Proyecto Fin de Carrera

DISEÑO Y CÁLCULO DE UNA ESTRUCTURA REFORZADA PARA LA CABINA DE UN CAMIÓN LIGERO DE TRANSPORTE

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SUMMARY

The target of this project is to develop a new structure for a light commercial vehicle interior cabin.

It is a real design, based in a vehicle accident when a tree collapsed into the cabin, and killed the two occupants.

The target is to add a reinforced structure for the interior of the cabin, and incorporate new resistant conditions so that the new cabin could be under hard conditions, similar to the conditions that happened in the accident in such a way that guarantee the safety of the occupants.

It will be done different design proposals and simulations of each one for every load case by using finite element method (FEM).

This is a research project in which it has been done analytic calculations, based on the information from the site accident in order to estimate the impact load based on energy balance.

The company provided a similar cabin so we could design the cabin, and get all information we could need from the garage.

It has been done several calculations, a general one with SOLIDWORKS, and also a specific one from the top part with NASTRAN PATRAN.

All the design was done with SOLIDWORKS, the background, truck and reinforced structure.

We well try to find the balance between aesthetics, price, and resistance and easy to manufacture because this design is pretended to be incorporated in the new vehicle range mentioned on this project.

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2. BACKGROUND

The reason for this project is because an accident happened on the cabin of a Toyota, when a 30 meters tree collapsed on the cabin.

Two of the occupants of the cabin were killed and the goal of the project is to design a structure strong enough to avoid such an event.

The project has been ordered by the Victoria Department of Environment to our company, Enkelam and Associates, who is the responsible of the design of the new structure.

In the Figure 1 we can see the result of the cabin, after the tree collapsed on the truck.

Figure 1.Cabin after accident

3. AIM

The object of this project is to achieve a reinforced structure for the interior of the cabin for truck ISUZU. This project is commissioned by the Environment Department, Victoria.

The main goal is to increase the strength of the cabin, getting an interior structure strong enough to avoid future accidents.

We made different designs until find the most viable one, an average between price, strength and aesthetic.

Our company bought an ISUZU cabin, in this way we can always check in our facility all that we need, as it is a investigation project, and we need to check the relevant dimensions of the cabin.

We can see in Figure 2 see our cabin, the survival volume and the impact position (green cylinder).

Figure 2. Survival volume and impact load

4. CABIN SPECIFICATION

Below there are the specifications of our cabin, as the main details that we have been using within the investigation stage. The ISUZU 300 and 450 cabins are identical.

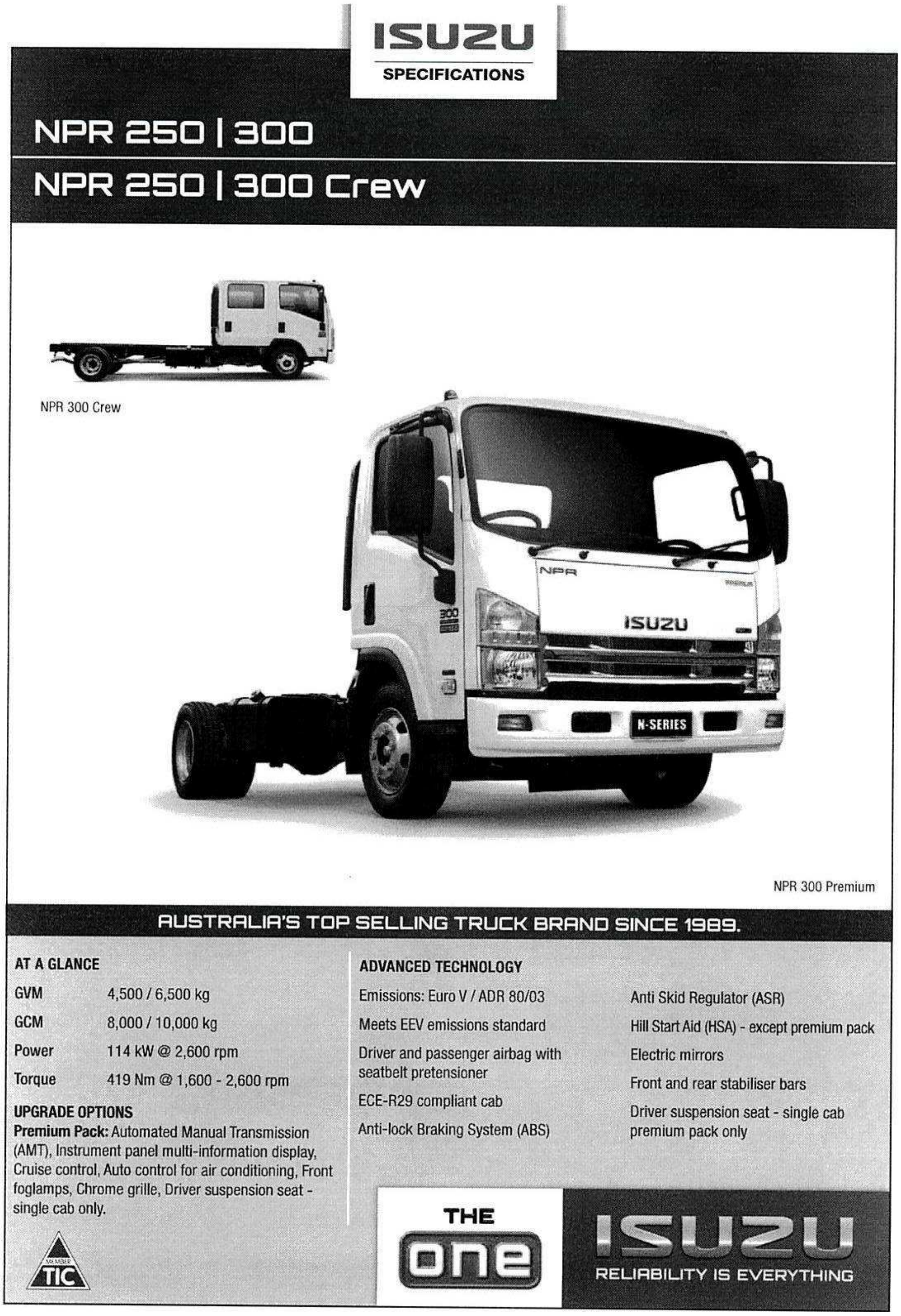


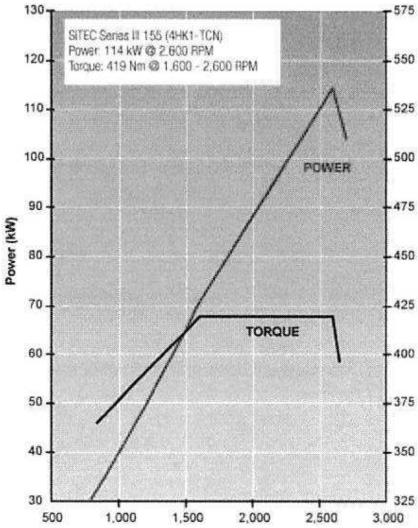
Figure 3. Isuzu specifications 1

NPR Medium | Crew

DRIVELINE AND CHASSIS SPECIFICATIONS

ENGINE: SITEC SERIES III 155 (ISUZU 4HK1-TCN)

Type: 4 cylinder 16 valve SOHC
Displacement: 5,193 cc
Compression ratio: 17.5:1
Bore x Stroke: 115 mm x 125 mm
Max power (DIN- NET): 114 kW (153 HP) @ 2,600 RPM
(JIS Gross): 118 kW (158 HP) @ 2,600 RPM
Max torque (DIN - NET): 419 Nm (309 lb.ft) @ 1,600 - 2,600 RPM
(JIS Gross): 434 Nm (320 lb.ft) @ 1,600 - 2,600 RPM
Induction system: Electronically controlled variable nozzle turbocharger with air-to-air intercooler.
Fuel injection: Direct injection high pressure common rail system.
Emission control system: Cooled EGR with exhaust Diesel Particulate Diffuser (DPD). ADR 80/03 (Euro V) compliant. EEV compliant.



CLUTCH

Standard model:
- Auto adjusting hydraulic control with vacuum assistance. Single plate 325 mm diameter.
- Total lining area: 966 cm²

Premium Pack:
- Fully automated hydraulically controlled wet clutch and fluid coupling with lock up.

TRANSMISSION

Isuzu MYY-6S
- PTO provision on LHS of transmission case. PTO drive from counter gear.
- Gear ratios (: 1)

1st	2nd	3rd	4th	5th	6th	Rev
5.979	3.434	1.862	1.297	1.000	0.750	5.701

Standard model:
- 6 speed manual. Synchromesh on gears 1-6.

Premium Pack:
- 6 speed Automated Manual Transmission (AMT) with both fully automatic and clutchless manual operation modes.

AXLES

Front: Isuzu F031
- Reverse Elliot I-beam. 3,100 kg capacity.

Rear: Isuzu R066
- Full floating Banjo type. Four differential pinions. 6,600 kg capacity.
- Drive ratio: 4.100:1

SUSPENSION

Front:
- **Single cab:** Single stage alloy steel taper leaf springs. **Crew cab:** Single stage alloy steel multi leaf springs.
- Double acting hydraulic shock absorbers. Stabiliser bar.

Rear:
- Multi leaf main spring, multi leaf helper spring.
- Double acting hydraulic shock absorbers. Stabiliser bar.

BRAKES

- Auto adjusting front disc and rear drum brakes with dual circuit hydraulic control, vacuum assistance and electronic brake force distribution (EBD).
- ABS and ASR traction control.
- Hill Start Aid (HSA) - except premium pack.
- Front disc diameter: 293 mm
- Rear drum size: 320 x 100 mm
- 190 mm diameter drum park brake mounted on rear of transmission.
- Vacuum controlled exhaust brake.

STEERING

- Power assisted recirculating ball steering.
- Gear ratio: 20.9:1
- Turns lock to lock: 5.4
- Maximum angle: 43° (inside wheel) / 33° (outside wheel)

WHEELS AND TYRES

- 17.5 x 6.00 six stud steel wheels.
- 205/75R 17.5 124/122M Michelin XZE2 Tubeless.
- Maximum tyre rating:
  Steer axle: 3,200 kg
  Drive axle: 6,000 kg
- 1 frame mounted spare wheel and tyre assembly.

CHASSIS FRAME

- Cold rivetted ladder frame. SAPH440 weldable steel sidemembers. Parallel side rails and rivetless top flange.
- Frame dimensions:
  Side rail (mm): 216 x 70 x 6.0
  Rear frame width (mm): 850

Figure 4. Isuzu specifications 2

FUEL TANK

- Frame mounted 140L steel fuel tank.
- Lockable fuel cap.

ELECTRICAL SYSTEM

- 24 volt electrical system.
- 80 amp alternator.
- 4.5 kW starter motor.
- 2 x 80D26L (630 CCA) batteries connected in series.

CABIN SPECIFICATIONS AND APPOINTMENTS

CAB EXTERIOR

- All steel construction. High tensile steel used for cab underframe. **Single cab:** Manual cab tilt to 45° with torsion bar assistance.
- Complies with ECE-R29 cab strength standard.
- **Single cab:** Liquid filled front and rear cab mounts. **Crew cab:** Rubber cab mounts.
- Heavy duty non slip entry steps.
- 90° opening internally reinforced front doors.
- Water spray suppression guards and front mudflaps.
- Laminated windscreen with shade band.
- Two speed windscreen wipers with intermittent wipe mode.
- Halogen multi-reflector headlamps incorporating turn signals. Additional door mounted side indicator lamps.
- Combination brake, turn, reverse and marker lamps, registration plate illumination lamps. Extended wiring harness. Reverse alarm.
- Roof-mounted clearance lamps.
- Heated and powered exterior main mirrors with flat glass and additional independently adjustable convex "spot" mirrors.
- **Standard model:** Body coloured grille. **Premium Pack:** Chrome grille.
- Body coloured impact resisting polycarbonate bumper with steel backing frame. **Premium Pack:** Includes front foglamps.

CAB INTERIOR

- Contoured adjustable driver's bucket seat. **Single cab Premium pack:** includes mechanical suspension.
- Front passenger bench seat with 2 seat capacity.
- **Crew cab:** Engine access provided under removable driver seat base and tiltable front passenger seat.
- **Crew cab:** Rear bench seat with 4 seat capacity.
- 3-point lap sash seatbelts in all outboard seating positions. Driver and outboard front passenger seatbelts fitted with pretensioner. Centre seat lap belts.
- Driver and outboard front passenger airbag.
- **Premium Pack:** Driver's footrest.
- Door and roof pillar entry assist grips. Crew cab: Full width rear grab rail with ashtray.
- Full interior trim, padded roof lining and vinyl floor covering. Driver and passenger windscreen header storage shelf.
- Tilt/Telescopic adjustable steering column, soft feel urethane steering wheel.
- Electric windows.
- Central locking with remote keyless entry and immobiliser.
- Twin cup holders. 24V cigarette lighter. Dashboard hook.
- Front door mounted storage pockets and driver's side ashtray.
- Centre console box with storage tray. Fold down storage tray behind centre seat backrest.
- Fully integrated air conditioning and heater/demister with 4-speed fan and outlets for windscreen, side windows, face and floor. **Standard model:** Manual control. **Premium Pack:** Auto control.
- Interior lamp with On/Door/Off switch. **Single cab:** fluorescent type. **Crew cab:** standard type.
- 2 DIN, two speaker radio/CD multimedia unit with 4.8" LCD touch screen and Bluetooth. Provision for SD card, USB and 3.5 mm plug inputs.
- DIN sized compartment for storage or for CB radio installation.

