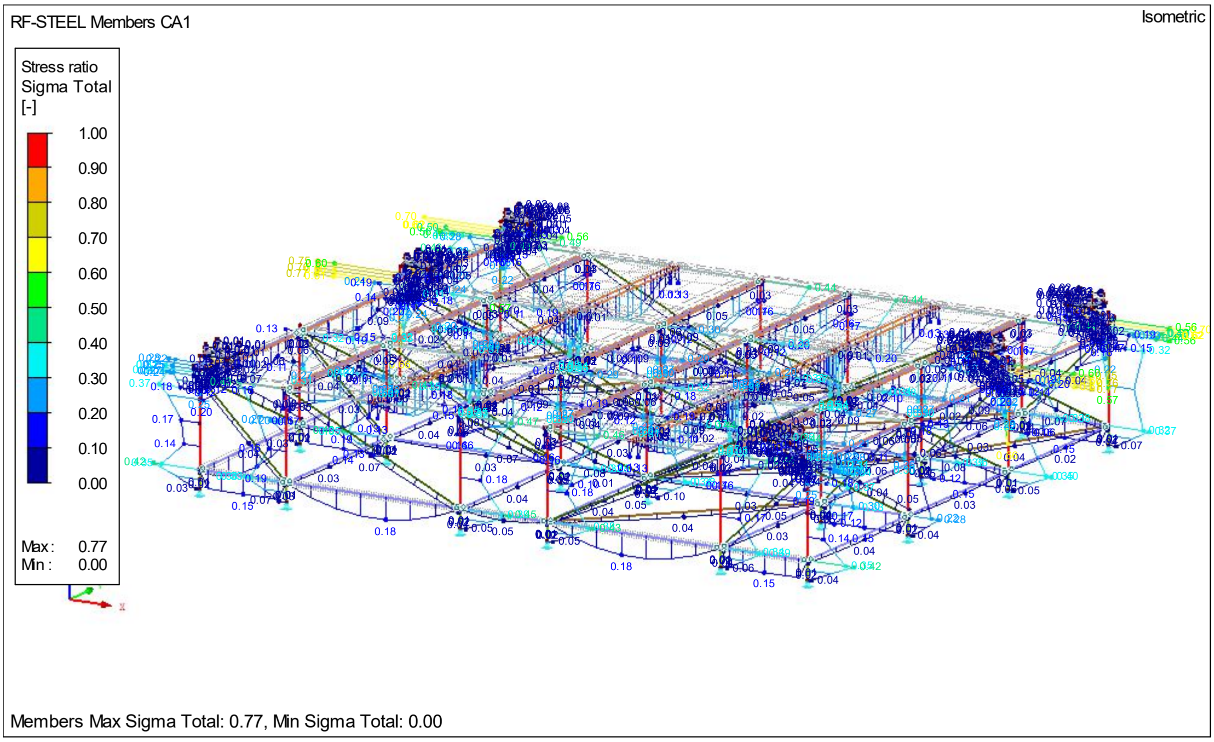
Members Max M-T: 0.58, Min M-T: -0.84 [kNm]

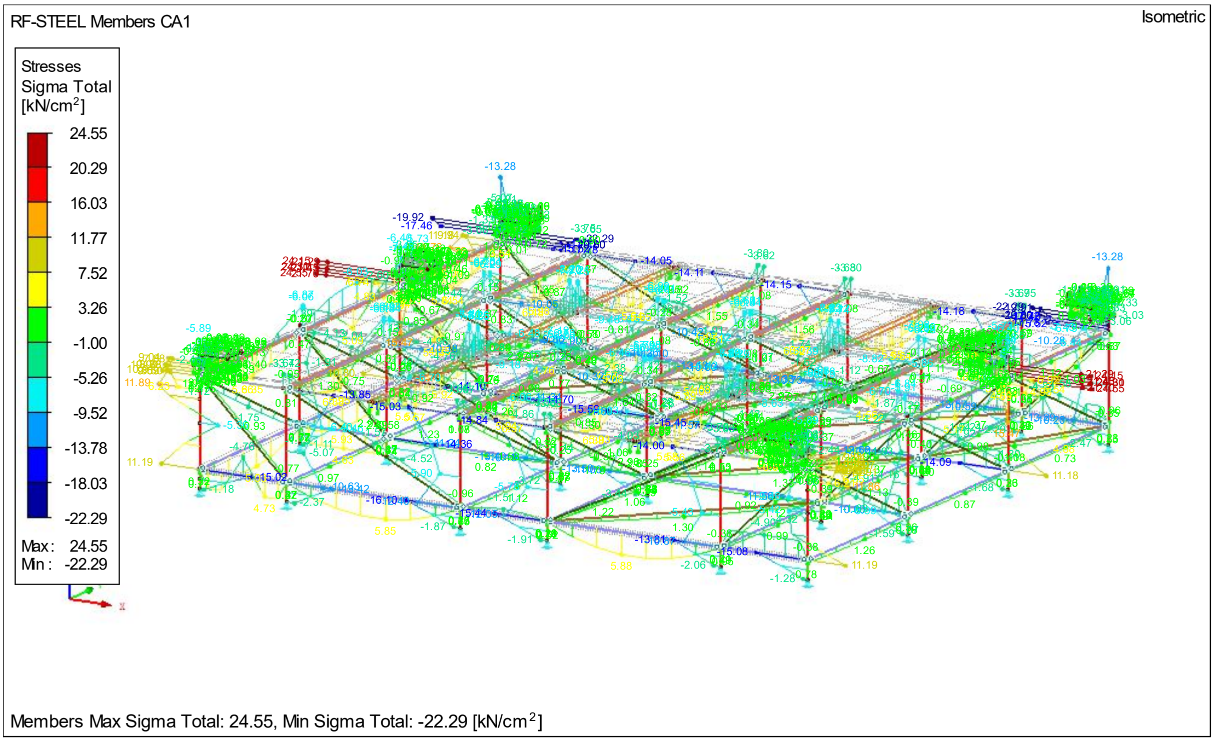

RC 1: CO1 or to CO5
Members Internal Forces M-y
Result Combinations: Max and Min Values
Isometric
Internal forces
M_y [kNm]
3.17
2.57
1.97
1.38
0.78
0.19
-0.41
-1.00
-1.60
-2.20
-2.79
-3.39
Max : 3.17
Min : -3.39
Members Max M-y: 3.17, Min M-y: -3.39 [kNm]


RC 1: CO1 or to CO5
Members Internal Forces M-z
Result Combinations: Max and Min Values
Isometric
Internal forces
M_z [kNm]
1.19
0.97
0.74
0.52
0.29
0.06
-0.16
-0.39
-0.61
-0.84
-1.07
-1.29
Max : 1.19
Min : -1.29
Members Max M-z: 1.19, Min M-z: -1.29 [kNm]

6.4 Stress analyse calculation for the stage components.

For the complete stage a stress calculation has been made.





Result of the stress analyse by cross section.

