

NOOL PROJEKT

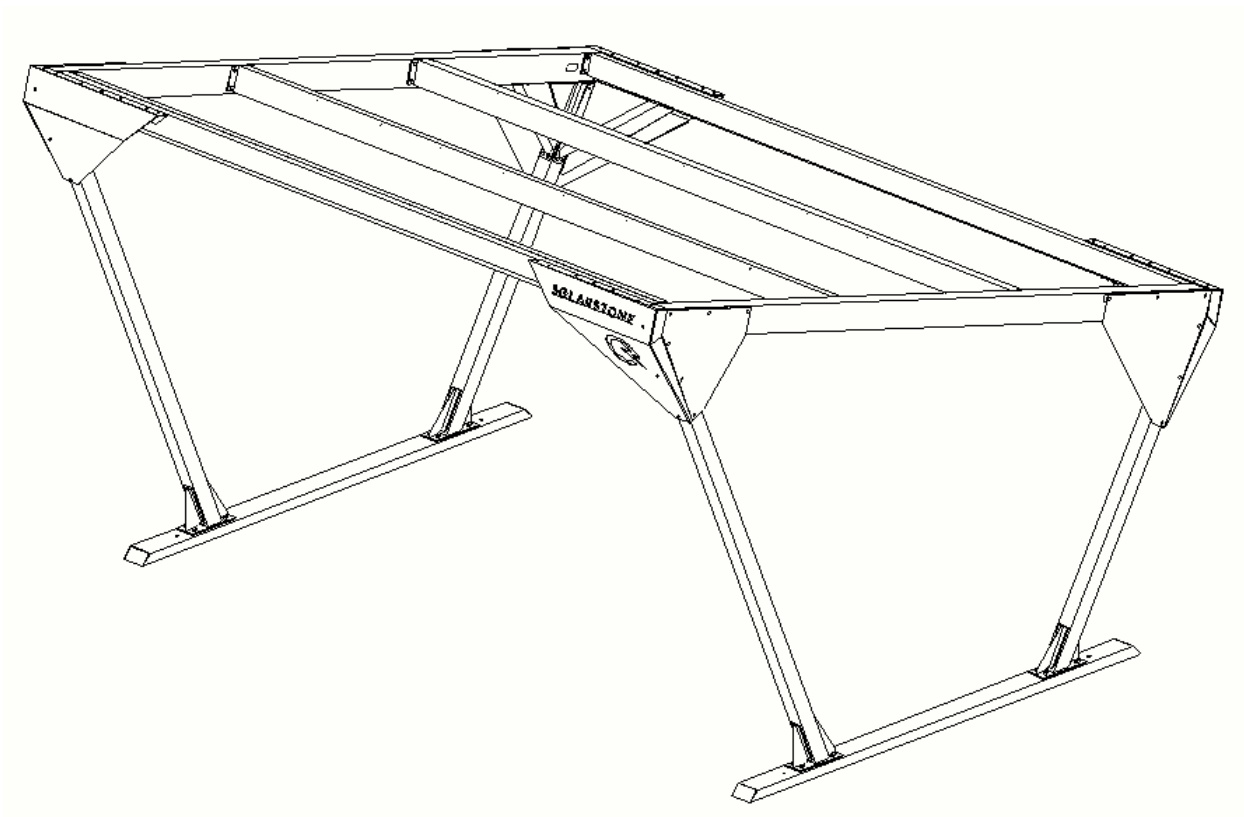
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Client	Solarstone OÜ
Issued by	Nool Projekt OÜ
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SISUKORD

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1 GENERAL INFORMATION

Nool Projekt OÜ takes responsibility for the strength of the design and technical solution only if all the information in this report, general drawings and general construction standards have been followed.

The report does not give solutions for foundations of the Carport. Soil characteristics vary and are dependent on location where a Carport is installed and we cannot consider all possible solutions that suit each and every location. Thus, the foundations need to be calculated by local specialists separately every time.

Under no circumstances can the loads specified in this report be exceeded.

In case of any questions regarding this report or the drawings please contact Nool Projekt OÜ.

2 ANALYSIS INFORMATION

Purpose of the analysis: To calculate the strength of the structure at wind and snow loads

Software: - SCIA Engineer structural analysis software
- IDEA StatiCa for connection design

Type of analysis: - Linear static
- Connections are designed by component-based finite element method (CBFEM)

Materials: All parts are made of steel S355. Plates are S355J2, hollow sections S355J2H

Material mechanical properties:

Material	Young's modulus E (GPa)	Poisson's ratio ν	Yield strength R_{eH} (= f_y) (MPa)	Ultimate tensile strength R_m (= f_u) (MPa)	Density ρ (kg/m ³)
S355	210	0,3	355	470...630	7850

