Site-specific calculation

# CT-AH-1012



| | |
|---|---|
| Content | : Site-specific calculation |
| Structure | : CT-AH-1012 |
| Manufacturer | : Kroftman |
| Document owner | : Kroftman |
| Reference number | : 241023 |
| Author | : Aromal. S |
| Checked by | : I. J. Bakker |
| Date | : 06-12-2024 |

# 1. Introduction

Kroftman has requested IB Tent Engineers to provide a construction report for their container shelter structure (CT-AH-1012), which measures 10 meters wide and 12 meters long. The structure has an arched roof frame mounted on containers, which act as side walls and partially form the gable walls. One gable wall is fully closed, while the other is completely open.

The Book is based on the NF EN 1991 -1-4 “Wind actions on buildings”.

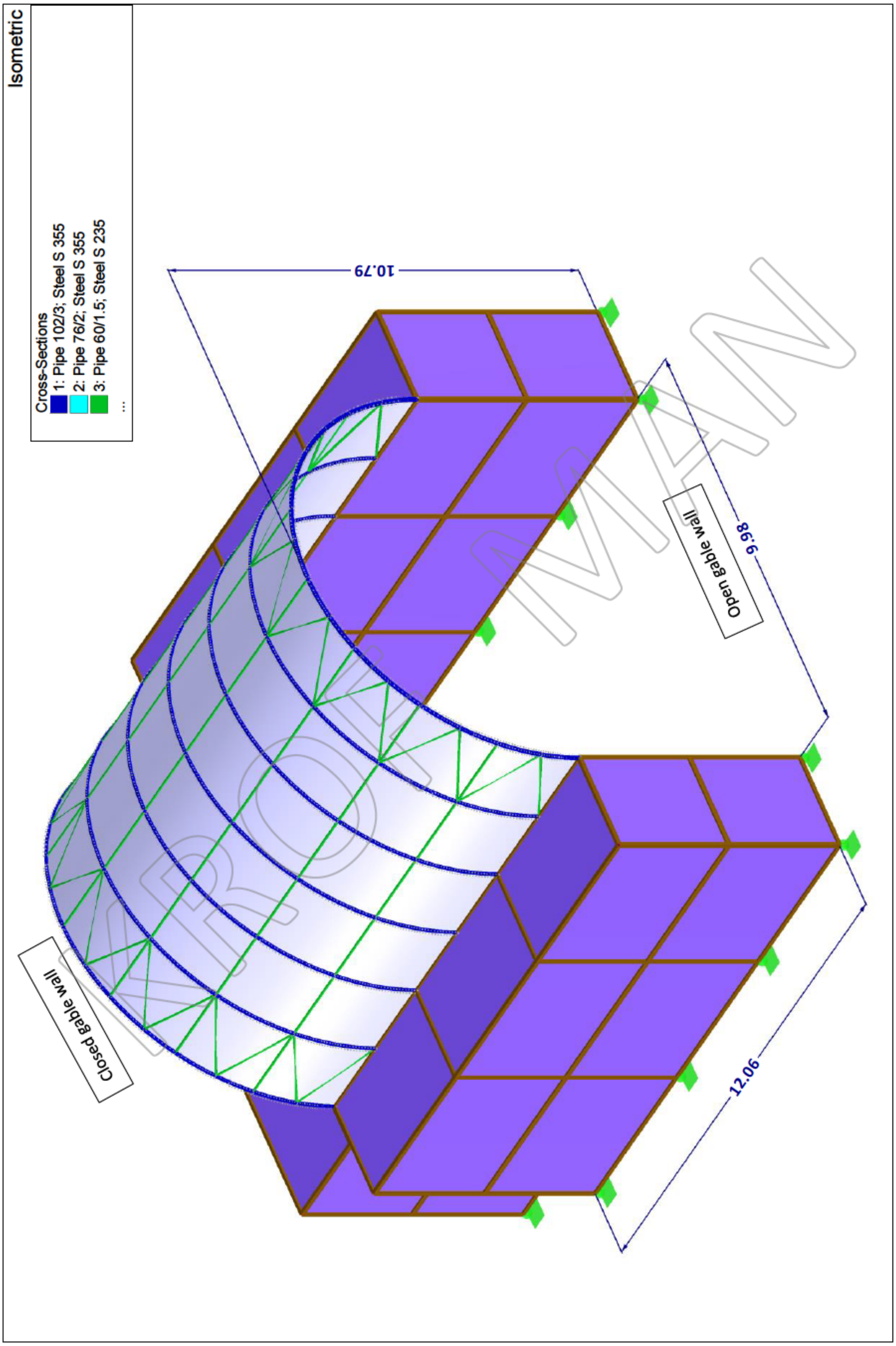
Location[redacted] Festival, France

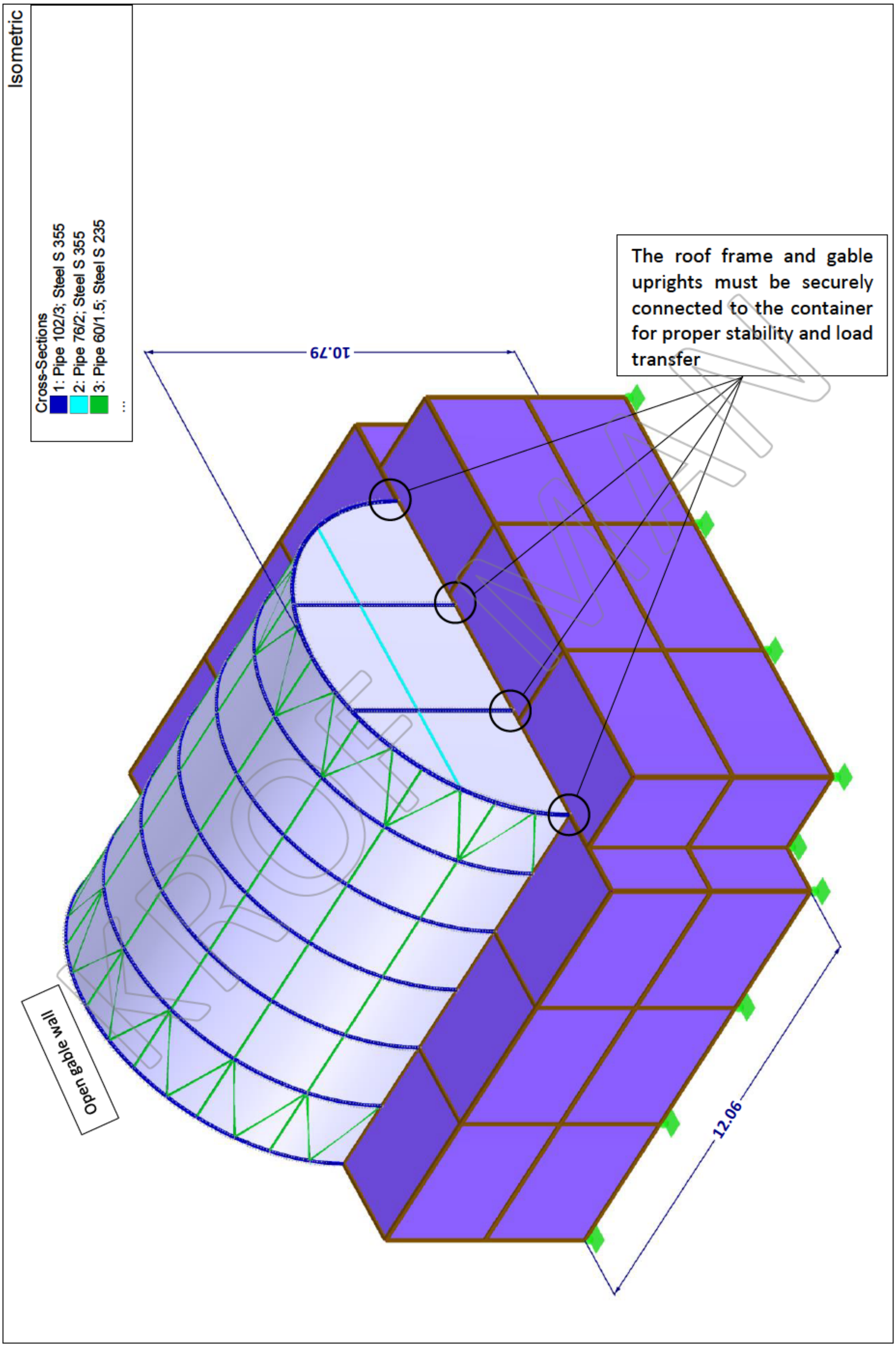
[redacted]

This investigation focuses on the strength of the roof frame and the required anchoring of the structure. The strength analysis is provided in the annex titled “240906 Kroftman Container Shelter 15 x 12m Build book Annex.” Additionally, the forces in the connections have been compared with the capacity of the details in the annex.

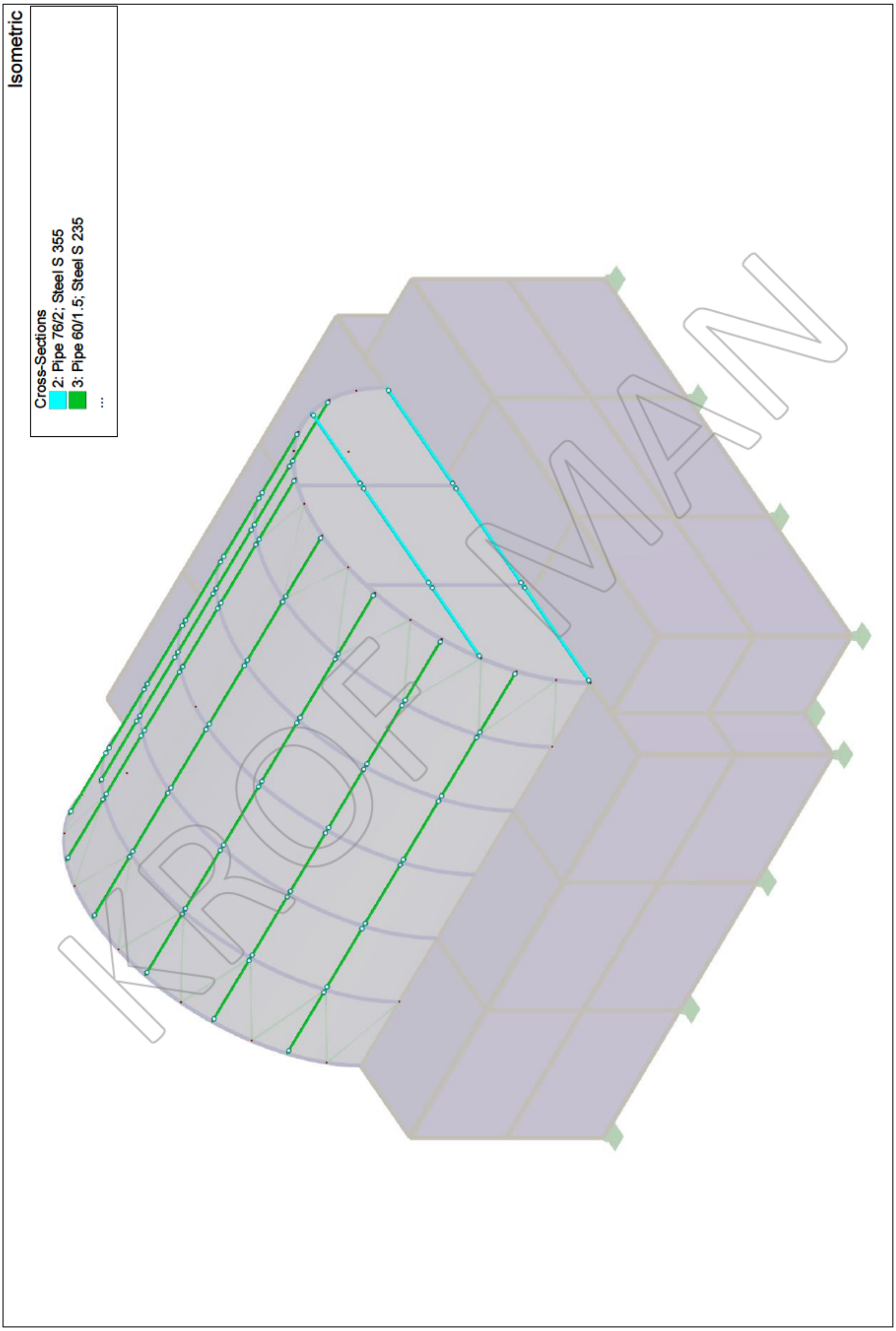
# 2. Contents

# 3. RFEM 3D computer model for analysing

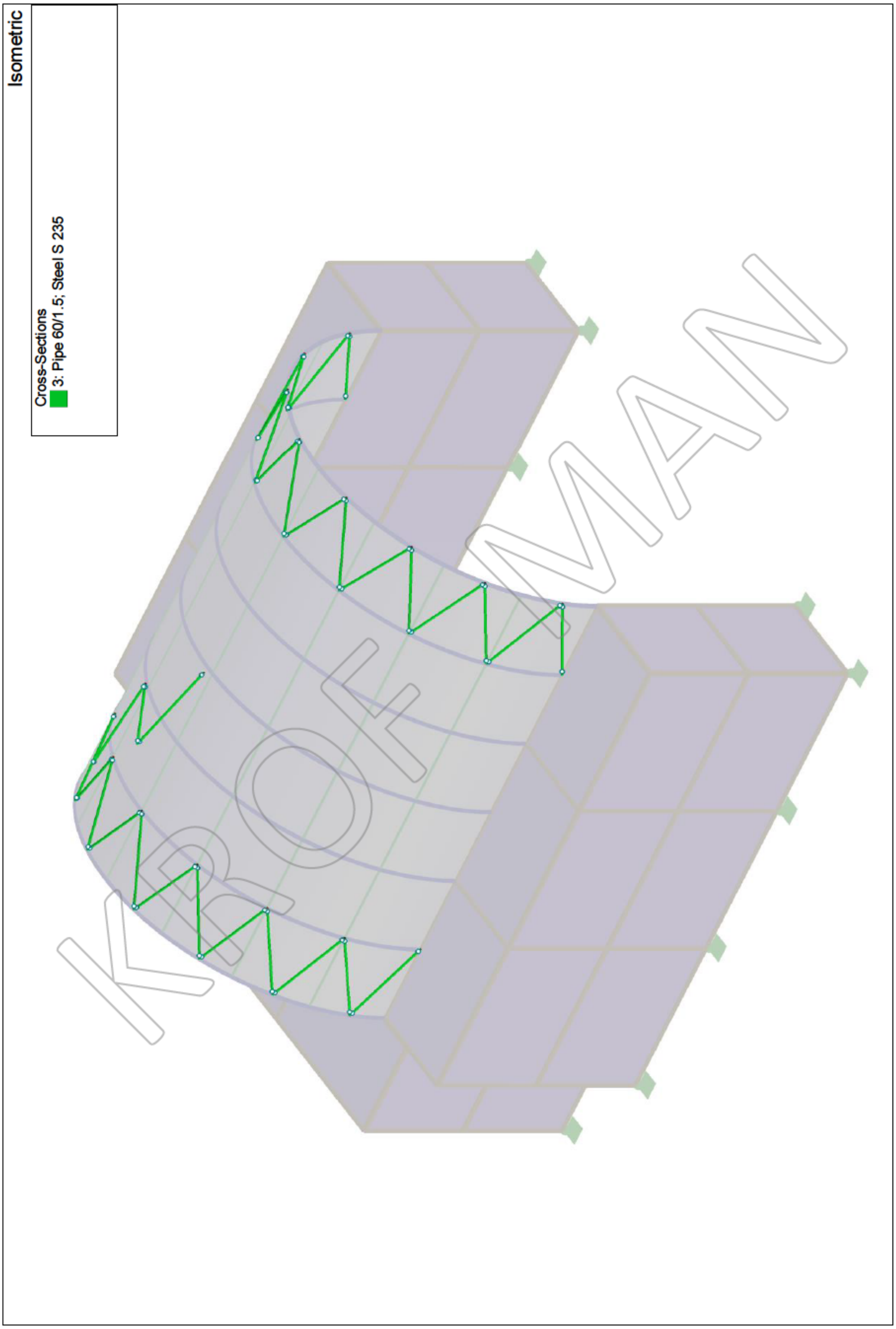



Isometric
Cross-Sections
1: Pipe 102/3; Steel S 355
2: Pipe 76/2; Steel S 355
3: Pipe 60/1.5; Steel S 235
...
10.79
The roof frame and gable uprights must be securely connected to the container for proper stability and load transfer
Open gable wall
12.06

## 3.1. Purlins


Isometric
Cross-Sections
2: Pipe 76/2; Steel S 355
3: Pipe 60/1.5; Steel S 235
...

