



CERN
CH1211 Geneva 23
Switzerland

EDMS NO. CMS-I-EG-0008 v.1	REV. 1.1	VALIDITY DRAFT
--------------------------------------	--------------------	--------------------------

Date: 2024-05-10

CMS UXC55 Tranches (The maximum load)

Abstract

This study investigates the maximum load capacity of the CMS UXC55 Tranches with the object of establishing safe operational limits for the structural and other applications. A series of finite element analyses (FEA) were conducted to assess the mechanical response of the tranches under different loading cases, load per m² and load per 300 X 100 mm². The results follow the European safety standards (Eurocodes 0 and 3). These results provide a basis for optimizing the deployment of CMS UXC55 tranches in engineering practice, ensuring both safety and efficiency in load-critical environments.

DOCUMENT PREPARED BY:

Ahmed Al Bahrani

DOCUMENT CHECKED BY:

Maytham Ezzeldine

DOCUMENT APPROVED BY:

Tristan Loiseau

DISTRIBUTION LIST:



TABLE OF CONTENTS

1.	Introduction	4
2.	Project Overview	7
3.	Project Components	8
3.1.	I-beam	8
3.2.	Bolts	8
3.3.	C-beam	9
3.4.	Steel plate	10
3.4.1.	PLATE	10
3.4.2.	RIBS	11
3.5.	L-shape steel	12
3.6.	T-shape steel	13
4.	Project strategy	14
4.1.	Case one: Loading zones per one m2	15
4.2.	Case two: Loading zones per 300 X 100 mm2	16
5.	Ansys model	17
5.1.	Boundary conditions	17
5.1.1.	STAGE ONE : SIMPLE MODEL	17
5.1.2.	STAGE TWO: (AS BUILT MODEL)	18
5.2.	Mesh sizing	21
6.	Safety standards (HSE)	22
7.	CMS cavern visit	23
7.1.	Notes about the real structure	24
8.	Results	27
8.1.	Model one : Simple model	27
8.2.	Model two: As built model	37
9.	How to improve the results	37
10.	Conclusion	37



Table of Acronyms

CERN	European Organization for Nuclear Research
CMS	Compact Muon Solenoid
UXC55	Underground Experimental Cavern of CMS
X0.5	The floor under CMS detector floor
X0	The floor under X0.5

1. Introduction

The UXC55 Tranches as it shown in figure 1 play a critical region for the movements of the Cable Chains of the CMS detector, also for other Cables and Pipes in X0 and X0.5 as shown in figure 3. The Tranches located in Underground Experimental Cavern of CMS on both sides of the CMS detector as shown in Figure 5 and Figure 6.

In the CMS detector floor, there are many heavy components move on the Tranches. For instances move Riser with roller, transfer New Forward Shielding Tower (NFS) with rollers as shown in figure 4, driving with heavy Scissor lift and etc. This report will present the maximum load capacity of the UXC55 Tranches.

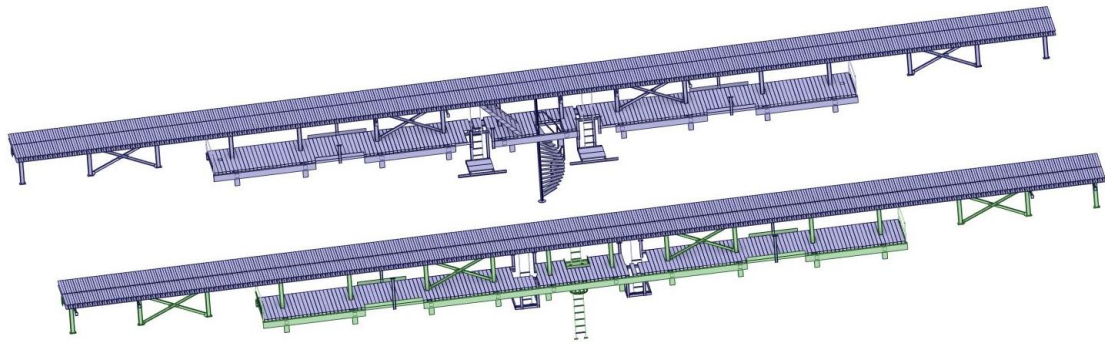


Figure 1: UXC55 Tranches

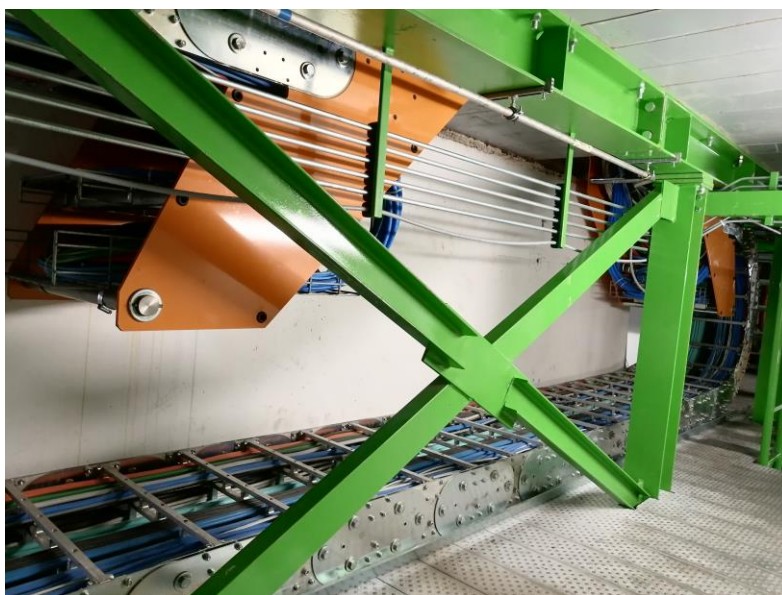


Figure 2: Cable Chain in X0.5



Figure 3: Cable trays and Pipes in X0 and X0.5

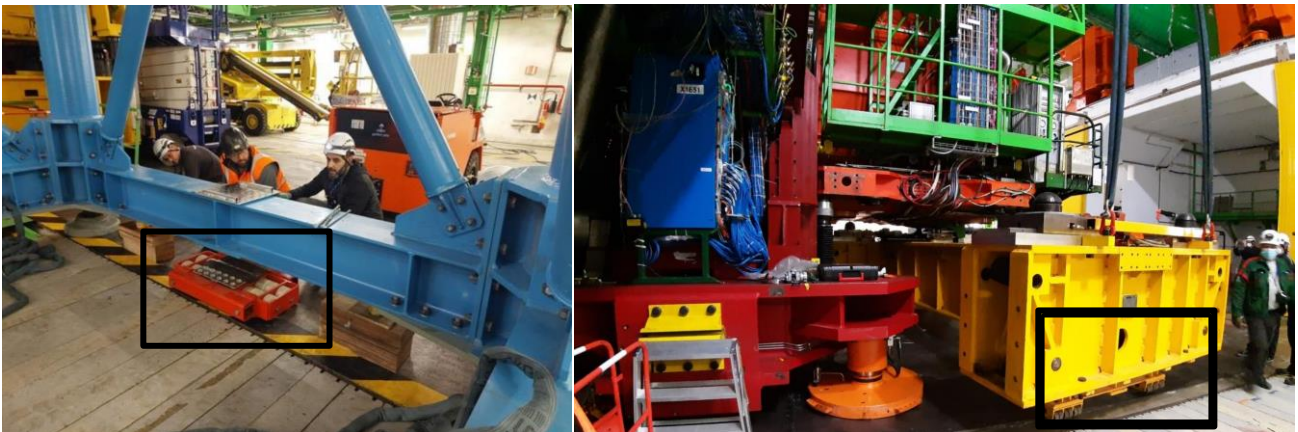


Figure 4: Transfer NFS Tower and Move Riser with roller

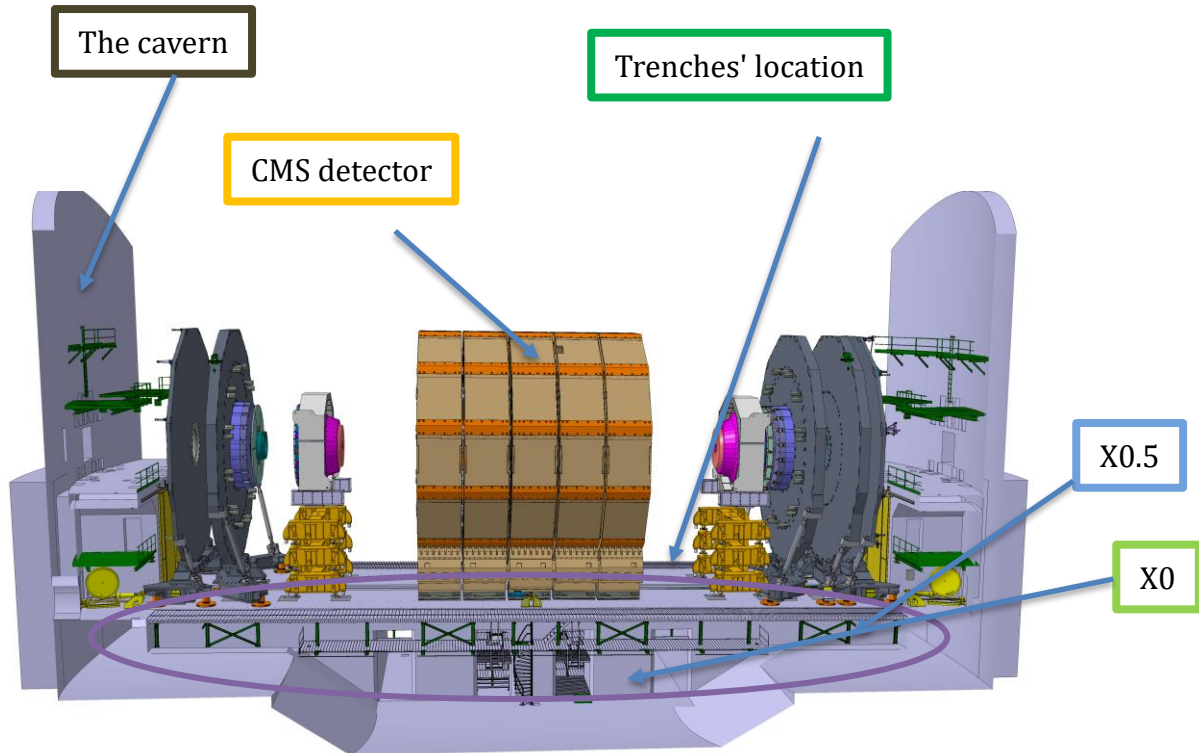


Figure 5: CMS Cavern (front view)

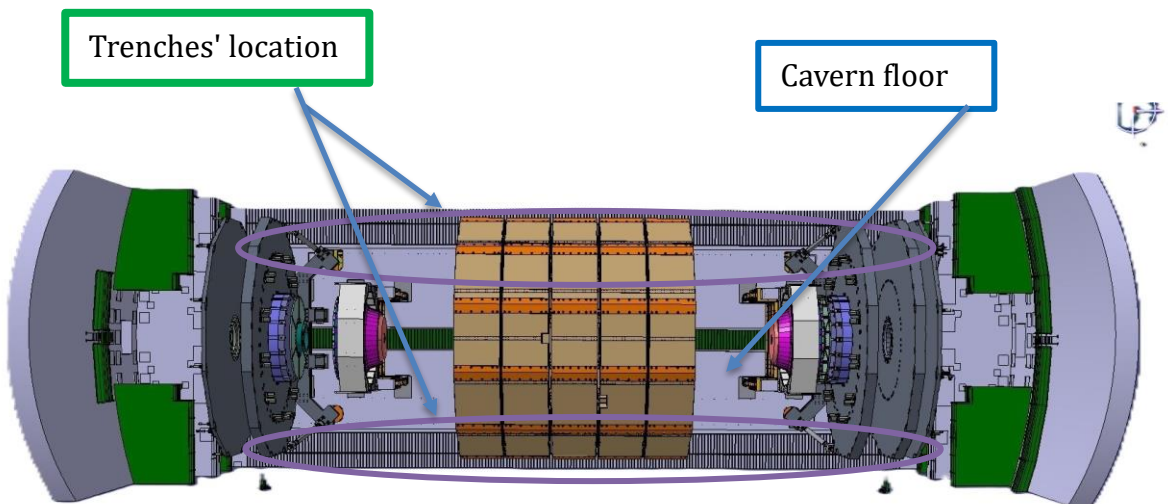


Figure 6: CMS Cavern (up view)

2. Project Overview

The primary objective of the project is to study the maximum load that can be handled by the UXC55 Tranches using finite element analyses (FEA) by design as built model and run it in Ansys software. This study follows the European safety standards (Eurocodes 0 and 3).