DRIVER CONTROLS

- Key-operated engine start/stop and steering lock. Engine idle speed control.
- HSA slow/fast engagement control and on/off switch - except premium pack.
- ASR on/off.
- DPD regeneration.
- **Premium Pack:** AMT slow/fast gear engagement control, 1st gear start and normal/economy gear selection modes.
- **Left side combination stalk:** Windscreen wipers, washers and exhaust brake.
- **Right side combination stalk:** Turn signals and headlamps. **Premium Pack:** Cruise control.

INSTRUMENTATION

- Electronically driven speedometer and tachometer. Digital odometer with integrated dual tripmeter. Engine coolant temperature and fuel level gauges.
- **Warning lamps:** Check engine, oil pressure, ABS, SRS airbag, alternator charge, service brakes, park brake, seat belt unfastened, low fuel level. **Premium Pack:** Check AMT.
- **Indicator lamps:** HSA (except premium pack), warm up system, high beam, ASR, DPD status, exhaust brake, turn signals. **Premium Pack:** Cruise control, econo-mode, 1st gear start.
- **Premium Pack:** Gear selection display.
- **Premium Pack:** Multi-information display. Shows service interval, instantaneous and average fuel consumption, DPD bar chart, hourmeter, voltmeter, time/day/date and includes 40-120 km/h adjustable vehicle speed warning.

OPTIONS AND GENUINE ACCESSORIES

Include the following (extra cost, request a brochure and further details from your Isuzu dealer):

- Satellite navigation - integrates with multimedia unit and includes NAVTEQ mapping.
- Up to three audio/visual reversing cameras - integrates with multimedia unit.
- Airbag compatible bullbar.
- 3,500 kg rated towbar.
- Air deflector.

THE one ISUZU RELIABILITY IS EVERYTHING

Figure 5. Isuzu specifications 3

ISUZU
SPECIFICATIONS

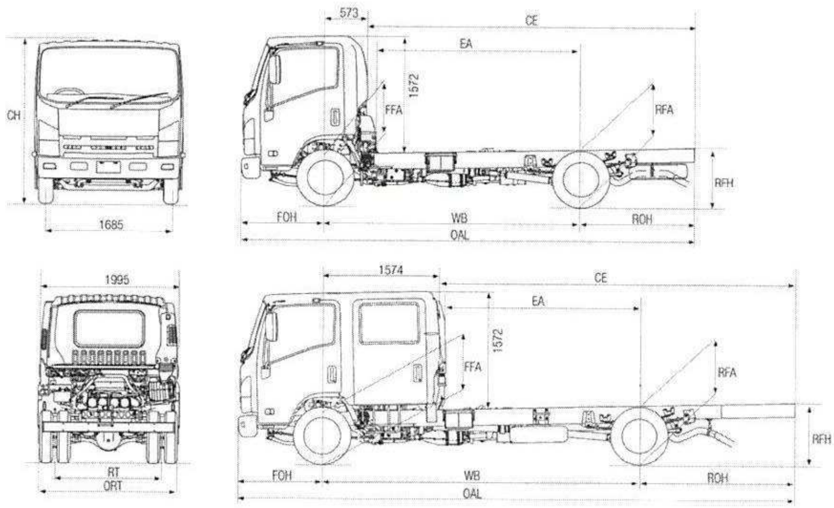
WEIGHTS (kg)

Models	Ratings*		Loading Limit* (at ground)		Cab Chassis Mass #		
	GVM	GCM	Front	Rear	Front	Rear	Total
NPR 250 / 300 Medium	4,500 / 6,500	8,000 / 10,000	3,100	6,000	1,740	870	2,610
NPR 250 / 300 Medium Premium	4,500 / 6,500	8,000 / 10,000	3,100	6,000	1,760	910	2,670
NPR 250 / 300 Crew	4,500 / 6,500	8,000 / 10,000	3,100	6,000	1,965	925	2,890
NPR 250 / 300 Crew Premium	4,500 / 6,500	8,000 / 10,000	3,100	6,000	1,985	965	2,950

Maximum Gross Trailer Mass: 750 kg (unbraked), 3,500 kg (braked) * Vehicle ratings and front/rear weight limits are subject to government regulatory requirements and weight distribution analysis. Consult your Isuzu dealer to select the correct vehicle for your specific application. # Cab chassis only as supplied and including 10 litres of fuel.

DIMENSIONS (mm)

Models	WB	OAL	FOH	ROH	EA	CE	RT	ORT	CH	FFA (unladen)	RFA (unladen)	RFH (unladen)	KERB TO KERB
NPR 250 / 300 Medium	3,365	5,985	1,110	1,510	2,680	4,302	1,650	2,115	2,265	665	800	840	12.4
NPR 250 / 300 Crew	4,175	7,338	1,110	2,053	2,510	4,654	1,650	2,115	2,265	660	800	860	15.3



PERFORMANCE (calcuated - typical paved road)

		Geared Speed* (top gear at peak power engine RPM)	Low Speed Gradeability (lowest forward gear assuming no wheel slip)	Engine Speed (top gear at 100km/h)
NPR 250	At 4,500 kg GVM	118 km/h @ 2,600 RPM	57%	2,210 RPM
NPR 300	At 6,500 kg GVM	118 km/h @ 2,600 RPM	39%	2,210 RPM

*Maximum speed achievable depends on vehicle frontal area as well as other factors. Consult your Isuzu dealer for more detailed information.

ISUZU WARRANTIES

STANDARD[1]		
New Vehicle	3 years • 100,000km • 2,000 hours	
Cab Perforation Corrosion	3 years • Unlimited km	
EXTENDED[2]		
4 years • 200,000 km	5 years • 250,000 km	6 years • 300,000 km
Isuzu Assist - 24 hour roadside assistance (3 years, unlimited km's)*		

ORDER CODES

Model	Code	Model	Code
NPR 250 / 300 Medium	NH-NPRCB-G11	NPR 250 / 300 Crew	NH-NPRGB-B11
NPR 250 / 300 Medium Premium	NH-NPRDB-D11	NPR 250 / 300 Crew Premium	NH-NPRHB-D11

[1] Subject to the conditions outlined in the IAL New Vehicle Warranty, the Isuzu NPR models carry a standard factory warranty which covers the owner: (i) for the entire vehicle, for the first 36 months or 100,000 km or 2,000 hrs (whichever comes first). (ii) against cab perforation corrosion, for 36 months and unlimited kilometres. [2] Extended Warranty as illustrated is available by purchase to cover the owner against the failure of original components, but may exclude some components and expendable items such as oil, filters, etc. Please consult with your Isuzu Dealer for full details obtained from a dedicated brochure available to customers. *Valid for three years from the date of new vehicle purchases.

ISUZU AUSTRALIA LIMITED ABN 97 006 962 572 ("IAL"). The information in this brochure was correct at time of printing, but all measurements, specifications and equipment are subject to change without notice. Some equipment may have been changed and/or is available at extra cost. IAL may make changes at any time without notice, in prices, colours, materials, equipment and models. IAL makes all reasonable attempts to ensure the availability of all vehicles and equipment. The information in this brochure is general in nature. Your Isuzu dealer can confirm all measurements, specifications and vehicle / equipment availability upon request.

TIC: Isuzu is a member of the Truck Industry Council - Safer Greener Essential.

April 2011. ARK0537

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ISUZU RELIABILITY IS EVERYTHING

Figure 6. Isuzu specifications 4

5. PROBLEM DESCRIPTION

5.1 Accident background

In the sketch below we can see the surroundings where the accident happened, giving the specific details to the understanding of the problem and to obtain a load magnitude.

In Figure 7, there is the detail of the tree. The tree is falling from a distance 25 meters, from the bush. The tree is 36.1 meters height, a base of 440mm diameter and in top 200mm. The tree mass was calculated at 1520Kg. It was broken at 1.8 meters above the base, and it impacted the top of the cabin.