## 3.2. Diagonals



# 4. Introduction to static analysis

The 3D Finite Element Software, “RFEM by Dlubal”, was used for performing a statical analysis.

For each configuration (in case there are multiple), a 3D model was analysed nonlinearly and according to the second-order theory. The printout of the RFEM report will be provided upon request.

An overview of the main structural beams with associated Unity Checks is to be found in chapter 6 of this report.

## 4.1. Standards

- EN 1990-1-1: “Fundamentals of Structural Design and NB”
- EN 13782_2015: “Tents – Safety”
- EN 1993-1-1: “Steel structures”
- NF EN 1991 -1-4 “Wind actions on buildings”

## 4.2. Use and safety factors

### 4.2.1. Use of structure

The structure in this calculation is meant to be used as a Semi-permanent structure. The reference period is set to 15 years

### 4.2.2. Consequence class

The Consequence Class is set to CC2, $K_{FI} = 1$ [1/1].

# 5. Loads on structure

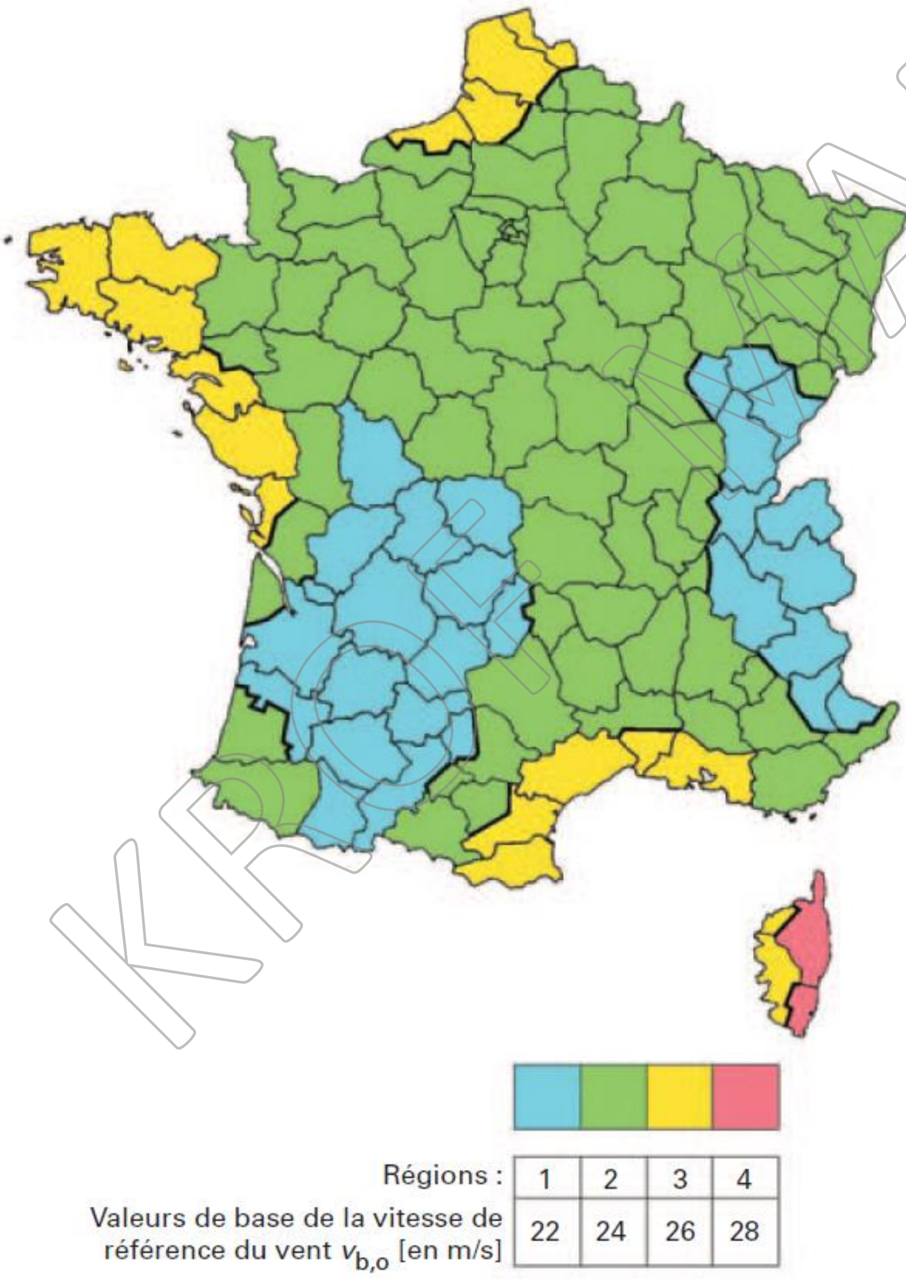
## 5.1. Own weight

The RFEM software has automatically included the weight of the components. Additionally, the weight of the 40-foot container has been added.

Weight of one container = 3750 kg.

## 5.2. Wind loads

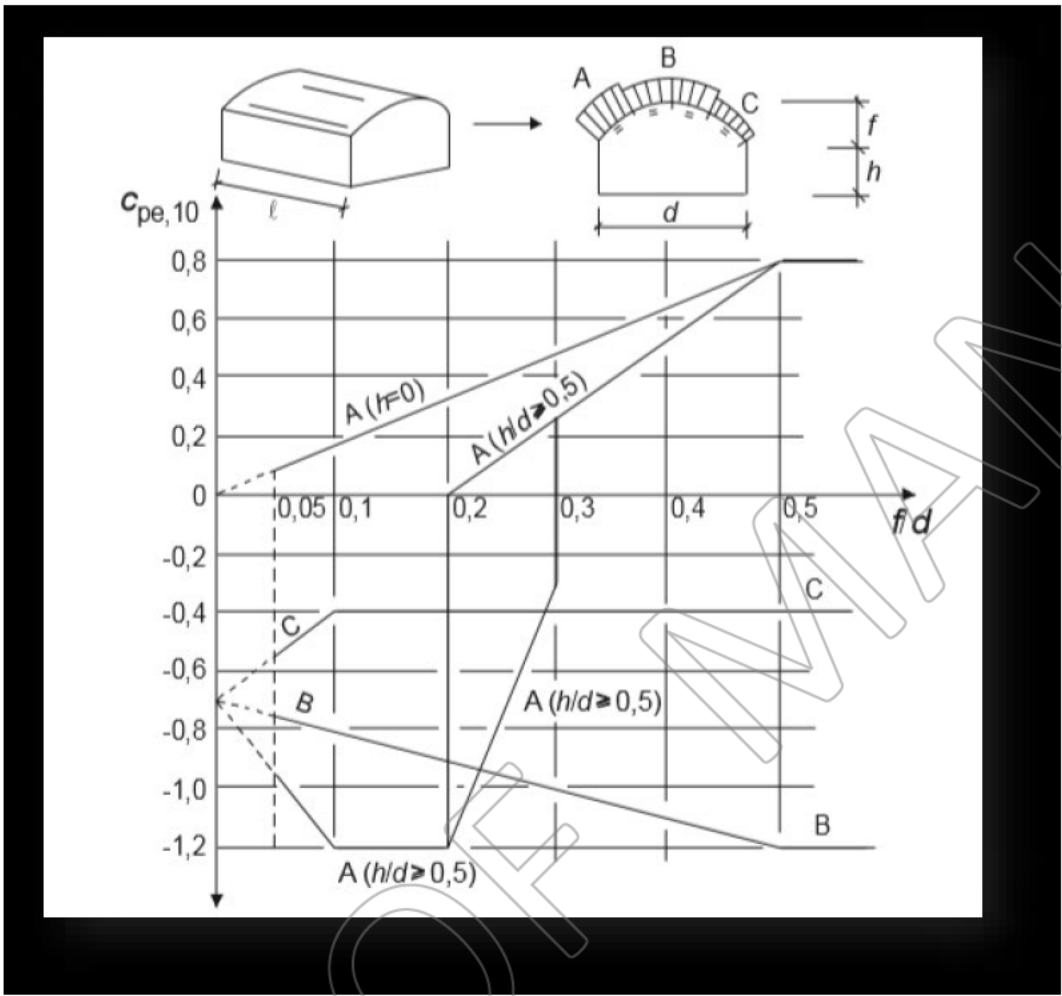
The wind loads on the structure are based on NF EN 1991-1-4 “Wind actions on buildings”.



| | | | |
|---|---|---|---|
| Project: | CT-AH-1012 | | |
| Structure: | 10 x 12 m | | |
| Date: | 23-10-2024 | | |
| According to the code: | NF EN 1991-1-4 | | |
| Wind zone: | 3 | | |
| Terrain category | III a | | |
| Reference period | 15 | Years | |
| $C_{prob}$ | 0.94 | | |
| Reference wind speed from map, $V_{b,0}$ | 26 | [m/s] | |
| Height of the structure above ground level, Z | 11 | m | |
| Roughness length of the terrain category, $Z_o$ | 0.2 | m | |
| Season factor, $C_{season}$ | 1 | | |
| Direction factor, $C_{dir}$ | 1 | | |
| Basic wind speed, $V_b$ | 24.336 | [m/s] | $V_b = C_{dir} \cdot C_{season} \cdot V_{b,0} \cdot C_{prob}$ |
| Terrain factor, $k_r$ | 0.209 | | |
| Roughness factor, $C_r(z)$ | 0.838 | | $C_r(z) = K_r \ln (Z / Z_o)$ |
| Orographic factor, $Co_{(z)}$ | 1 | | |
| Average wind speed, $V_{m(z)}$ | 20.38 | [m/s] | $v_m(z) = c_r(z) \cdot c_0(z) \cdot v_b$ |
| Turbulance factor, $k_I$ | 0.97 | | |
| Density of air, ρ | 1.225 | Kg/m³ | |
| Turbulence intensity, $I_{v(z)}$ | 0.242 | | $I_v(z) = \frac{\sigma_v}{v_m(z)} = \frac{k_1}{c_0(z) \cdot \ln(z/z_0)}$ |
| Dynamic wind pressure, $q_{p(z)}$ | **686** | N/m² | $q_p(z) = [1 + 7 \cdot I_v(z)] \cdot \frac{1}{2} \cdot \rho \cdot v_m^2(z) = c_e(z) \cdot q_b$ |

## 5.3. Wind pressure coefficients

According to NF EN 1991-1-4_2005, wind pressure coefficients have been applied for arched roofs as per the below scheme.




f = 5.04 m

h = 5.79 m

d = 10 m

f/d = 0.504

The wind pressure coefficients for different zones are as follows.

A = 0.8

B = -1.2

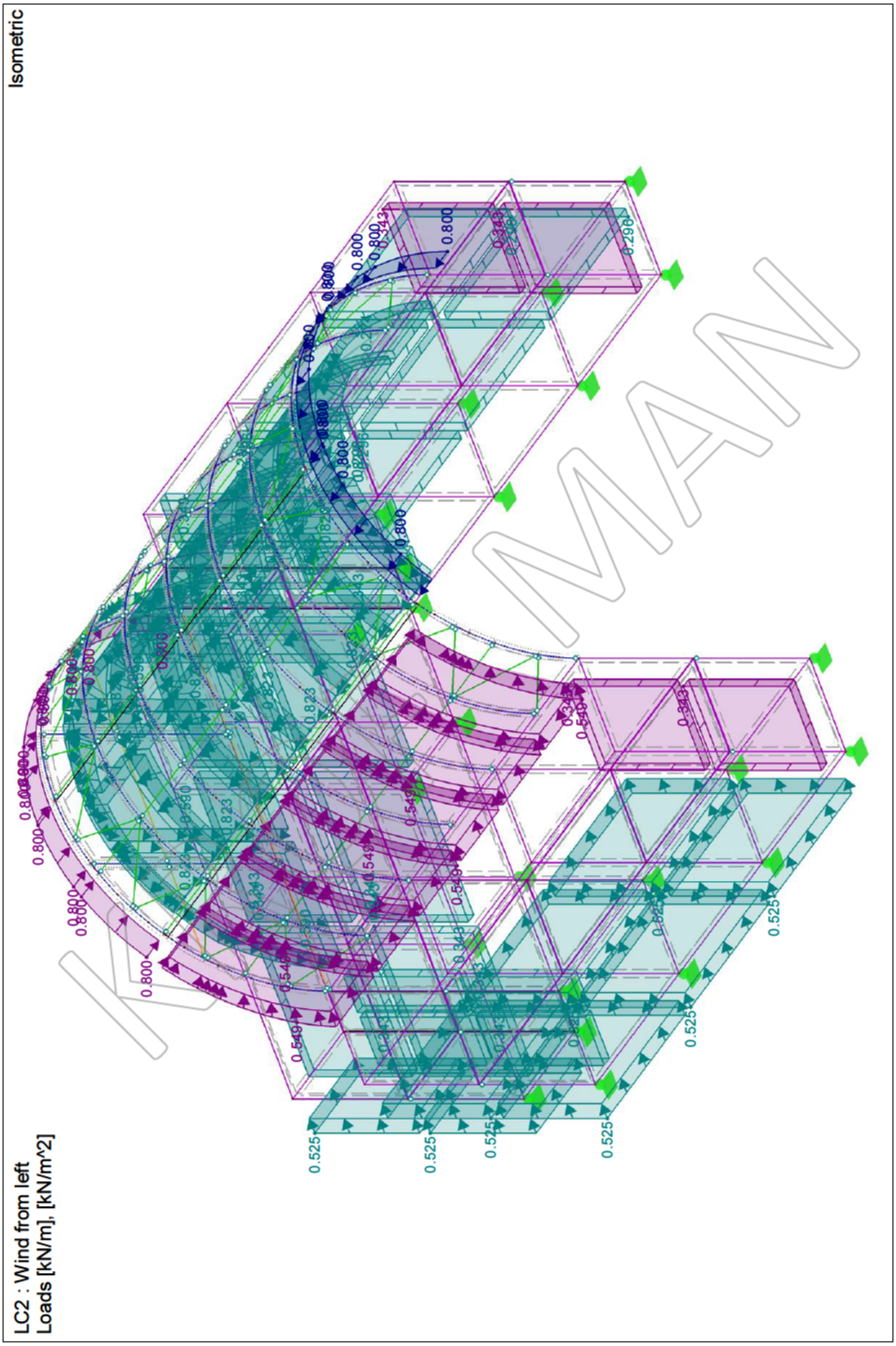
C = -0.4

For wind acting from the left, internal wind pressure coefficients on the closed gable wall are calculated by averaging the wind zone areas and their corresponding pressure coefficients.