Figure 7: UXC55-0

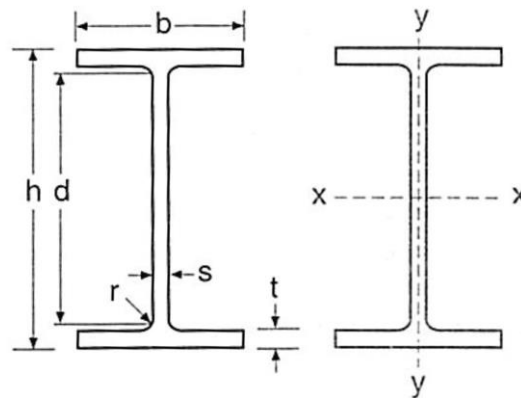


Figure 8: X0

3. Project Components

3.1. I-beam

There are different sizes of I-beams used in the UXC55 tranches' structure. The below figure 9 show the different sizes.



I-beam	Width (b) mm	Hight (h) mm
1	200	190
2	160	152
3	200	200

Figure 9: I-beam

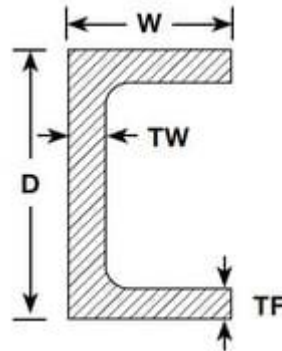
3.2. Bolts

The bolts sizing used in the UCX55 structure as shown in the table below.

Bolts	Size
1	M12
2	M16
3	M20

3.3. C-beam

In the UXC55 tranches' structure many different C-beam used. The below figure 10 explain the sizes.



C-beam	Width (W) mm	Depth (D) mm
1	50	100
2	65	160
3	50	120
4	95	270

Figure 10: C-beam

3.4. Steel plate

There are many steel plates used in the UXC55 tranches' structure, they used as a plate to connect some parts as shown in figure 11. Another use of the steel plates is that used as ribs to increase the strength of the horizontal I-beam, and the down structure connected to the wall as shown in figure 12. The table in figure 12 describe the sizes of the steel plates used in the structure of the UXC55 tranches.

3.4.1. Plate

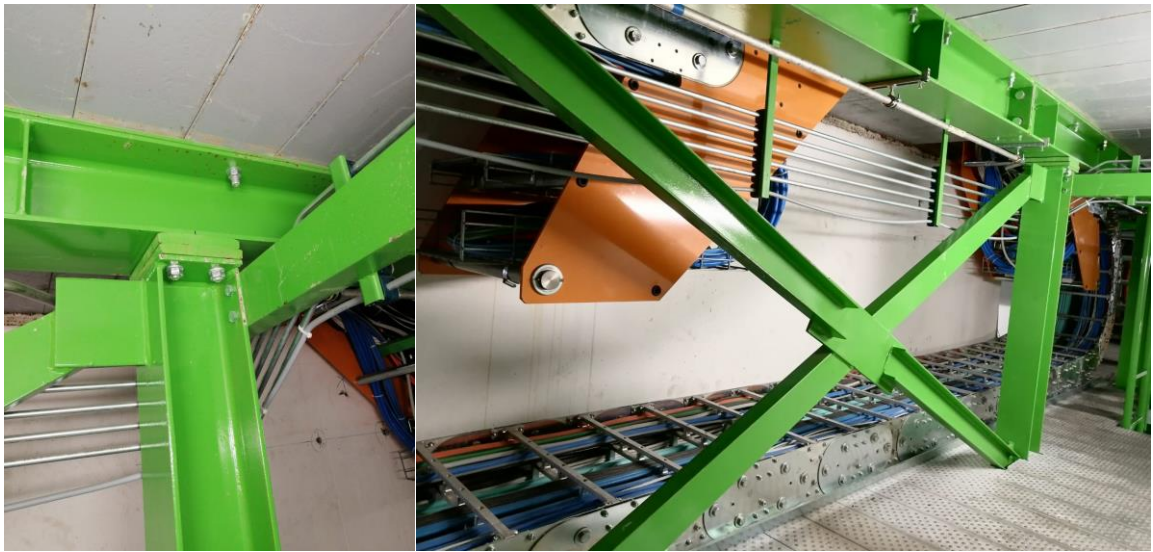
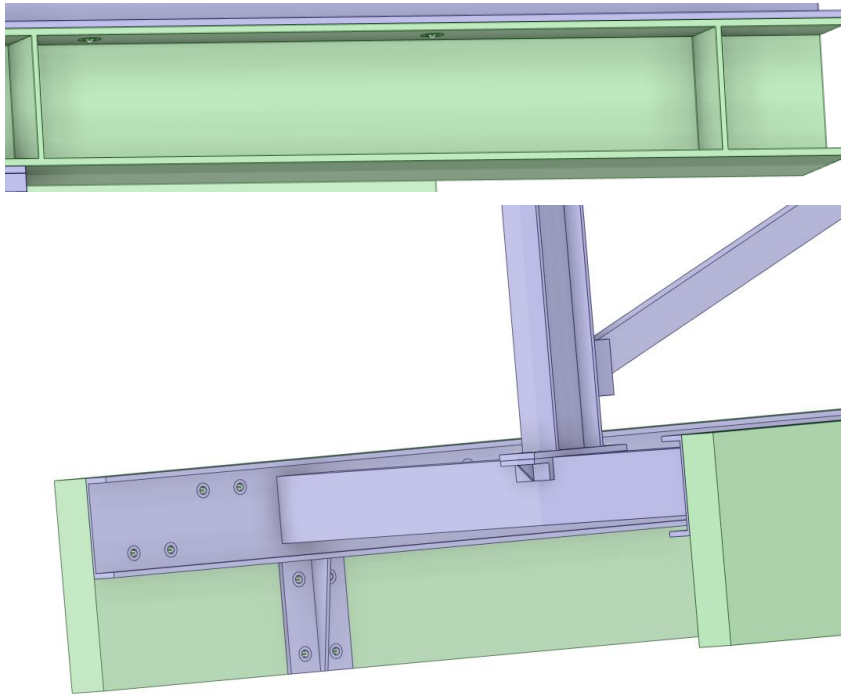


Plate	Thickness (mm)
1	10

Figure 11 : Steel plates

3.4.2. Ribs

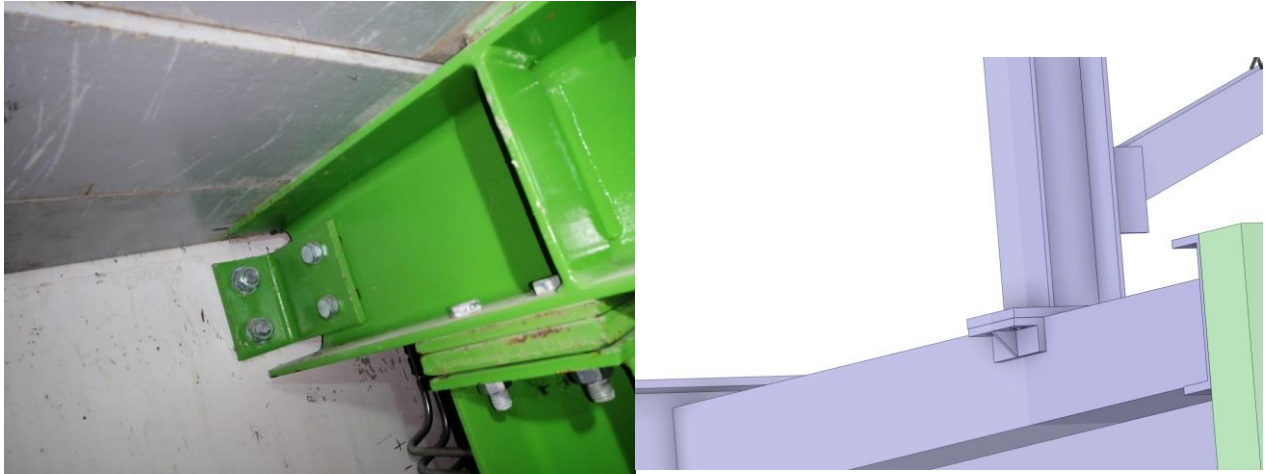


Ribs	Thickness (mm)
1	10
2	8
3	16

Figure 12: Ribs

3.5. L-shape steel

The L-shape steel used in the ends of the UXC55 tranches' structure to connect them to the wall as shown in figure 13. Also, they used to connect the vertical I-beams to the boxes as shown in figure 13. The table in figure 13 show the thickness of the L-shape steel.

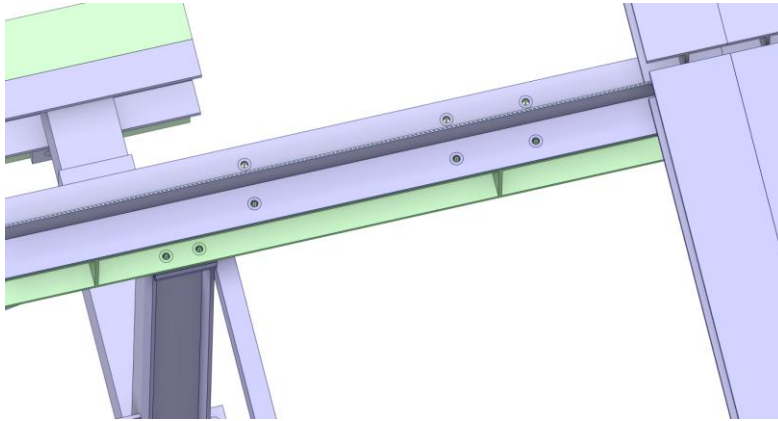


L-shape	Thickness (mm)
1	12
2	14

Figure 13 : L-shape steel

3.6. T-shape steel

The T-shape connected to the horizontal I-beam as shown in the figure14. The table in figure 14 show the thickness of the T-shape.