Section No.	Member No.	Location x [m]	S-Point No.	Load-ing	Stress Type	Stress [kN/cm²] Existing	Limit	Stress Ratio
1	QRO 50x3.2 (Hot Formed)							
	173	0,139	13	CO1	Sigma Total	15,47	23,50	0,66
	116	0,000	13	CO1	Tau Total	-3,75	13,57	0,28
	173	0,139	13	CO1	Sigma-eqv	15,85	23,50	0,67
2	Ring 16/2							
	187	0,282	11	CO1	Sigma Total	1,67	23,50	0,07
	186	0,000	23	CO1	Tau Total	-0,13	13,57	0,01
	187	0,282	11	CO1	Sigma-eqv	1,67	23,50	0,07
3	RO 48.3x4.0 (Hot Formed)							
	124	0,025	10	CO3	Sigma Total	-0,67	23,50	0,03
	22	0,000	1	CO1	Tau Total	0,71	13,57	0,05
	22	0,000	1	CO1	Sigma-eqv	1,26	23,50	0,05
4	RO 38x4.5 | DIN EN 10220							
	652	0,210	1	CO1	Sigma Total	-16,10	35,50	0,45
	257	0,105	16	CO2	Tau Total	-1,18	20,50	0,06
	652	0,210	1	CO1	Sigma-eqv	16,10	35,50	0,45
5	RO 48.3x3.2 (Hot Formed)							
	340	0,000	7	CO1	Sigma Total	24,55	32,00	0,77
	340	0,000	8	CO3	Tau Total	-5,75	18,48	0,31
	340	0,000	7	CO1	Sigma-eqv	25,73	32,00	0,80
6	RO 48.3x3.2 (Hot Formed)							
	46	1,184	18	CO2	Sigma Total	-6,03	32,00	0,19
	660	0,000	19	CO3	Tau Total	-1,08	18,48	0,06
	46	0,888	18	CO2	Sigma-eqv	6,03	32,00	0,19
7	RO 48.3x3.2 (Hot Formed)							
	684	1,465	10	CO1	Sigma Total	-1,87	32,00	0,06
	721	2,317	1	CO2	Tau Total	-0,12	18,48	0,01
	684	1,465	10	CO1	Sigma-eqv	1,87	32,00	0,06
8	RO 48.3x2.6 (Hot Formed)							
	694	1,150	10	CO1	Sigma Total	-2,08	23,50	0,09
	718	0,000	19	CO1	Tau Total	-0,98	13,57	0,07
	694	1,150	10	CO1	Sigma-eqv	2,10	23,50	0,09
9	RO 42.4x3.2 (Hot Formed)							
	246	0,000	7	CO1	Sigma Total	21,70	35,50	0,61
	246	0,000	8	CO3	Tau Total	-5,13	20,50	0,25
	246	0,000	7	CO1	Sigma-eqv	22,76	35,50	0,64
11	HK 50/30/4/4/4/4							
	445	2,072	14	CO3	Sigma Total	-8,29	22,50	0,37
	825	2,072	8	CO3	Tau Total	2,88	12,99	0,22
	822	0,000	10	CO2	Sigma-eqv	8,71	22,50	0,39

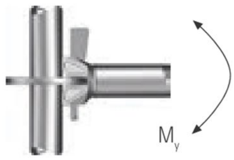
Maximum utilisation is 77% which occurs in the top of the Layher pole where the base unit of the tunnel stage is attached.

6.5 Layher information design values.

The used Layher system is the Layher K2000+ system.
When parts need to be replaced by Layher Variant II system, take care that these will be in places with less internal forces.

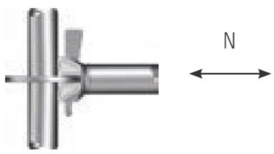
Z-8.22-64: K 2000+

Biegemoment



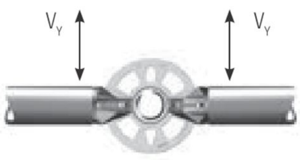
Biegemoment
$M_{y,\,Rd} = \pm$ 101,0 kNcm

Normalkraft

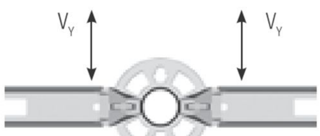


$N_{Rd} = \pm$ 31,0 kN

Horizontale Querkraft

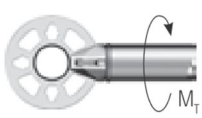


O-Riegel: $V_{y,\,Rd} = \pm$ 10,0 kN



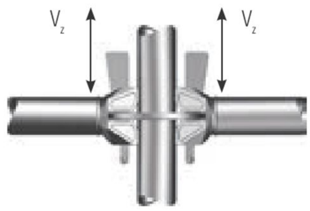
U-Riegel: $V_{y,\,Rd} = \pm$ 5,9 kN

Torsionsmoment



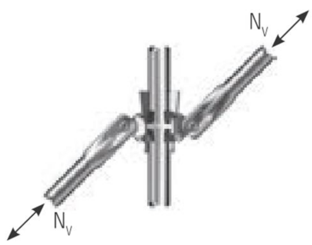
$M_{T,\,Rd} = \pm$ 52,5 kNcm

Vertikale Querkraft



Vertikale Querkraft, Einzelanschluss
$V_{z,\,Rd} = \pm$ 26,4 kN
Vertikale Querkraft je Lochscheibe
$\sum V_{z,\,Rd} = \pm$ 105,6 kN

Normalkraft, Diagonale



Beanspruchbarkeiten der Vertikaldiagonalen für Feldhöhe 2,00 m für **K 2000+**:

	Druck								Zug
Feldlänge [m]	0,73	1,09	1,40	1,57	2,07	2,57	3,07	4,14	alle Feldlängen
$N_{V,Rd}$ [kN]	-16,1	-16,8	-15,5	-14,8	-12,4	-10,2	-8,3	-5,3	+17,9

K 2000+ Bauteile können mit Bauteilen der Variante LW, Variante II und Variante I vermischt werden. Beanspruchbarkeiten siehe Zulassung Z-8.22-64 und Z-8.22-949.

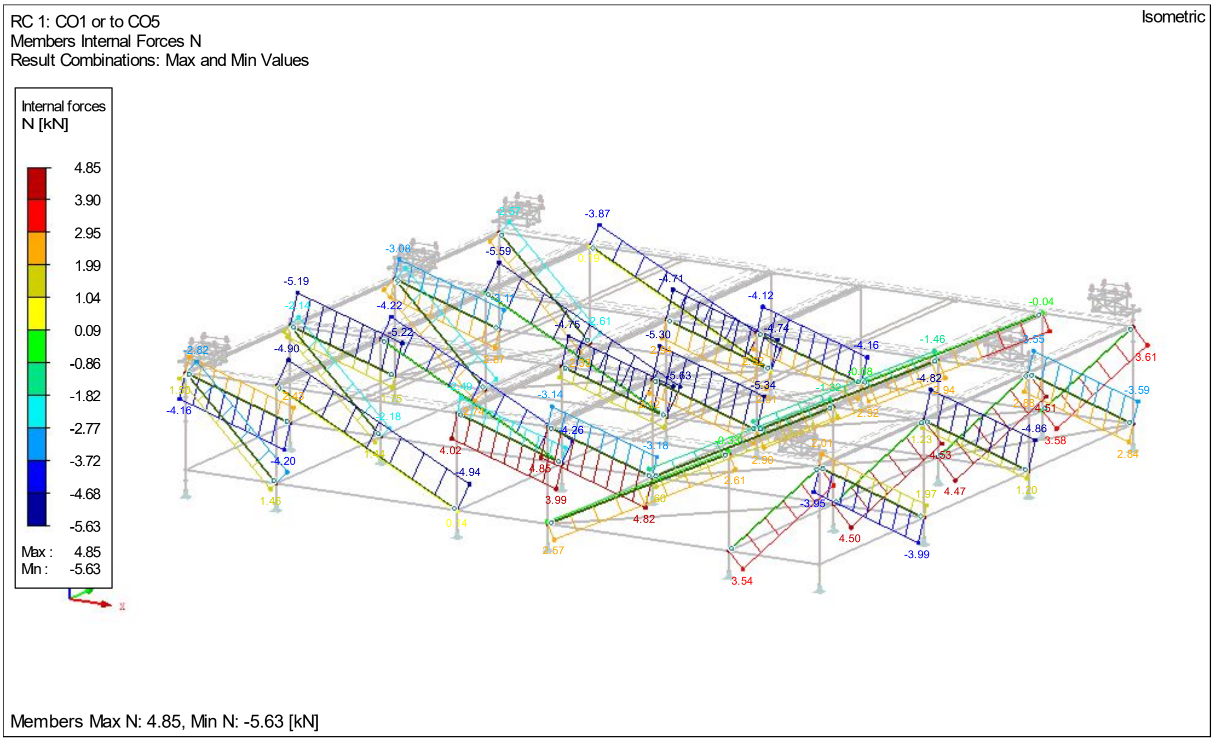
Rd = Beanspruchbarkeit,
(enthält Teilsicherheitsbeiwert γ_M)

* „Zulässige Lasten" bzw. „Gebrauchslasten" erhält man durch Division der Beanspruchbarkeit durch 1,5 (= γ_F)

15

6.6 Check of the Layher diagonals.

The Maximum compression of the Layher K2000+ diagonals is according to the figure in chapter 6.5. In the next figure the minimum and maximum forces are displayed.