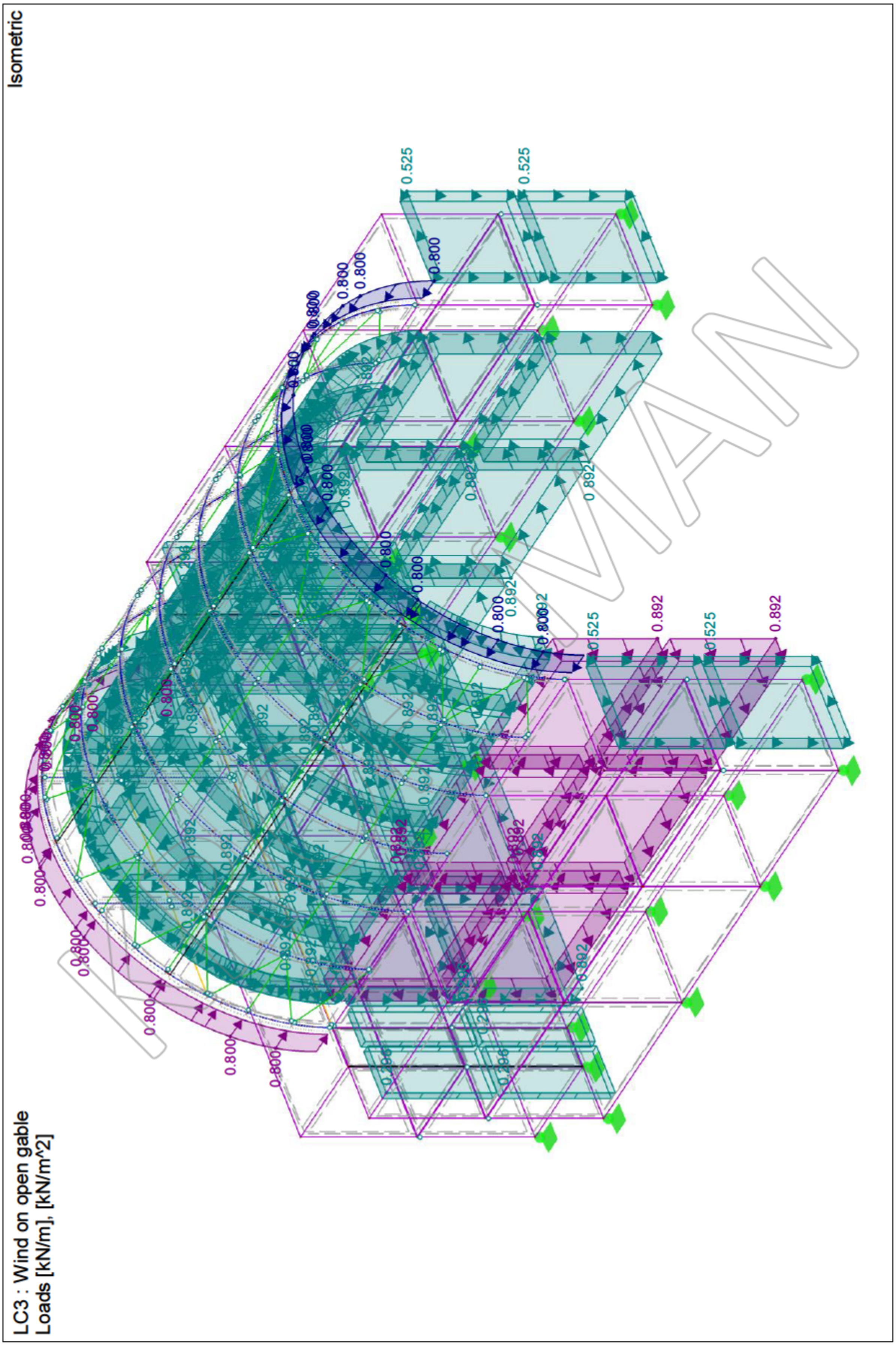
For wind acting through the open gable wall, internal wind pressure coefficients on the roof and side walls are applied as $C_p$ = 1.3.

The wind pressure coefficients for the sidewalls and roof are applied as per the scheme illustrated on the following pages.

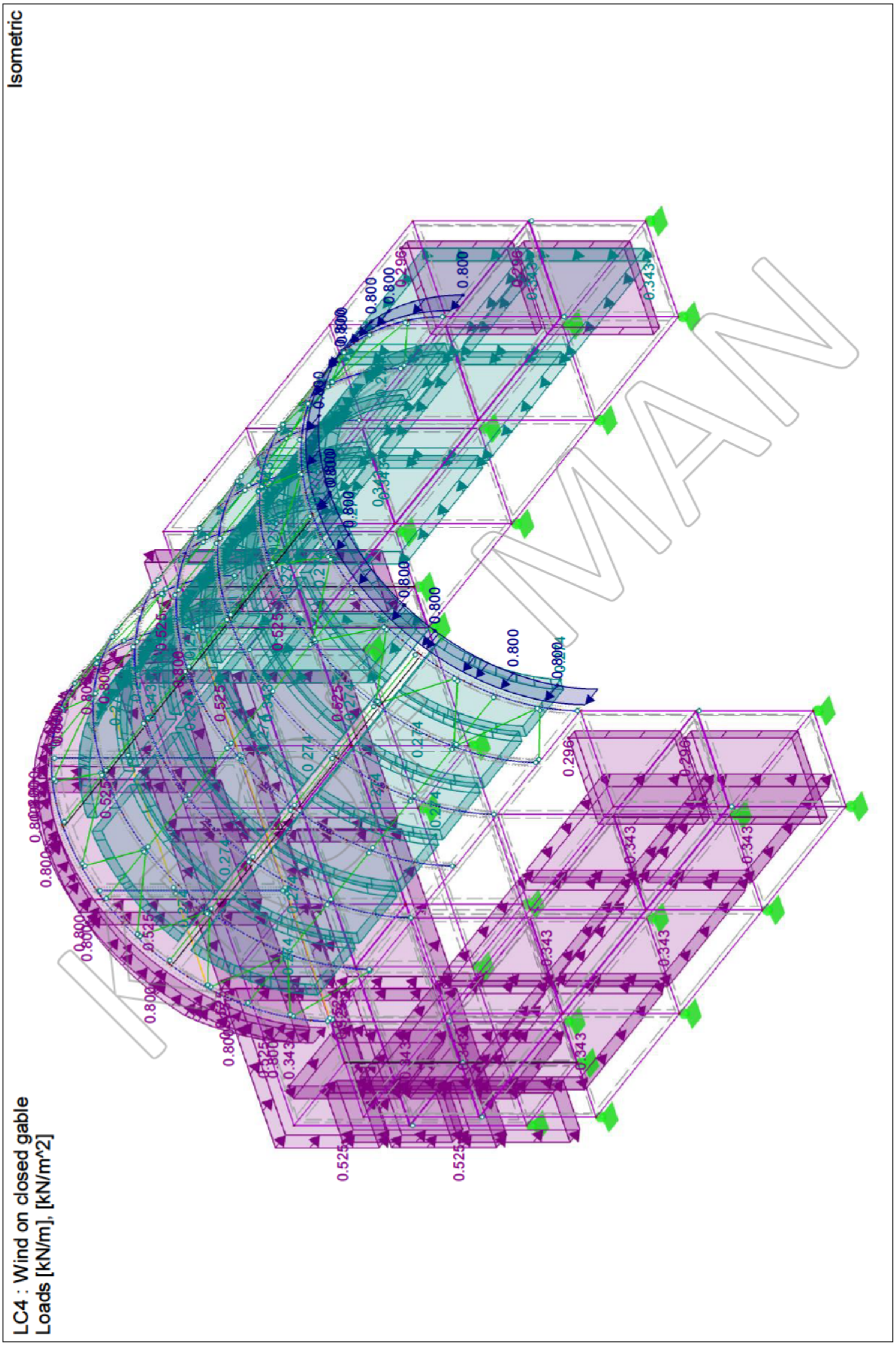
### 5.3.1. Wind load: Wind from left (LC2) – $C_p \times q_p$



### 5.3.2. Wind load: Wind on open gable (LC3) – $C_p \times q_p$



### 5.3.3. Wind load: Wind on closed gable (LC4) – $C_p \times q_p$



## 5.4. Seismic forces

Seismic forces may generally not be conserved because of the flexibility and light weight of the tent. Therefore, seismic forces have not been examined.

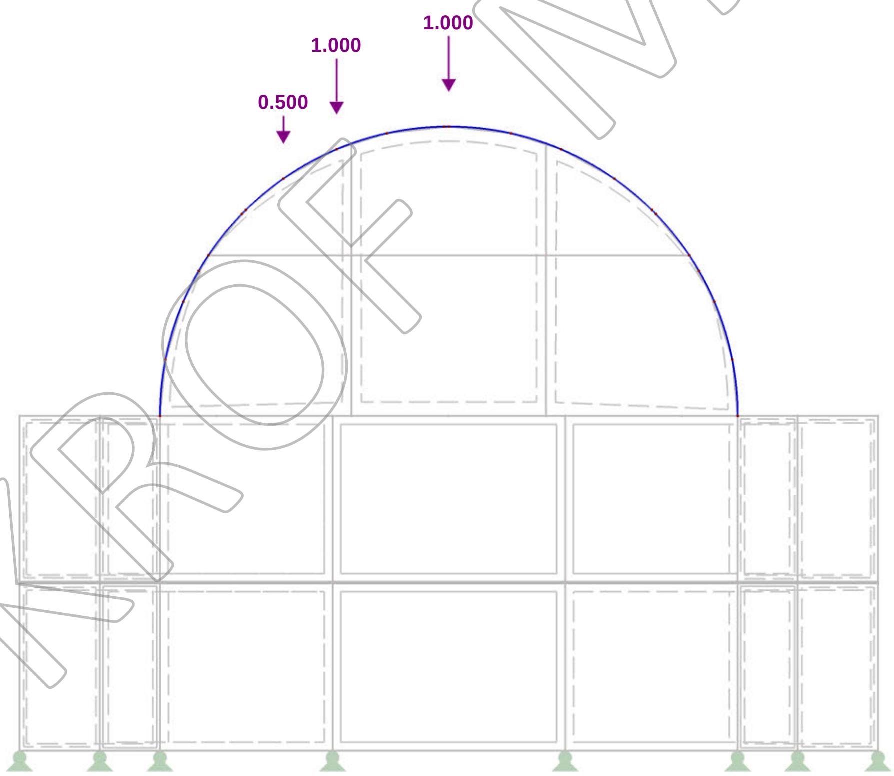
## 5.5. Live loads

This static analysis includes no floors, stairways, landings, ramps, raised floors, or platforms.

## 5.6. Roof weights

The additional roof weights (signs, lights, speakers and other hanging weights) should not exceed the weight of 250 kg per frame. This weight should be equally distributed amongst the entire span but may also be distributed amongst one-half spans. Roof weights are to be hung from the main frames only. Never use a purlin to hang weight from.

- If concentrated loads of more than 100 kg (1 kN) need to be applied, contact your rental company to get these loads and positions approved.
- Use dedicated brackets or clamps to apply the loads onto the roof frames.
- Unforeseen dynamic effects of hanging weights during (peak) winds are not taken into account. Prevent increasing movements due to own frequency and weights.



## 5.7. Snow load on roof frame

**The maximum allowable roof weight onto fabric like sand or snow is chosen to 0.5 kN/m² (+/- 50 kg/m²).**

**According to EN 1991-1-3_2003, snow load has been applied for arched roofs as per the below scheme.**

**NOTE 2**: Rules for considering the effect of snow fences for snow loads on cylindrical roofs may be given in the National Annex.

(2) The undrifted load arrangement which should be used is shown in Figure 5.6, case (i).

(3) The drifted load arrangement which should be used is shown in Figure 5.6, case (ii), unless specified for local conditions.

**NOTE:** Based on local conditions an alternative drifting load arrangement may be given in the National Annex.

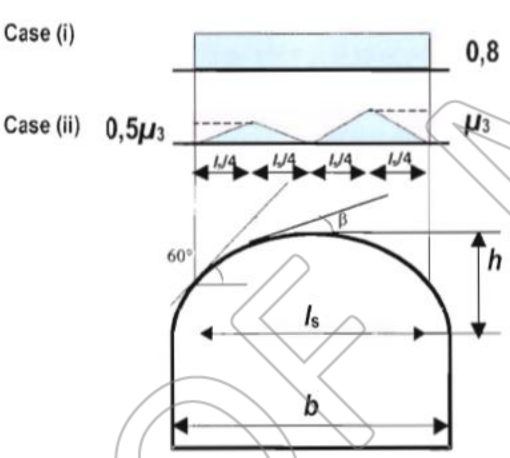



**Figure 5.6: Snow load shape coefficients for cylindrical roof**



h = 5.04 m

b = 10 m

h/b = 5.04 / 10 = 0.504

$\mu_3$ = 2

Therefore,

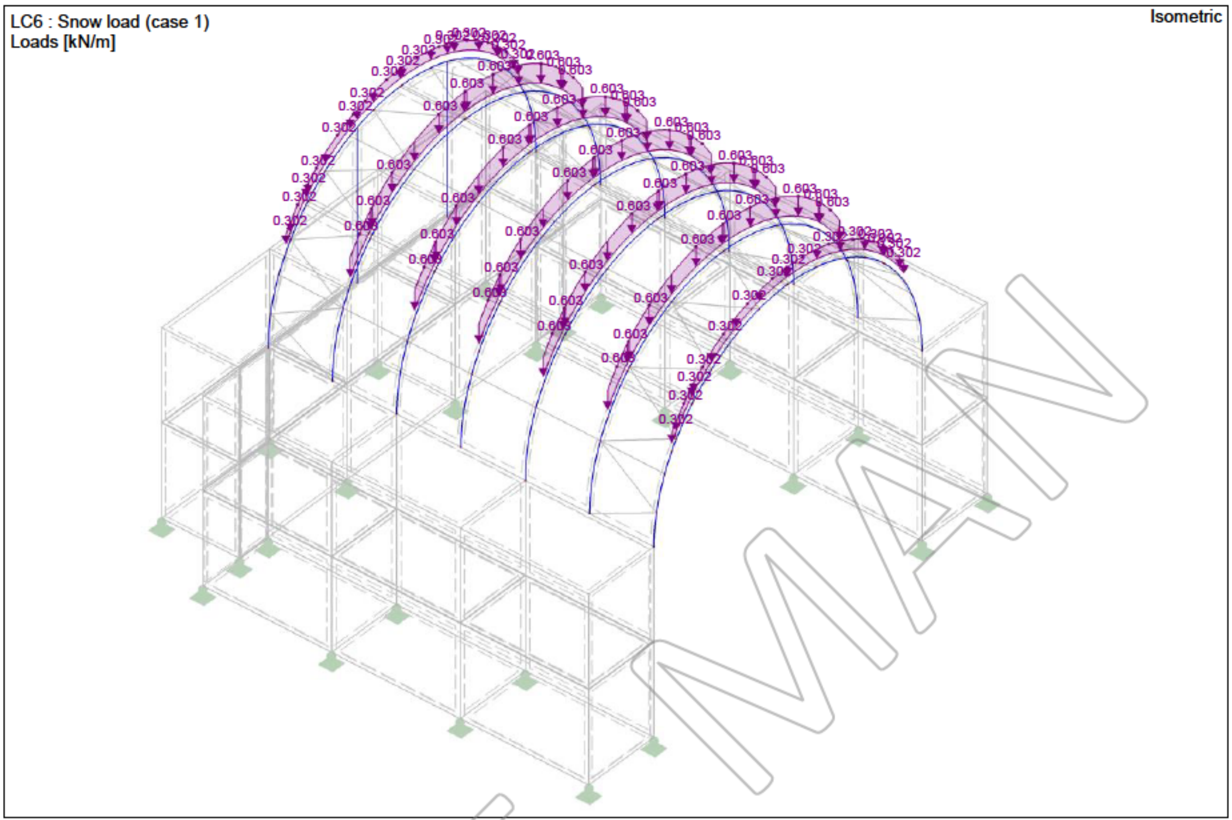
**Snow load (case 1)** = 0.8 x 0.75 x 0.5 = 0.3 kN/m²