T-shape	Thickness (mm)
1	9

Figure 14: T-shape

4. Project strategy

The study has two different loading cases. Case one studies the behaviour of the tranches within a distributed load per m^2 (as a standard). Case two studies the behaviour of the tranches within a concentrated load per $300 \times 100 \text{ mm}^2$ (the size of cherry picker's wheel).

The study had done to a half of the tranche with two models. Model one was simple model that almost as one part as shown in figure 15, we did this model to understand the general behaviour of the UXC55 tranches' structure. The second model was as built model which describe the behaviour of the bolts, the joints, the frictional between the beams and the concrete and etc as shown in figure 16.

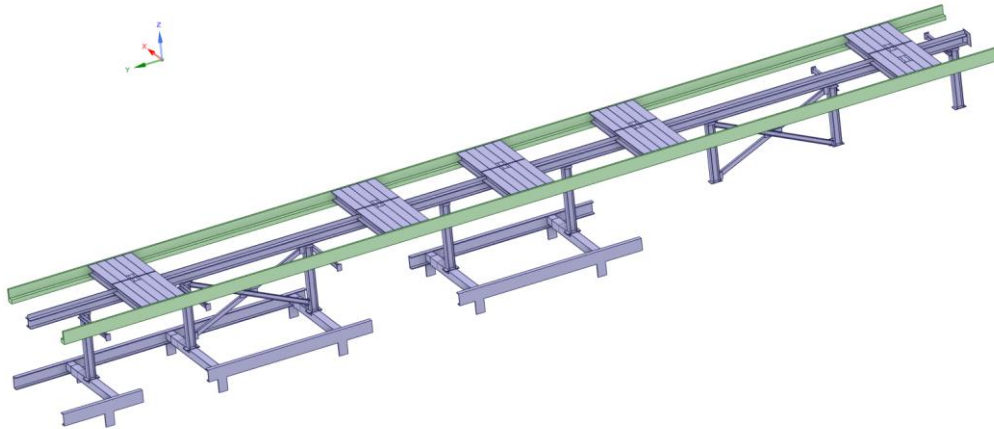


Figure 15: Simple model

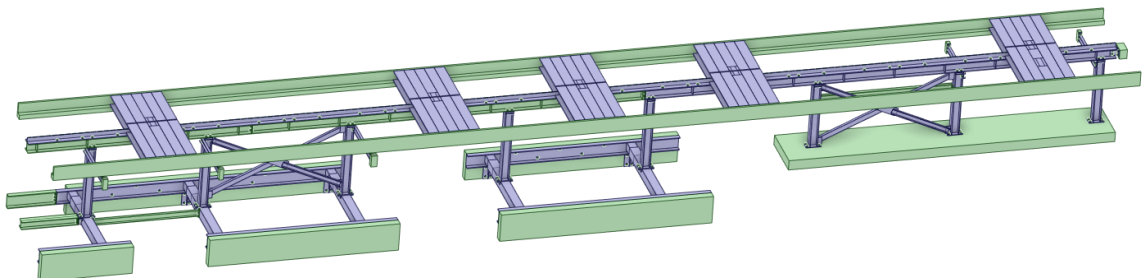


Figure 16: As built model

4.1. Case one: Loading zones per one m2

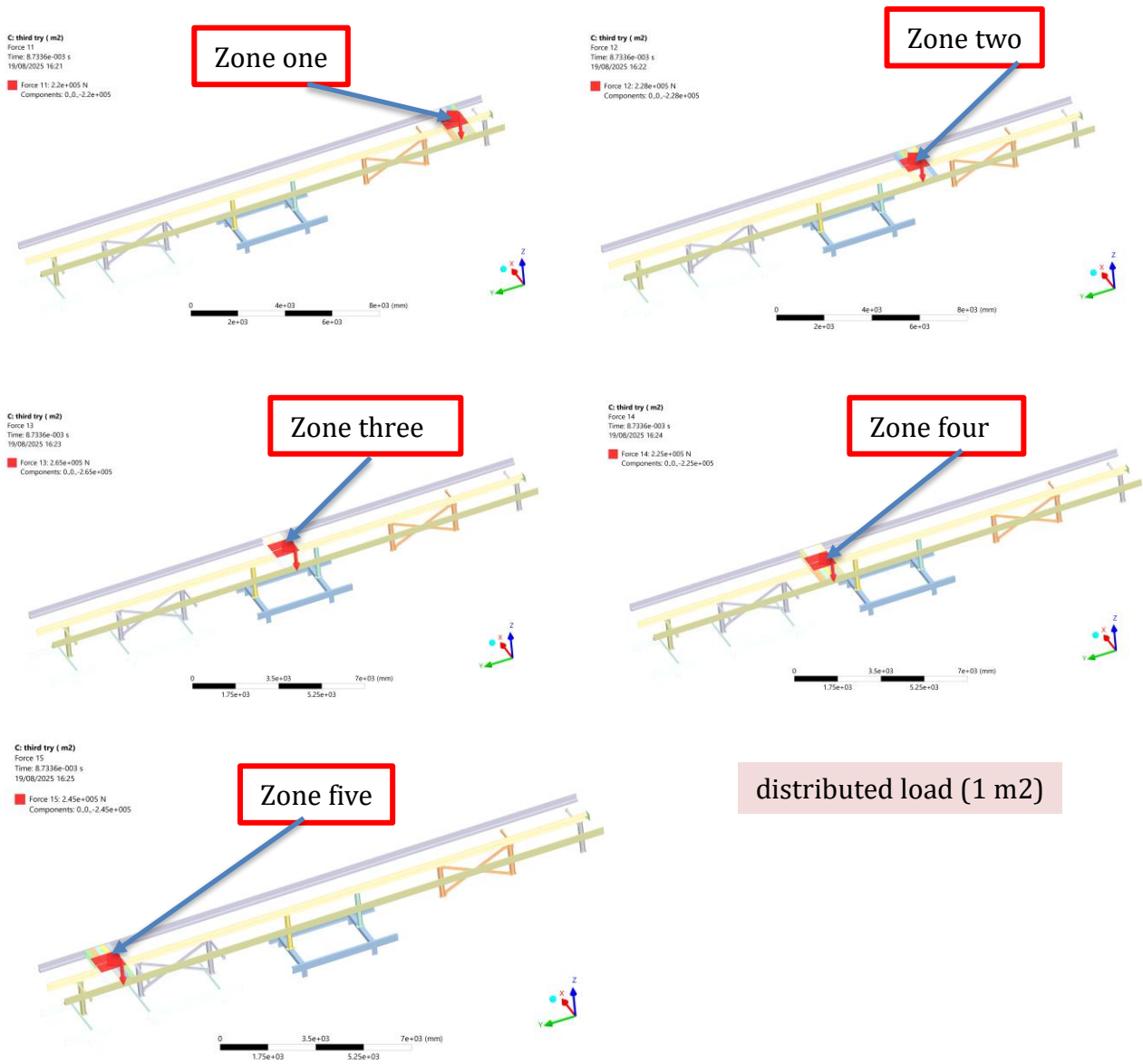


Figure 17: load zones per m2

4.2. Case two: Loading zones per 300 X 100 mm²

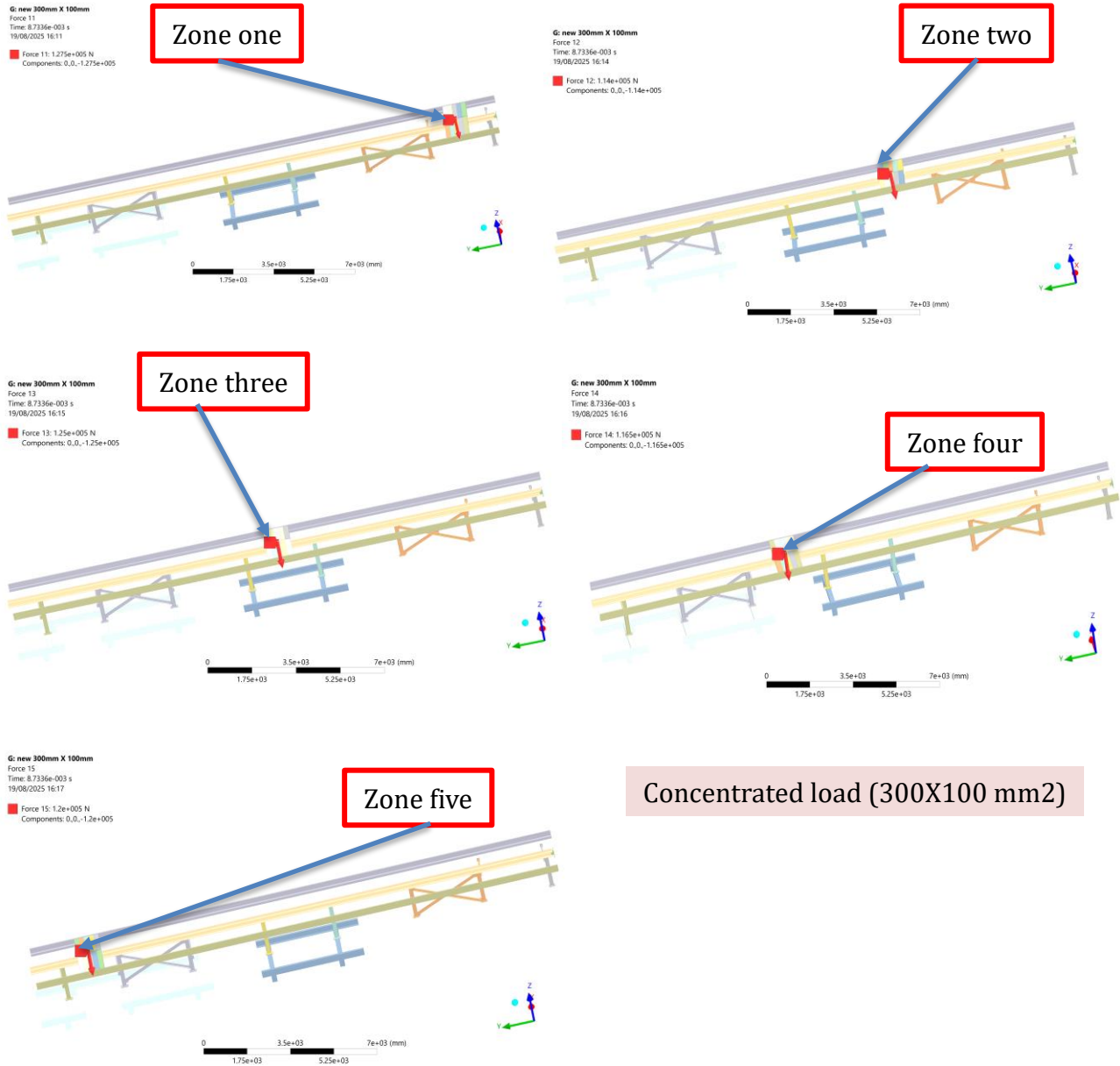


Figure 18: Load zones per 300 X 100 m²

5. Ansys model

5.1. Boundary conditions

5.1.1. Stage one : Simple model

The model almost as one part only the top and the bottom of the vertical I-beams connected with a bonded connection, also the five I-beams zones connected to each other and to the concrete and the horizontal I-beam with the frictional connection. The other parts connected by fixed support as shown I figure 19. The loads of the hidden I-beam applied to the structure. Frictionless support applied to the cutted area as the structure does not in here as shown in figure 20.