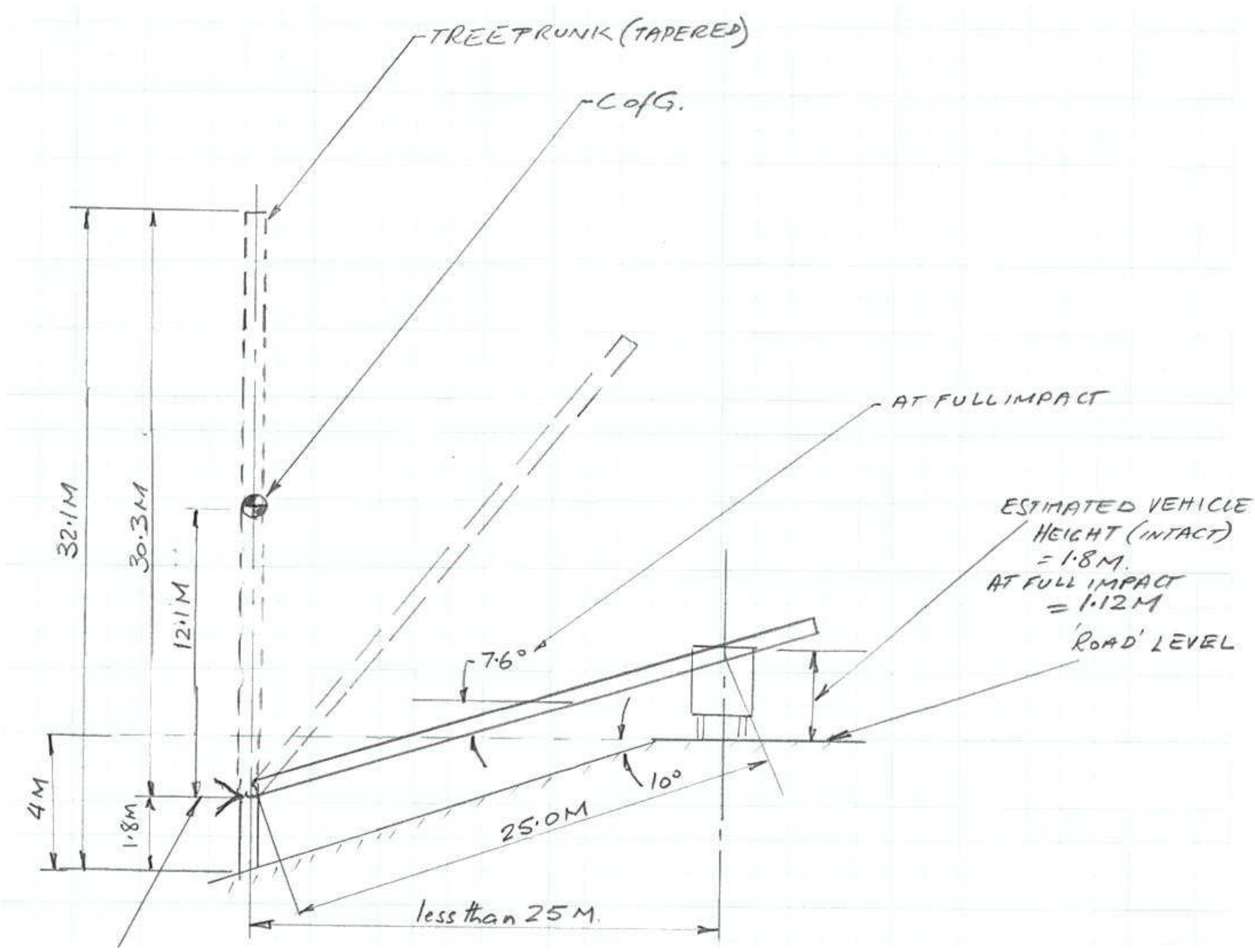

Figure 7a. Tree detail. Cabin collapsing

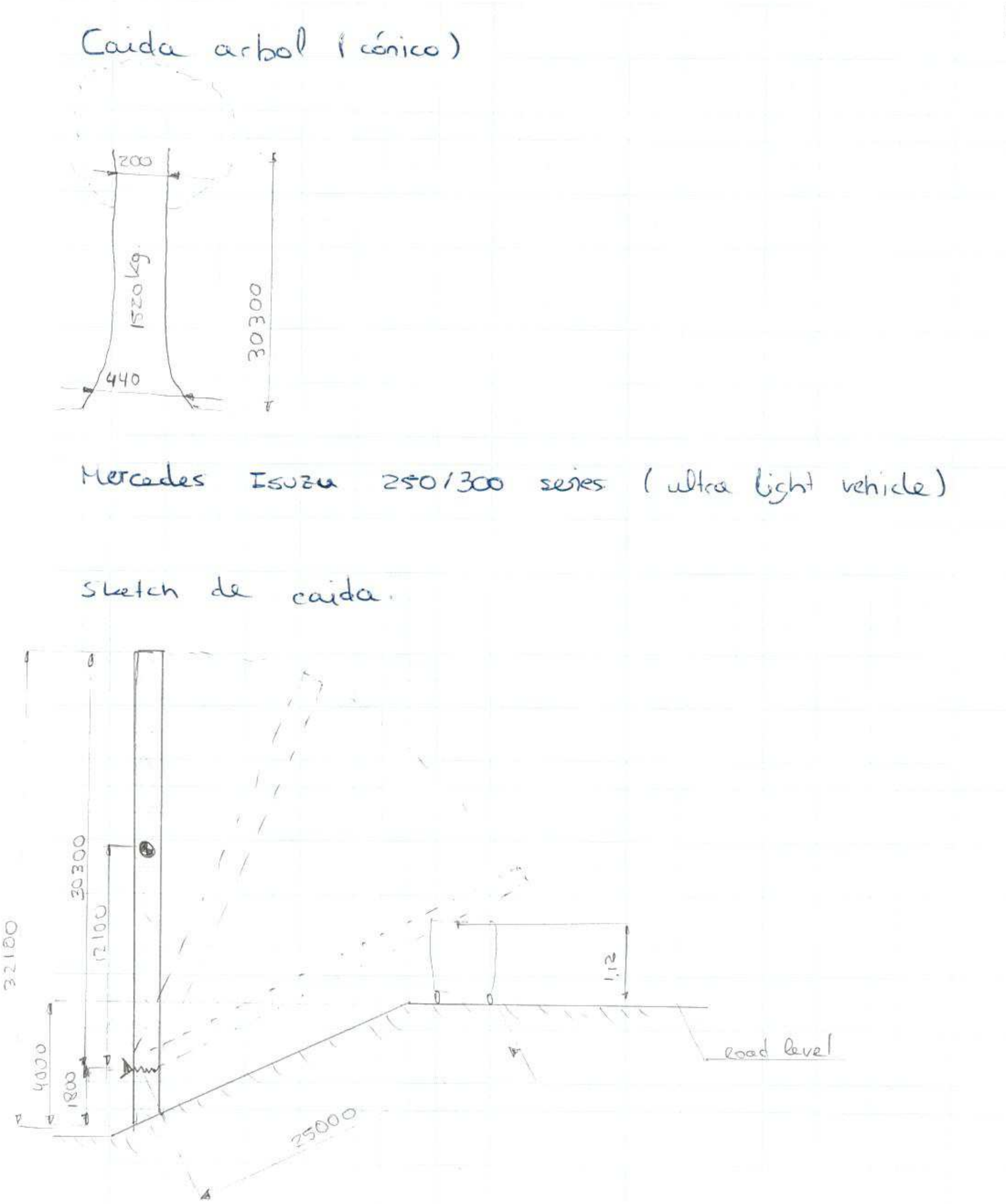

Figure 7b. Tree detail

This is sketch of the cabin deformation, just to have a basic idea for the next calculations.

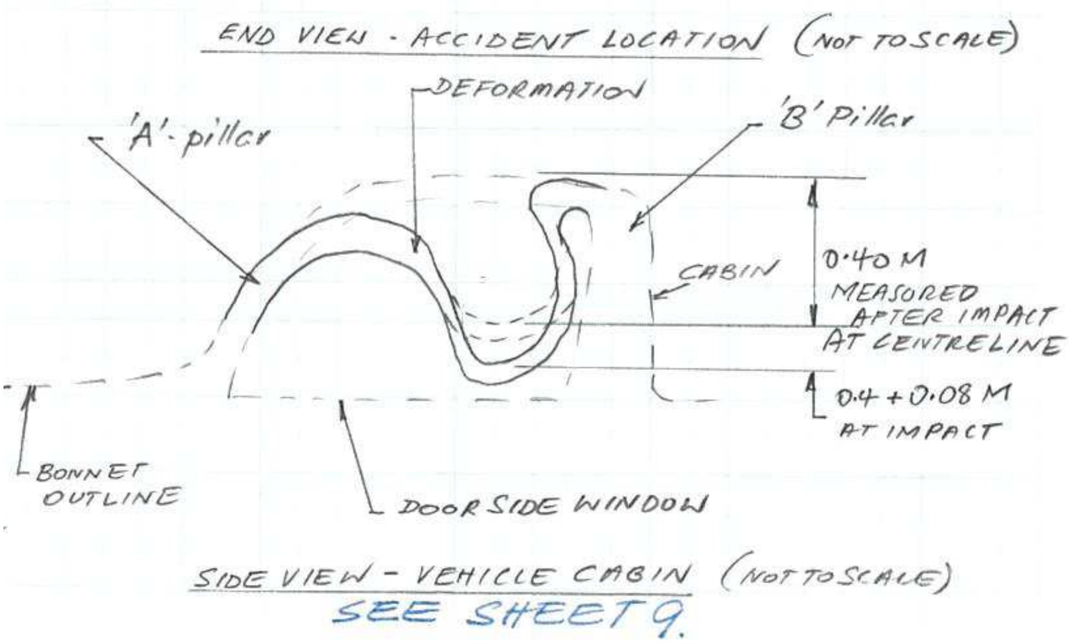

Figure 8. Deformation

5.2 Manual calculation and impact load

This is a required stage in our project, and one of the most important. Below there is a hand calculation where we finally obtain the impact load.

As follows we can see the main measures of the cabin, in Figure 9.

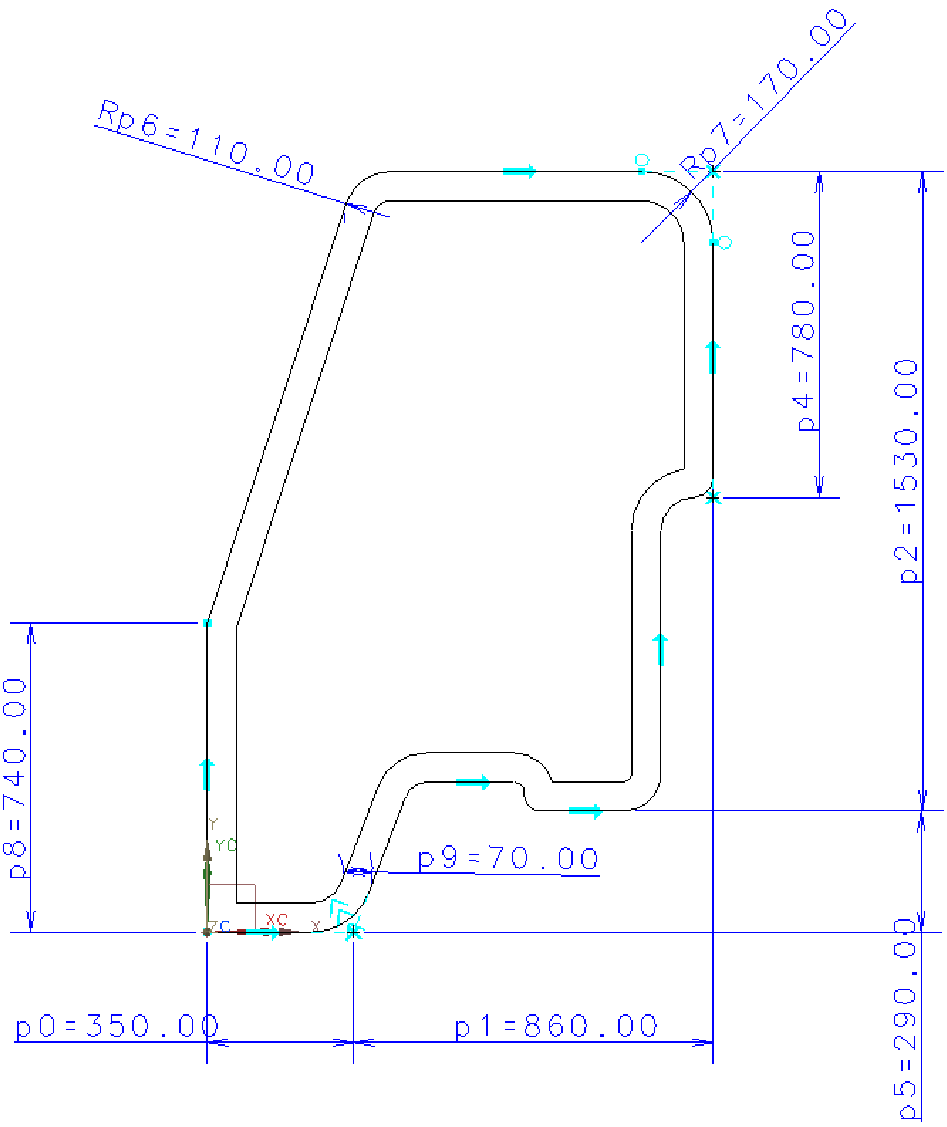

Figure 9. Cabin Measures

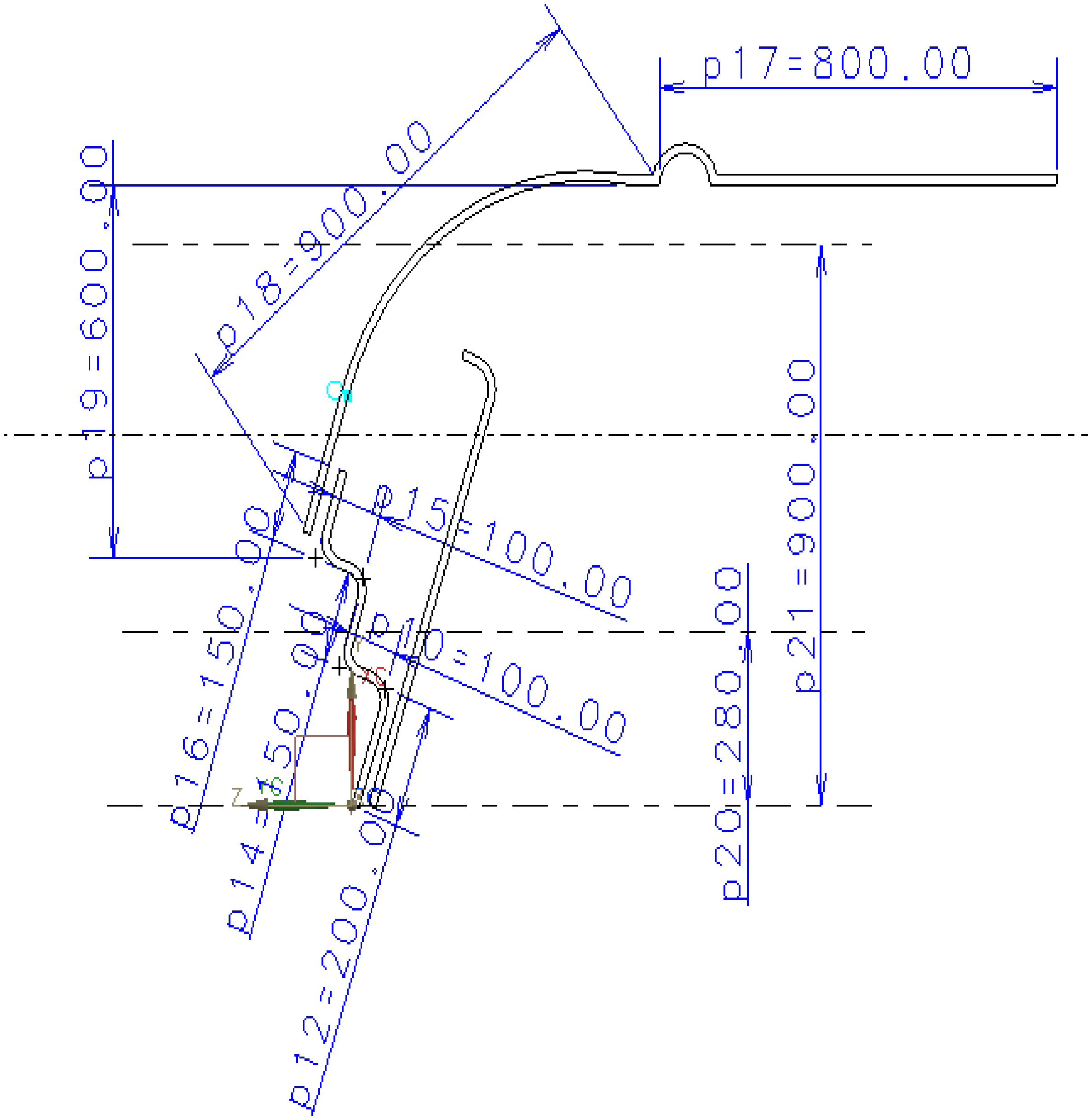

Figure 10. Manual calculation 1

<u>Manual estimation for the impact force:</u>

We have design some sketches for the correct estimation of the impact load.