**Snow load (case 2)**

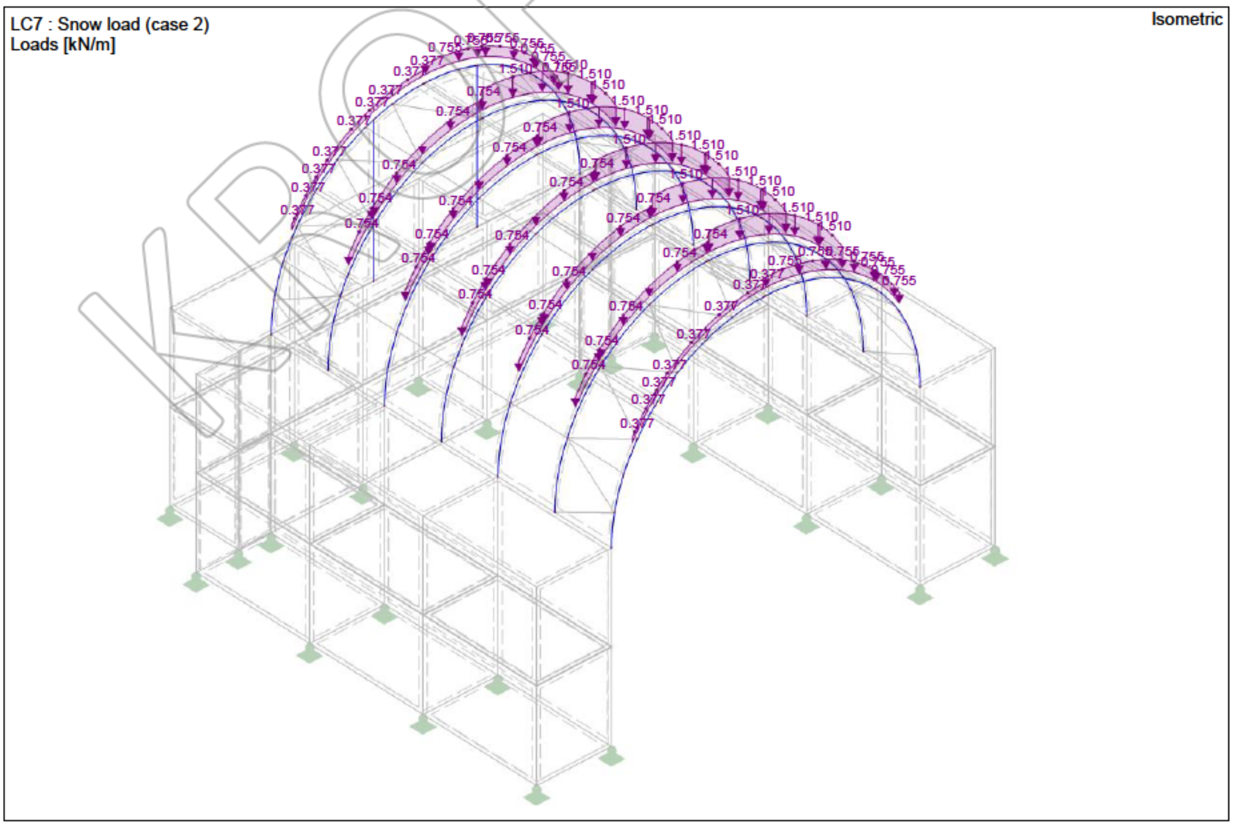
- 0.5 x $\mu_3$ x 0.75 x 0.5 = 0.375 kN/m²
- $\mu_3$ x 0.75 x 0.5 = 0.75 kN/m²

The snow load has been applied to the roof as per the illustrated below.

### 5.7.1. Snow load - case: 1




### 5.7.2. Snow load - case: 2



## 5.8. Imperfections

Imperfections have been taken into account by adding an additional load case, “imperfection” according to EN 1993-1-1: 2005-07.

## 5.9. Load cases and combinations

### 5.9.1. Load cases

| Load Case | Load Case Description | To Solve | EN 1990 \| NEN:2011 Action Category | Self-Weight - Factor in Direction Active | X | Y | Z |
|---|---|---|---|---|---|---|---|
| LC1 | Own Weight | + | Permanent | + | 0.000 | 0.000 | -1.000 |
| LC2 | Wind from left | + | Wind | - | 0.000 | 0.000 | 0.000 |
| LC3 | Wind on open gable | + | Wind | - | 0.000 | 0.000 | 0.000 |
| LC4 | Wind on closed gable | + | Wind | - | 0.000 | 0.000 | 0.000 |
| LC5 | Roof weights | + | Permanent/Imposed | - | 0.000 | 0.000 | 0.000 |
| LC6 | Snow load 1 | + | Snow (H ≤ 1000 m a.s.l.) | - | 0.000 | 0.000 | 0.000 |
| LC7 | Snow load 2 | + | Snow (H ≤ 1000 m a.s.l.) | - | 0.000 | 0.000 | 0.000 |
| LC8 | Imperfections | + | Imperfection | - | 0.000 | 0.000 | 0.000 |

### 5.9.2. Load combinations

| Load Combin. | DS | Load Combination Description | To Solve | LC.1 Factor | LC.1 No. | LC.2 Factor | LC.2 No. | LC.3 Factor | LC.3 No. | LC.4 Factor | LC.4 No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 0 | Wind from left | + | 1.350 | LC1 | 1.500 | LC2 | 1.000 | LC8 | | |
| CO2 | 0 | Wind on open gable | + | 1.350 | LC1 | 1.000 | LC8 | 1.500 | LC3 | | |
| CO3 | 0 | Wind on closed gable | + | 1.350 | LC1 | 1.500 | LC4 | 1.000 | LC8 | | |
| CO4 | 0 | Wind from left and roof weights | + | 1.350 | LC1 | 1.350 | LC2 | 1.350 | LC5 | 1.000 | LC8 |
| CO5 | 0 | Wind on open gable and roof weights | + | 1.350 | LC1 | 1.350 | LC3 | 1.350 | LC5 | 1.000 | LC8 |
| CO6 | 0 | Snow load | + | 1.350 | LC1 | 1.000 | LC8 | 1.500 | LC6 | | |
| CO7 | 0 | Snow load 2 | + | 1.350 | LC1 | 1.000 | LC8 | 1.500 | LC7 | | |
| CO8 | 0 | Anchoring wind from left | + | 1.000 | LC1 | 1.500 | LC2 | | | | |
| CO9 | 0 | Anchoring wind on open gable | + | 1.000 | LC1 | 1.500 | LC3 | | | | |
| CO10 | 0 | Anchoring wind on closed gable | + | 1.000 | LC1 | 1.500 | LC4 | | | | |
| CO11 | 0 | Wind from left (SLS) | + | 1.000 | LC1 | 1.000 | LC2 | | | | |

# 6. Check on main elements

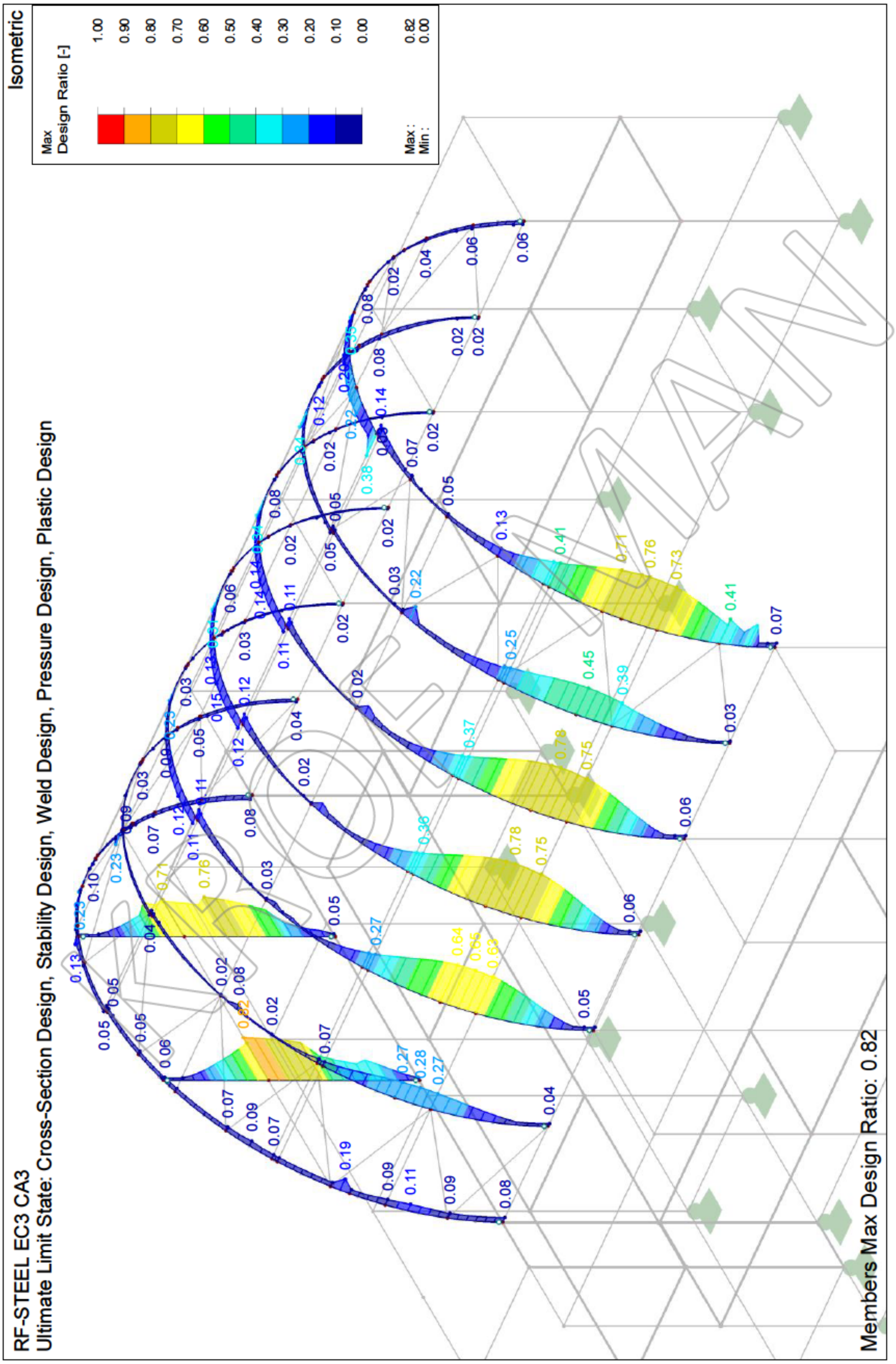
## 6.1. Steel

The steel members have been checked according to all relevant equations within the EN 1993: Steel structures.

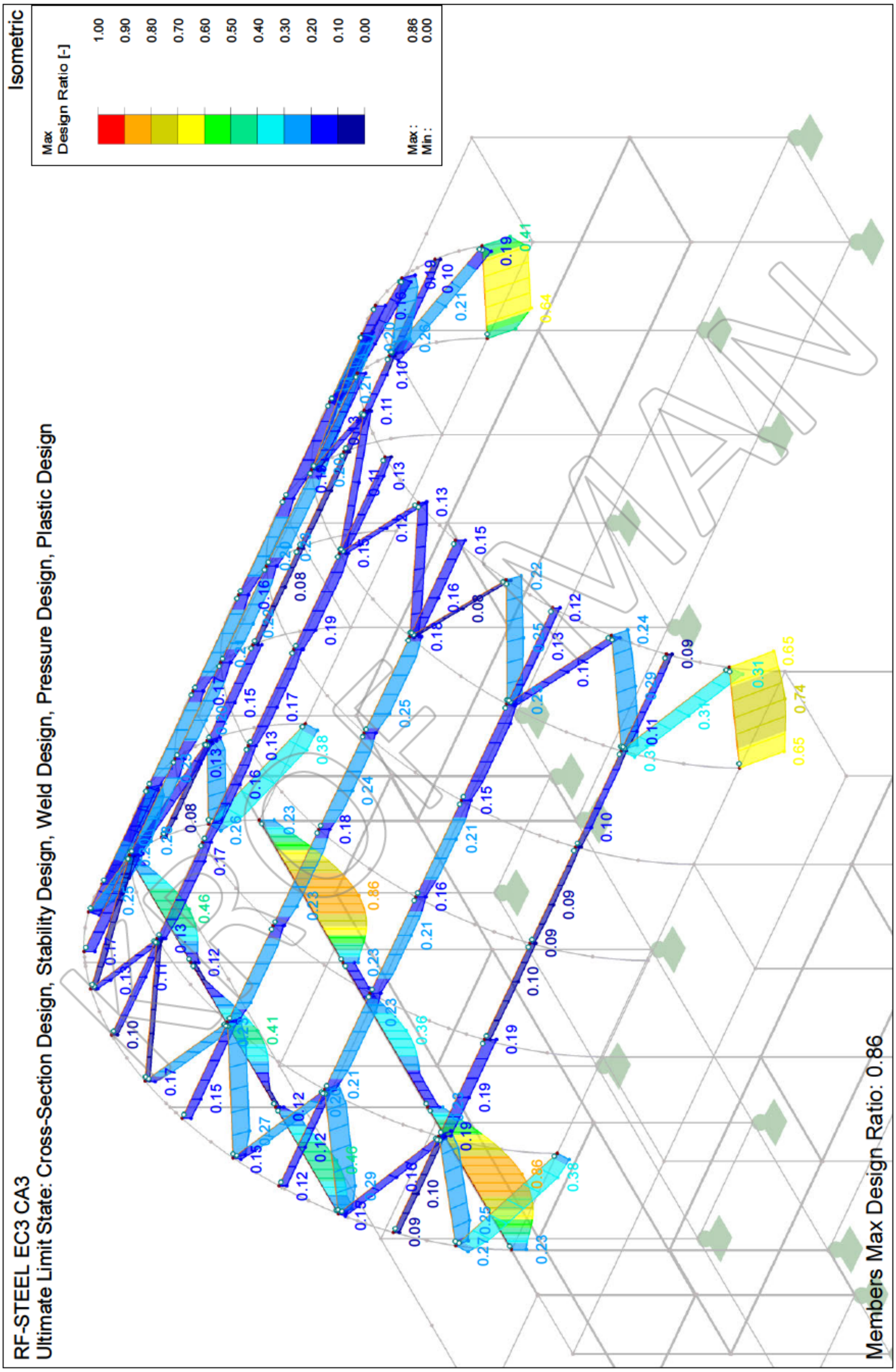
Conclusion: All members were found to fulfil the requirements.