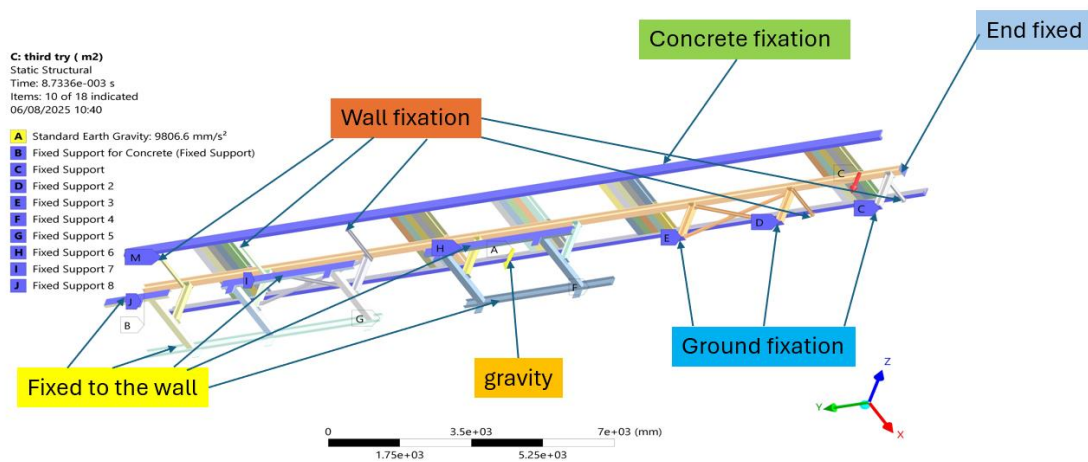


Figure 19: Boundary conditions

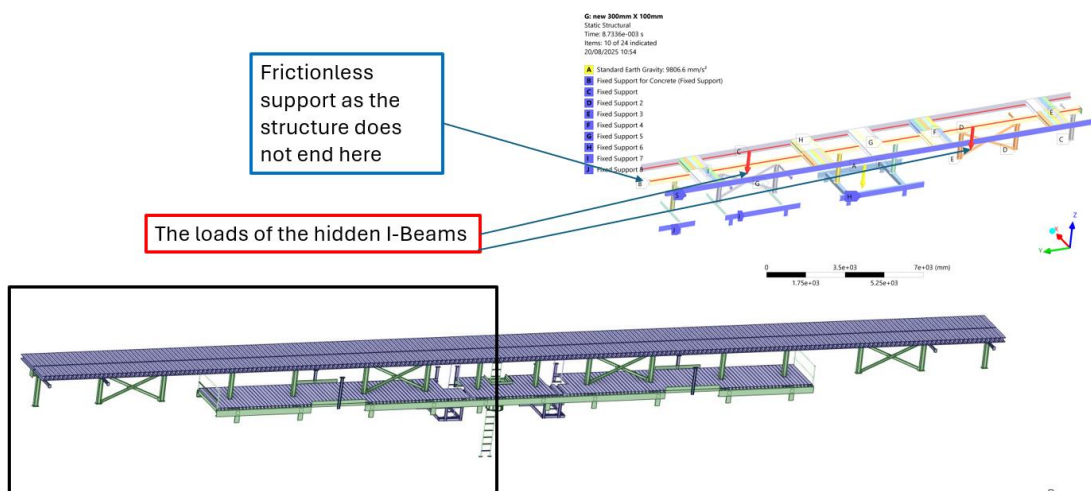


Figure 20: Structure situation

5.1.2. Stage two: (As built model)

In this model the concrete fixed by fixed support, the loads of the hidden I-beams applied, and the dead load added to the gravity as shown in figure 21.

The beam to beam and beam to concrete connected by frictional connection as shown in figure 26.

The bolts done as extracted beam, then they connected using joints and a bolt pretension applied to the extracted beam as shown in figure 22, 23, 24, 25.

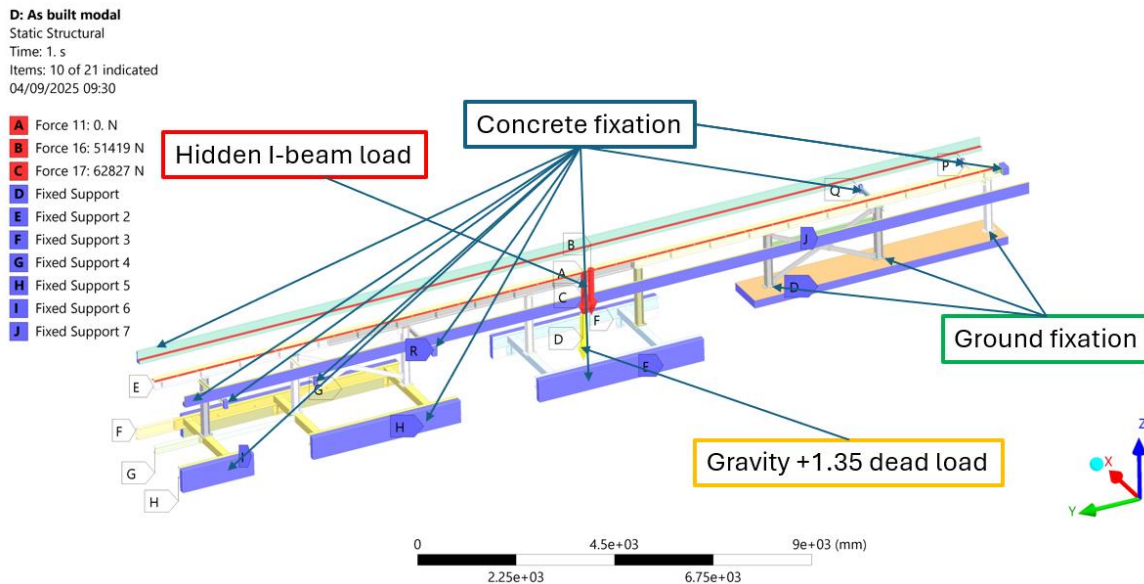


Figure 21: Boundary conditions

Fixed - Beam (Extracted Profile2) To zone four\Down box 4-5
Items: 10 of 566 indicated
04/09/2025 09:34

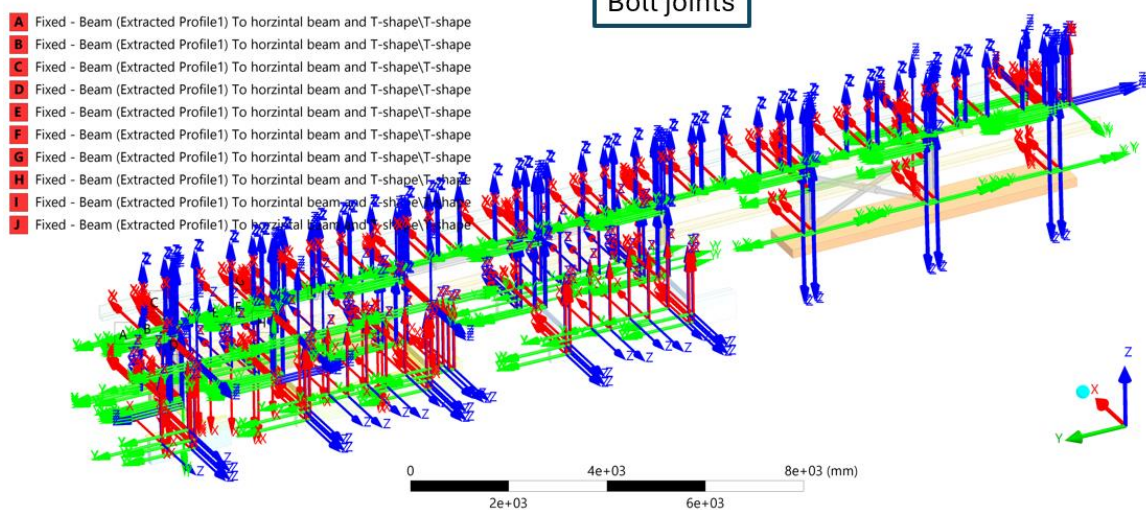


Figure 22: Bolt joints

D: As built modal

Static Structural

Time: 1. s

Items: 10 of 304 indicated

04/09/2025 09:30

- A** Force 11: 0. N
- B** Force 16: 51419 N
- C** Force 17: 62827 N
- D** Bolt Pretension: 87920 N
- E** V-beam down + I-beamBolt Pretension: 87920 N
- F** V-beam down + I-beamBolt Pretension 2: 87920 N
- G** V-beam down + I-beamBolt Pretension 3: 87920 N
- H** V-beam down + I-beamBolt Pretension 4: 87920 N
- I** V-beam down + I-beamBolt Pretension 5: 87920 N
- J** V-beam down + I-beamBolt Pretension 6: 87920 N