The maximum N_{ed} in a diagonal is 5.63 kN. According to the table on page 211 the maximum design force for this diagonal is 12.4 kN

Check of the diagonals

$N_{ed} / N_{rd} < 1$

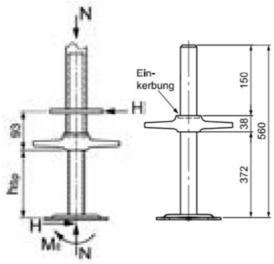
$5.63 / 12.4 = 0.45 < 1$

6.7 Check of the Layher Spindle's.

In the next table the spindle loading capacity in conjunction with height is given

Fußspindeln – Belastungstabellen

FUSSSPINDEL 60



Ersatzquerschnittswerte der Spindel

A = 3,84 cm²
W_{el} = 2,61 cm³
W_{pl} = 3,26 cm³
I = 3,74 cm⁴

Material: EN 10219-S235JRH
→ Rollgewinde: $f_{y,k}$ = 280,0 N/mm²

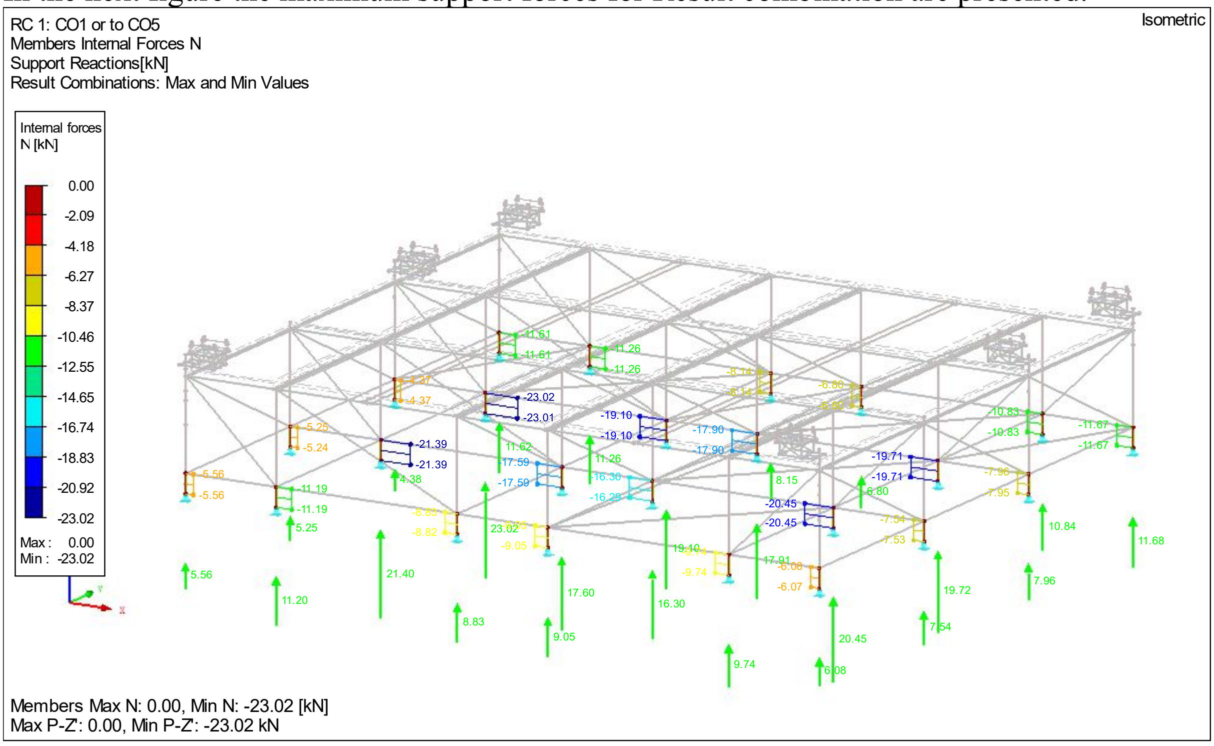
Tab. 12 Belastung Fußspindeln

Aus-spindel-länge h_{Sp} [cm]	Zulässige Vertikallast N [kN]* bei gleichzeitiger Wirkung einer Horizontallast H [kN]																										Zul. Horizontallast H [kN] wenn N = 0
	H = 0,0		H = 0,5		H = 1,0		H = 1,5		H = 2,0		H = 2,5		H = 3,0		H = 3,5		H = 4,0		H = 4,5		H = 5,0		H = 5,5		H = 6,0		
	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	
0	39	53	39	51	39	51	39	51	39	50	39	49	39	49	38	–	38	–	37	–	36	–	36	–	35	–	26,3
5	39	52	39	51	39	50	39	48	38	–	37	–	36	–	35	–	34	–	33	–	32	–	31	–	30	–	7,8
10	39	51	39	49	38	–	37	–	36	–	34	–	33	–	30	–	29	–	28	–	26	–	25	–	–	–	4,6
15	39	49	38	–	36	–	35	–	33	–	31	–	29	–	–	–	–	–	–	–	–	–	–	–	–	–	3,2
20	38	–	36	–	34	–	32	–	29	–	27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2,5
25	37	–	34	–	31	–	28	–	23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2,0
30	35	–	31	–	27	–	21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1,7
35	32	–	27	–	21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1,5
37	30	–	25	–	17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1,4

*Die zulässigen Vertikallasten wurden berechnet unter Anwendung des Berechnungsmodells nach DIN EN 12811-1, Abs. 10.2.3.2. Zur Erfassung der Biegesteifigkeit des Ständerrohres, der Schnittgrößenanteile aus Theorie II. Ordnung und der maximalen Beanspruchbarkeit der Ständer wurden folgende Raumgerüste mit Rastermaß 2,57 x 2,57 m berücksichtigt:
2,00 m Lagenhöhe für Stieldruckkräfte $N_1 \leq 39$ kN
1,50 m Lagenhöhe für Stieldruckkräfte 39 kN < $N_2 \leq 54$ kN