Table 1. Material mechanical properties

Location of installation: Norway

Surface treatment: Hot-dip galvanized and painted

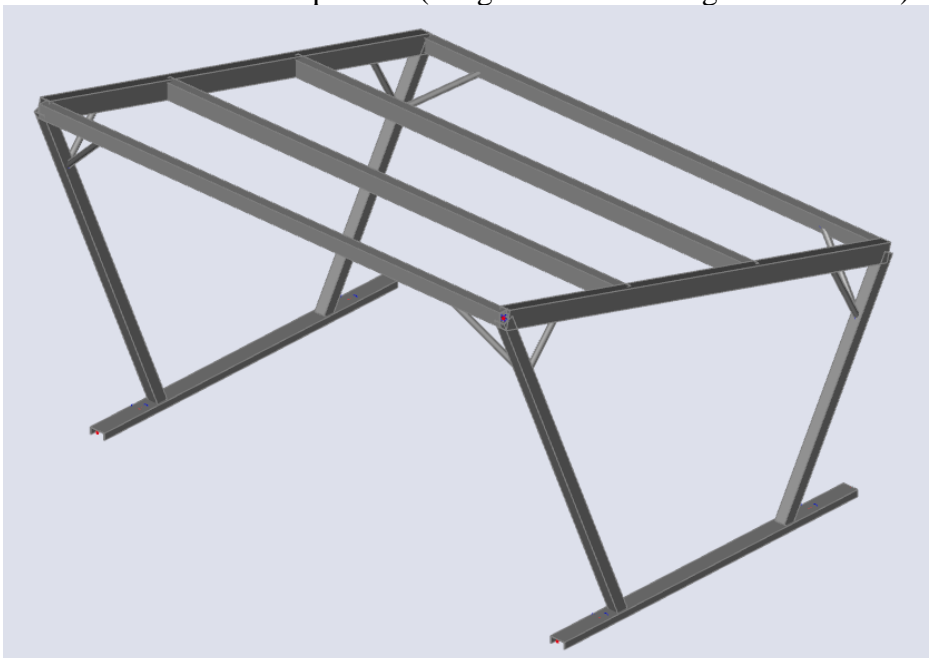
3 MODEL

Geometry of the model is derived from the drawings and instructions provided by Solarstone OÜ. The calculation is performed in multiple load combinations (snow, wind, combinations of those two) while for connection design only the most critical combinations are considered.

For all calculations, the model has been simplified by removing the following structurally irrelevant elements:

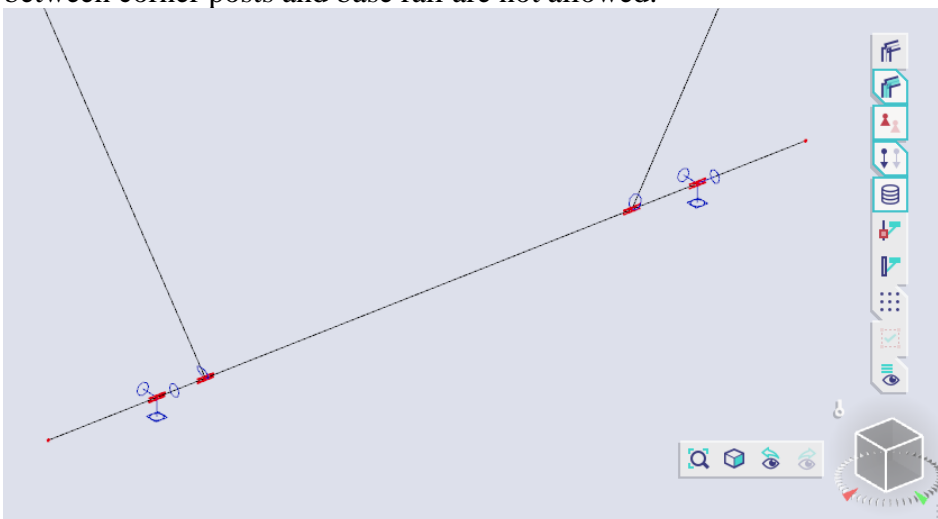
- Welded end plates of hollow sections that have no structural significance
- Steel triangle-shaped corner flashings

Calculation model with profiles (image from SCIA Engineer software):



All connections between elements are hinged, allowing rotations, except for the connection between corner post and base rail, where rotations along the length of the base rail are not allowed.

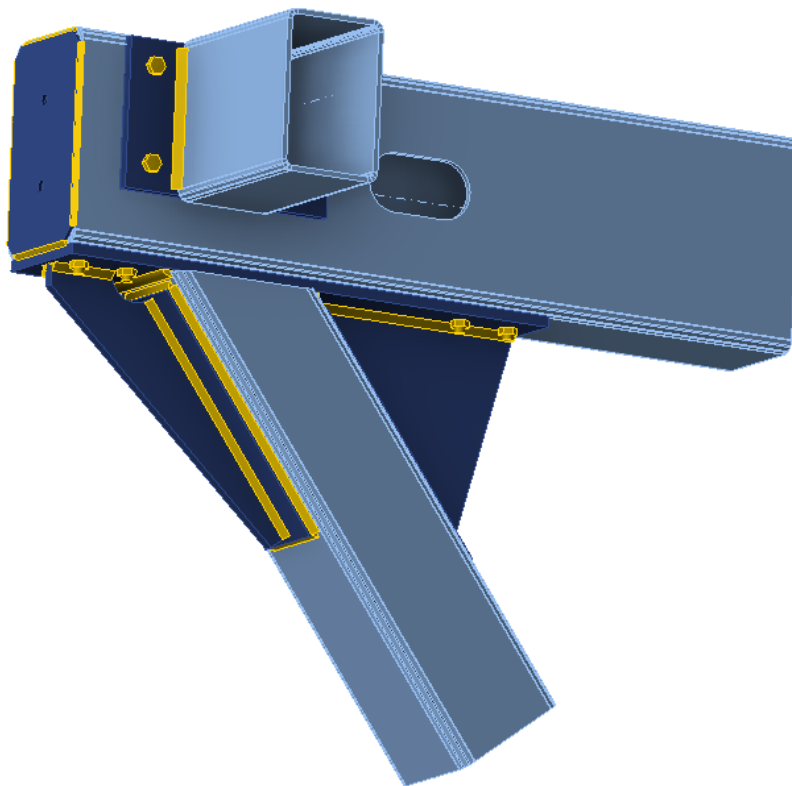
Image from SCIA Engineer software showing that the rotations around Y-axis (green coloured) between corner posts and base rail are not allowed.



4 CONNECTIONS

All connections are represented in IDEA StatiCa software as closely to real-life connection as possible, for both bolted and welded connections.

Below is the upper corner connection that does not consider steel triangle-shaped corner flashings (image from IDEA StatiCa software):



5 LOADS

The structure is mostly affected by snow and wind loads. Calculations are performed according to Eurocode Standards as well as Norwegian National Annexes.

Wind loads on Carport are assigned as those for canopies, not for buildings. Characteristic loads have been determined by EN 1991-1-4.