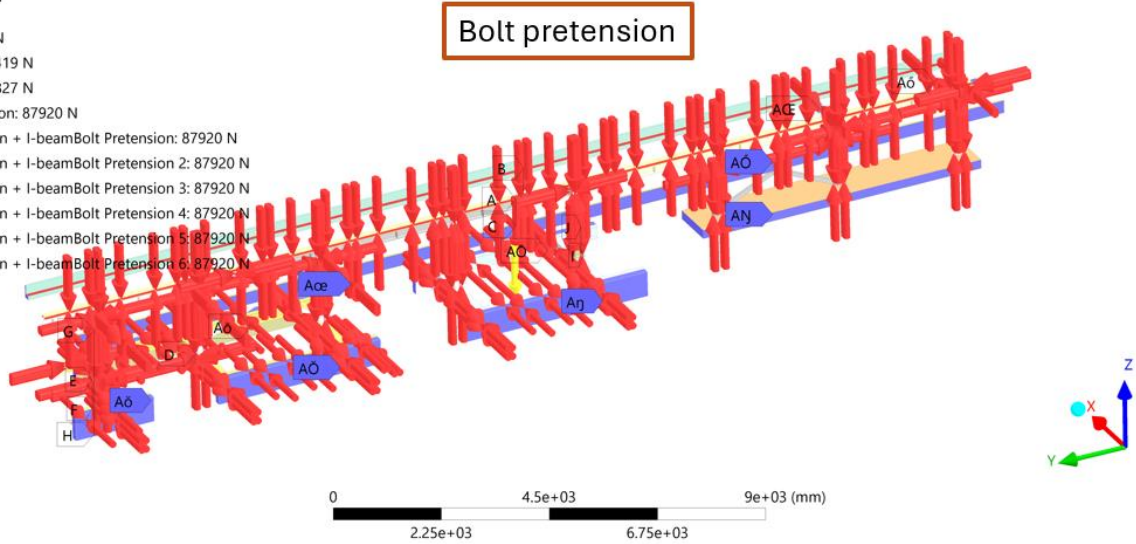


Figure 23: Bolt pretension

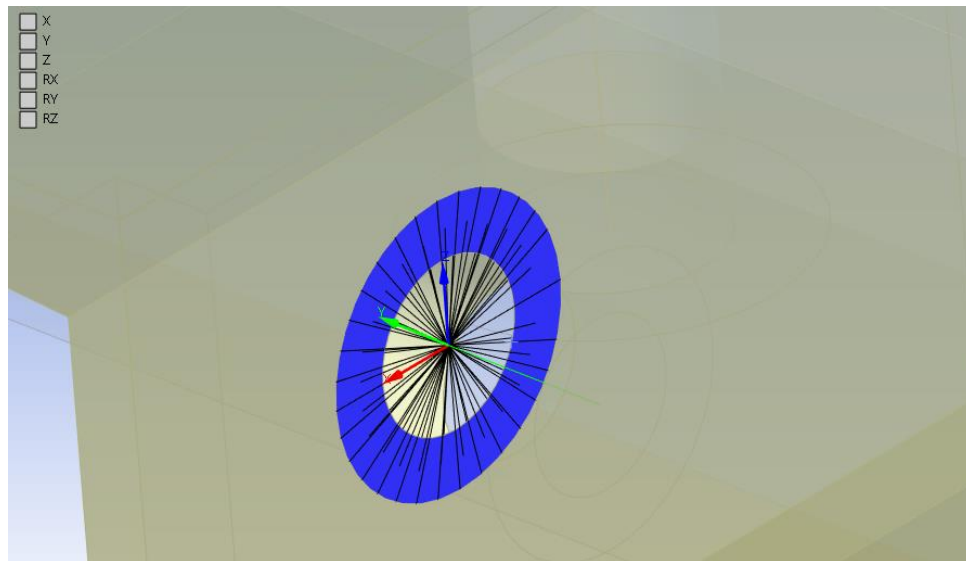


Figure 24: Bolt joint

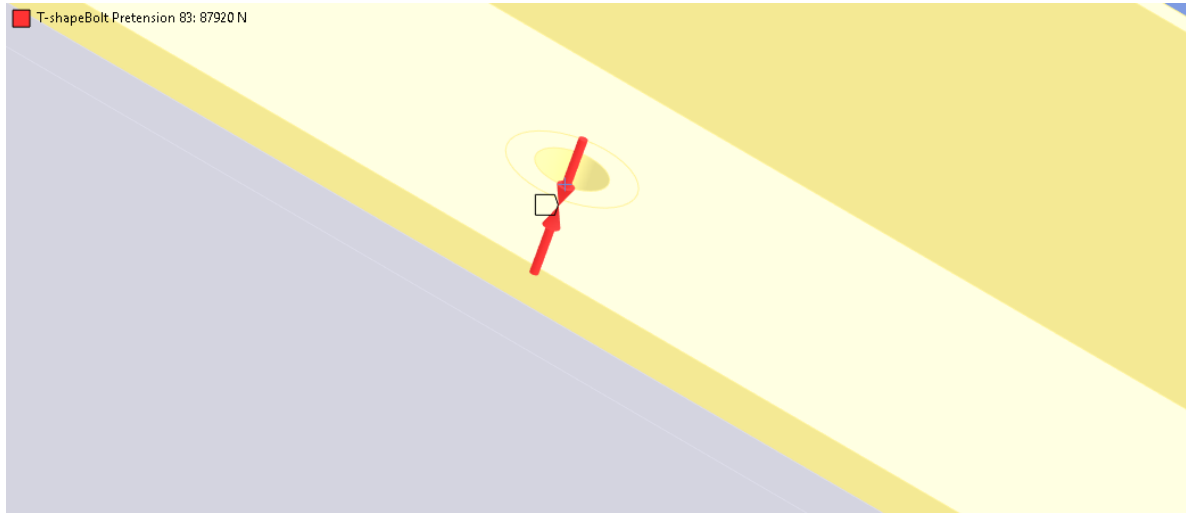


Figure 25: Bolt pretension

Frictional - horizontal beam and T-shape\I-beam 2 To horizontal beam and T-shape\I-beam 3
Items: 10 of 61 indicated
04/09/2025 09:35

- A** Frictional - zone five\Up plat To horizontal beam and T-shape\I-beam 3 (Contact Bodies)
- A** Frictional - zone five\Up plat To horizontal beam and T-shape\I-beam 3 (Target Bodies)
- B** Frictional - zone one\up plat To horizontal beam and T-shape\I-beam 1 (Contact Bodies)
- B** Frictional - zone one\up plat To horizontal beam and T-shape\I-beam 1 (Target Bodies)
- C** Frictional - zone three\Up plat To horizontal beam and T-shape\I-beam 1 (Contact Bodies)
- C** Frictional - zone three\Up plat To horizontal beam and T-shape\I-beam 1 (Target Bodies)
- D** Frictional - zone three\Up plat To zone three\Shim (Contact Bodies)
- D** Frictional - zone three\Up plat To zone three\Shim (Target Bodies)
- E** Frictional - Multiple To Concrete\Concrete (End) (Contact Bodies)
- E** Frictional - Multiple To Concrete\Concrete (End) (Target Bodies)

Frictionless support

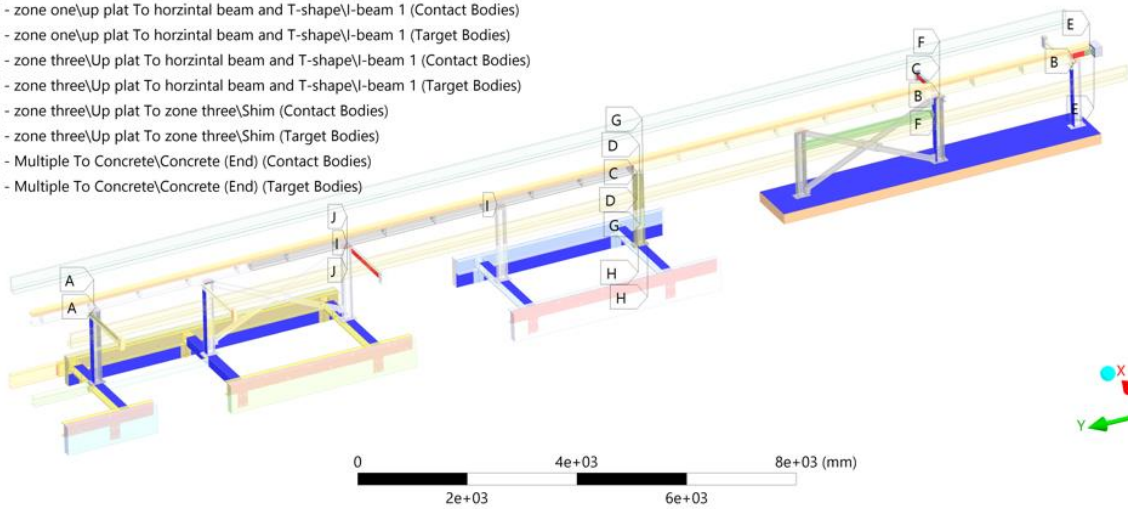


Figure 26: Frictionless support

5.2. Mesh sizing

Mesh sizing	
Element size	50 mm
Resolution	7

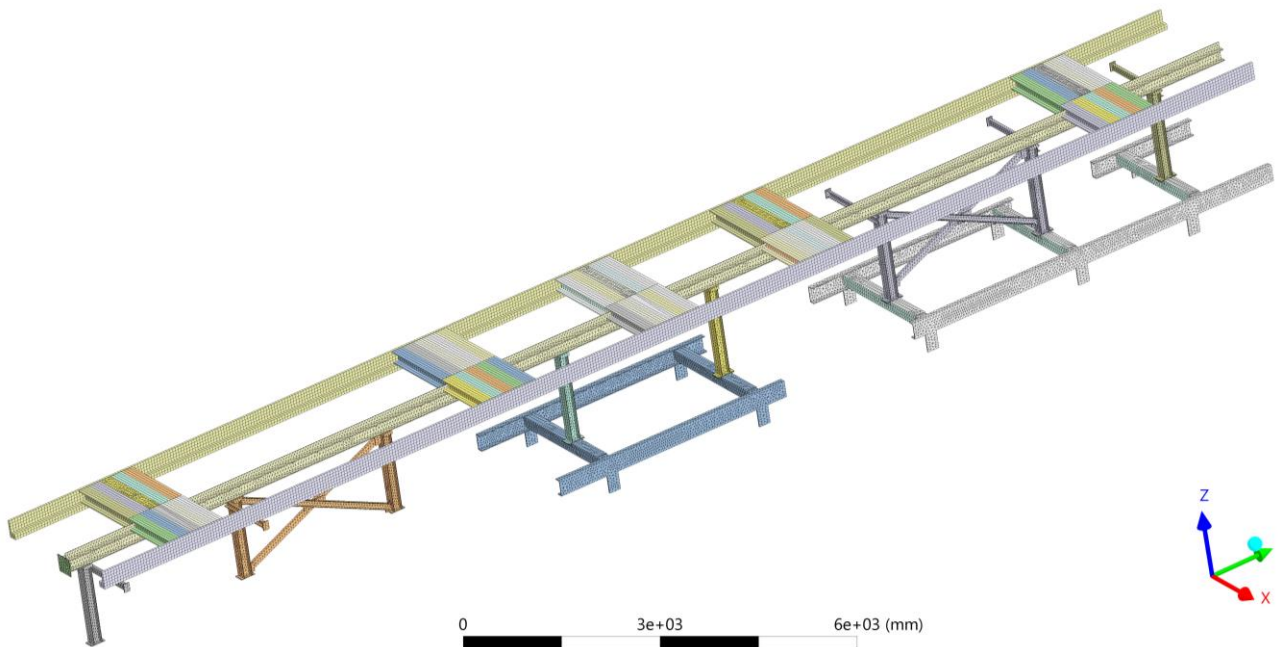


Figure 27: Mesh

6. Safety standards (HSE)

This study follows European standards:

- **Eurocode 0 (EN 1990) Basis of Structural Design**

Which states the following:

1.35 dead load + 1.5 live load

Reduction factor = 0.89

1.2 dead load + 1.5 live load

- **Eurocode 3 (EN 1993) Design of steel structures**

Which states the following:

- For the Bolt pretention

$$F_p = 0.7 * f_y * A_s$$

Table 3.1: Nominal values of the yield strength f_{yb} and the ultimate tensile strength f_{ub} for bolts

Bolt class	4.6	4.8	5.6	5.8	6.8	8.8	10.9
f_{yb} (N/mm ²)	240	320	300	400	480	640	900
f_{ub} (N/mm ²)	400	400	500	500	600	800	1000

Figure 28: Yield strength in different bolt classes

7. CMS cavern visit

- The current Tranches model has many mistakes and mis parts. For example, there are many ribs in the horizontal I-beam not provided in the current model, there is an I-beam in the middle of the Tranches which does not show in the current model, the Bolts, the joints and etc.
- We visited the CMS cavern to verify the accuracy of the 3D model (As built modal).



Figure 29: Joint and Ribs



Figure 30: Bolts



Figure 31: Ground fixation



Figure 32: Wall fixation

7.1. Notes about the real structure

- A. The C-beam in zone 3 connected to the ground, only in one side of the tranche, and that side does not has a C-beam in zone 2, and no supported C-beam connected to the wall. (the zones shown in the Figures 17, 18).



Figure 33: C-beam connected to the ground



Figure 34: C-beam in zone 2



Figure 35: supported c-beam connected to the wall

- B. The bolts not distributed in a same way, like you can find 5 bolts in one half of the tranche and the other half may be 10 bolts (same location).
- C. In the middle of one tranche there is an I-beam, but the other tranche there is a C-beam.