## 6.2. Steel Unity check (Wind)

### 6.2.1. Main frames

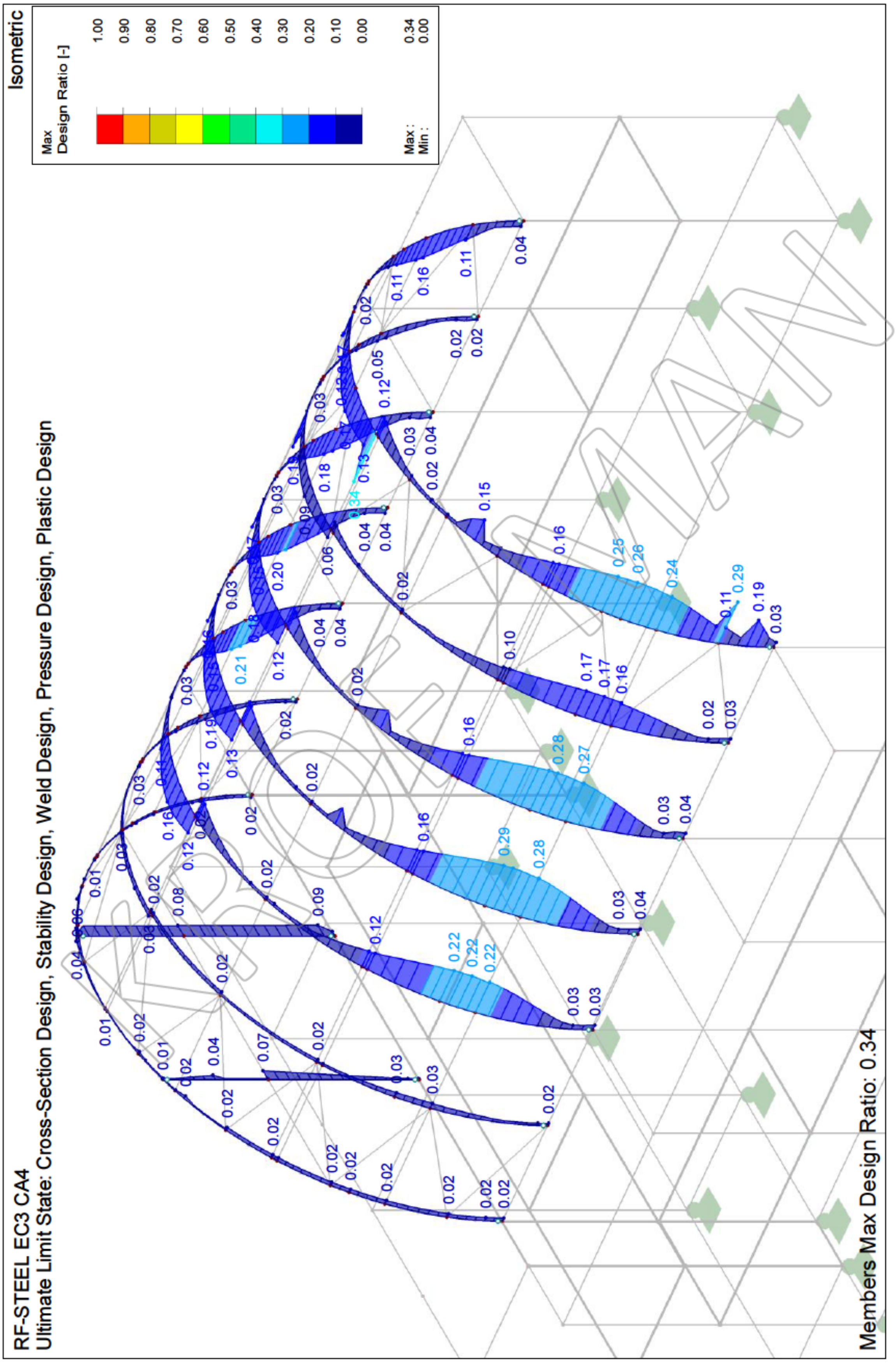


### 6.2.2. Purlins & diagonals

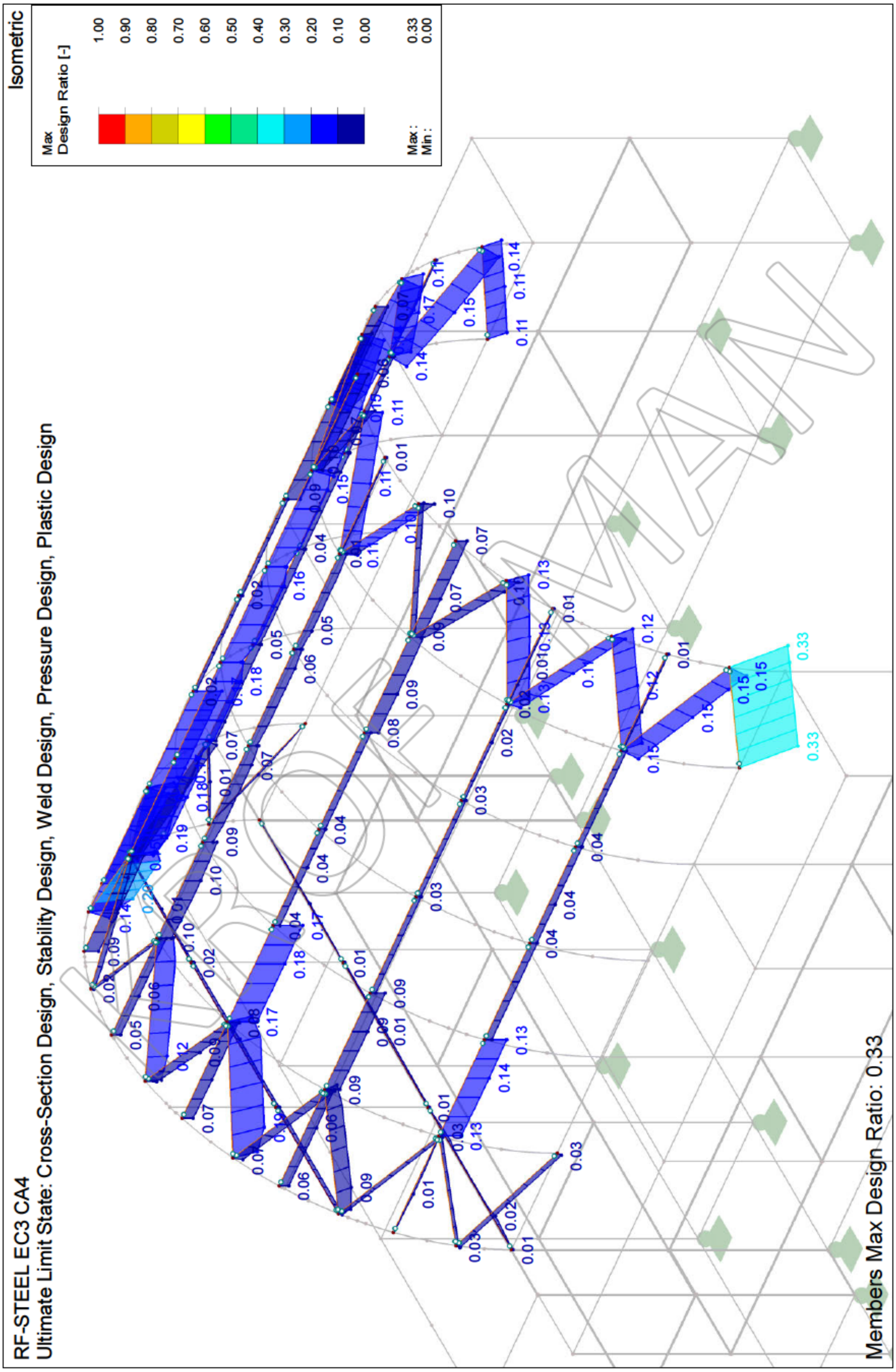


## 6.3. Steel Unity check (Snow)

### 6.3.1. Main frames

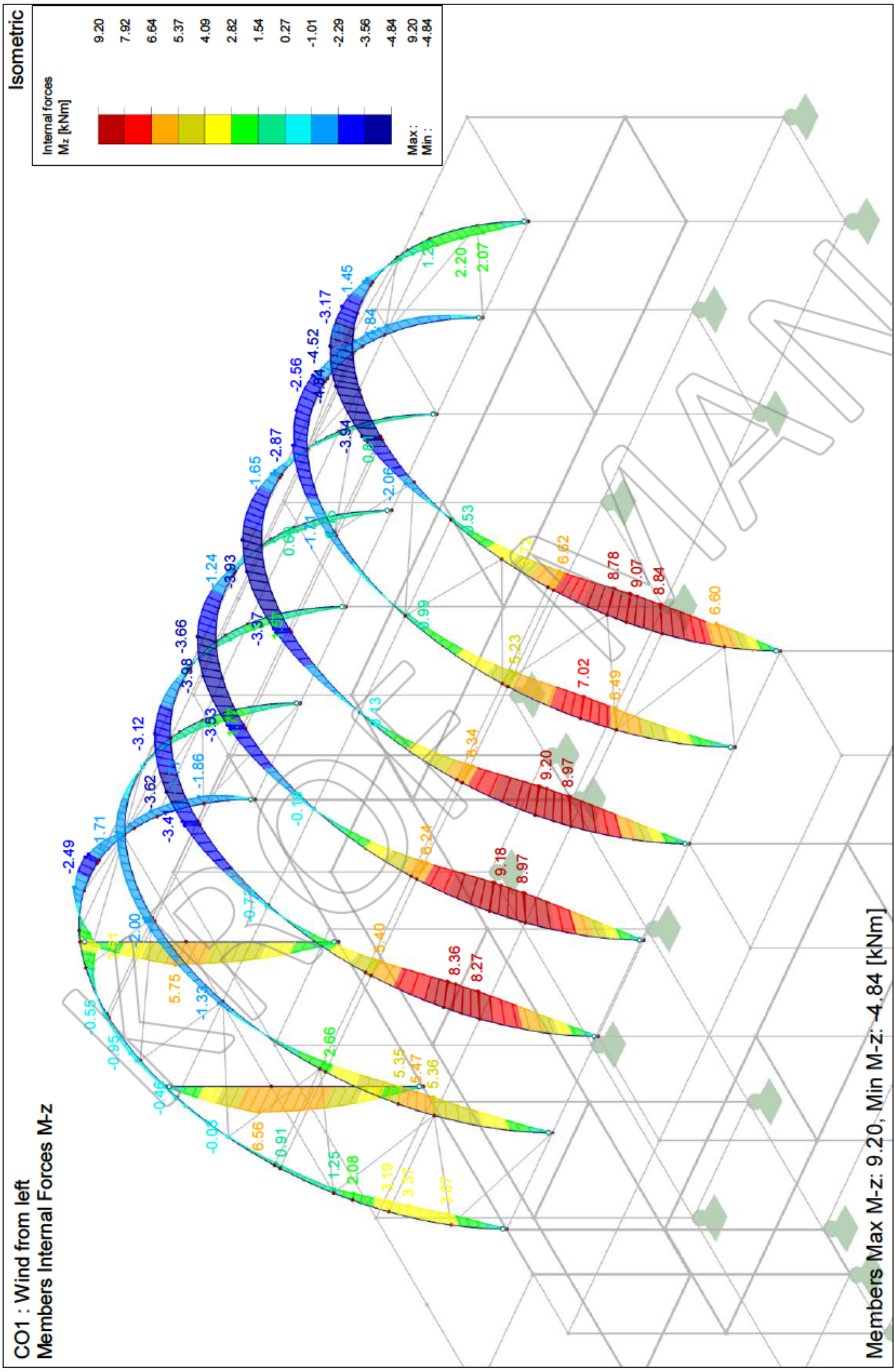


### 6.3.2. Purlins & diagonals



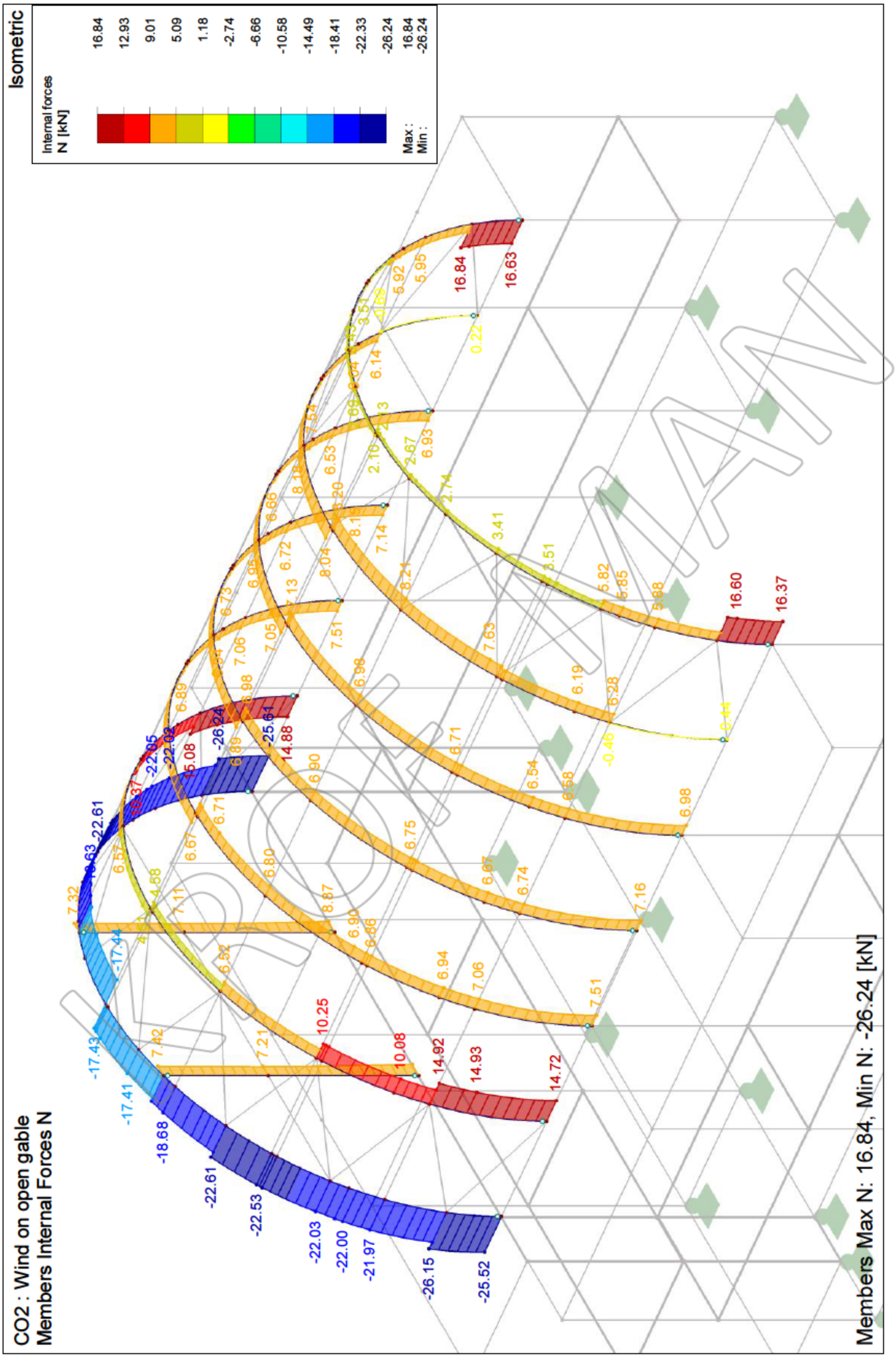
## 6.4. Decisive loadings

### 6.4.1. Bending moment



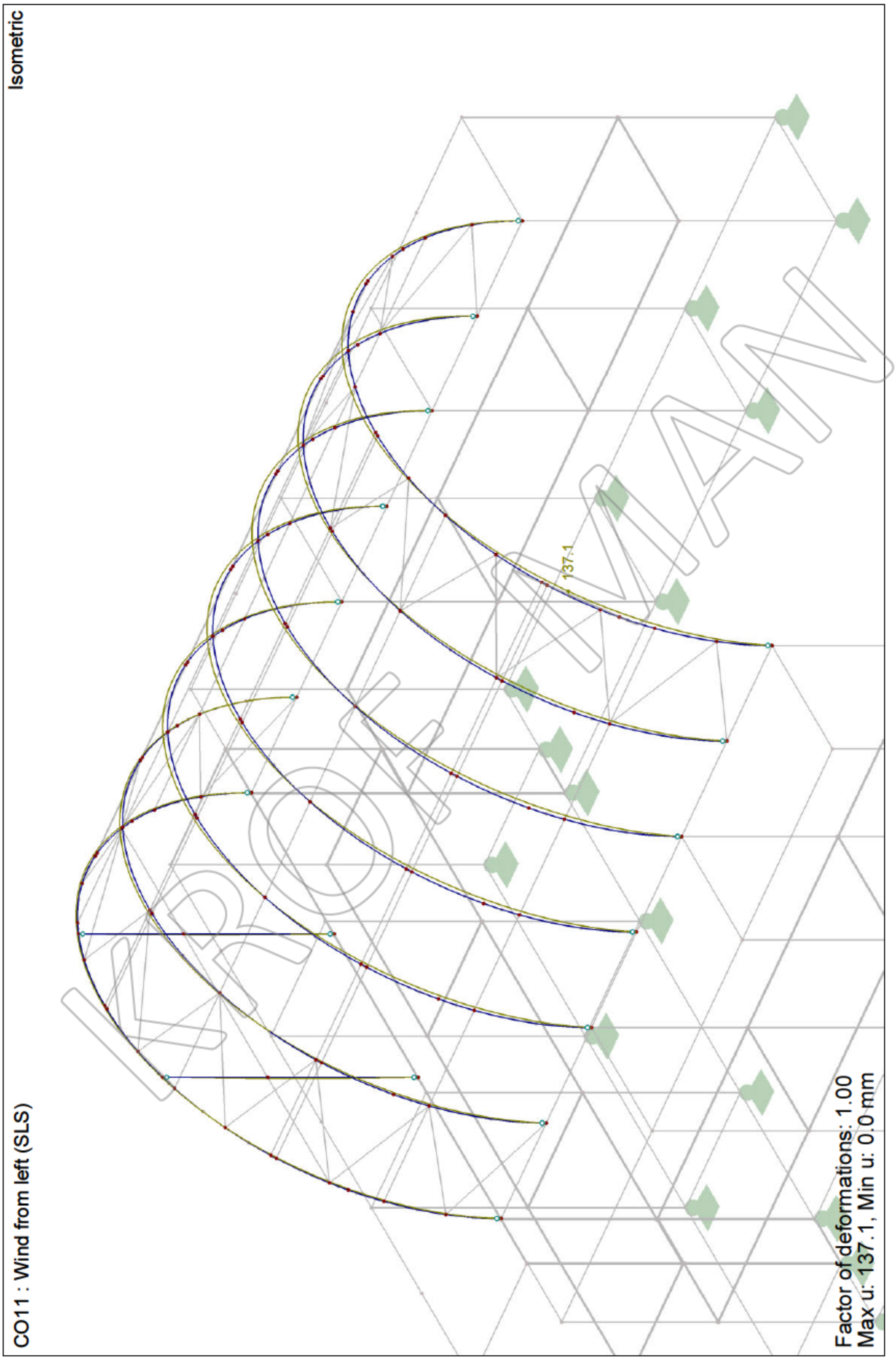

Maximum bending moment = 9.20 kNm (CO1)

### 6.4.2. Normal force




Maximum normal force = 26.24 kN (CO2)

### 6.4.3. Deformation (SLS)




The main profile has a maximum deformation of 137 mm due to serviceability limit state (SLS).

## 6.5. Comparison of forces in the components/connections

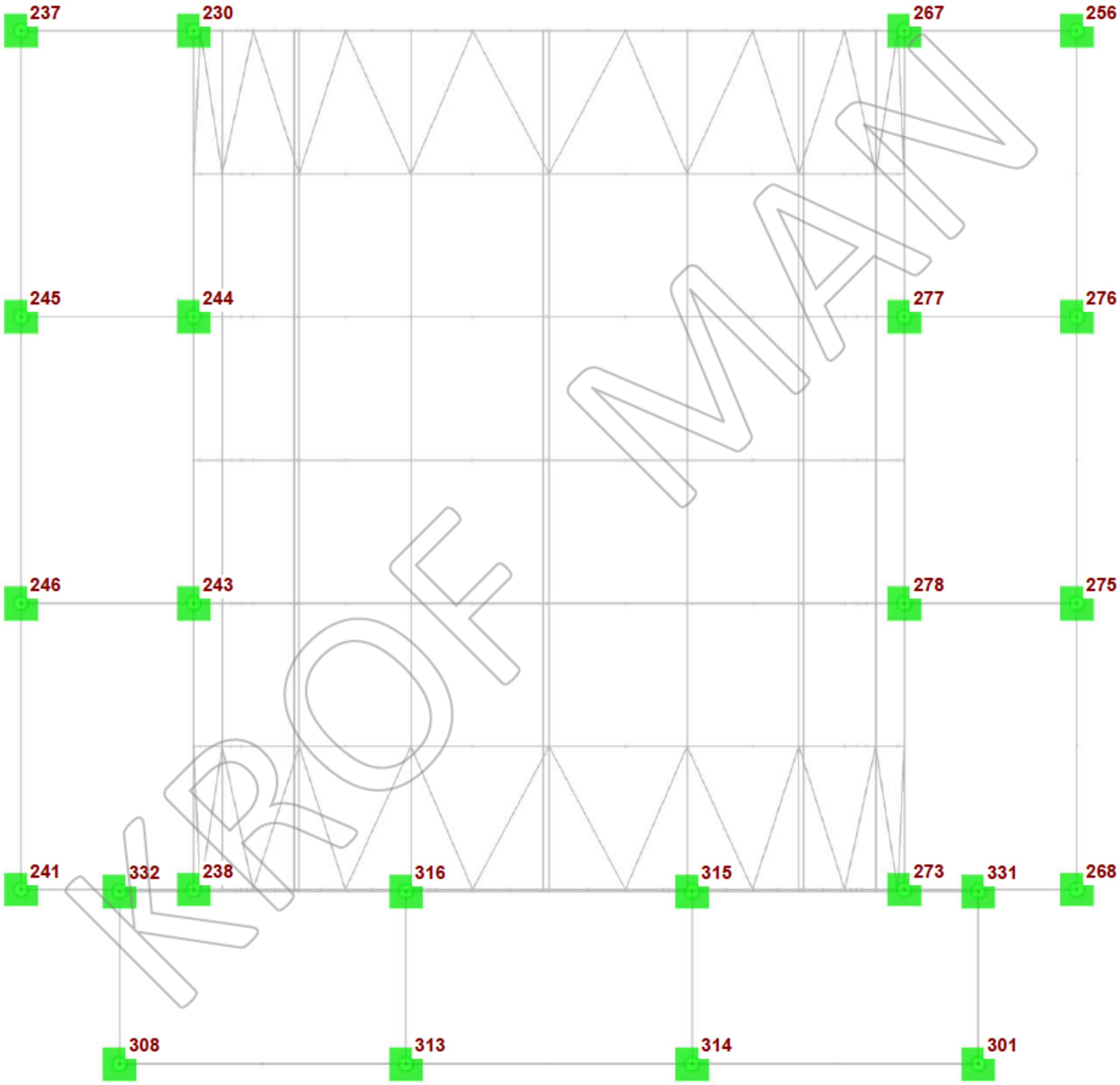
A comparison of the loads for Double container structure CT-AH-1012 with the reference building book (240906 Kroftman Container Shelter 15 x 12 m Build book Annex 1) has been performed and reported in the table below. It is found that the resulting forces in the Double container structure CT-AH-1012 are loads lower than in previous studies for most of the structural elements. But for a few structural elements, the forces are greater than in previous studies, and these higher forces do not lead to any failure of the structural elements.

| Acting loadings based on the static "240906 Kroftman Container Shelter 15 x 12m Build book Annex 1" | | | | |