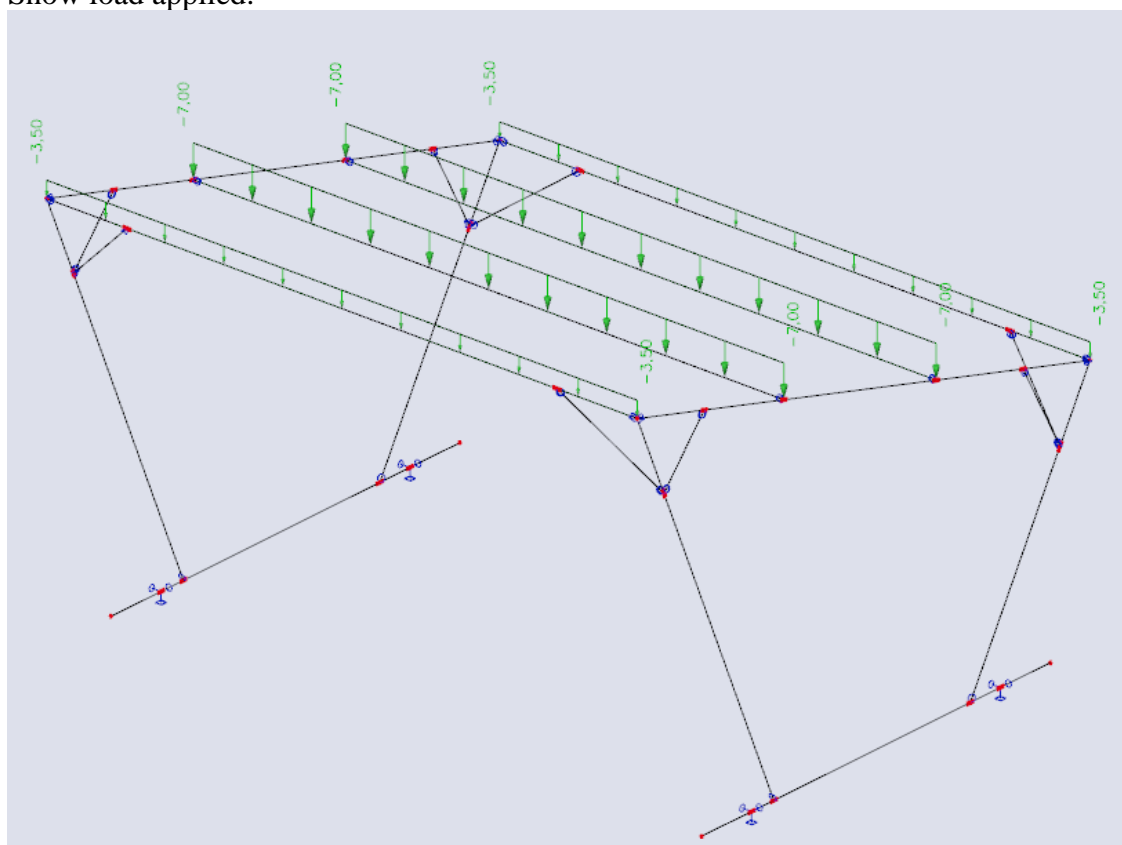
Characteristic snow loads have been determined by EN 1993-1-3, with characteristic value for snow load on the ground of $5,0 \text{ kN/m}^2$. For roofs with an angle of $0 \dots 30^\circ$, snow load can be multiplied by 0,8. The angle of the roof of Carport is 15° . Snow load on the roof has been scaled to $4,0 \text{ kN/m}^2$. There are areas in Norway where snow loads exceed $5,0 \text{ kN/m}^2$ on the ground. Both the distributor of the Carport and the local contractors have to keep that in mind. Nool Projekt OÜ does not take responsibility for Carports that are installed at areas with higher than $5,0 \text{ kN/m}^2$ snow load on the ground.

In addition, these loads have also been combined to check every possible exceptional case.

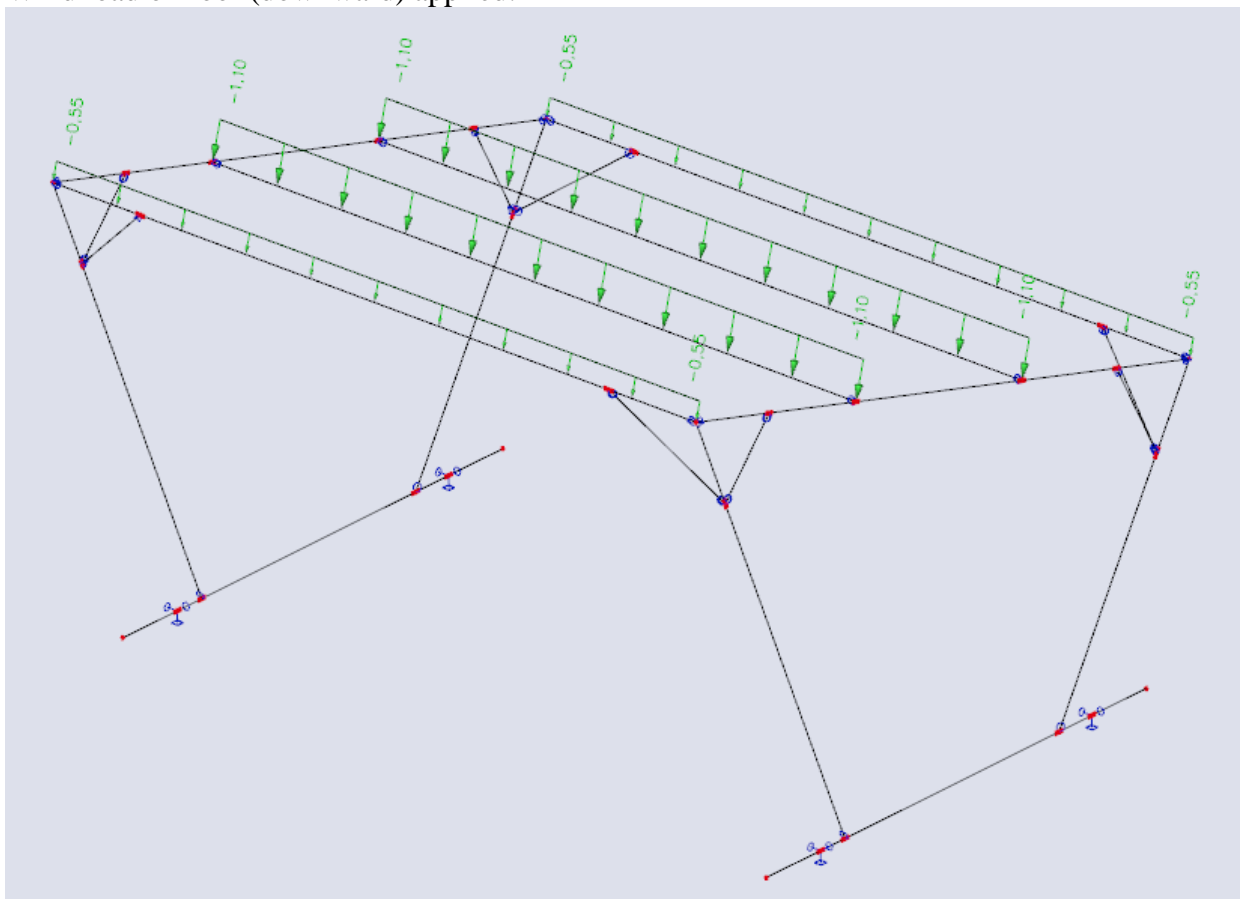
Load case	Characteristic load value	Load type
A1: Self-weight of the structure	Taken into account automatically by SCIA Engineer software according to profiles used in the model	Permanent
A2: Additional weight (solar panels)	$0,15 \text{ kN/m}^2$	Permanent
B: Snow load	$5,0 \times 0,8 = 4,0 \text{ kN/m}^2$	Variable
C1: Wind load on roof (downward)	$0,62 \text{ kN/m}^2$	Variable
C2: Wind load on roof (upward)	$1,35 \text{ kN/m}^2$	Variable
C3: Wind load on walls	$1,0 \text{ kN/m}^2$	Variable