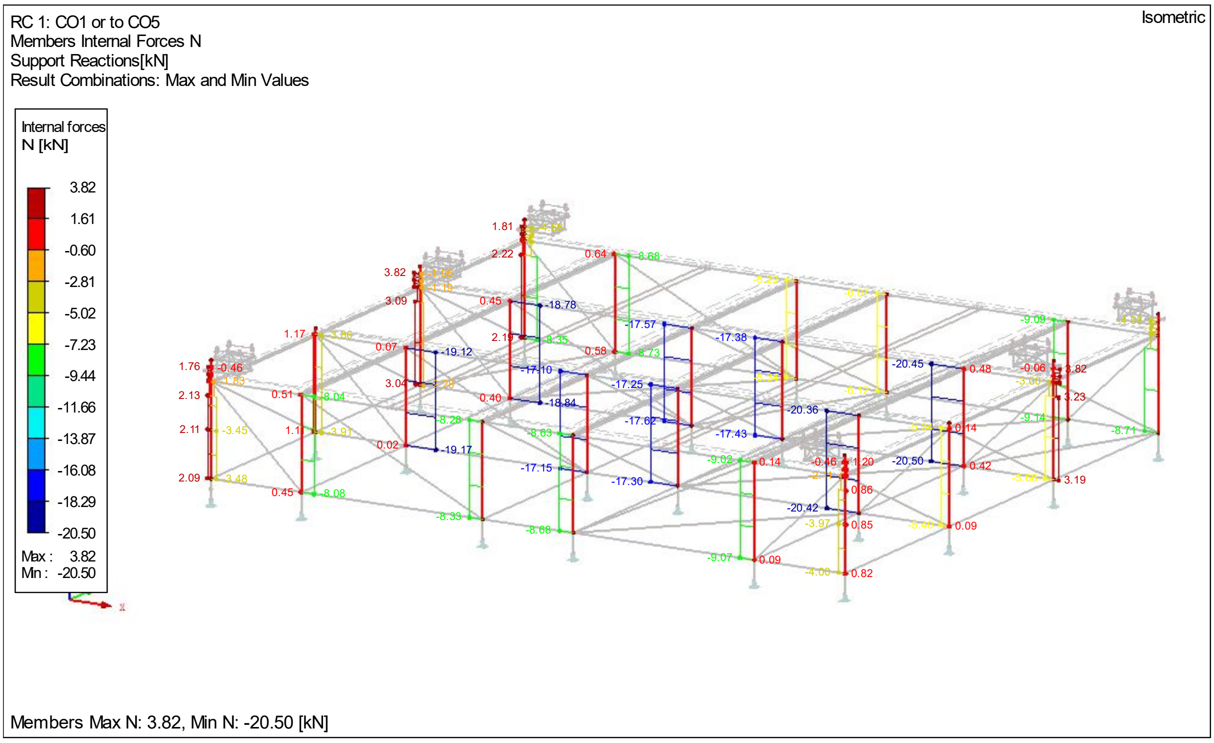
(–) Bei dieser Kombination von Ausspindellänge und Horizontallast ist die Biegebeanspruchbarkeit der Spindel überschritten.

In the next figure the maximum support forces for Result combination are presented.



The maximum support force is 23.02kN.
The maximum total horizontal force is 27.48 kN. This force will be divided over the 24 spindles. 27.48 / 24 = 1.145 kN of horizontal force per spindle. According to the table of the Layher spindle the combination between the vertical and the horizontal force allows for a maximum spindle length of 30 cm on the highest loaded spindles.

6.8 Check of the Layher columns.



Proof against buckling.

$\beta = 0.9$

$L_{cr} = 0.9 * 100 = 90$ cm

$A = 4.53$ cm²

$I = 11.60$ cm^4

$W = 4.80$ cm³

$i = 1.60$cm

$\lambda_1 = \pi * \sqrt{(210000/320)} = 80{,}48$

$\bar{\lambda} = 90 / (1.6 * 80.48) = 0.699$

Buckling curve for hollow section line c (table 6.2 from en-1993-1-1)