Área = 121 + 22+ + 22 + 16.5 + 22 + 99 + 880 = 1182.5 cm2

Mom. = 6655 + 1474 + 454 + 8910 + 96800 = 114293

y = 121x55 + 22*10 + 22*20 + 16.5*27.5 + 22*37 + 99*90 + 110*880 = 97cm

Ixx = ((1.1*110^3)/12 + 121*42^2 + 1.1*20^3/12 + 22*87^2 + 22*77^2 + (1.1*15^3)/12 + 16.5*69^2 + 22*59^2 + 99*7^2 + (1.1*45^3)/12 + (800*1.3^3)/12 + 800*1.3*13^2) / 1182.5= 978*10^3 mm4

Zxx min = (978*10^3)/97 = 10080 mm3

Zxx max = (978*10^3)/13 = 75231 mm3

<u>Fstat.</u>

Theoretical spam (Theoretical point) = 860 – 150 = 710 mm

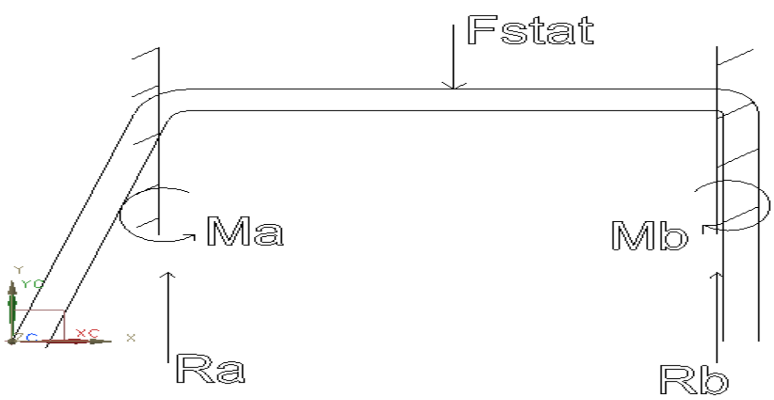

Figure 1. Reaction sketch.

BMa,b = Wl/8 = (Fstat*710)/8

Ra = Rb = Fstat/2

σy= 250 MPa

M = σy*Zmin = 10080x250

Fstat = (10080 x 250 x 8) / 710 = 28394 N = 2894 Kg

Max. deflection at centre:

- (M*L^3) / (192*E*I) = 28940*0710^3 / 192*978*10^3*200 = -0.3mm

Note: Ixx is too large. Unsupported roof.

Spam gives false indication.

Recalculate Ixx.

Y = 114293 – 110*(750x1.1)/1182.5-825 = 66cm

Ixx = (1.1*110^3)/12 + 121*11^2 + 1.1*20^3/12 + 22*56^2 + 22*46^2 + (1.1*15^3)/12 + 16.5*38^2 + 22*28^2 + 99*24^2 + (1.1*45^3)/12 + (1.1*60^3)/12 = 371*10^3 mm3

Zxx min = 371*10^3/66 = 5621 mm^3

Zxx max = 371*10^3 / 44 = 8432 mm^3

σy*Zmin = M = 250*5621 = 1.4*10^6 Nmm

Fstat = 250*5621*8/750 = 15833 N = 1614 Kg

Deflection

-WL^3/192EI = 15833*750 / 192*371*10^3*200*10^3 = -0.4mm

A static force of 833 N will cause a deflection of 0.4mm

A point force in the centre = Fpoint = (1.4*10^6*8)/860 = 13072 N (1334 Kg)

Deflection = (-0.4*13072*860^3)/15833*710^3 = 0.59

Impact force S' = S * ((Wt/Wc)*(3Wt/(3Wt + Wc)))^1/2

Wt = Tree Mass = 1520 Kg

Wc = Cabin Mass + Front gear = F A load = 2500 Kg.

S' = 250 * ((1520/2500)*(3*1520/(3*1520+ 2500)))^1/2= 157 MPa (No Ok)

COSNIDER ASMS OF CABIN ONLY

S' = 250 * ((1520/700)*(3*1520/(3*1520+ 700)))^1/2= 157 MPa (Could be OK)

CONSIDER Wc=Wt

Then

S' = S * (1 + (1 + (2h/e)); h= 12m

E = SI/E

S’ = 250 * (1 + (1 + (2*12000/464) = 2075 MPa (High, but possible. Use it!)

The calculated force = 1317 Kg

It will be with a factor of 8.3 = 1317x2075/250 = **10931 Kg**

From the manual calculations, we deduce that the impact force is 10932 Kg, almost 11 tons. We have checked that we can use 75x50x3 box section beams, but these calculations are only an approximation.

Later we will see that with SOLIDWORKS, the stresses in the joints are really high, so we will have to change their dimensions and also reinforce the beams.

The impact load is distributed at the top of the structure, and we will only consider static and linear calculations.

6. MODEL RESEARCH

After the hand calculation, we designed a sketch which is the starting point for the rest of the model design.

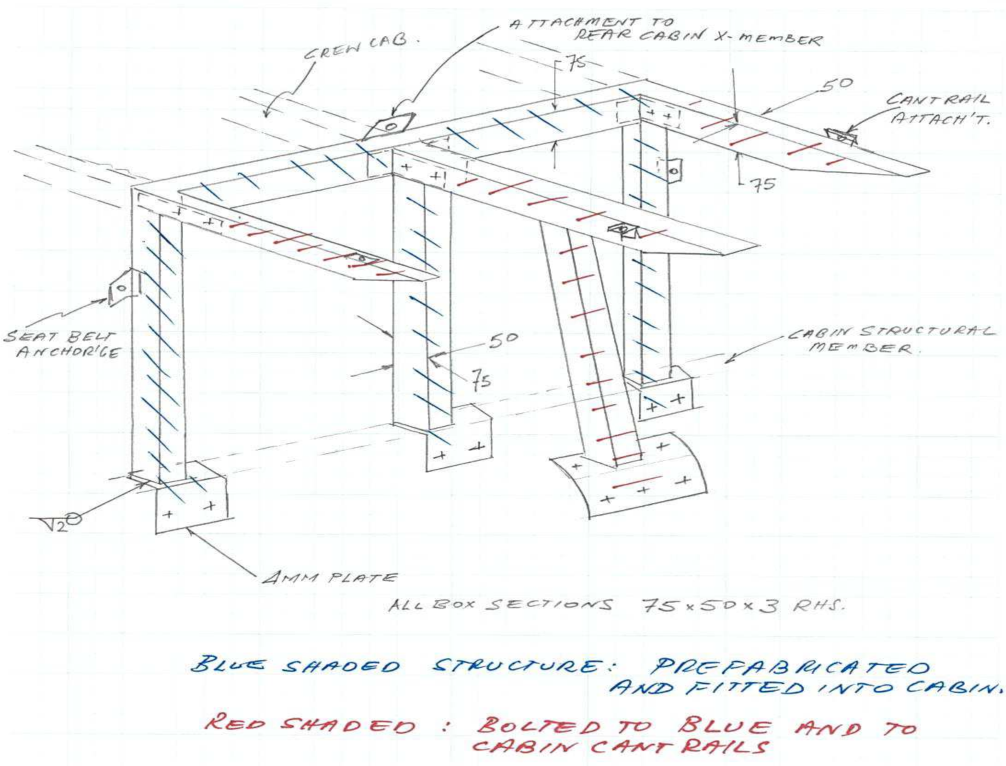

Figure 12. Sketch 1

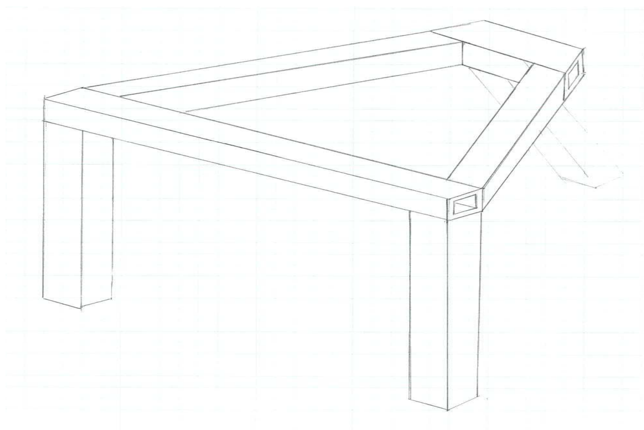

Figure 13. Sketch 2

Before designing, we will try to find an aesthetic model, but we have to check the stresses first.

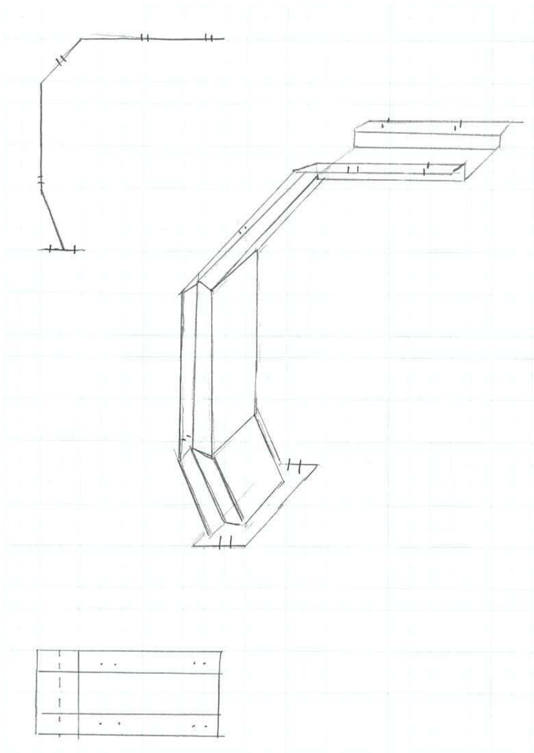

Figure 14. Sketch 3

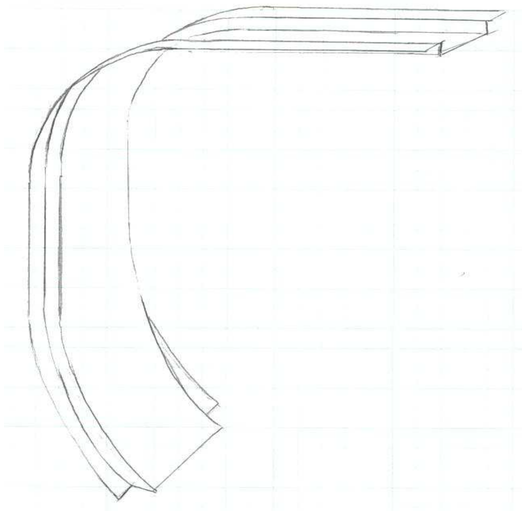

Figure 15. Sketch 4

That model was the first idea, because it is a small model, aesthetic, economic and easy to assemble. An important point was to retain occupant space within the cabin, and the comfort inside the cabin is an important point.

The problem of this model were the stresses, really high, and not sustainable.

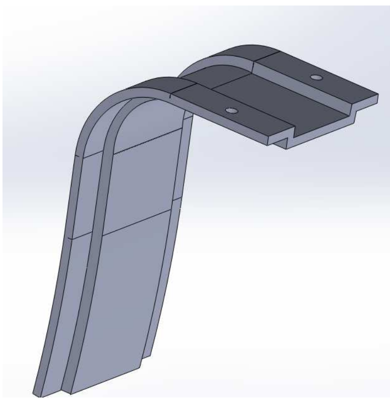

Figure 16 a. Sketch 5

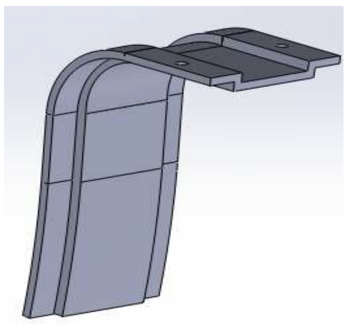

Figure 16 b. Sketch 6

Below, there is a basic analysis where we can see that the stresses are unacceptable

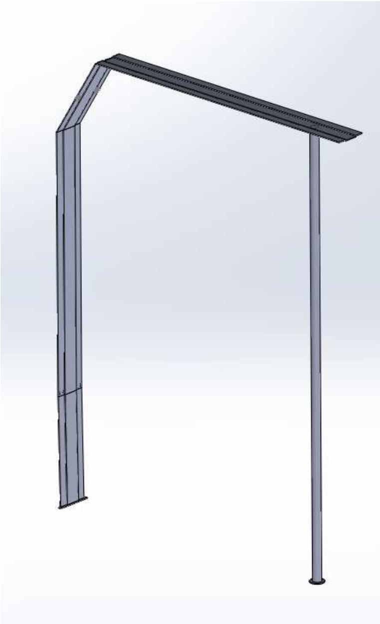

Figure 17 a. Basic calculation 1

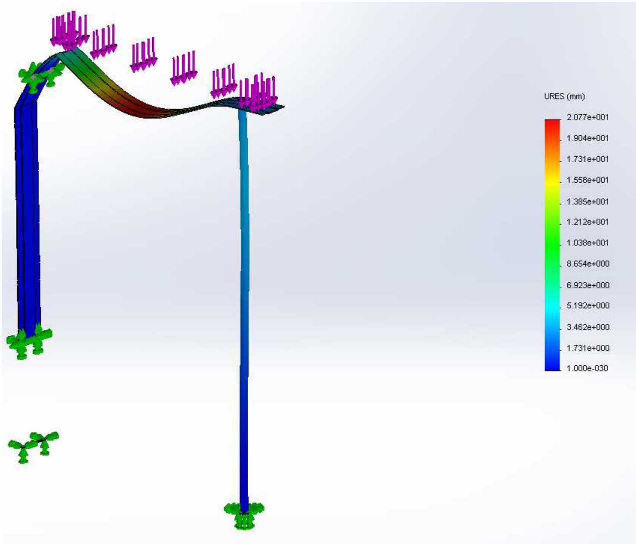

Figure 17 b. Basic calculation 2

The next idea was using circular section, but we had the same problem as before, the appearance was better but the stresses obtained are unacceptable.