Table 2. Load cases

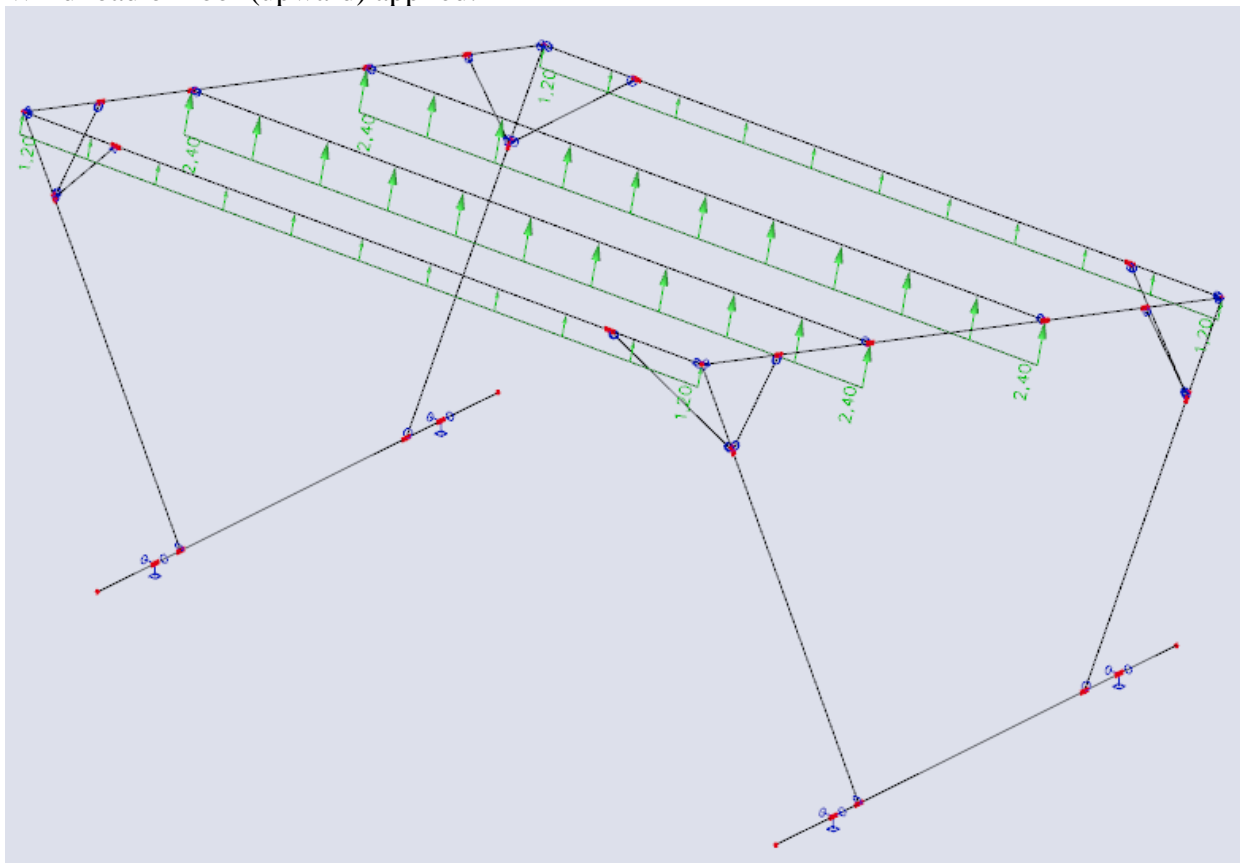
Snow load applied:



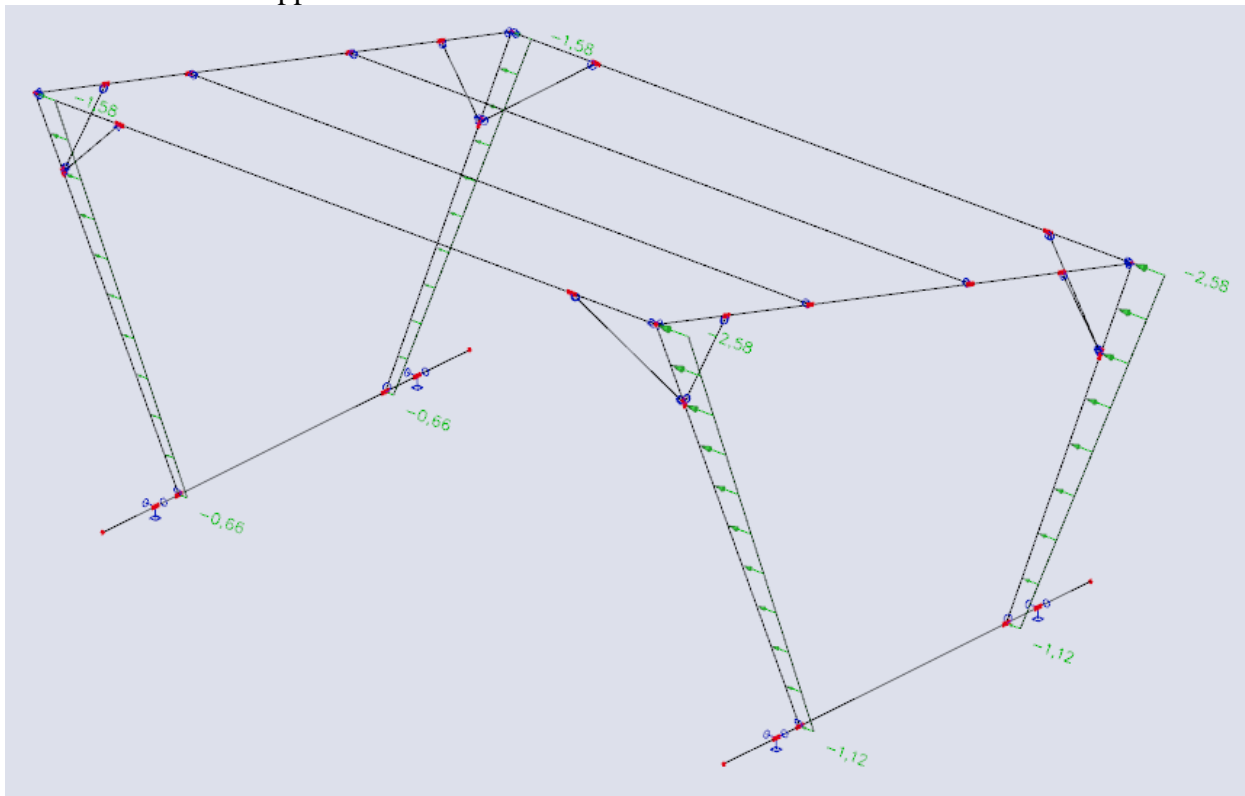
Wind load on roof (downward) applied:



Wind load on roof (upward) applied:



Wind load on walls applied:



5.1 Load combinations

Ultimate Limit State

1. Dominant Snow	$1,2*A1 + 1,2*A2 + 1,5*B$
2. Dominant Snow + Wind on roof (down)	$1,2*A1 + 1,2*A2 + 1,5*B + (1,5*0,6)*C1$
3. Dominant Snow + Wind on walls	$1,2*A1 + 1,2*A2 + 1,5*B + (1,5*0,6)*C3$
4. Dominant Wind on roof (up)	$1,0*A1 + 1,0*A2 + 1,5*C2$
5. Dominant Wind on roof (up) + Wind on walls	$1,0*A1 + 1,0*A2 + 1,5*C2 + 1,5*C3$
6. Dominant Wind on roof (down) + Snow	$1,2*A1 + 1,2*A2 + 1,5*C1 + (1,5*0,7)*B$
7. Dominant Wind on walls + Snow	$1,2*A1 + 1,2*A2 + 1,5*C3 + (1,5*0,7)*B$

Serviceability Limit State

1. Snow	$1,0*A1 + 1,0*A2 + 0,5*B$
2. Wind on roof (up)	$1,0*A1 + 1,0*A2 + 0,2*C2$
3. Wind on roof (up) + Wind on walls	$1,0*A1 + 1,0*A2 + 0,2*C2 + 0,2*C3$
4. Wind on roof (down) + Snow	$1,0*A1 + 1,0*A2 + 0,2*C1 + 0,2*B$