$\alpha = 0{,}49$

$\Phi = 0.5 * (1 + \alpha * (\bar{\lambda} - 0.2) + \bar{\lambda}^2)$

$\Phi = 0.5 * (1 + 0.49 * (0.699 - 0.2) + 0.699^2) = 0.866$

$\chi_{min} = 1 / (\Phi + \sqrt{(\Phi^2 - \bar{\lambda}^2)})$

$\chi_{min} = 1 / (0.866 + \sqrt{(0.866^2 - 0.699^2)}) = 0.505$

$N_{b,rd} = \chi * A * f_0 / 1.1$

$N_{b,rd} = 0.505 * 4.53 * 32 / 1.1 = 66.59$ kN

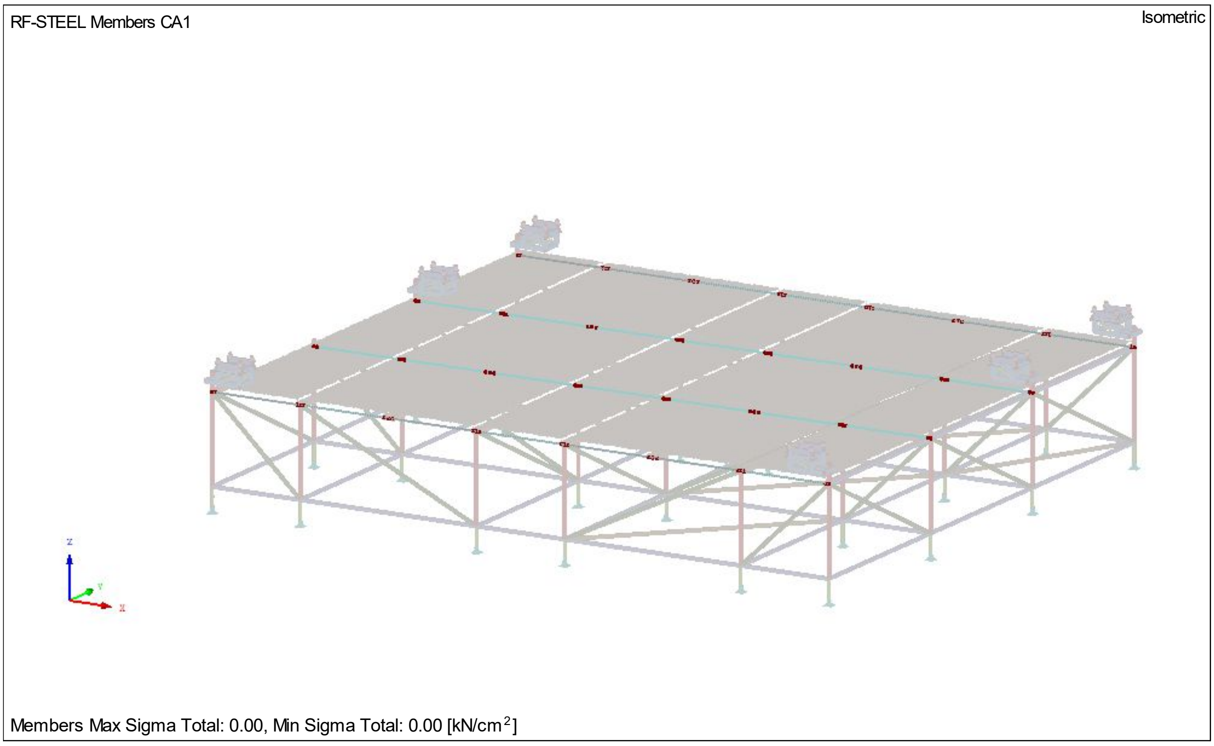
$N_{ed,\ max} = 20.50$ kN

check $= N_{ed,\ max} / N_{b,rd} < 1$

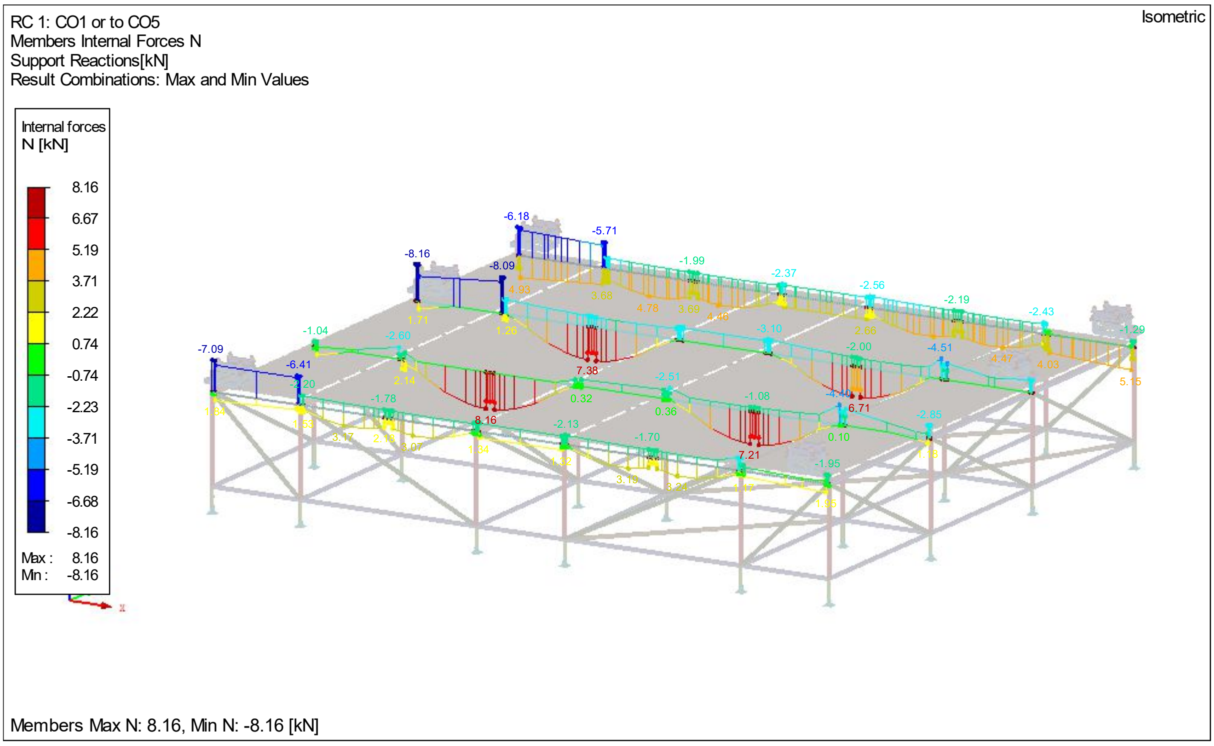
$20.50 / 66.59 = 0.31 < 1$

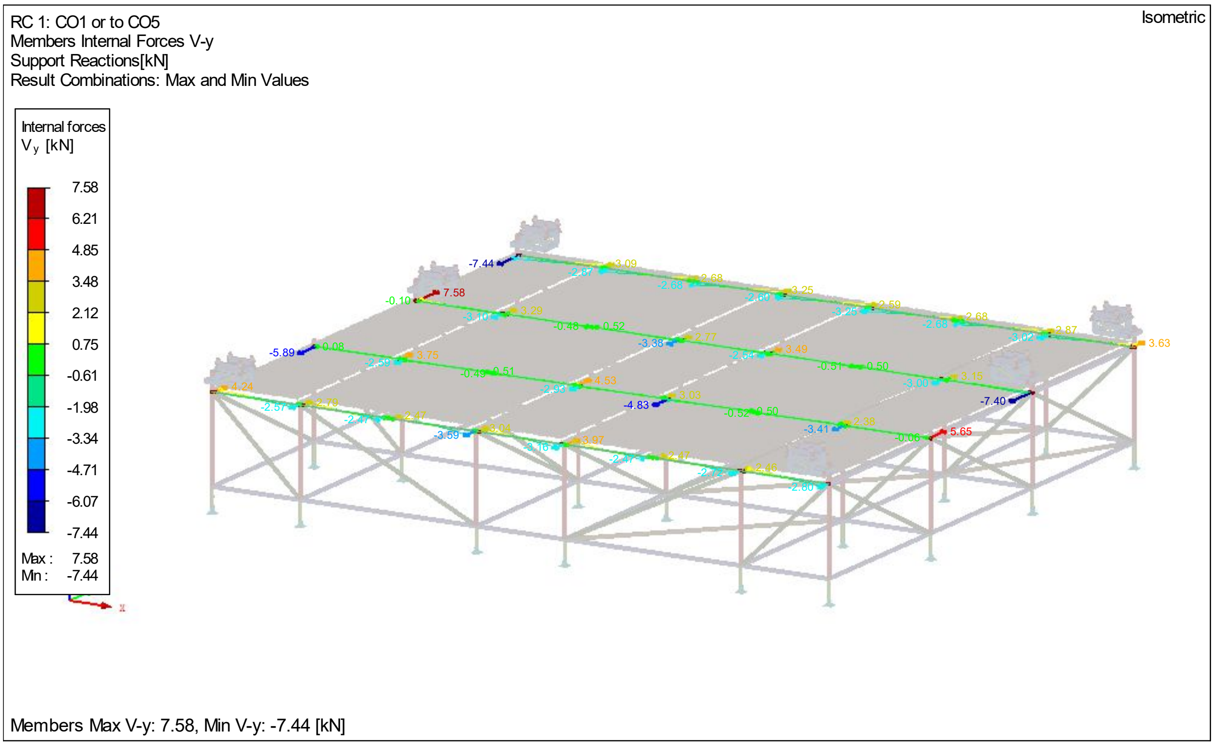
6.9 Check of the Event Layher staging system.

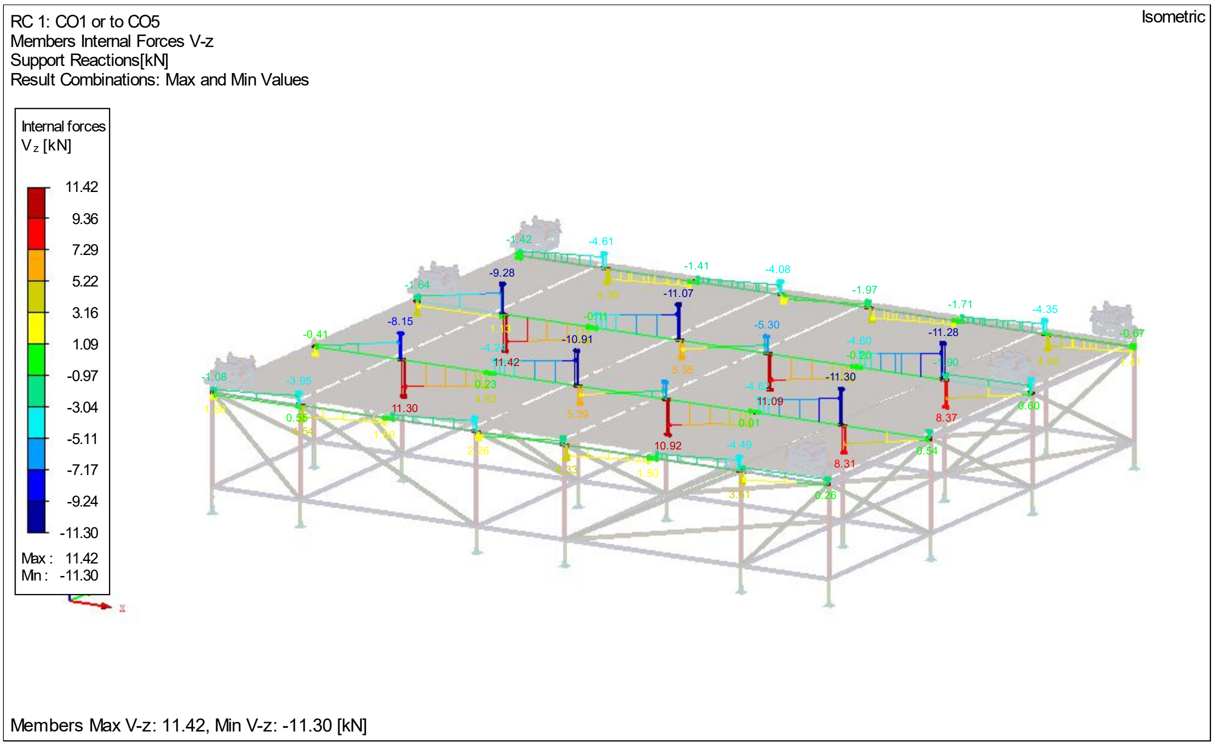
The event Layher staging system exist of Layher transom beams with a decking system on top.