|---|---|---|---|---|
| **Sl No.** | **Component / Connection** | **material** | **Acting loadings according to the CTS1512 Build book Annex** | **Acting loadings in CT-AH-1012 France** |
| 1 | Main profile (Roof frame & gable column) | S355 | $N_{Ed}$ = 34.95 kN | $N_{Ed}$ = 7.90 kN |
| | | | $M_{y\,Ed}$ = 7.89 kNm | $M_{y\,Ed}$ = 9.20 kNm |
| 2 | Frame to frame connection | S355 | $N_{Ed}$ = 34.95 kN | $N_{Ed}$ = 26.24 kN |
| 3 | Heavy duty container clamps | S355 | $N_{Ed}$ = 25.68 kN | $N_{Ed}$ = 26.24 kN |
| 4 | Bridge strip connection | S235 | $V_{zEd}$ = 34.96 kN | $V_{zEd}$ = 9.03 kN |
| 5 | Base rail to container connection at corner | S235 | $N_{Ed}$ = 16.04 kN | $N_{Ed}$ = 23.04 kN |
| | | | $V_{zEd}$ = 21.83 kN | $V_{zEd}$ = 9.03kN |
| 6 | Roof diagonal (Ø60 x 1.5 mm) | S235 | $N_{Ed}$ = 11.85 kN | $N_{Ed}$ = 14.78 kN |
| 7 | Purlins (Ø60 x 1.5 mm) | S235 | $N_{Ed}$ = 11.73 kN | $N_{Ed}$ = 7.60 kN |

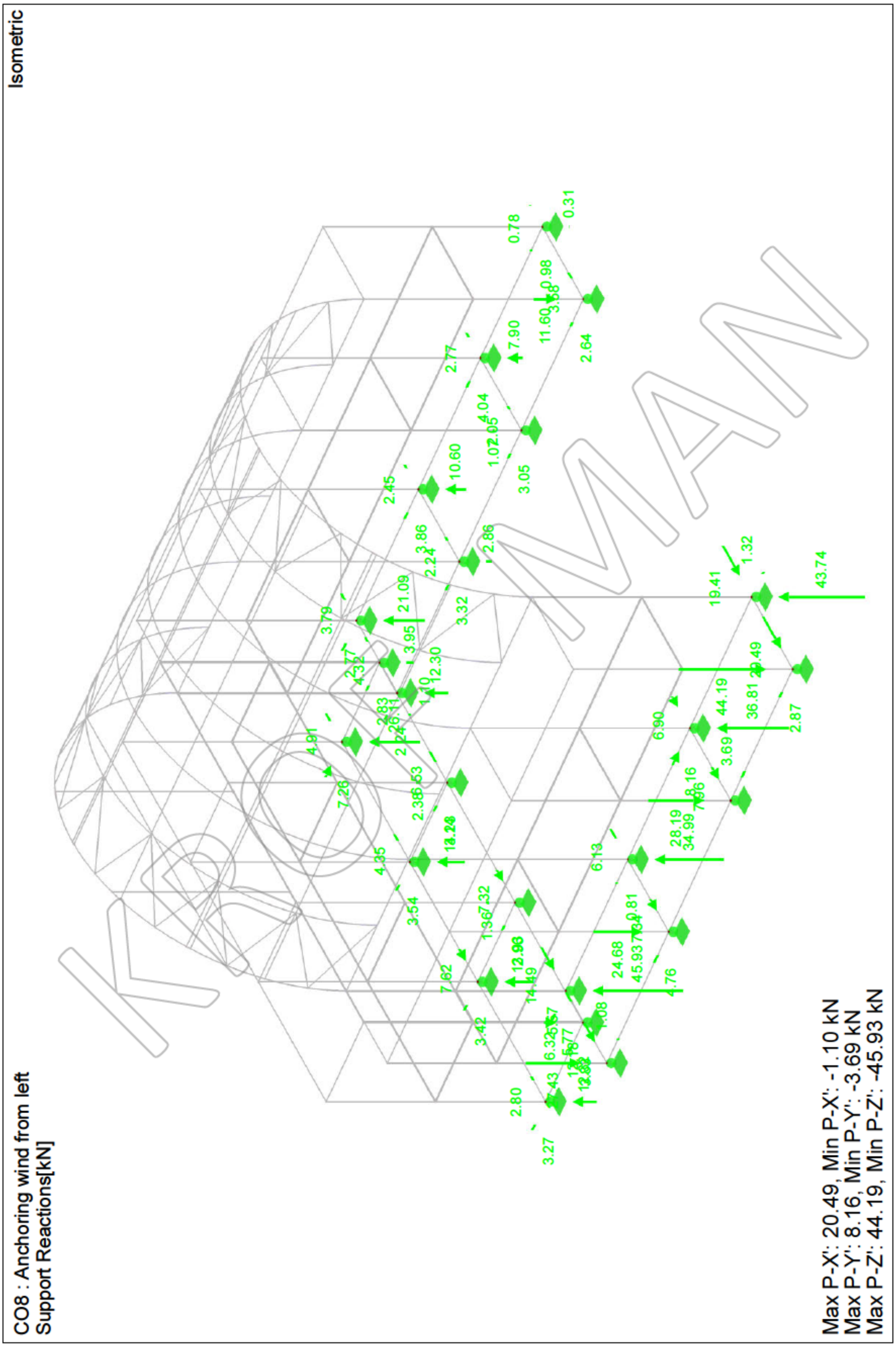
# 7. Reaction forces

**The RFEM analysis model incorporates a container-shaped rigid body to reflect real-life conditions. In actual construction, these containers are placed directly on the ground, increasing their contact surface area. Eight supports were applied to each container-shaped rigid body to achieve a more realistic simulation. This setup ensures a more accurate simulation of load distribution and ground interaction.**