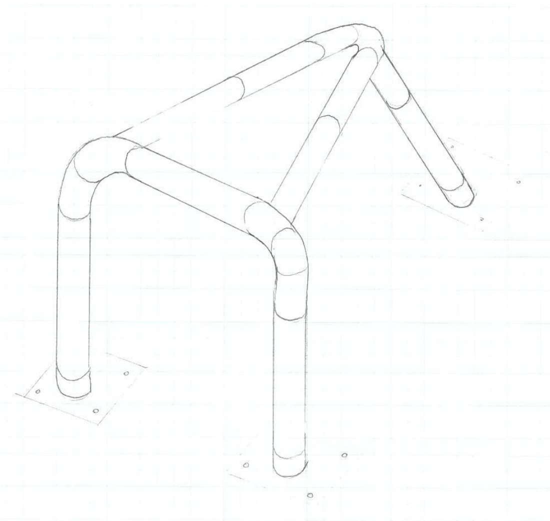

Figure 17 a. Sketch 7

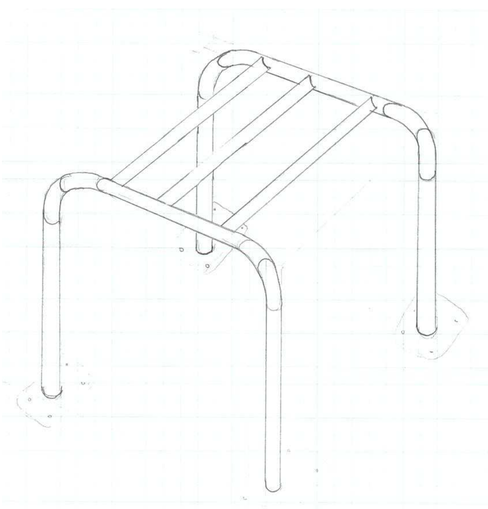

Figure 17 b. Sketch 8

Here is a picture from SolidWorks of the circular section design.

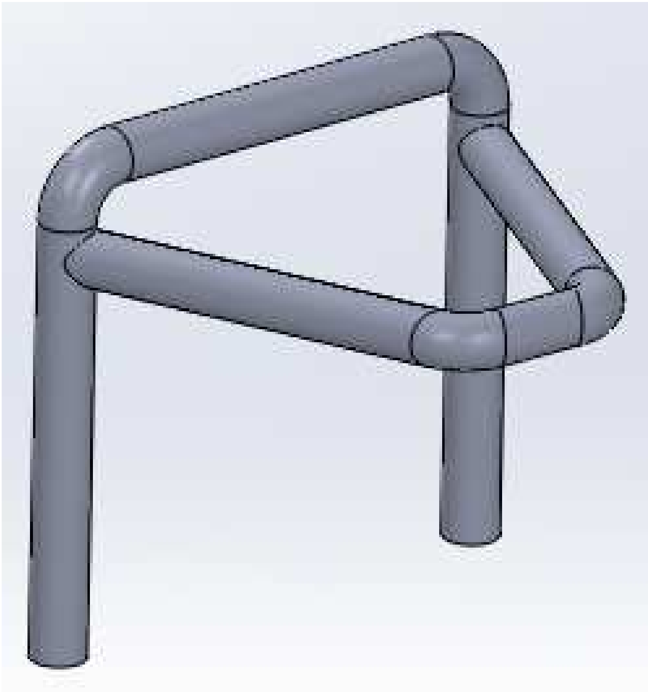

Figure 18. Sketch

From these designs we finally decided our model, as we can see in the next pages. These initial determinations helped us to verify the stresses, and decide which the acceptable model is considering strength, price and aesthetics, always falling under the max yield strength of the material, 355 MPa.

7. FINAL MODEL

7.1 Geometry description

After several designs, we finally settle down our final model. We chose box section beams, reinforced in the critical points.

There are three different assemblies in this model, the top assembly, right side assembly, left side assembly. The top assembly is made of four 150x60x2 box section beams welded to a 100x60x2 box section beam. The central beam is made of welded plates, because it is the only way to reinforce the center of the beam, otherwise the deformation would be unacceptable.

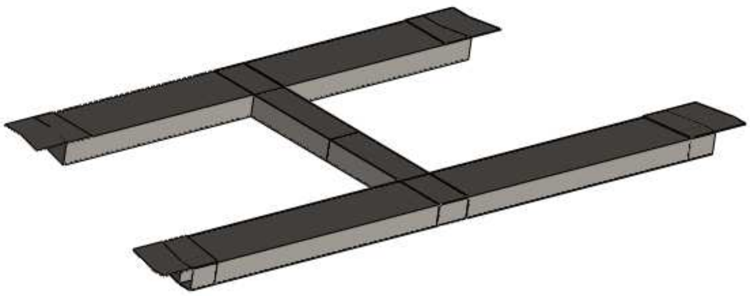

Figure 19. Top part

Below there is the central beam, 100x60x2, with four gussets, one just in the middle, two in both sides, and other two in the connection between the 150x60x2 beam.

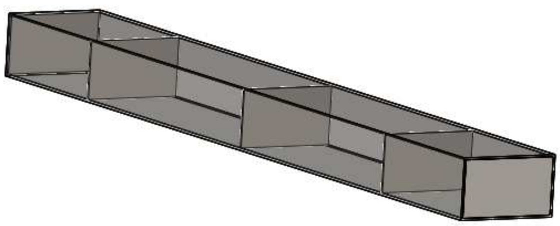

Figure 20. 150x60x2 beam

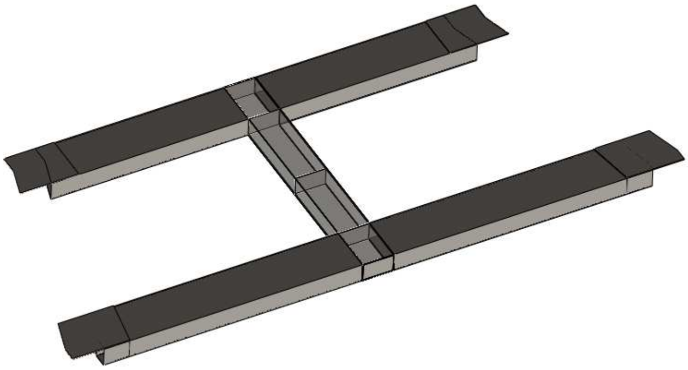

Figure 21. Top part

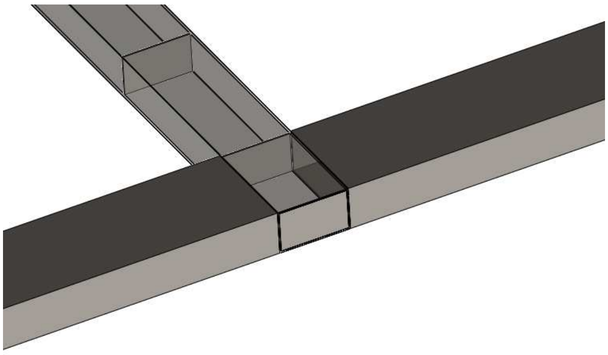

Figure 22. Connection 150x60x2 beam with central beam. Reinforces.

Another important point is the connection between the top part and the left and right sides for assembly. It was also an important consideration for the comfort of the cabin occupants, so we considered a top plate welded to the top part of the 150x60x2 beam. That part is bolted to both sides.

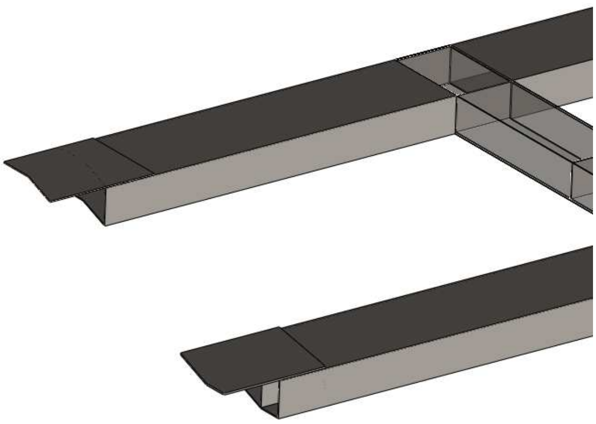

Figure 23. Connection

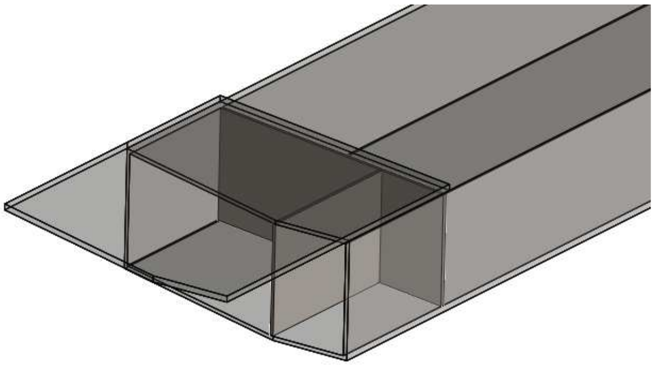

Figure 24. Detail connection

Views of the top attachment.

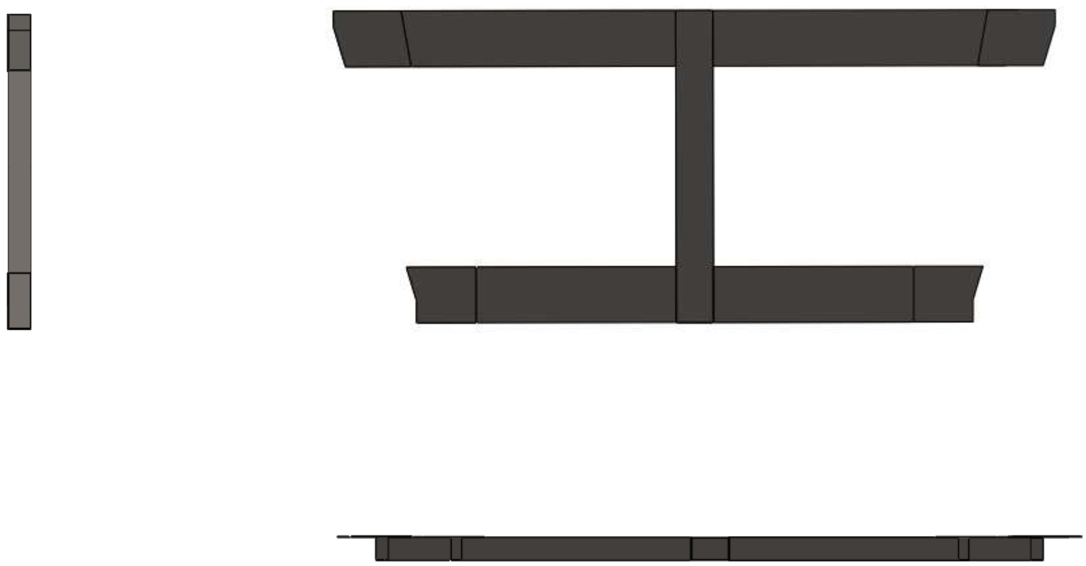

Figure 25. Top part views

The sides are symmetrical. This assembly is made of three box section 100x60x2. The top beam is made of welded plates, and it is necessary to have an intermediate reinforcement, and also to conform to the.

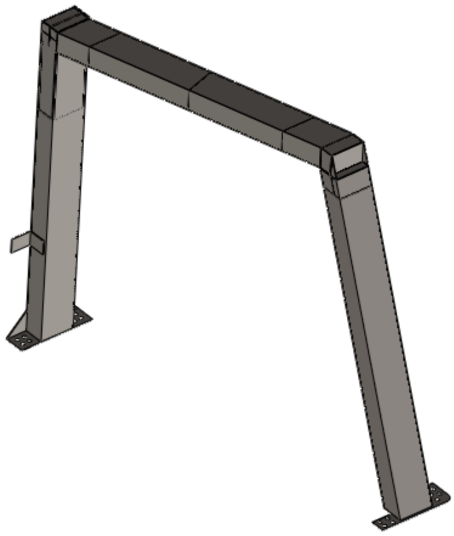

Figure 26. Right side assembly

The central beam is made of welded plates, reinforced in the middle, and also in both sides, at the connection to the other two beams. That reinforcement is necessary.