In the next figures the internal forces of the floor beam are shown.

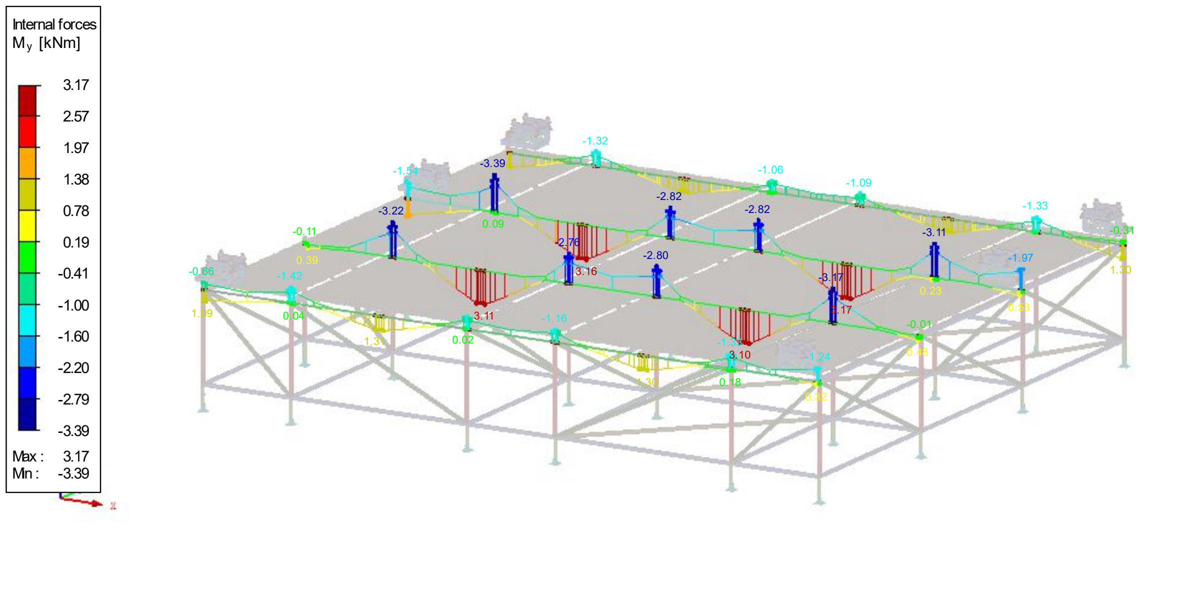



RC 1: CO1 or to CO5
Members Internal Forces V-y
Support Reactions[kN]
Result Combinations: Max and Min Values
Isometric
Internal forces
V y [kN]
7.58
6.21
4.85
3.48
2.12
0.75
-0.61
-1.98
-3.34
-4.71
-6.07
-7.44
Max : 7.58
Min : -7.44
Members Max V-y: 7.58, Min V-y: -7.44 [kN]


RC 1: CO1 or to CO5
Members Internal Forces V-z
Support Reactions[kN]
Result Combinations: Max and Min Values
Isometric
Internal forces
V z [kN]
11.42
9.36
7.29
5.22
3.16
1.09
-0.97
-3.04
-5.11
-7.17
-9.24
-11.30
Max : 11.42
Min : -11.30
Members Max V-z: 11.42, Min V-z: -11.30 [kN]

RC 1: CO1 or to CO5
Members Internal Forces M-y
Support Reactions[kN]
Result Combinations: Max and Min Values

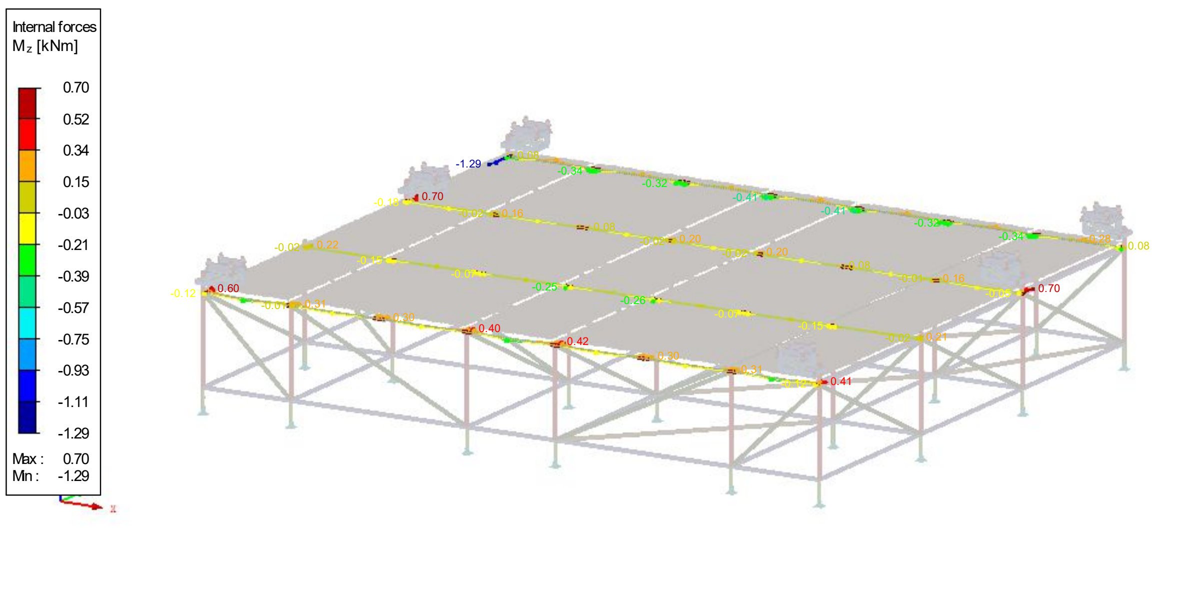
Isometric



Members Max M-y: 3.17, Min M-y: -3.39 [kNm]

RC 1: CO1 or to CO5
Members Internal Forces M-z
Support Reactions[kN]
Result Combinations: Max and Min Values

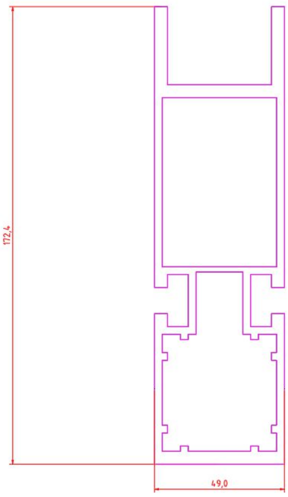
Isometric



Members Max M-z: 0.70, Min M-z: -1.29 [kNm]

Profiel berekening.