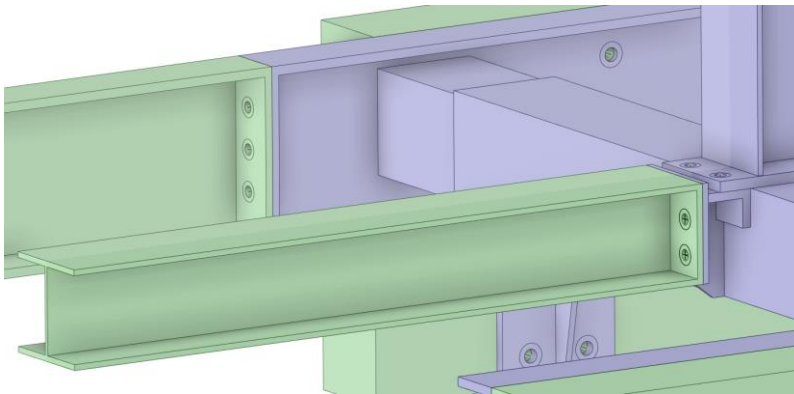


Figure 36: Mid I-beam



Figure 37: Mid C-beam

D. In zone three, one tranche has a C-beam connect the boxes (down), but the other tranche has two c-beams connected to each other.



Figure 38: Zone 3 down double C-beams



Figure 39: Zone 3 down one C-beam

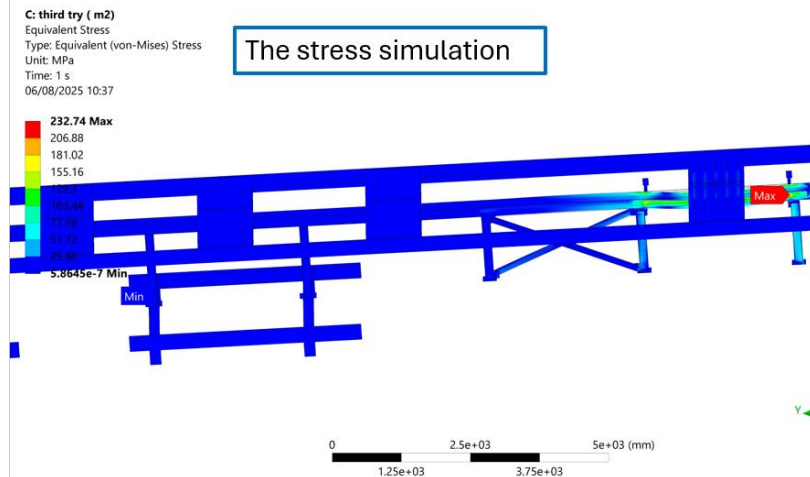
8. Results

8.1. Model one : Simple model

- Case one: Distributed load per m2

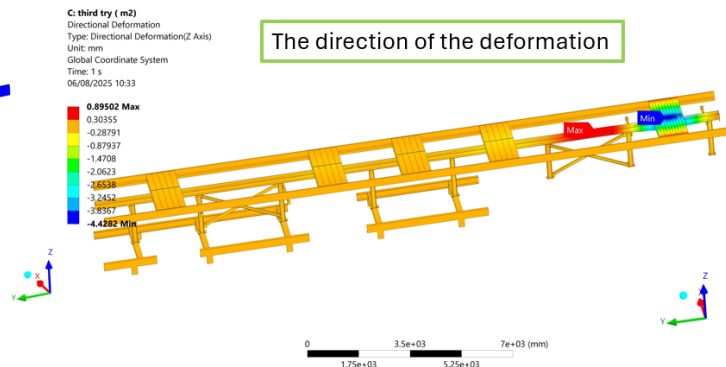
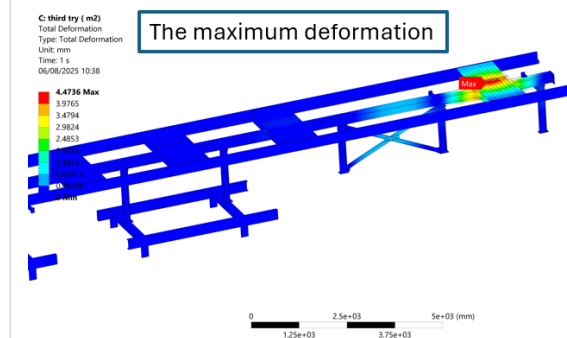
- Zone one

The force applied: 220 KN



Zone one

The force applied: 220 KN

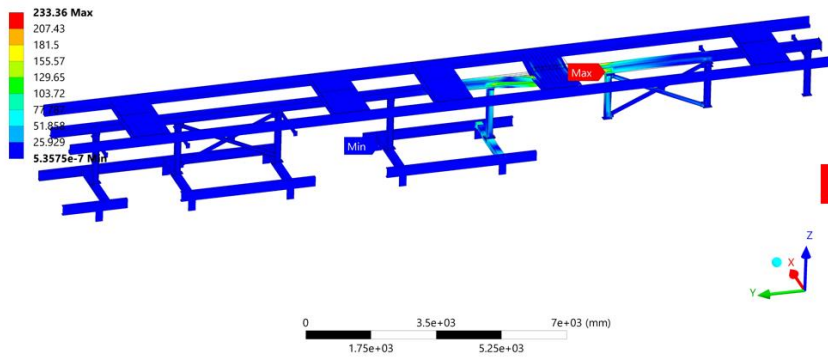


Zone two

The applied force: 228KN

C: third try (m2)
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s
06/08/2025 11:17

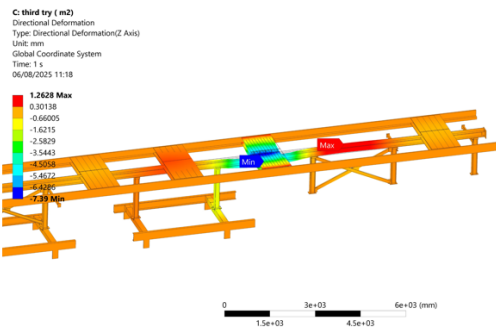
The stress simulation



The maximum stress is 233.36 MPa

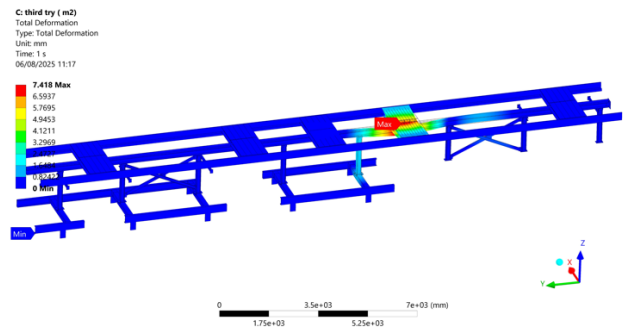
The force applied: 228 KN

The directional deformation simulation



The directional deformation: -7.39 mm to 1.26mm

The deformation simulation



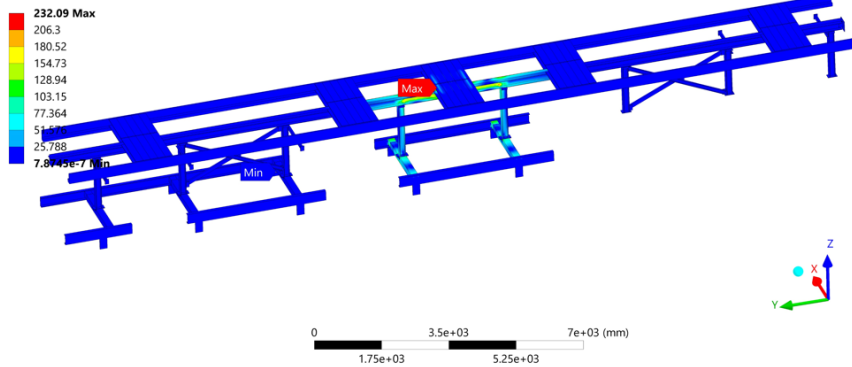
The max deformation is 7.4mm

Zone three

The force applied: 265 KN

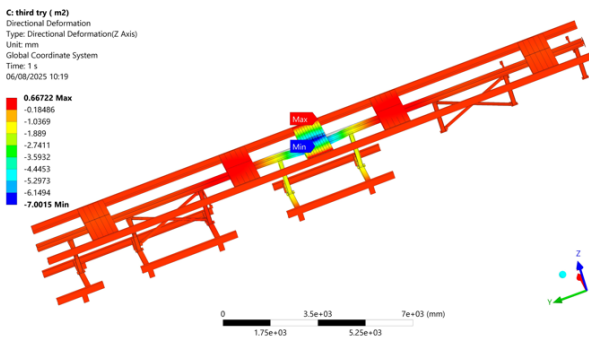
C: third try
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s
05/08/2025 15:49

The stress simulation

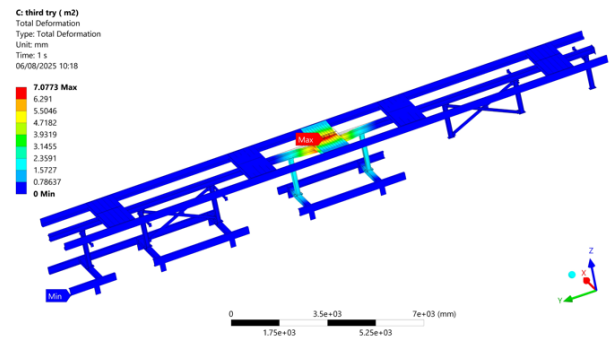


The force applied: 265 KN

The directional deformation simulation



The deformation simulation

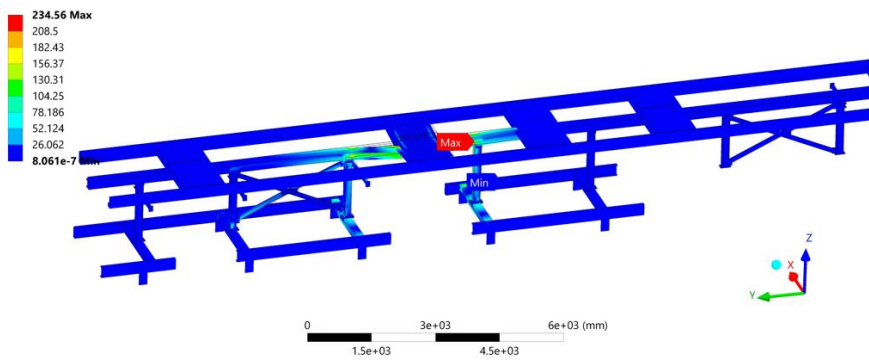


Zone four

The force applied: 225 KN

C: third try (m2)
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s
06/08/2025 11:41