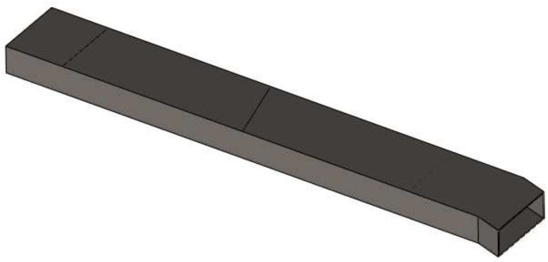

Figure 25. Top beam

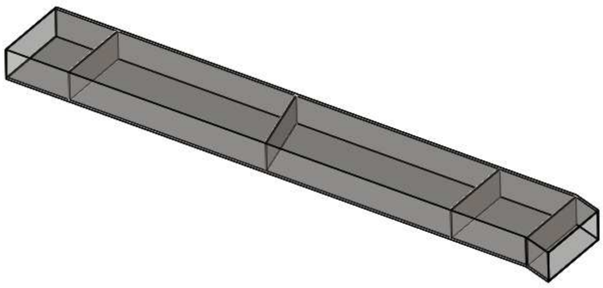

Figure 26. Top beam. Reinforcement

This is the other beam, bolted to the front structure, also 100x60x2, reinforced with plates at the top.

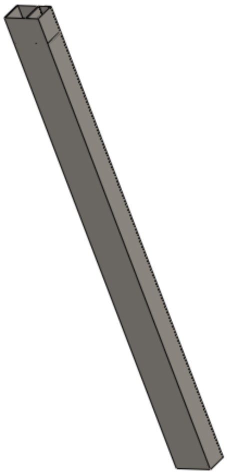

Figure 26. Front beam

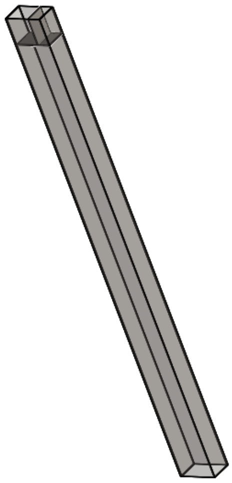

Figure 27. Front beam reinforcement

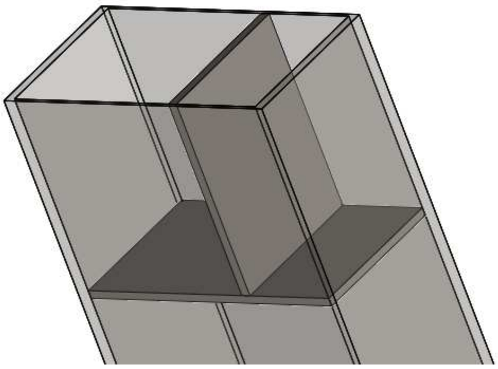

Figure 28. Reinforcement detail

The other 150x60x2 beam, is bolted to the back part, and also reinforced at the top. This beam is important in our model, and the reinforcement is different than the others. When checking stresses without this reinforcement, it was found that the stresses were too high.

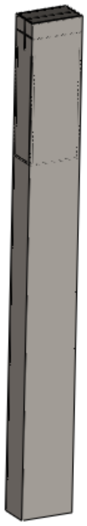

Figure 29. Back beam

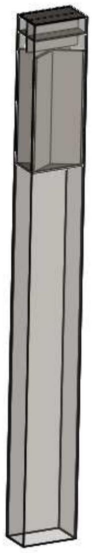

Figure 30. Back beam reinforcement

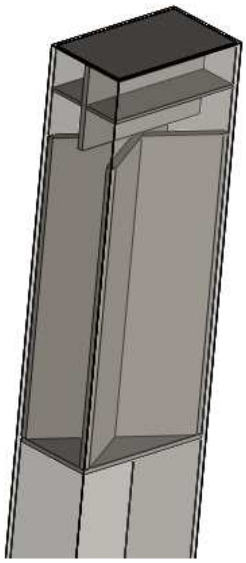

Figure 31. Reinforcement detail

Below figs. 32, 33 are shown the front and back join between the 100x60x2 beams, and the cabin structure. In Figure 31 we can see that we reinforced the connection with two rectangular plates, to reduce the stresses. Also we added a plate, to restrict the displacement.

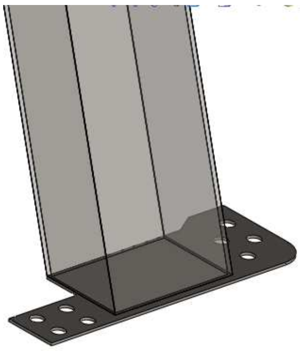

Figure 32. Front joint

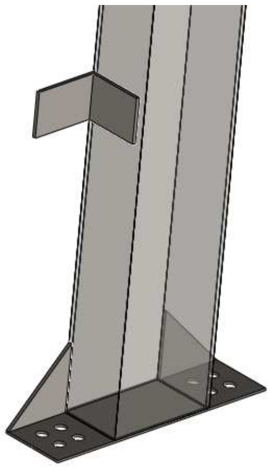

Figure 33. Back joint and reinforcement.

All beams are connected by welding.

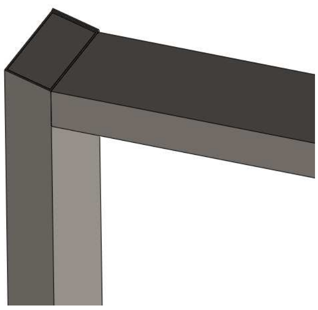

Figure 34 a. Welded beams

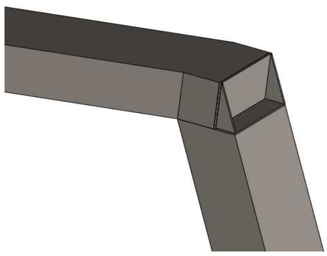

Figure 34 b. Welded beams

In the front part there is also reinforcement as shown in Figure 32. There is also a plate in the back part, to reduce the stresses.

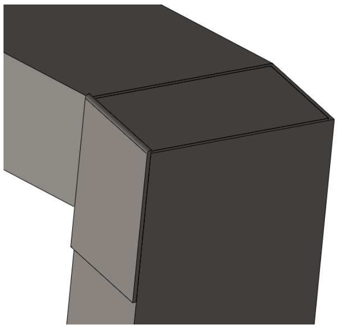

Figure 35. Reinforcement Plate

Here some views of the right side assembly.

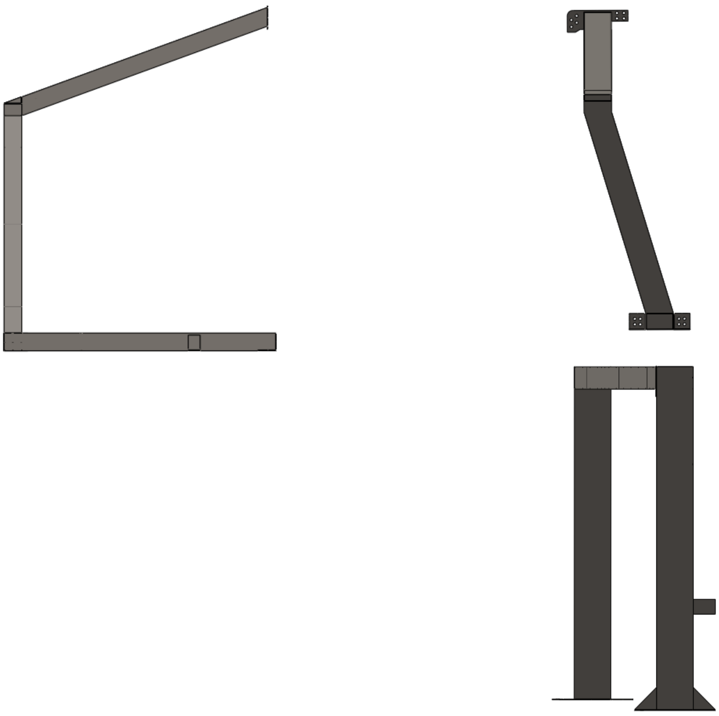

Figure 36. Right side assembly views

Below the whole model, three assemblies bolted as shown.

Figure 37. ISO view

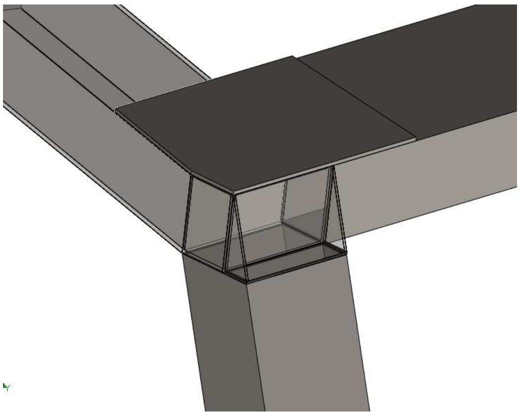

Figure 38 a. Front connection

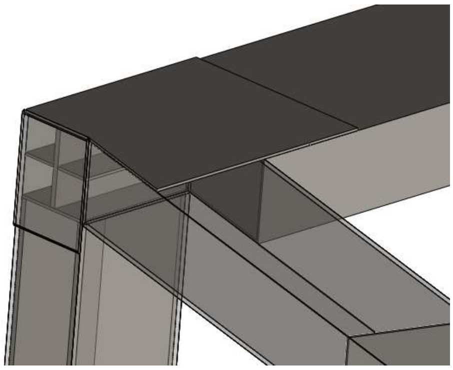

Figure 38 b. Back connection

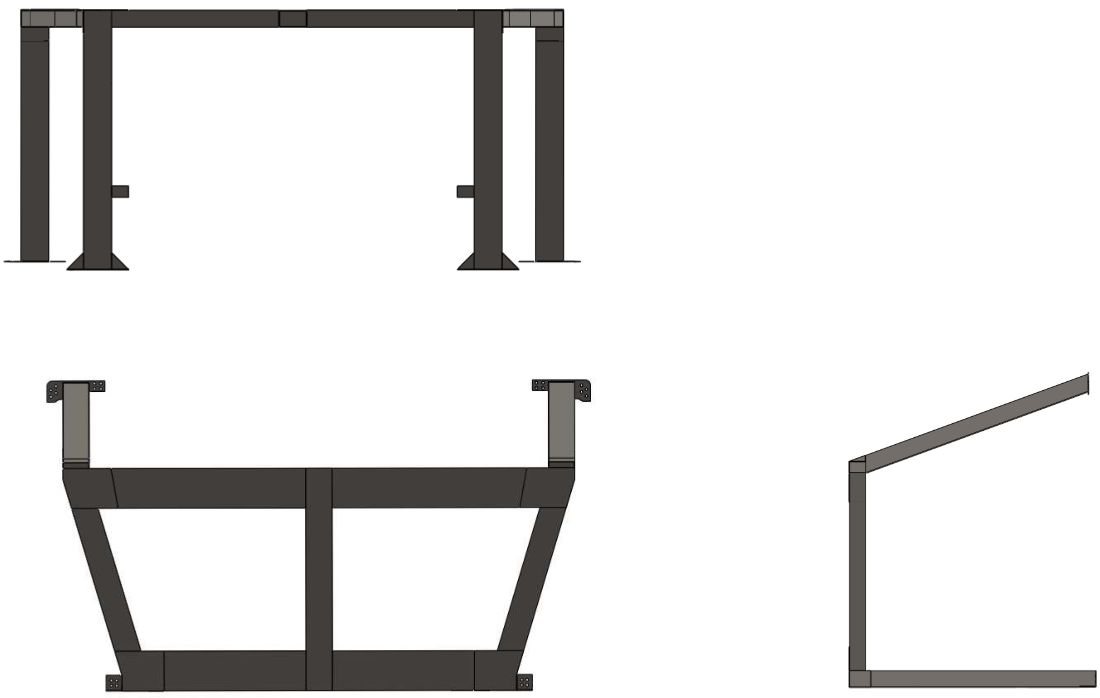

Figure 39. Final model views.

7.2 Cabin design

For an accurate design of our model, it was necessary that with an approximate design of the cabin ISUZU. Each part was provided with the real measures, using surfaces in Solidworks.

The front and rear cabin supports one down first.