Layher Event Beam speciaal profiel Aluminium 6005A T6



I_1	[INCH^4]	5542580
I_2	[INCH^4]	701985
S_c	[INCH]	90.03
S_t	[INCH]	82.38
A	[INCH^2]	1878.072

$Wy = I_1 / e_y = 554 / 8.25 = 67.15$ cm³

$N_{ed} = 8.16$

$\sigma N_{ed} = N_{ed} / A = 8.16 / 18.78 = 0.43$ kN/cm²

$V_{y,ed} = 7.58$ kN

$\sigma v_{z,ed} = V_{y,ed} / A = 7.58 / 18.78 = 0.41$ kN/cm²

$V_{z,ed} = 12.52$ kN

$\sigma v_{z,ed} = V_{z,ed} / A = 11.42 / 18.78 = 0.61$ kN/cm²

My,ed = 3.39 kNm

$\sigma M_{y,ed} = M_{y,ed} / Wy = 339 / 67.15 = 5.05$ kN/cm²

Mz,ed = 1.29 kNm

$\sigma M_{z,ed} = M_{z,ed} / Wy = 129 / 67.15 = 1.92$ kN/cm²

$\sigma tot = \sigma N_{ed} + 0,58 * \sigma v_{z,ed} + 0,58 * \sigma v_{z,ed} + \sigma M_{y,ed} + \sigma M_{y,ed}$

$0.43 + 0.58 * 0.41 + 0.58 * 0.61 + 5.05 + 1.92 = 7.99$ kN/cm²

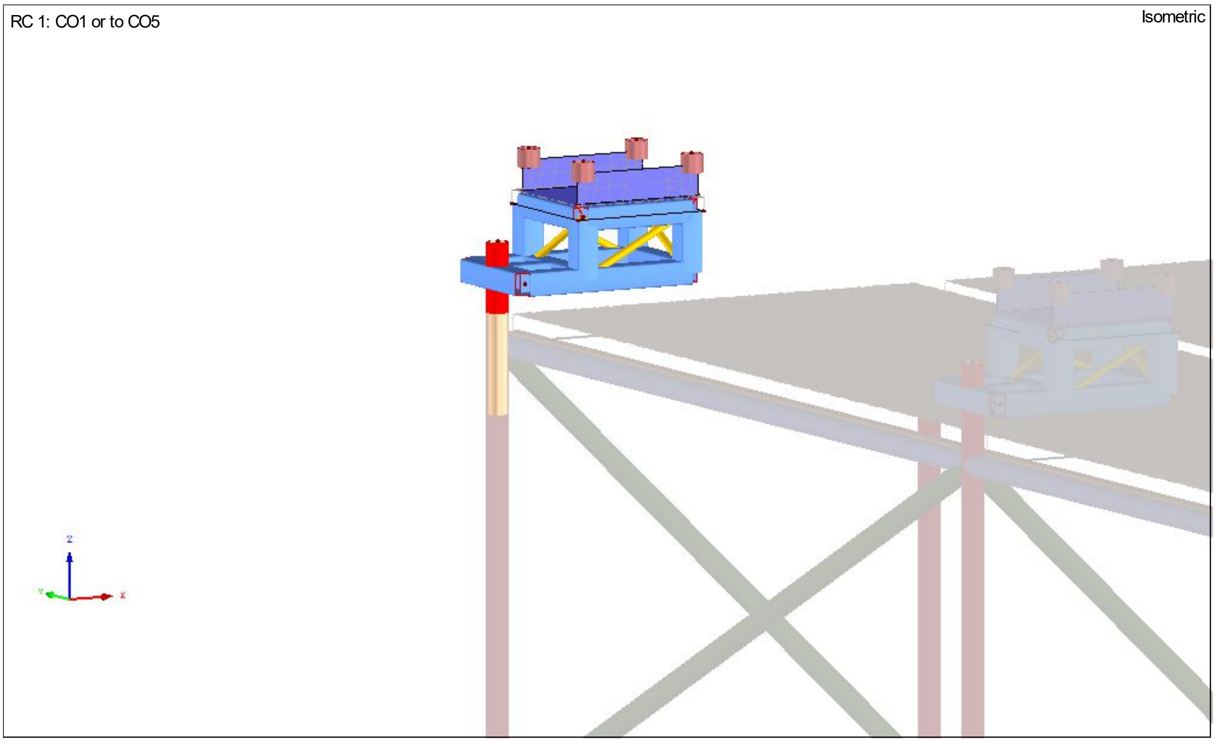
Check

$\sigma tot / (fy / \gamma) < 1$

$7.99 / (22.5 / 1.1) = 0.39 < 1$

6.10 Check of the truss connection to the Layher stage.

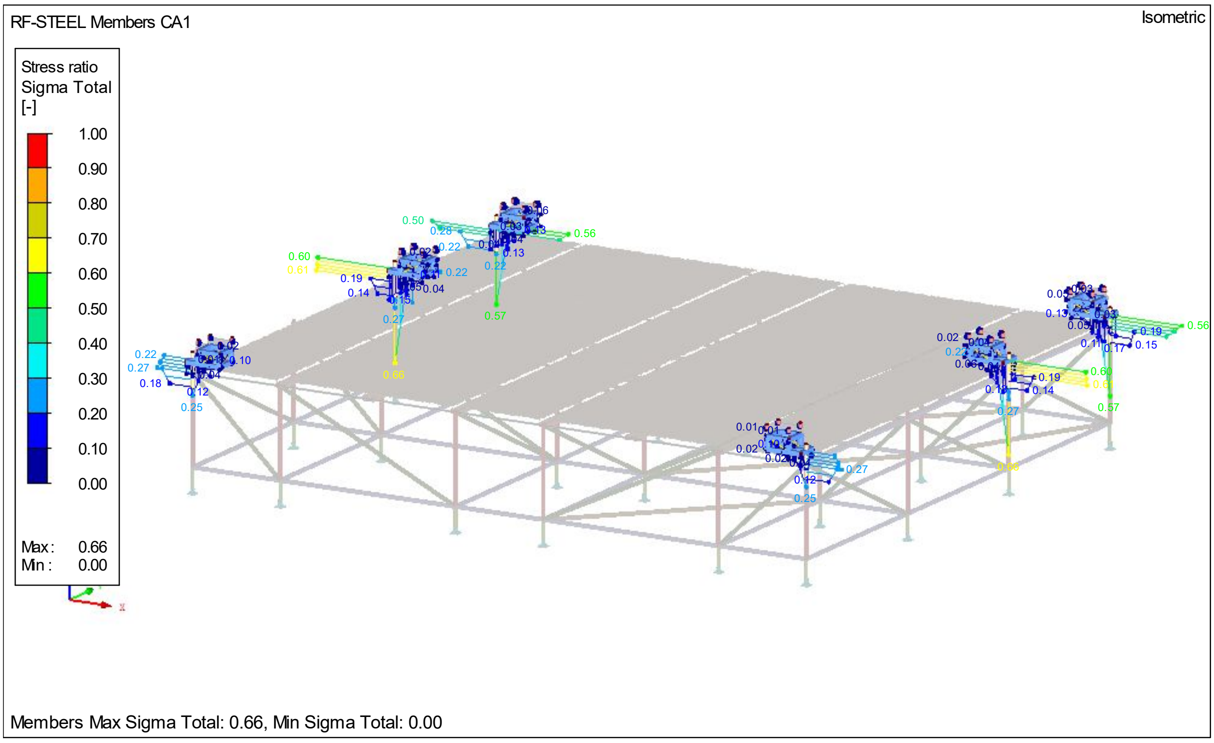
The Layher bases are inserted in the RFem model.