The stress simulation

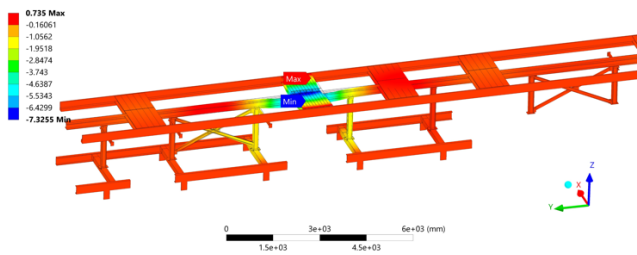


The maximum stress is 234.56 MPa

The force applied: 225 KN

The directional deformation simulation

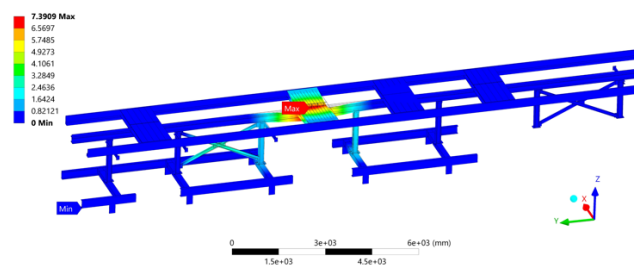
C: third try (m2)
Directional Deformation
Type: Directional Deformation(Z Axis)
Unit: mm
Global Coordinate System
Time: 1 s
06/08/2025 11:42



The directional deformation: -7.3 mm to 0.735 mm

The deformation simulation

C: third try (m2)
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s
06/08/2025 11:41



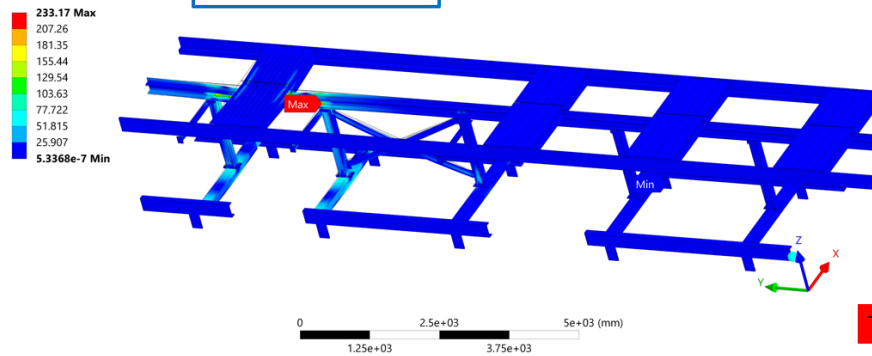
The max deformation is 7.4 mm

Zone five

The force applied: 245 KN

C: third try (m2)
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s
06/08/2025 12:11

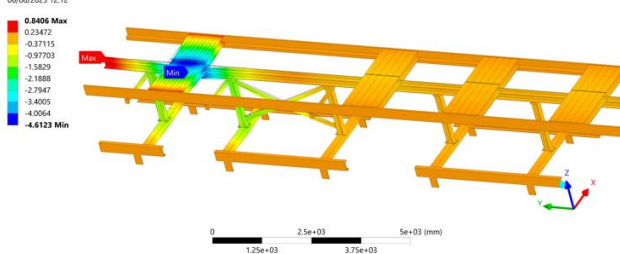
The stress simulation



The force applied: 245 KN

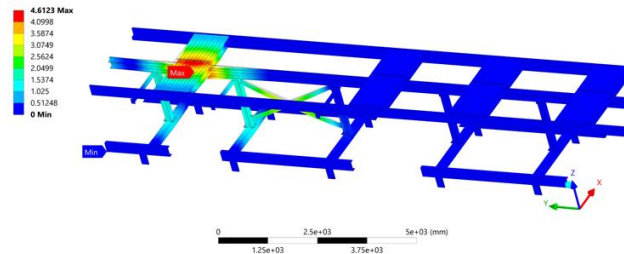
C: third try (m2)
Directional Deformation
Type: Directional Deformation(Z Axis)
Unit: mm
Global Coordinate System
Time: 1 s
06/08/2025 12:12

The directional deformation simulation



C: third try (m2)
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s
06/08/2025 12:11

The deformation simulation



Zones	Maximum load (KN)	Max stress (MPa)	Max deformation (mm)
1 (weakest)	220	232.74	4.47
2	228	233.36	7.4
3 (Strongest)	265	232.09	7
4	225	234.56	7.4
5	245	233.17	4.6

Case two: Concentrated load per 300 X 100 mm²

F: 300mmx100mm

Equivalent Stress

Type: Equivalent (von-Mises) Stress

Unit: MPa

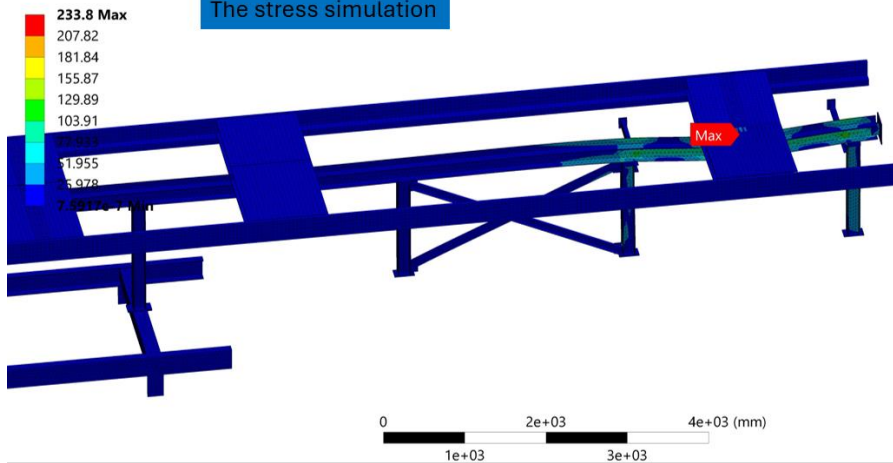
Time: 1 s

08/08/2025 14:10

Zone one

The force applied: 127.5 kN

The stress simulation



The max stress is 233.8 MPa

The force applied: 127.5 kN

The directional deformation simulation

F: 300mmx100mm

Directional Deformation

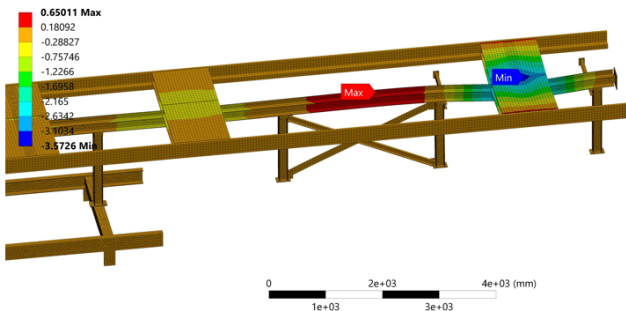
Type: Directional Deformation(Z Axis)

Unit: mm

Global Coordinate System

Time: 1 s

08/08/2025 14:10



The directional deformation: -3.57 mm to 0.65 mm

The deformation simulation

F: 300mmx100mm

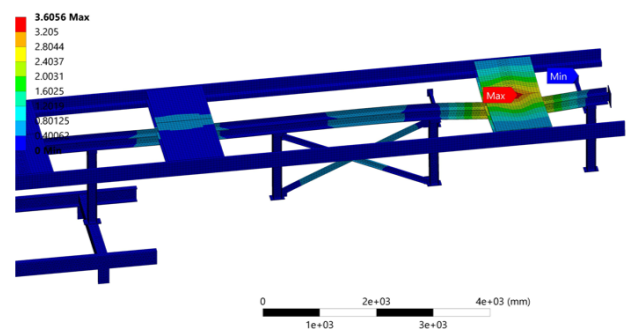
Total Deformation

Type: Total Deformation

Unit: mm

Time: 1 s

08/08/2025 14:10



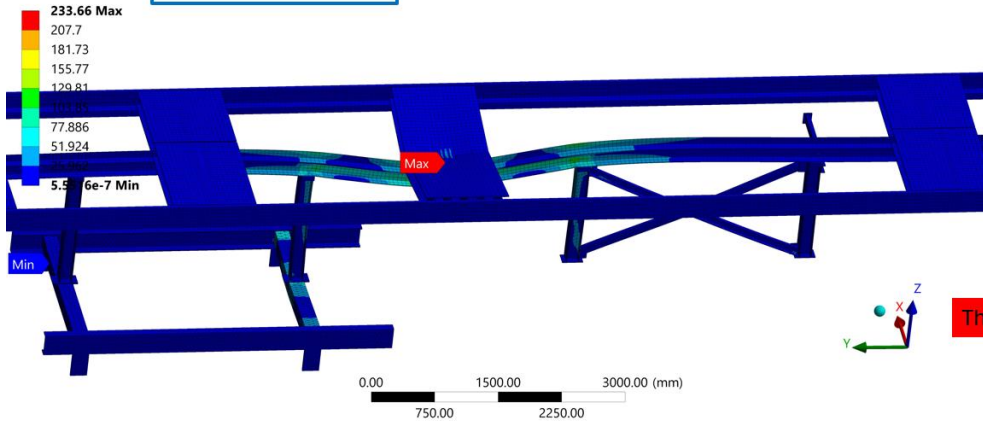
The max deformation is 3.6 mm

Zone two

F: 300mmx100mm
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s
08/08/2025 16:05

The force applied: 114 kN

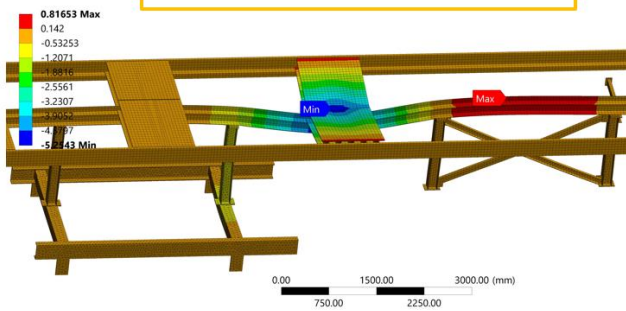
The stress simulation



The force applied: 114 kN

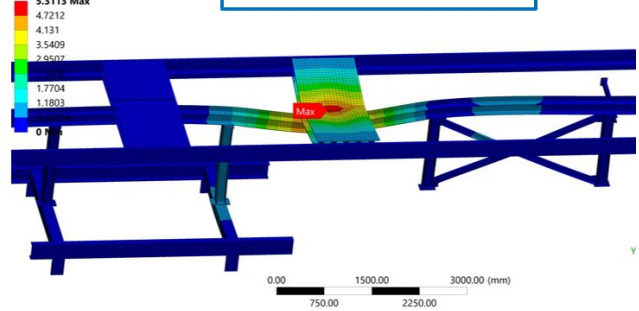
F: 300mmx100mm
Directional Deformation
Type: Directional Deformation(Z Axis)
Unit: mm
Global Coordinate System
Time: 1 s
08/08/2025 16:04

The directional deformation simulation



F: 300mmx100mm
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s
08/08/2025 16:05