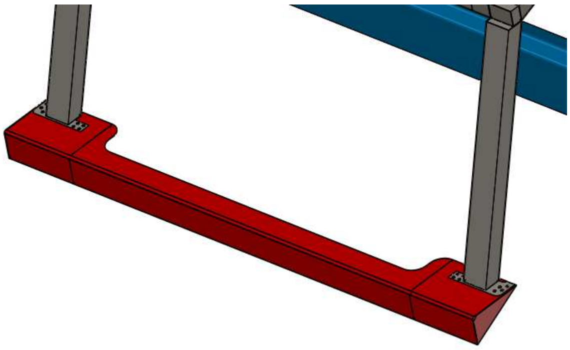

Figure 40. Front detail 1

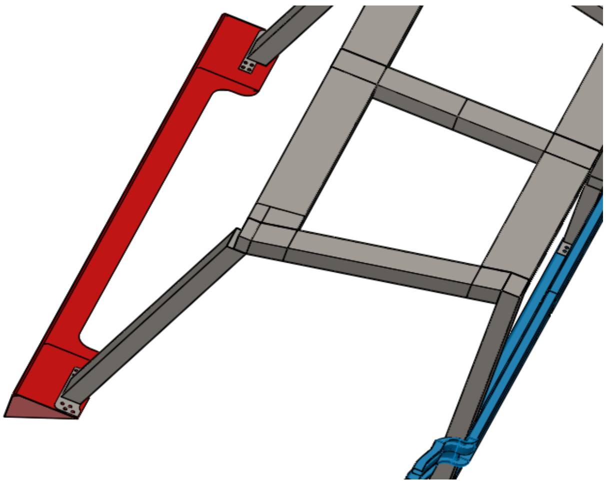

Figure 41. Front detail 2

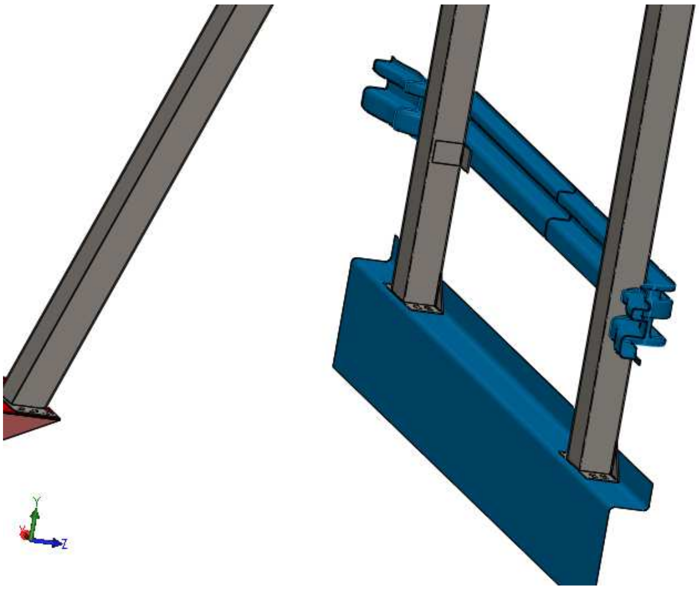

Figure 42. Back detail 1

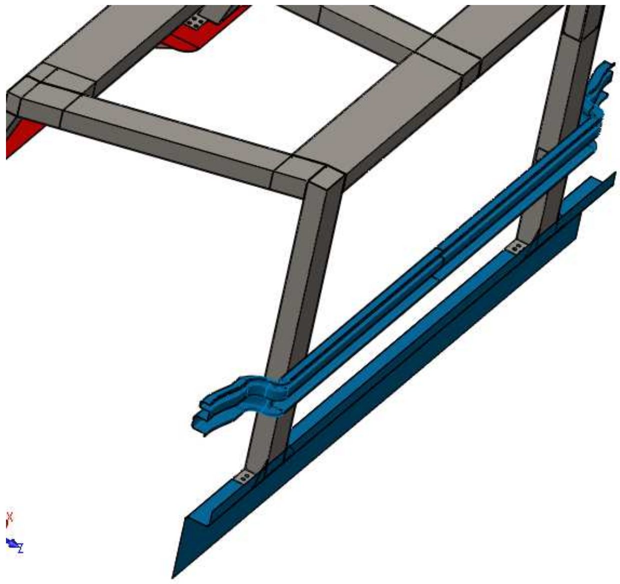

Figure 43. Back detail 2

Here we can see the three main elements which the structure is screwed.

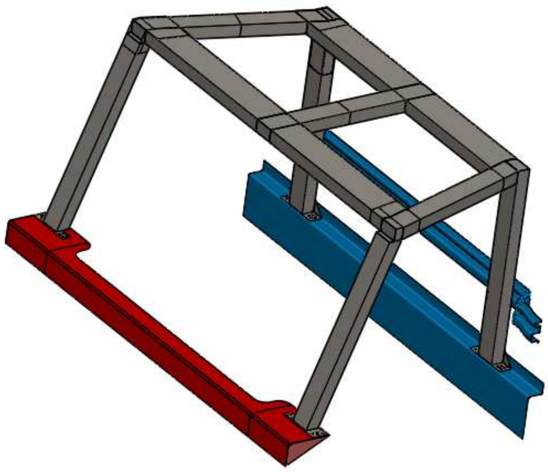

Figure 44. Support detail

.

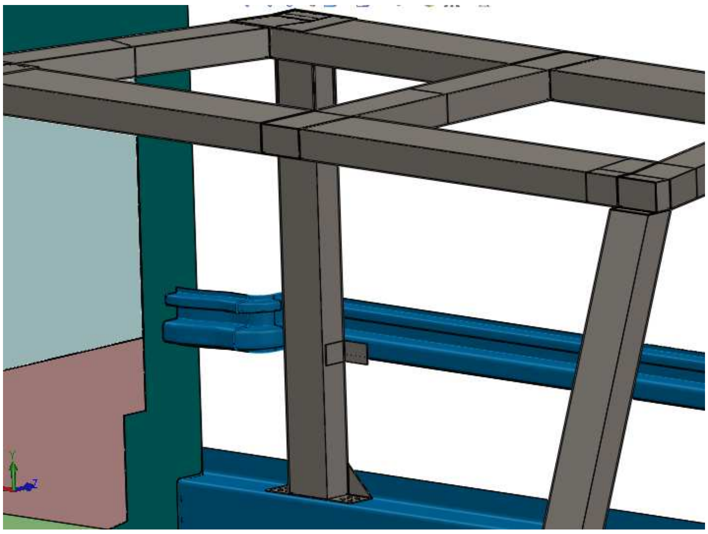

Figure 45. Back support

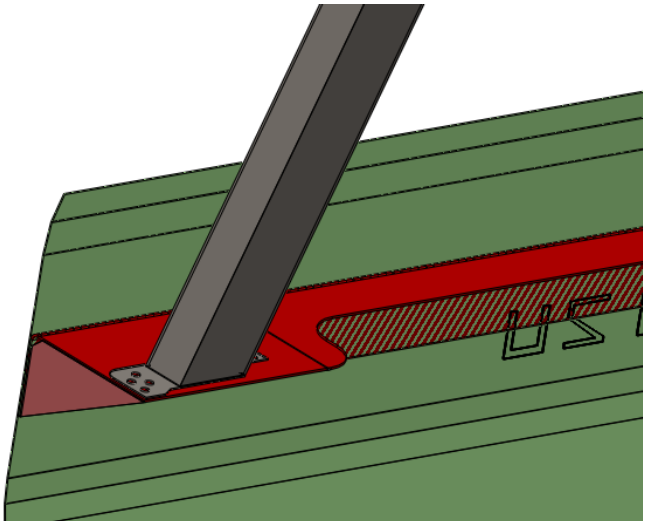

Figure 46. Front support

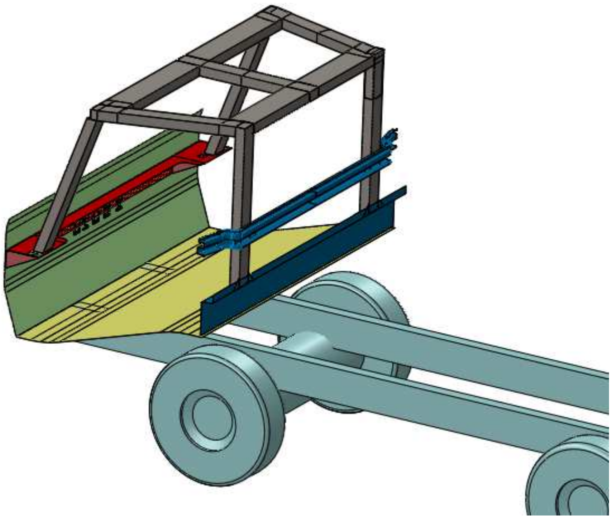

Figure 47. Supports and chassis.

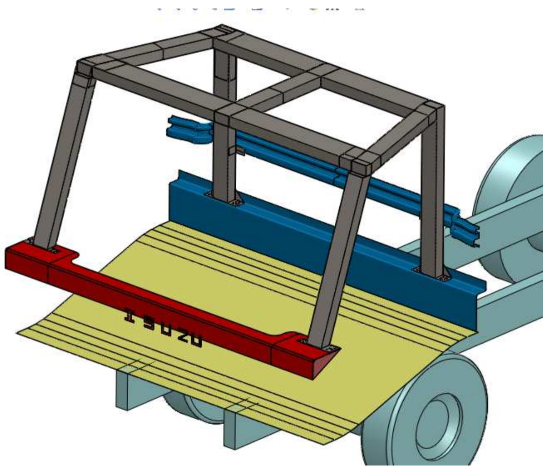

Figure 48. Ground

Using these elements, and the rest of the cabin, just an initial design was established with the real measures. Design details are shown below.