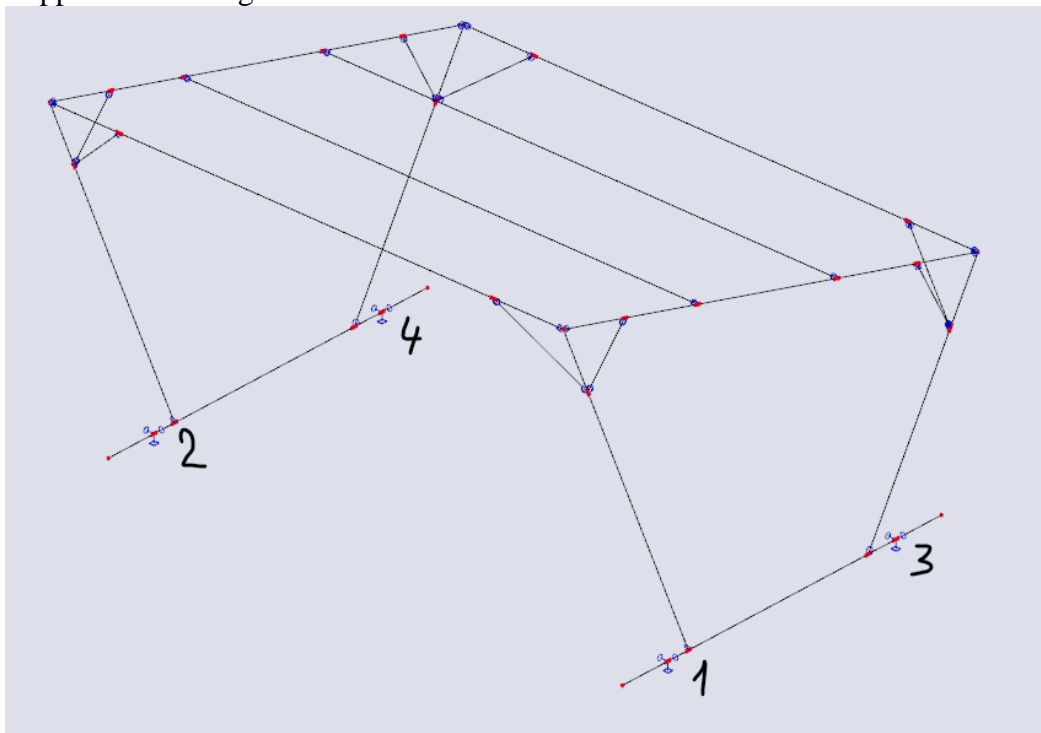
6 SUPPORTS

All supports are hinged, allowing rotations around axes while not allowing any movement along any axes.

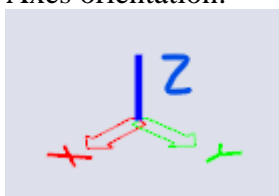
7 RESULTS

7.1 Extreme support reactions

Support numbering:



Axes orientation:



Extreme support reactions are factored according to the corresponding ultimate limit state (ULS) combination.

Force direction	Support 1	Support 2	Support 3	Support 4
Maximum vertical force DOWN – ULS 2				
Z	63,7 kN	63,7 kN	45,8 kN	45,8 kN
X	8,4 kN	8,4 kN	-10,6 kN	-10,6 kN
Y	-2,8 kN	2,8 kN	-4,2 kN	4,2 kN
Maximum vertical force UP – ULS 5				
Z	-26,4 kN	-14,1 kN	-3,7 kN	2,3 kN
X	-1,0 kN	2,8 kN	7,8 kN	6,4 kN
Y	10,2 kN	7,5 kN	7,8 kN	4,1 kN

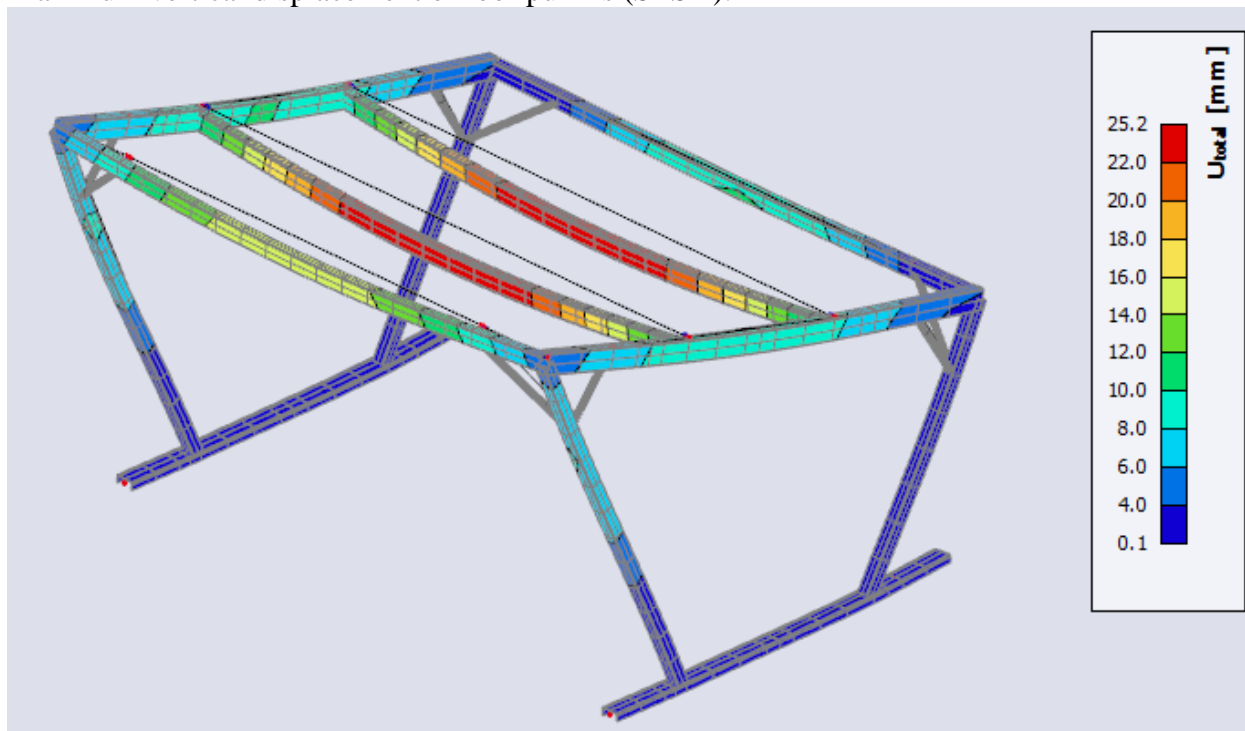
Table 3. Extreme support reactions

Due to the fact that wind can blow from different directions, all 4 supports should withstand the vertical compression force of 63,7 kN and the vertical tension force of 26,4 kN. This should be considered when designing foundations for Carport.