The deformation simulation



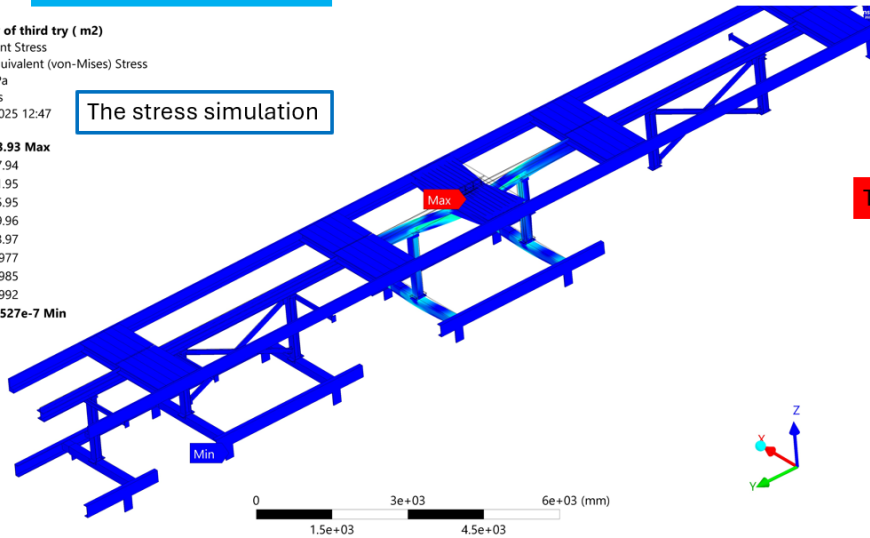
Zone three

The force applied: 125 kN

G: Copy of third try (m2)
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s
11/08/2025 12:47

The stress simulation

233.93 Max
207.94
181.95
155.95
129.96
103.97
77.977
51.985
25.992
7.6527e-7 Min



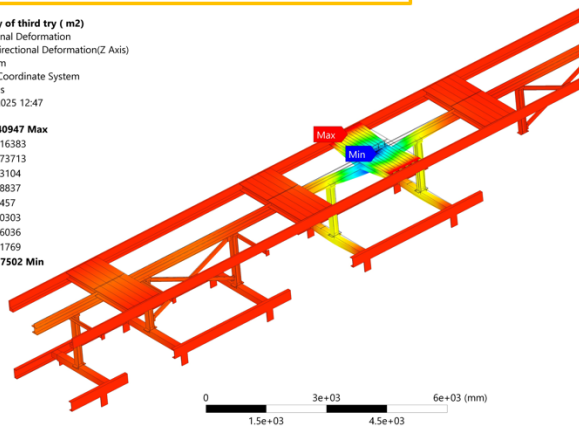
The max stress is 233.93 MPa

The force applied: 125 kN

The directional deformation simulation

G: Copy of third try (m2)
Directional Deformation
Type: Directional Deformation(Z Axis)
Unit: mm
Global Coordinate System
Time: 1 s
11/08/2025 12:47

0.40947 Max
-0.16383
-0.73713
-1.3104
-1.8837
-2.457
-3.0303
-3.6036
-4.1769
-4.7502 Min

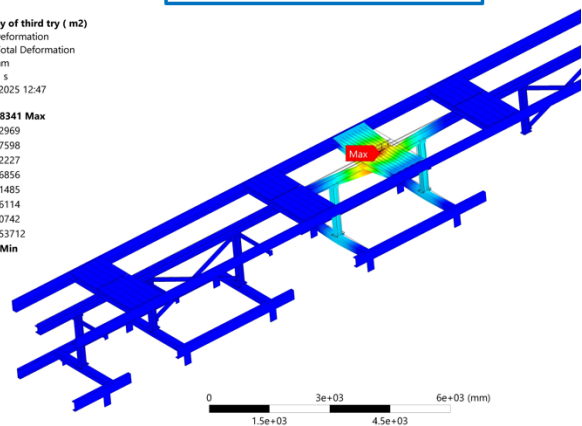


The directional deformation: -4.75 mm to 0.41 mm

The deformation simulation

G: Copy of third try (m2)
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s
11/08/2025 12:47

4.8341 Max
4.2969
3.7598
3.2227
2.6856
2.1485
1.6114
1.0742
0.53712
0 Min



The max deformation is 4.8 mm

Zone four

G: Copy of third try (m2)

Equivalent Stress

Type: Equivalent (von-Mises) Stress

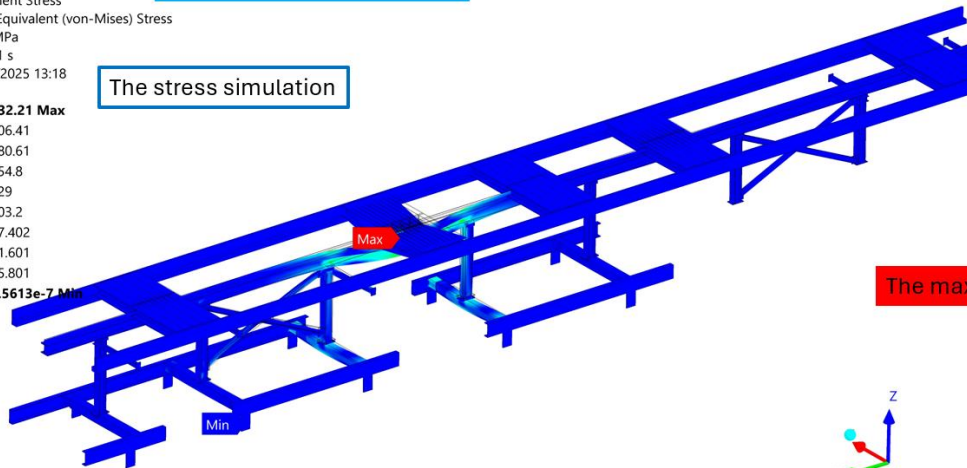
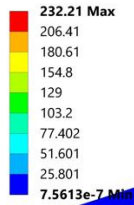
Unit: MPa

Time: 1 s

11/08/2025 13:18

The force applied: 116.5 KN

The stress simulation



The max stress is 232.21 MPa



The force applied: 116.5 KN

The directional deformation simulation

G: Copy of third try (m2)

Directional Deformation

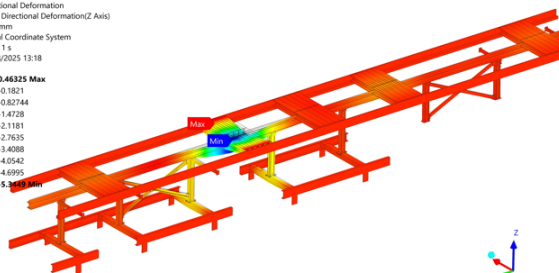
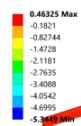
Type: Directional Deformation(Z Axis)

Unit: mm

Global Coordinate System

Time: 1 s

11/08/2025 13:18



The deformation simulation

G: Copy of third try (m2)

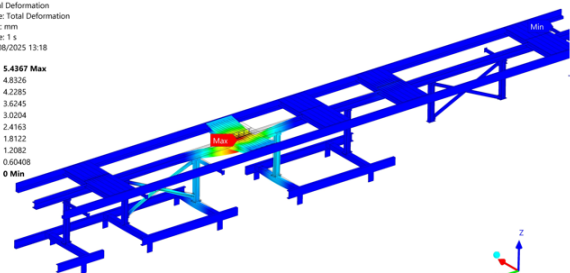
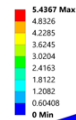
Total Deformation

Type: Total Deformation

Unit: mm

Time: 1 s

11/08/2025 13:18



The directional deformation: -5.345 mm to 0.46 mm

The max deformation is 5.437 mm

Zone five

The force applied: 136.5 KN

G: Copy of third try (m2)

Equivalent Stress

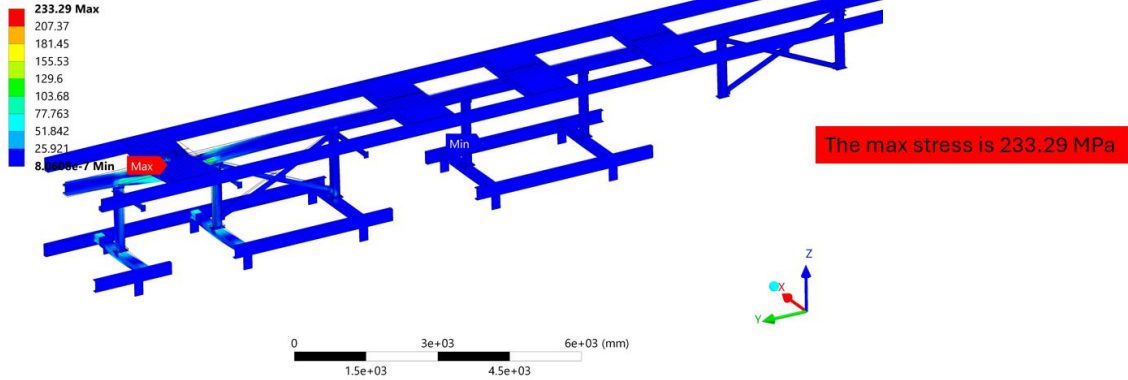
Type: Equivalent (von-Mises) Stress

Unit: MPa

Time: 1 s

11/08/2025 13:52

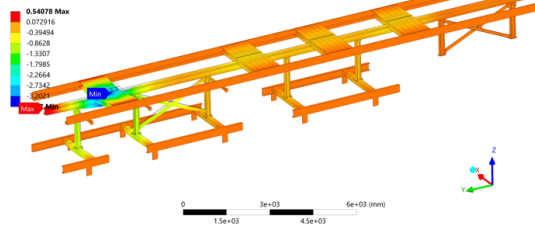
The stress simulation



The force applied: 136.5 KN

The directional deformation simulation

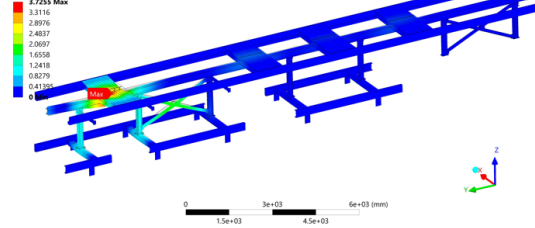
G: Copy of third try (m2)
Directional Deformation
Type: Directional Deformation(Z Axis)
Unit: mm
Global Coordinate System
Time: 1 s
11/08/2025 13:53



The directional deformation: -3.67 mm to 0.541 mm

The deformation simulation

G: Copy of third try (m2)
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s
11/08/2025 13:53



The max deformation is 3.7 mm

Zones	Maximum load (KN)	Max stress (MPa)	Max deformation (mm)
1	127.5	233.8	3.6
2 (weakest)	114	233.66	5.3
3	125	233.93	4.8
4	116.5	232.21	5.437
5 (strongest)	136.5	233.29	3.7

8.2. Model two: As built model

The model is ready, but the results will be added by another person of the department.

• Final results with the safety factors in both cases

The case	The maximum load with the safety factor
Simple model: Case one per m2	146.67 KN
Simple model: Case two per 300X100mm2	76 KN
As built model: Case one per m2	Will be added later
As built model: Case two per 300X100 mm2	Will be added later

The above table present the maximum load on the UXC55 Tranches in both cases distributed load (m2) and concentrated load (300X100 mm2).

9. How to improve the results

1. Design a model for every tranche (they are not symmetric).
2. Every half of the tranche also not symmetric.
3. Increase the loading zones or apply the load for the full I-beam platform.
4. Apply the loads of Cable chains, cable trays, pipes and the walking sheet metals.

10. Conclusion

This study shows the behaviour of the UXC55 tranches in two models, simple model and as built model. Also, it described the maximum load in five zones with different loading cases, case one distributed load per m2 and case two concentrated load per 300 X 100 mm2. The study followed the Eurocodes 0 and 3. Finally, this study very important because it show the behaviour of the UXC55 tranches under different loading cases that will ensure both safety and efficiency in load-critical environments.