## 7.1. Node numbers



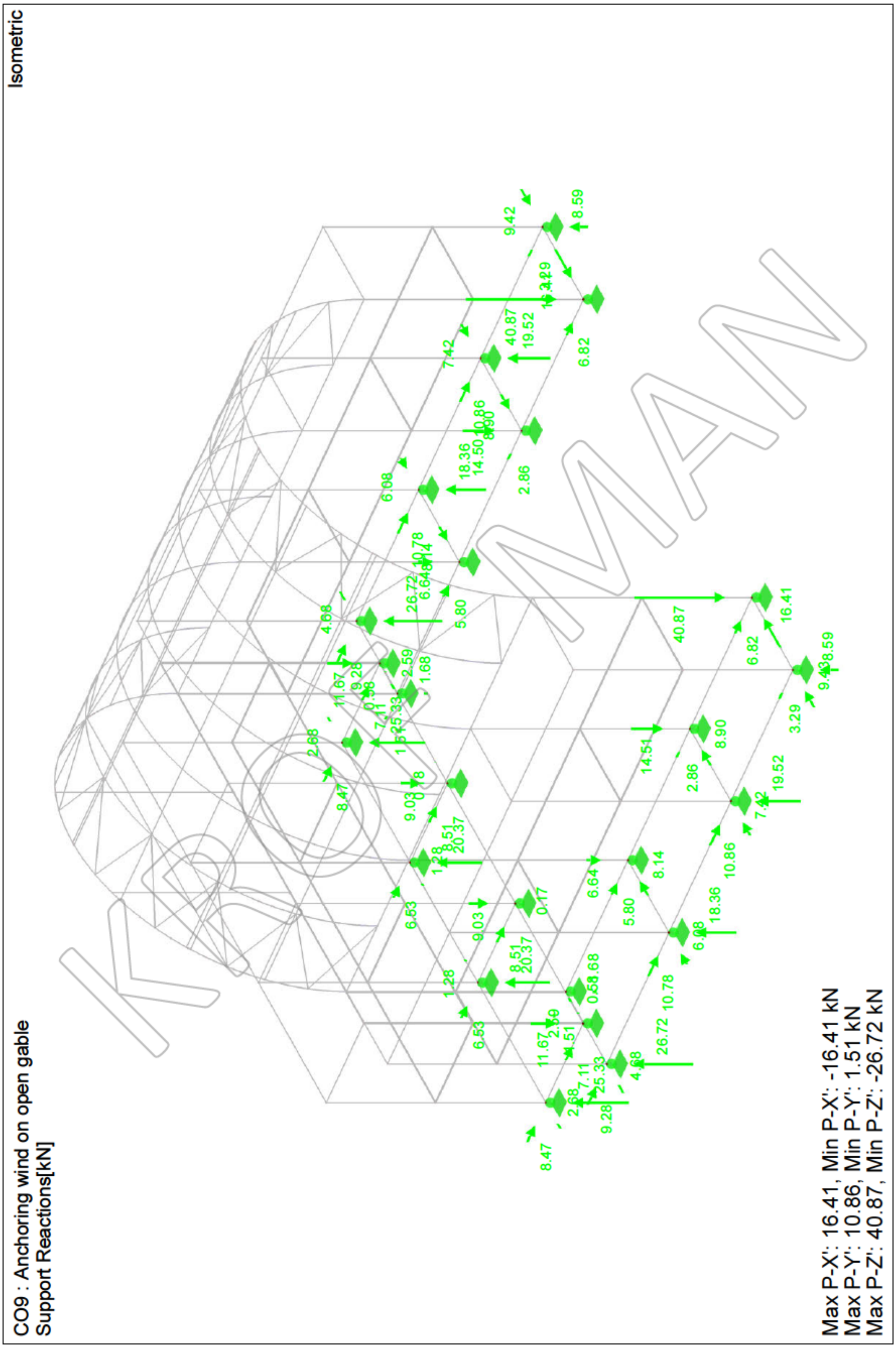
## 7.2. Anchoring wind from left reaction forces (CO8)



### 7.2.1. Reaction forces (CO8)

| Node | Support Forces [kN] | | |
|---|---|---|---|
| No. | $P_{X'}$ | $P_{Y'}$ | $P_{Z'}$ |
| 230 | 19.41 | -1.32 | -43.74 |
| 237 | 20.49 | 2.87 | 44.19 |
| 238 | 14.49 | 5.77 | -45.93 |
| 241 | 12.18 | -1.08 | 27.43 |
| 243 | 6.13 | 0.81 | -34.99 |
| 244 | 6.90 | 8.16 | -36.81 |
| 245 | 7.96 | -3.69 | 28.19 |
| 246 | 7.34 | 4.76 | 24.68 |
| 256 | 0.78 | 0.98 | -0.31 |
| 267 | 3.58 | 2.64 | 11.60 |
| 268 | 3.79 | 4.32 | -21.09 |
| 273 | -1.10 | 2.24 | -12.30 |
| 275 | 2.45 | 3.86 | -10.60 |
| 276 | 2.77 | 4.04 | -7.90 |
| 277 | 2.05 | 3.05 | 1.07 |
| 278 | 2.24 | 3.32 | -2.86 |
| 301 | 4.91 | 7.26 | -26.11 |
| 308 | 2.80 | 3.27 | -12.32 |
| 313 | 7.62 | 3.42 | -13.93 |
| 314 | 4.35 | 3.54 | -14.23 |
| 315 | 6.53 | 3.14 | 2.38 |
| 316 | 7.32 | 2.96 | 1.36 |
| 331 | 2.77 | 2.83 | -3.95 |
| 332 | 5.57 | 3.83 | 6.32 |
| Σ Forces | 153.33 | 70.98 | -139.85 |
| Σ Loads | 153.33 | 70.98 | -139.85 |

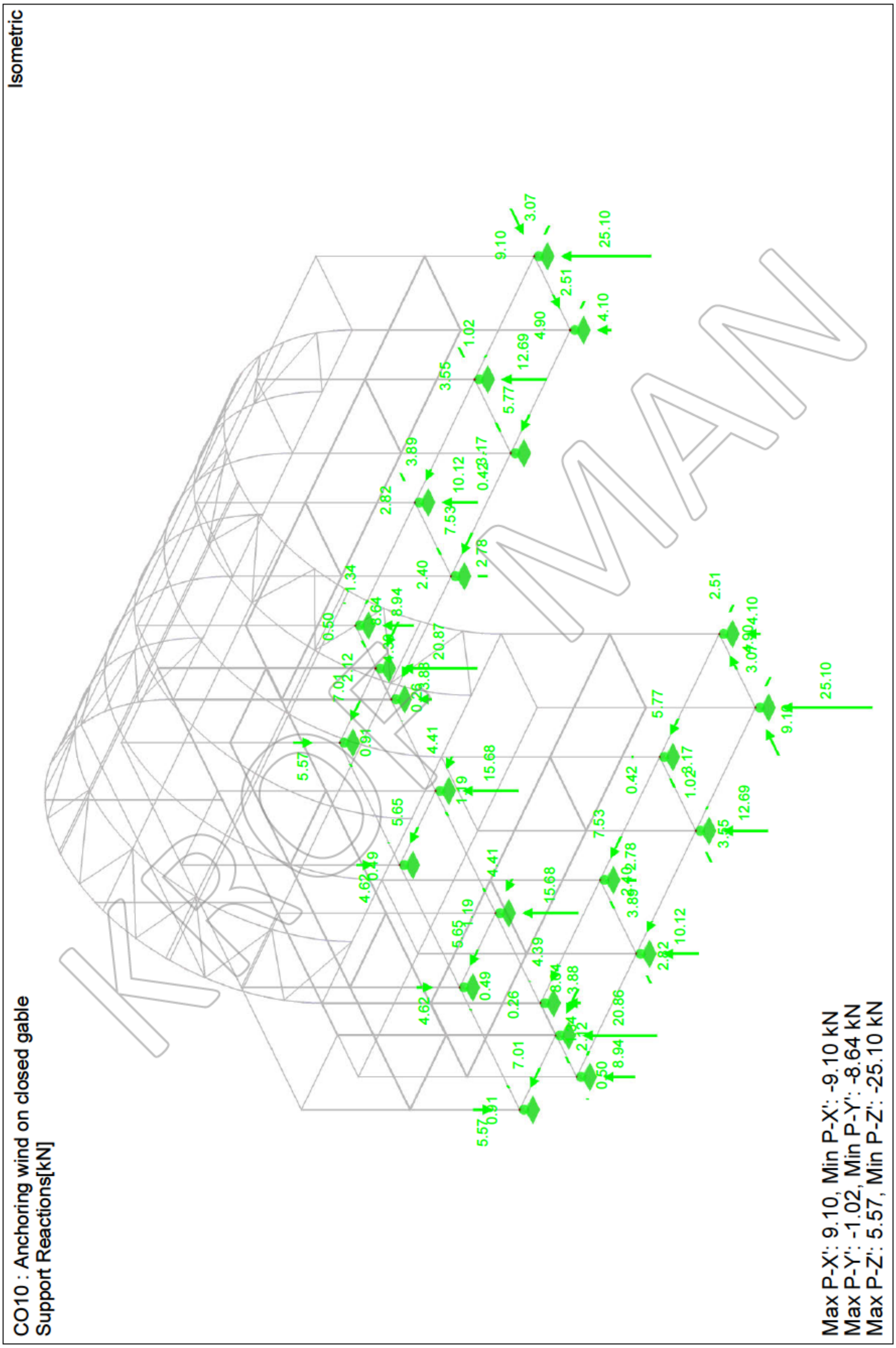
## 7.3. Anchoring wind on open gable reaction forces (CO9)



### 7.3.1. Reaction forces (CO9)

| Node | Support Forces [kN] | | |
| --- | --- | --- | --- |
| No. | $P_{X'}$ | $P_{Y'}$ | $P_{Z'}$ |
| 230 | -16.41 | 6.82 | 40.87 |
| 237 | -9.43 | 3.29 | -8.59 |
| 238 | -0.58 | 1.51 | -1.68 |
| 241 | -4.68 | 9.28 | -26.72 |
| 243 | -8.14 | 5.80 | 6.64 |
| 244 | -8.90 | 2.86 | 14.51 |
| 245 | -7.42 | 10.86 | -19.52 |
| 246 | -6.08 | 10.78 | -18.36 |
| 256 | 9.42 | 3.29 | -8.59 |
| 267 | 16.41 | 6.82 | 40.87 |
| 268 | 4.68 | 9.28 | -26.72 |
| 273 | 0.58 | 1.51 | -1.68 |
| 275 | 6.08 | 10.78 | -18.36 |
| 276 | 7.42 | 10.86 | -19.52 |
| 277 | 8.90 | 2.86 | 14.50 |
| 278 | 8.14 | 5.80 | 6.64 |
| 301 | 2.68 | 8.47 | -25.33 |
| 308 | -2.68 | 8.47 | -25.33 |
| 313 | 1.28 | 6.53 | -20.37 |
| 314 | -1.28 | 6.53 | -20.37 |
| 315 | 0.18 | 8.51 | 9.03 |
| 316 | -0.17 | 8.51 | 9.03 |
| 331 | -2.59 | 7.11 | 11.67 |
| 332 | 2.59 | 7.11 | 11.67 |
| Σ Forces | 0.00 | 163.63 | -75.69 |
| Σ Loads | 0.00 | 163.63 | -75.69 |

## 7.4. Anchoring wind on closed gable reaction forces (CO10)



### 7.4.1. Reaction forces (CO10)

| Node No. | Support Forces [kN] | | |
|---|---|---|---|
| | $P_{X'}$ | $P_{Y'}$ | $P_{Z'}$ |
| 230 | -4.90 | -2.51 | -4.10 |
| 237 | -9.10 | -3.07 | -25.10 |
| 238 | 0.26 | -4.39 | -3.88 |
| 241 | -0.50 | -1.34 | -8.94 |
| 243 | -2.40 | -7.53 | -2.78 |
| 244 | -3.17 | -5.77 | 0.42 |
| 245 | -3.55 | -1.02 | -12.69 |
| 246 | -2.82 | -3.89 | -10.12 |
| 256 | 9.10 | -3.07 | -25.10 |
| 267 | 4.90 | -2.51 | -4.10 |
| 268 | 0.50 | -1.34 | -8.94 |
| 273 | -0.26 | -4.39 | -3.88 |
| 275 | 2.82 | -3.89 | -10.12 |
| 276 | 3.55 | -1.02 | -12.69 |
| 277 | 3.17 | -5.77 | 0.42 |
| 278 | 2.40 | -7.53 | -2.78 |
| 301 | -0.91 | -7.01 | 5.57 |
| 308 | 0.91 | -7.01 | 5.57 |
| 313 | -0.49 | -5.65 | 4.62 |
| 314 | 0.49 | -5.65 | 4.62 |
| 315 | -1.19 | -4.41 | -15.68 |
| 316 | 1.19 | -4.41 | -15.68 |
| 331 | 2.12 | -8.64 | -20.87 |
| 332 | -2.12 | -8.64 | -20.86 |
| Σ Forces | 0.00 | -110.48 | -187.10 |
| Σ Loads | 0.00 | -110.48 | -187.10 |