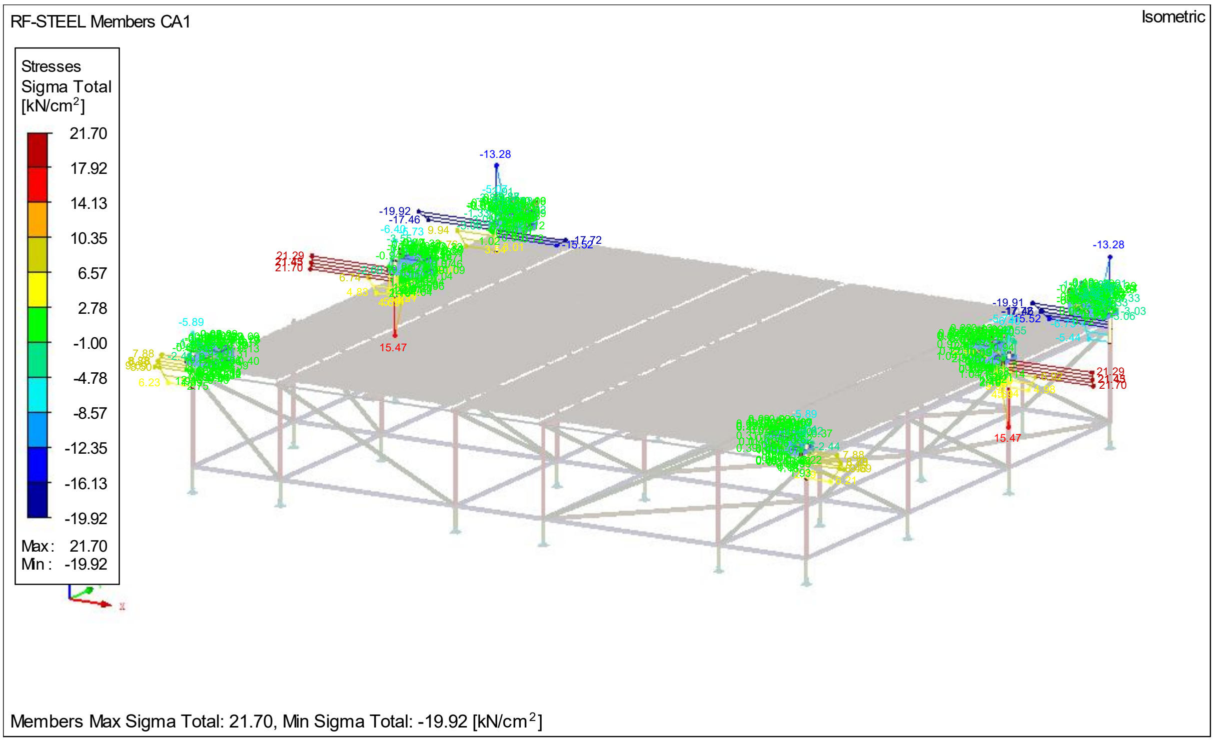


The Truss base will be mounted with an insert to the main Layher column.
This insert need to be fixed with a pin or bolt to the main Layher column.

The main profiles of the base unit are made from 50x50x3 S235
Diagonals of the base unit are made from 16x2 S235
The insert of the base is made from 42.4x3.2 S355

Maximum stress analyses for the members





Result from the stress analyse

Section No.	Member No.	Location x [m]	S-Point No.	Load-ing	Stress Type	Stress [kN/cm^2] Existing	Limit	Stress Ratio
1	QRO 50x3.2 (Hot Formed)							
	173	0,139	13	CO1	Sigma Total	15,47	23,50	0,66
	116	0,000	13	CO1	Tau Total	-3,75	13,57	0,28
	173	0,139	13	CO1	Sigma-eqv	15,85	23,50	0,67
2	Ring 16/2							
	187	0,282	11	CO1	Sigma Total	1,67	23,50	0,07
	186	0,000	23	CO1	Tau Total	-0,13	13,57	0,01
	187	0,282	11	CO1	Sigma-eqv	1,67	23,50	0,07
3	RO 48.3x4.0 (Hot Formed)							
	124	0,025	10	CO3	Sigma Total	-0,67	23,50	0,03
	22	0,000	1	CO1	Tau Total	0,71	13,57	0,05
	22	0,000	1	CO1	Sigma-eqv	1,26	23,50	0,05
9	RO 42.4x3.2 (Hot Formed)							
	246	0,000	7	CO1	Sigma Total	21,70	35,50	0,61
	246	0,000	8	CO3	Tau Total	-5,13	20,50	0,25
	246	0,000	7	CO1	Sigma-eqv	22,76	35,50	0,64

Maximum utilisation is 66%

Interal PROTRUSS S31

Truss series	PROTRUSS S31
Truss manufacturer	Interal T.C. the Netherlands
Truss series calculated by:	MICHEL.ENGINEERE
Structural report number:	2014-0067

Design internal forces for the complete truss

Normal force main chord	+/- 50.914 kN
Normal force coupling system	+/- 60.54 kN
Normal force diagonals	+/- 10.415 kN
Bending moment $M_{yR,d}$	24.34 kNm
Bending moment $M_{zR,d}$	24.34 kNm
Normal Force $N_{R,d}$	203.66 kN
Transversal Force $V_{yr,d}$	14.73 kN
Transversal Force $V_{zr,d}$	14.73 kN

Truss geometry

Main chords	48x3 EN AW-6082T6
Diagonals	16x2 EN AW-6082T6
Coupling system	CONICAL COUPLING SYSTEM
Height	239 mm Centre to centre distance main chords
Width	239 mm Centre to centre distance main chords
A	16.96 cm^2
I_y	2466 cm^4
I_z	2466 cm^4
i_y	12.06 cm
i_z	12.06 cm

The Main chord of the Protruss S31 has been produced from the material aluminium EN AW 6060 T6 instead of EN AW 6082 T6. This has been done because of the small radius of the arch trusses. This results in a lower maximum normal force in the main chord.

The lower Maximum normal force in the main chord is.
Limiting factor is the weld of the coupler to the main chord.
The coupling system and braces are the same and will have no influence.

$N_{rd,Haz\ Chord} = A_{eff} * f_{uk,haz}*0.8 * 1 / \gamma m2 = 4.241 * 10 * 0.8 * 1/1.25 = 27.14$ kN
$M_{Rd,\ main\ chord} = W_{chord} * f_{uk,haz}*0.8 * 1 / \gamma m2 = 4.493 * 10 * 0.8 * 1/1.25 = 28.75$ kNcm

All the structural geometry such as sectional area and moment of inertia and of the truss will stay the same as printed above

Interal PROTRUSS T31

Truss series	PROTRUSS T31
Truss manufacturer	Interal T.C. the Netherlands
Truss series calculated by:	MICHEL.ENGINEERE
Structural report number:	2014-0067

Design internal forces for the complete truss	
Normal force main chord	+/- 50.215 kN
Normal force coupling system	+/- 60.54 kN
Normal force diagonals	+/- 7.792 kN
Bending moment $M_{yR,d}$	9.48 kNm
Bending moment $M_{zR,d}$	10.95 kNm
Normal Force $N_{R,d}$	137.4 kN
Transversal Force $V_{yr,d}$	11.02 kN
Transversal Force $V_{zr,d}$	11.02 kN

Truss geometry	
Main chords	48x3 EN AW-6082T6
Diagonals	16x2 EN AW-6082T6
Coupling system	CONICAL COUPLING SYSTEM
Height	207 mm Centre to centre distance main chords
Width	239 mm Centre to centre distance main chords
A	12.72 cm^2
I_y	1244 cm^4
I_z	1244 cm^4
i_y	9.89 cm
i_z	9.89 cm