7.2 Extreme displacements

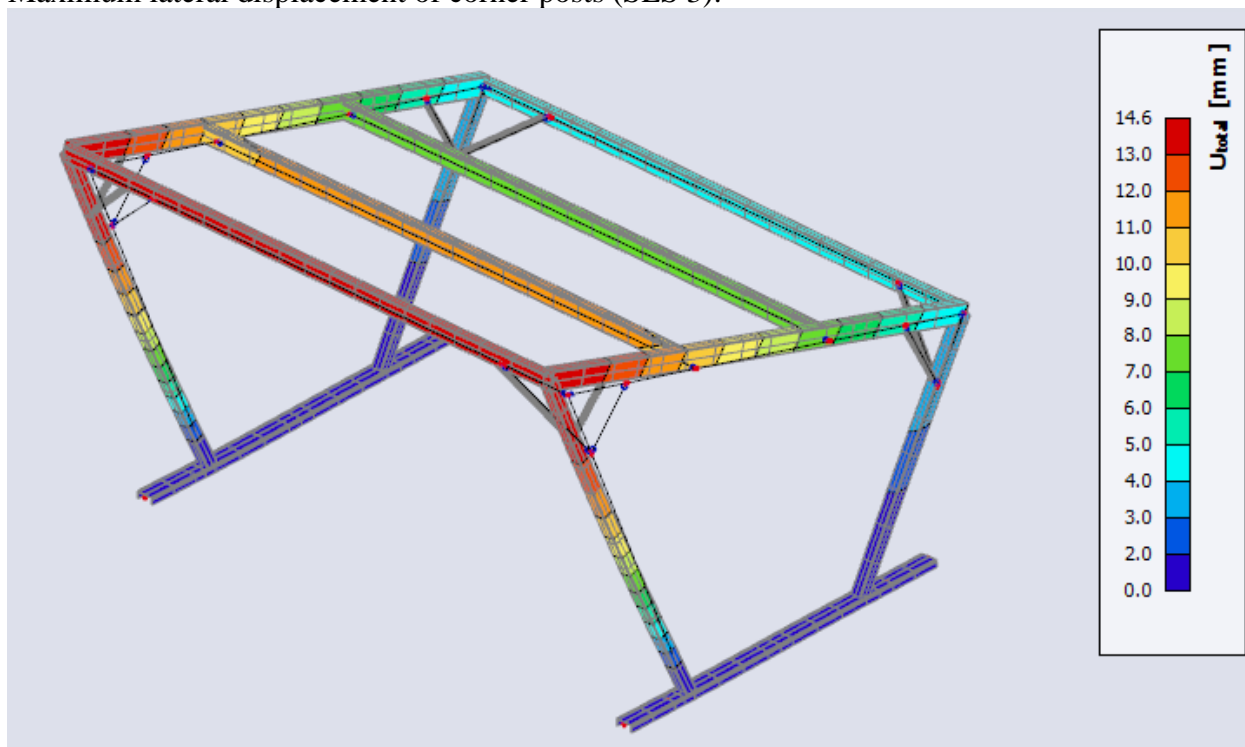
Only serviceability limit state (SLS) combinations are taken into account for extreme displacements.

Maximum vertical displacement of roof purlins (SLS 1):



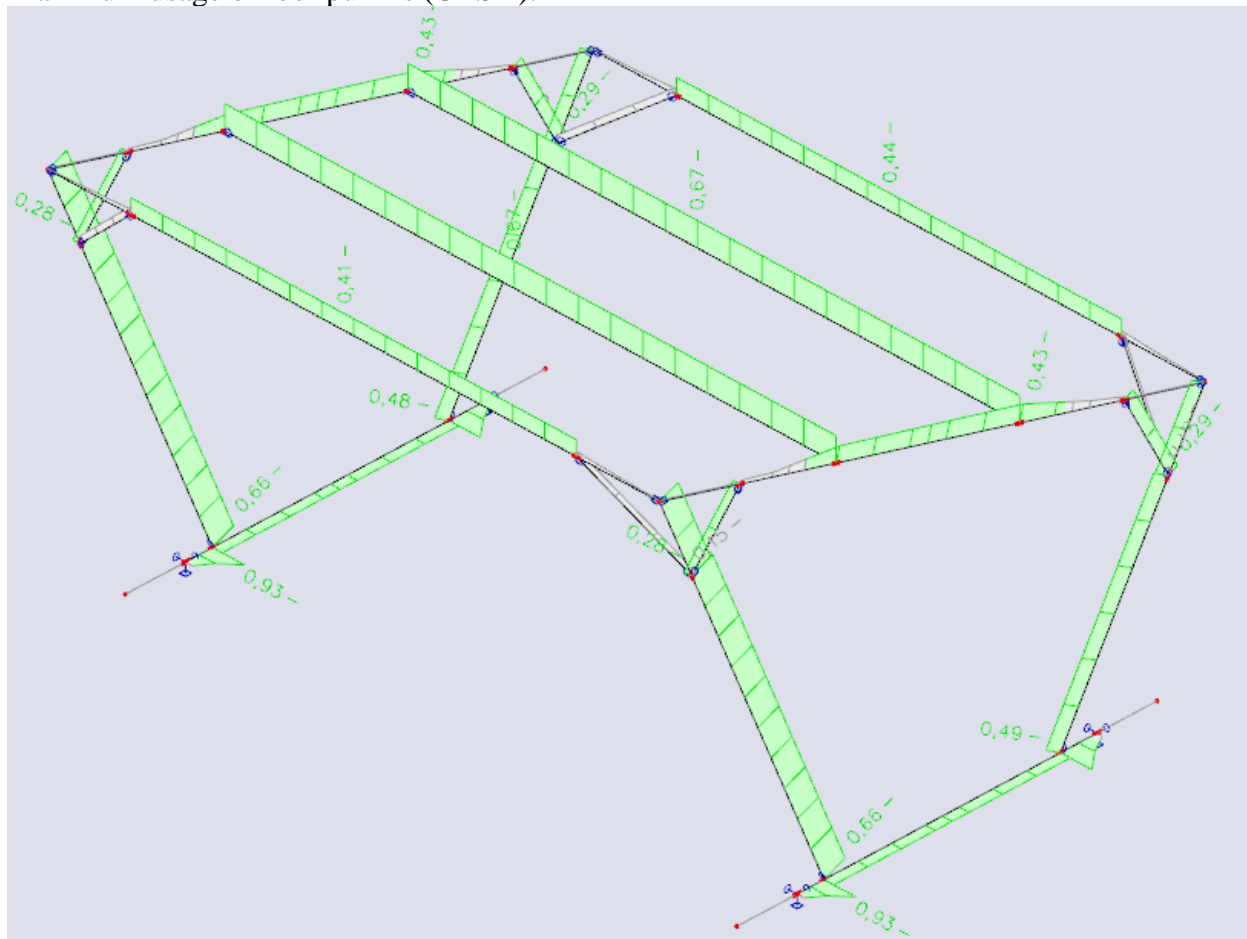
According to Solarstone OÜ, the maximum vertical displacement allowed for solar panels is 25 mm.