# 8. Anchoring

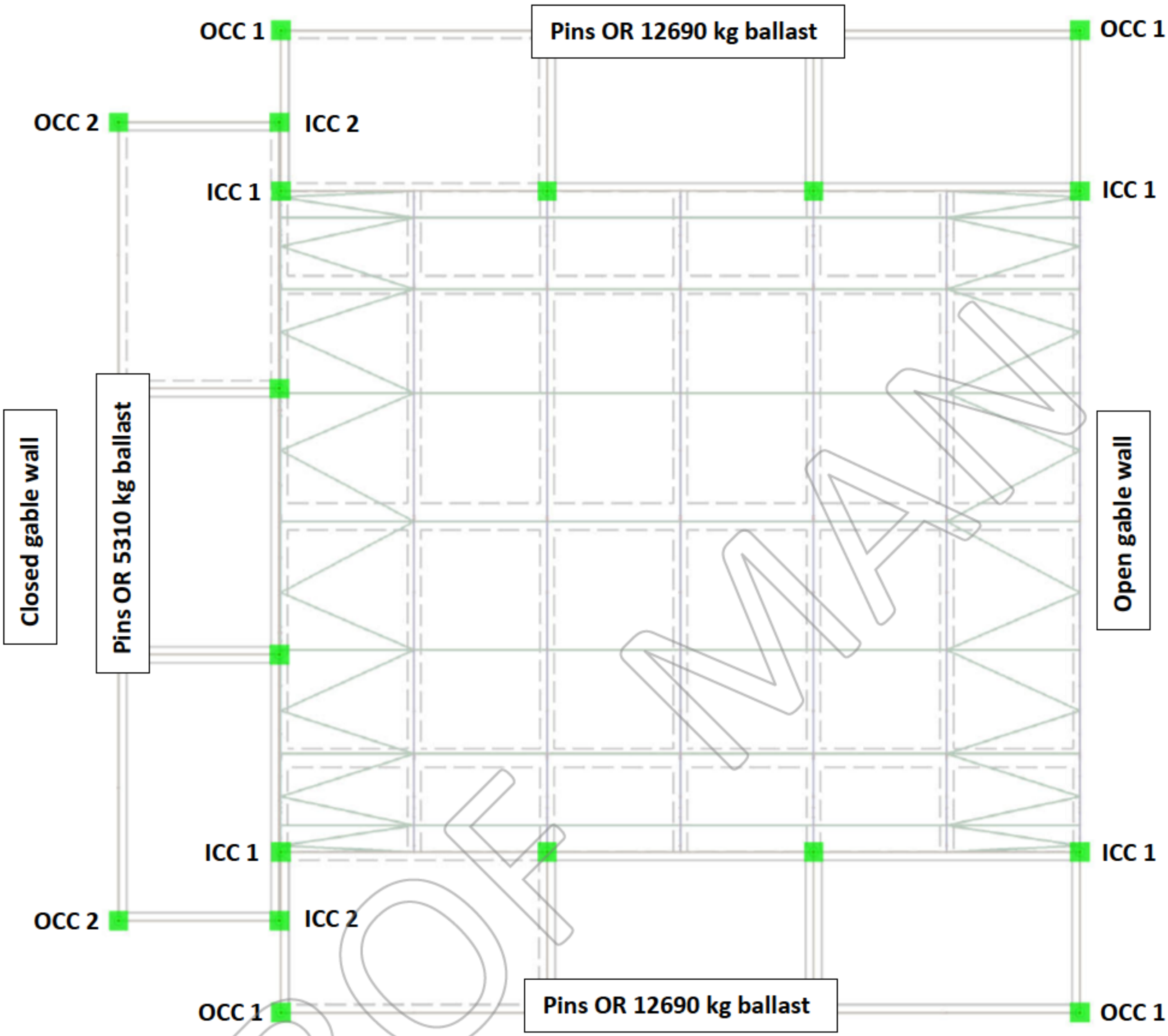
This build book assumes a certain pull-out resistance of an anchor pin. The factor $f_{\text{load}}$ gives the pull-out value, which partly depends on the pull-out angle.

The assumed $f_{\text{load}}$ = 17 N/cm$^2$

The anchor pin (Ø25 x 1200 mm) should have a minimum holding capacity of 3.4 kN per pin.

To perform the anchoring calculation, a pin diameter of Ø25 mm with an effective length of 800 mm (Ø25 x 1200 mm) has been applied, and the friction coefficient in case of ballast anchoring is μ = 0.6.

## 8.1. Anchoring overview




Pin: Ø25 x 1200mm

| Position | No. of Pins | | Ballast |
|---|---|---|---|
| OCC 1 | 19 | OR | 12690 kg |
| OCC 2 | 4 | OR | 5310 kg |
| ICC 1 | 10 | OR | - |
| ICC 2 | 7 | OR | - |

friction coefficient, $\mu = 0.6$

**Note:**

- The 12690 kg ballast must be applied to the outer wall between OCC 1 – OCC 1.
- The 5310 kg ballast must be applied to the outer wall between OCC 2 – OCC 2.
- If the required number of pins cannot be applied specifically to the containers corner positions, it may be sufficient to place them along the container's length side (outer positions for OCC and inner positions for ICC).

## 8.2. Anchoring calculation - Anchor pin Ø2.5 x 120 cm

For 45° pull, $f_{\text{load}}$ = 17 N/cm²

For 0° pull, $f_{\text{load}}$ = 6.5 N/cm²

Diameter of the pin, d = Ø2.5 cm

Length of the pin = 120 cm

Allowable effective length, l = 80 cm

### 8.2.1. Side containers

#### 8.2.1.1. Wind from left (CO8)

**To determine Pin.**

Total horizontal force per container in 'X' direction,

$\sum F_X$ = 19.41 + 20.49 + 6.90 + 7.96 + 6.13 + 7.34 + 14.49 + 12.18 = 94.9 kN

Total horizontal force per container in 'Y' direction,

$\sum F_Y$ = 2.87 - 1.32 – 3.69 + 8.16 + 4.76 + 0.81 – 1.08 + 5.77 = 16.28 kN

Total horizontal force per container, $\sum F_{xy} = (94.9^2 + 16.28^2)^{0.5}$ = 96.29 kN

Total down force per container = -(43.74 + 36.81 + 34.99 + 45.93) = -161.47 kN

Resistance to the horizontal sliding due to the down force = -161.47 x 0.6 = -96.88

Remaining horizontal force per container = 96.29 – 96.88 = -0.59 < 0

#### 8.2.1.2. Wind on open gable (CO9)

**To determine Pin.**

Total horizontal force per container in 'X' direction,

$\sum F_X$ = 16.41 + 9.43 + 8.90 + 7.42 + 8.14 + 6.08 + 0.58 + 4.68 = 61.64 kN

Total horizontal force per container in 'Y' direction,

$\sum F_Y$ = 6.82 + 3.29 + 2.86 + 10.86 + 5.80 + 10.78 + 1.51 + 9.28 = 51.2 kN

Total horizontal force per container, $\sum F_{xy} = (61.64^2 + 51.2^2)^{0.5}$ = 80.13 kN

Total down force per container = -(8.59 + 19.52 + 18.36 + 26.72 + 1.68) = -74.87 kN

Resistance to the horizontal sliding due to the down force = -74.87 x 0.6 = -44.92

Remaining horizontal force per container = 80.13 – 44.92 = 35.21 kN

The containers are anchored to the ground at each corner using anchor pin and brackets.

The horizontal force remaining per container corner = 35.21 / 4 = **8.80 kN**

If the required number of pins cannot be applied specifically to the containers corner positions, it may be sufficient to place them along the container's length side (outer positions for OCC and inner positions for ICC).

**Outer corners of container position 1 (OCC 1);**

Decisive load combination CO8;

The outer side of the container experiences the highest uplift forces. To address this, the reaction forces on the outer side are gathered and split into two factors. This helps to determine the critical force at each outer corner.

Total uplift/downforce available per container on the outer side,

$\sum F_Z = 44.19 + 28.19 + 24.68 + 27.43 = 124.49$ kN

The uplift remaining in each OCC position, $Z_V = 124.49 / 2 = 62.25$ kN

Horizontal force remaining per container corner = 0 kN (Chapter 8.2.1.1)

$Z_{Ed} = 62.25$ kN

Capacity per pin, $Z_{Rd} = f_{\text{load}} \times d \times l$

$f_{\text{load}} = 17$ N/cm$^2$

Capacity per pin, $Z_{Rd} = 17 \times 2.5 \times 80 = 3400$ N = 3.4 kN

Number of pins required to anchor down the position OCC 1 = 62.25 / 3.4 = **18.31**

**Pos. OCC 1: 19 pins**

**Inner corners of container position 1 (ICC 1);**

Decisive load combination CO9;

The uplift forces on the inner side are gathered and split into two factors.

Total uplift/downforce available per container on the inner side,

$\sum F_Z = 40.87 + 14.51 + 6.64 = 62.02$ kN

The uplift remaining in each ICC position, $Z_V = 62.02 / 2 = 31.01$ kN

Horizontal force remaining per container corner = 8.8 kN (Chapter 8.2.1.2)

$Z_{Ed} = (31.01^2 + 8.80^2)^{0.5} = 32.23$ kN

Capacity per pin, $Z_{Rd} = f_{\text{load}} \times d \times l$

$f_{\text{load}} = 17$ N/cm$^2$

Capacity per pin, $Z_{Rd} = 17 \times 2.5 \times 80 = 3400$ N = 3.4 kN

Number of pins required to anchor down the position ICC 1 = 32.23 / 3.4 = **9.48**

**Pos. ICC 1: 10 pins**

### 8.2.2. Gable side container

#### 8.2.2.1. Wind on open gable (CO9)

**To determine Pin;**

Total horizontal force per container in 'X' direction,

$\sum F_X = 2.68 – 2.59 – 1.28 + 0.17 + 1.28 - 0.18 - 2.68 + 2.59 = 0.01$ kN

Total horizontal force per container in 'Y' direction,

$\sum F_Y = 8.47 + 7.11 + 8.51 + 6.53 + 8.51 + 6.53 + 7.11 + 8.47 = 61.24$ kN

Total horizontal force per container, $\sum F_{xy} = (61.24^2 + 0.01^2)^{0.5} = 61.24$ kN

Total down force per container = -(25.33 + 20.37 + 20.37 + 25.33) = -91.4 kN

Resistance to the horizontal sliding due to the down force = -91.4 x 0.6 = -54.84

Remaining horizontal force per container = 61.24 – 54.84 = 6.4 kN

The containers are anchored to the ground at each corner using anchor pin brackets fixed to them.

Therefore, the horizontal force remaining per container corner = 6.4 / 4 = **1.6 kN**

#### 8.2.2.2. Wind on closed gable (CO10)

**To determine Pin;**

Total horizontal force per container in 'X' direction,

$\sum F_X = 2.12 – 0.91 – 1.19 + 0.49 + 1.19 - 0.49 + 0.91 – 2.12 = 0$ kN

Total horizontal force per container in 'Y' direction,

$\sum F_Y = 8.64 + 7.01 + 4.41 + 5.65 + 4.41 + 5.65 + 8.64 + 7.01 = 51.42$ kN

Total horizontal force per container, $\sum F_{xy} = (51.42^2 + 0^2)^{0.5} = 51.42$ kN

Total down force per container = -(20.86 + 15.68 + 15.68 + 20.87) = -73.09 kN

Resistance to the horizontal sliding due to the down force = -73.09 x 0.6 = -43.85

Remaining horizontal force per container = 51.42 – 43.85 = 7.57 kN

The containers are anchored to the ground at each corner using anchor pin brackets fixed to them.

Therefore, the horizontal force remaining per container corner = 7.57 / 4 = **1.89 kN**

**Outer corners of container position 2 (OCC 2);**

Decisive load combination CO10;

The uplift forces on the outer side are gathered and split into two factors. This helps to determine the critical force at each inner corner.

Total uplift/downforce available per container on the outer side,

$\sum F_Z = 5.57 + 4.62 + 4.62 + 5.57 = 20.38$ kN

The uplift remaining in each OCC position, $Z_V = 20.38 / 2 = 10.19$ kN

Horizontal force remaining per container corner = 1.89 kN (Chapter 8.2.2.2)

$Z_{Ed} = (10.19^2 + 1.89^2)^{0.5} = 10.36$ kN

Capacity per pin, $Z_{Rd} = f_{\text{load}}$ x d x l

$f_{\text{load}}$ = 17 N/cm$^2$

Capacity per pin, $Z_{Rd}$ = 17 x 2.5 x 80 = 3400 N = 3.4 kN

Number of pins required to anchor down the position OCC 2 = 10.36 / 3.4 = **3.05**

**Pos. OCC 2: 4 pins**

**Inner corners of container position 2 (ICC 2);**

Decisive load combination CO9;

The inner side of the container experiences the highest uplift forces. To address this, the reaction forces on the inner side are gathered and split into two factors. This helps to determine the critical force at each outer corner.

Total uplift/downforce available per container on the inner side,

$\sum F_Z = 11.67 + 9.03 + 9.03 + 11.67 = 41.4$ kN

The uplift remaining in each ICC position, $Z_V = 41.4 / 2 = 20.70$ kN

Horizontal force remaining per container corner = 1.6 kN (Chapter 8.2.2.1)

$Z_{Ed} = (20.70^2 + 1.6^2)^{0.5} = 20.76$ kN

Capacity per pin, $Z_{Rd} = f_{\text{load}}$ x d x l

$f_{\text{load}}$ = 17 N/cm$^2$

Capacity per pin, $Z_{Rd}$ = 17 x 2.5 x 80 = 3400 N = 3.4 kN

Number of pins required to anchor down the position ICC 2 = 20.76 / 3.4 = **6.1**

**Pos. ICC 2: 7 pins**

## 8.3. Anchoring ballast calculation

### 8.3.1. Side containers

#### 8.3.1.1. Wind from left (CO8: Decisive combination)

**Ballast requirement per container;**

Total Uplift available per container,

$\sum F_Z$ = 44.19 + 28.19 + 24.68 + 27.43 = 124.49 kN

Total horizontal force per container in 'X' direction,

$\sum F_X$ = 19.41 + 20.49 + 6.90 + 7.96 + 6.13 + 7.34 + 14.49 + 12.18 = 94.90 kN

Total horizontal force per container in 'Y' direction,

$\sum F_Y$ = 2.87 - 1.32 – 3.69 + 8.16 + 4.76 + 0.81 – 1.08 + 5.77 = 16.28 kN

Total horizontal force per container, $\sum F_{xy} = (94.90^2 + 16.28^2)^{0.5}$ = 96.29 kN

Resistance to the horizontal sliding due to the down force,

= -(43.74 + 36.81 + 34.99 + 45.93) = -161.47 kN

Required resistance for horizontal sliding = $\sum F_x$ = 96.29 / 0.6 = 160.48 kN

Remaining horizontal sliding shortage = 160.48 – 161.47 = -0.99 kN < 0

Ballast required = (124.49) x 1000 / 9.81 = 12690.11 kg

**12690 kg ballast is required per container.**

### 8.3.2. Gable side container

#### 8.3.2.1. Wind on open gable (CO9: Decisive combination)

**Ballast requirement per container;**

Total Uplift available per container,

$\sum F_Z = 11.67 + 9.03 + 9.03 + 11.67 = 41.4$ kN

Total horizontal force per container in 'X' direction,

$\sum F_X = 2.68 – 2.59 – 1.28 + 0.18 + 1.28 - 0.17 + 2.59 – 2.68 = 0.01$ kN

Total horizontal force per container in 'Y' direction,

$\sum F_Y = 8.47 + 7.11 + 8.51 + 6.53 + 8.51 + 6.53 + 7.11 + 8.47 = 61.24$ kN

Total horizontal force per container, $\sum F_{xy} = (61.24^2 + 0.01^2)^{0.5} = 61.24$ kN

Resistance to the horizontal sliding due to the down force = -(25.33 + 20.37 + 20.37 + 25.33) = -91.4 kN

Required resistance for horizontal sliding = $\sum F_x = 61.24 / 0.6 = 102.1$ kN

Remaining horizontal sliding shortage = 102.1 – 91.4 = 10.7 kN

Ballast required = (10.7 + 41.4) x 1000 / 9.81 = 5310.55 kg

**5310 kg ballast is required per container.**