Maximum lateral displacement of corner posts (SLS 3):



7.3 Extreme unity checks

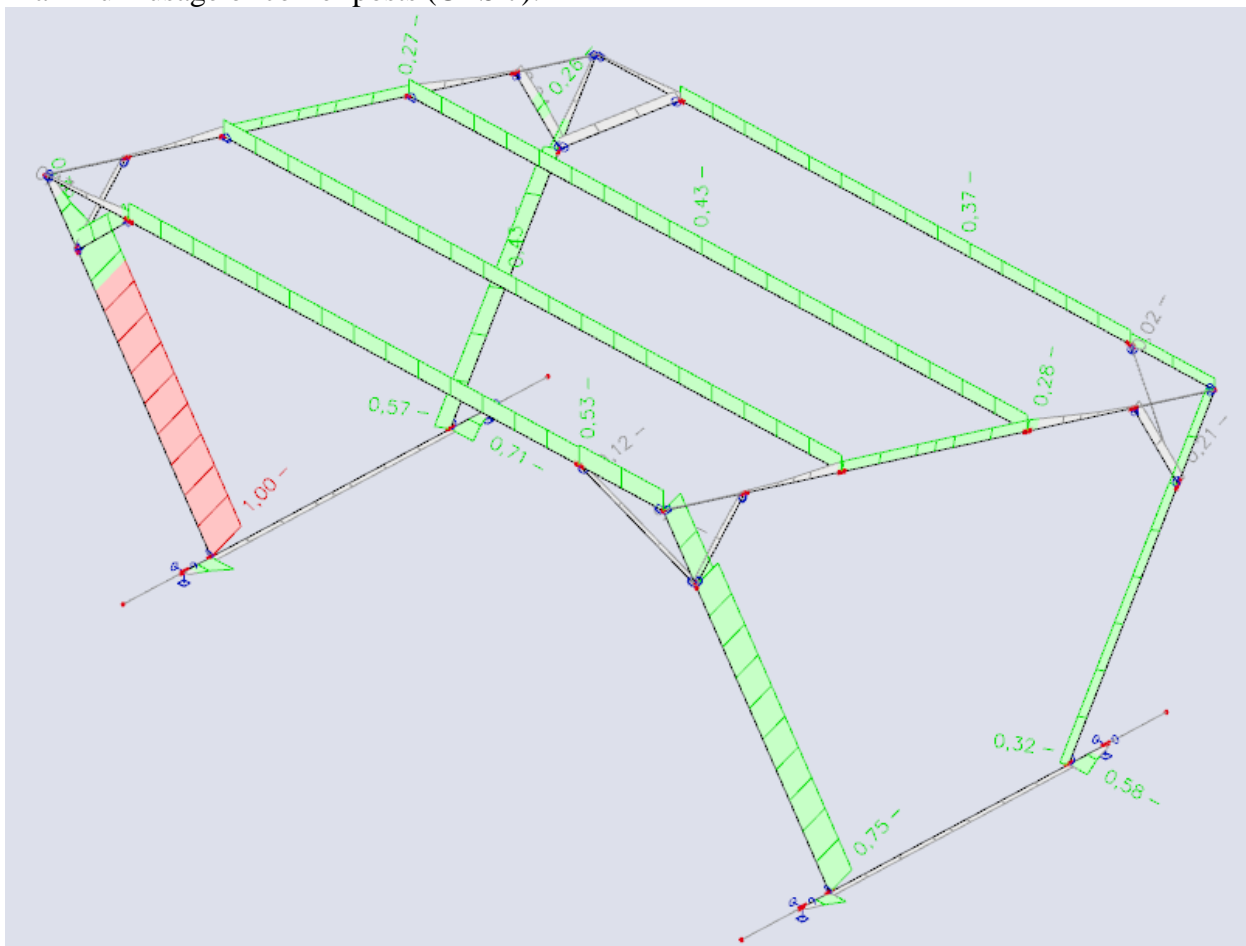
Maximum usage of roof purlins (ULS 2):



As can be seen from the image, the maximum usage of the roof purlins in the middle of the roof is 67%. This means that the sections for purlins are defined by vertical displacement limits, not by ultimate section strength.

The roof purlins at the ends and roof beams seemingly could be made smaller or with thinner walls but that is not actually the case. Connection design dictated the required minimum wall thicknesses and thus these elements are slightly oversized in terms of linear static calculations.

Maximum usage of corner posts (ULS 7):



As can be seen from the image, the sections of front corner posts can achieve the usage of 100%. This is due to stability check. Section check usage is only about 66% of the section's strength so there is no risk of the post losing its load capacity. Stability is the determining factor because the posts are cantilevered. It is not an actual concern because steel structures are capable of redistributing forces among other elements and the probability of the post actually losing its stability is low. The load combination that causes this also has a rather low probability of occurrence.

8 CONCLUSIONS

The Carport can be manufactured and installed according to manufacturing and general drawings that are provided by Nool Projekt OÜ.

Under no circumstances can the base loads (which are characteristic loads that are applied directly to the structure) specified in Table 2 be exceeded. The responsibility of determining the suitability of the product in various areas lies on the distributor and local contractors.

The foundations for Carport need to be determined and calculated every time according to the geological circumstances of a given location.