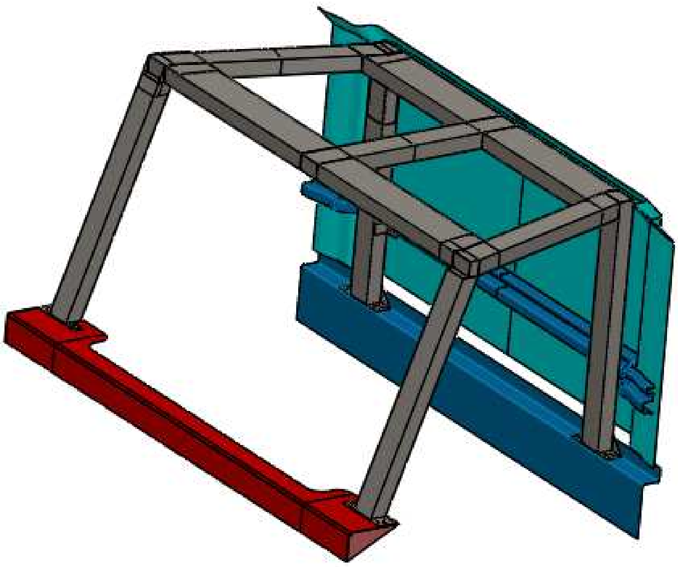

Figure 49. Cabin design 1

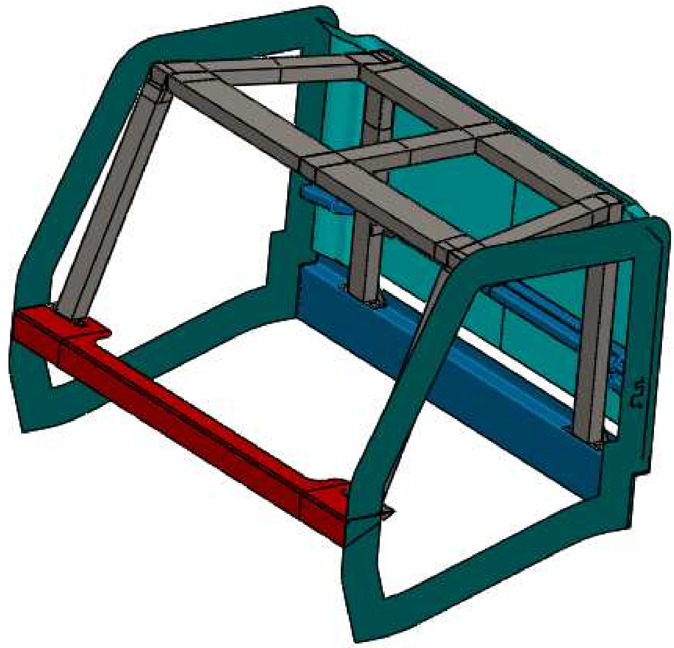

Figure 50. Cabin design 2

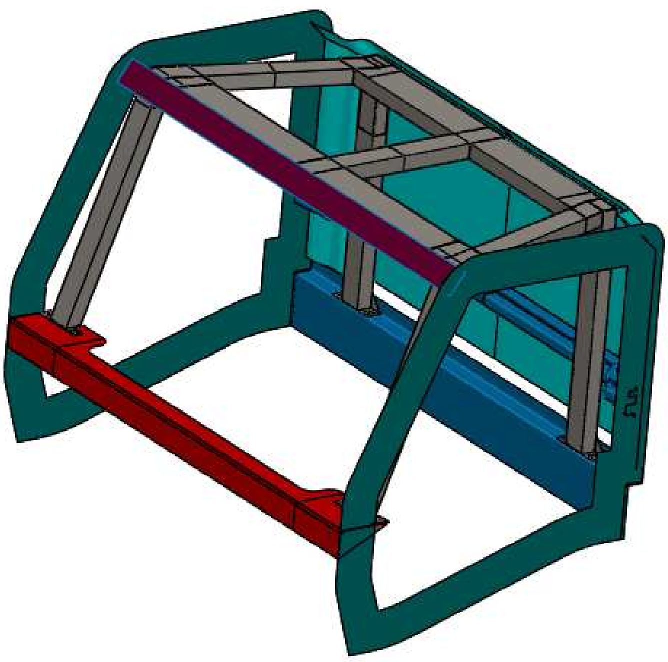

Figure 51. Cabin design 3

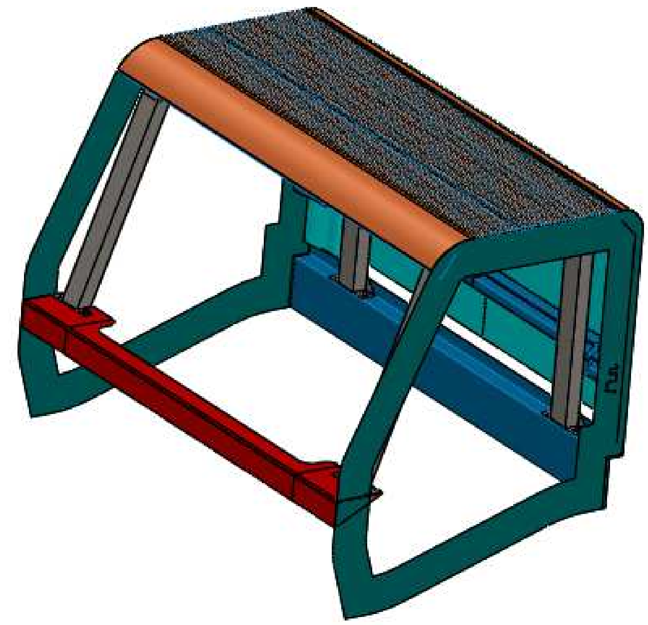

Figure 52. Cabin design 4

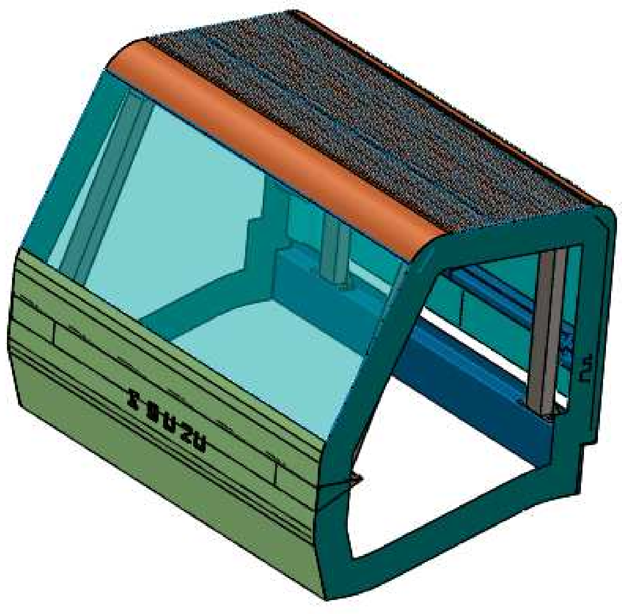

Figure 53. Cabin design 4

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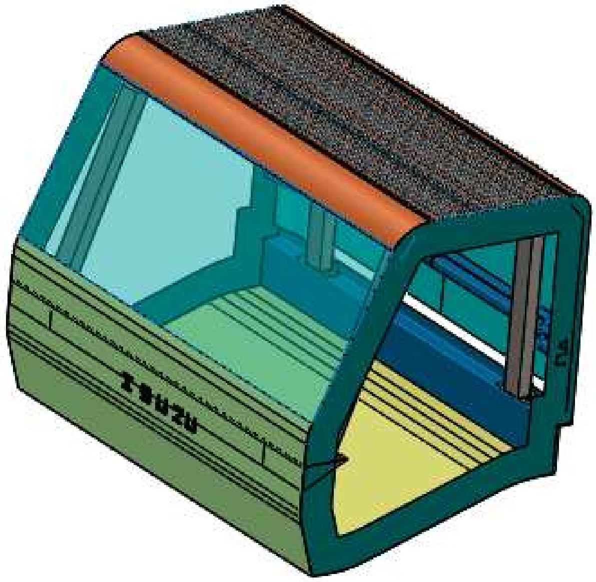


Figure 54. Cabin design 5

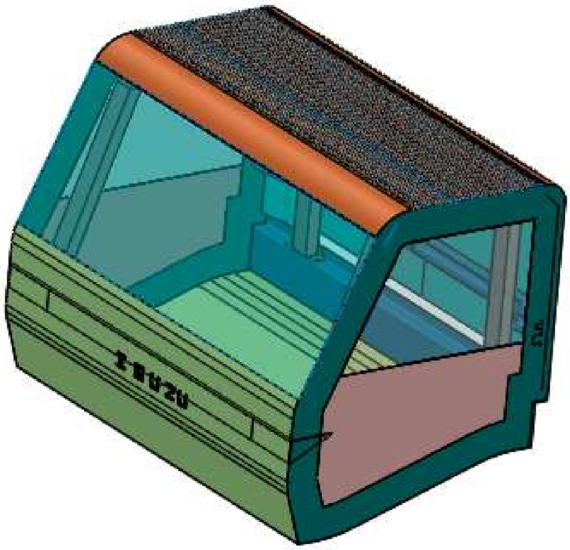


Figure 55. Cabin design 6

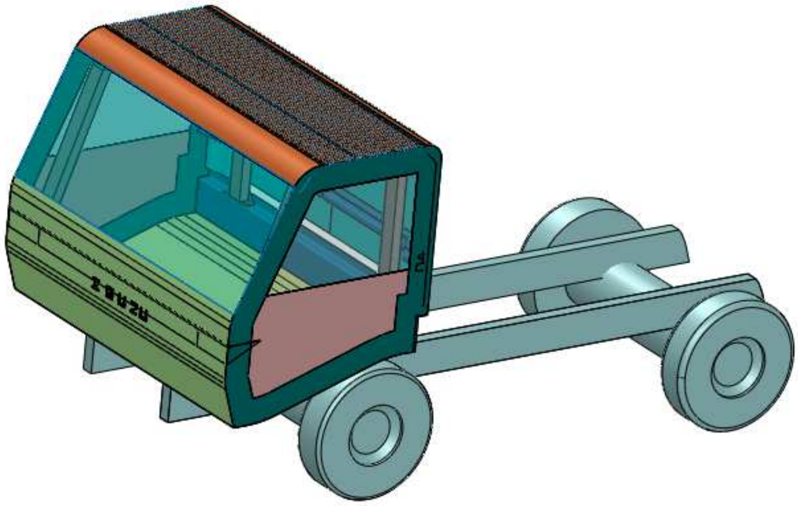


Figure 56. Final model

7.3 Accident site

The site where the accident happened needs to be drawn. Below, is show a schematic of the site which we have created.

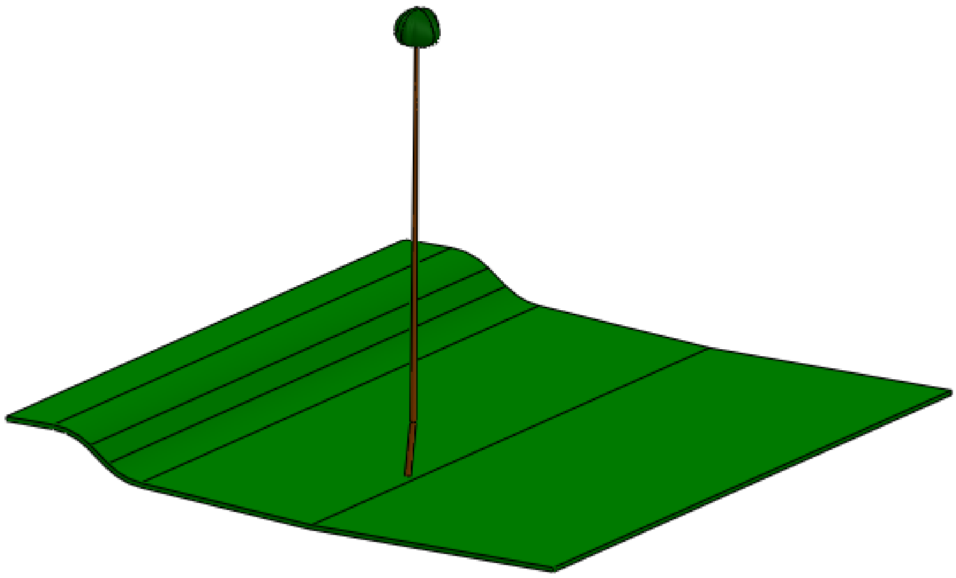


Figure 57. Tree design

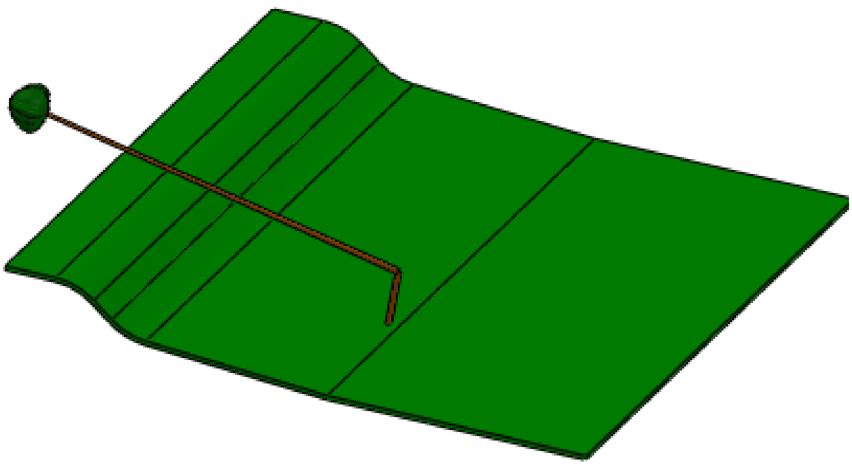


Figure 58. Fallen tree

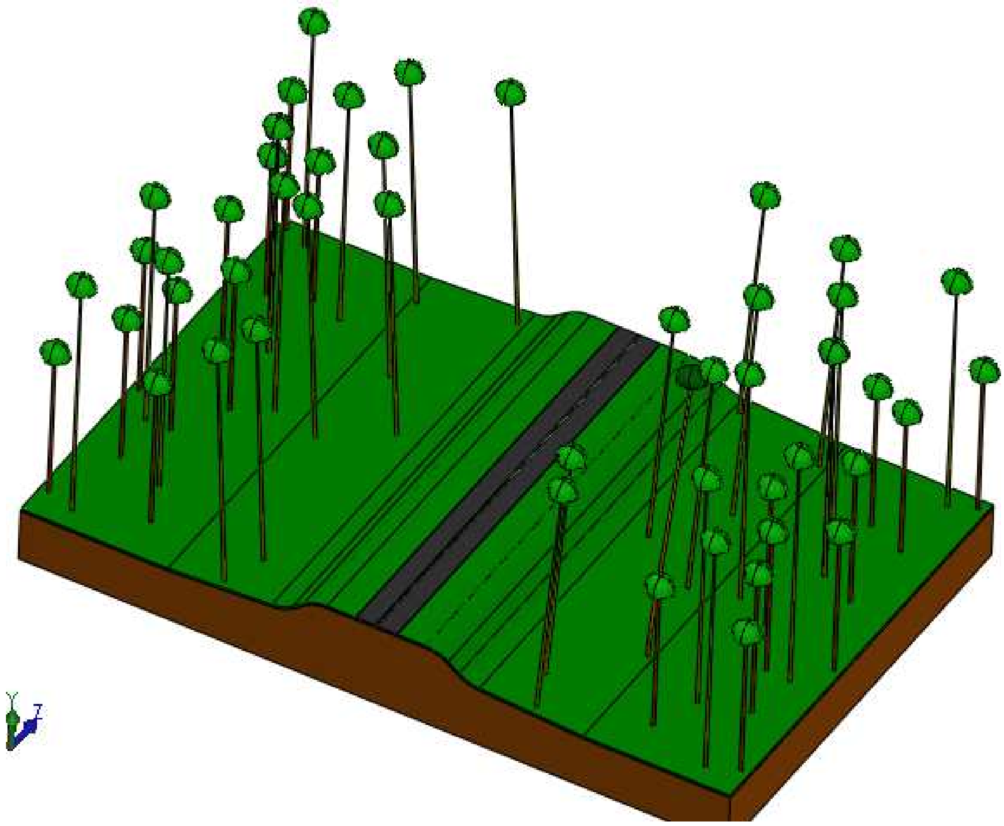


Figure 58. Bush

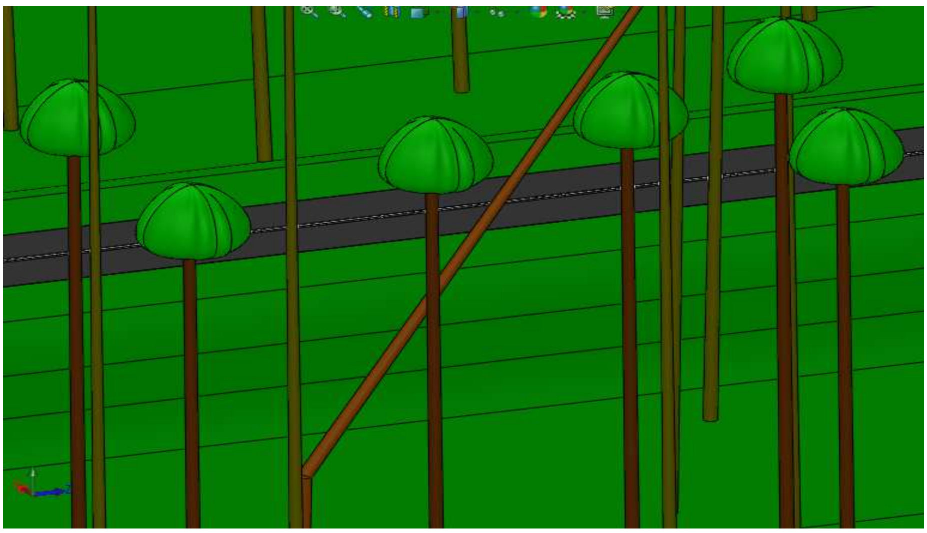


Figure 58. Bush detail

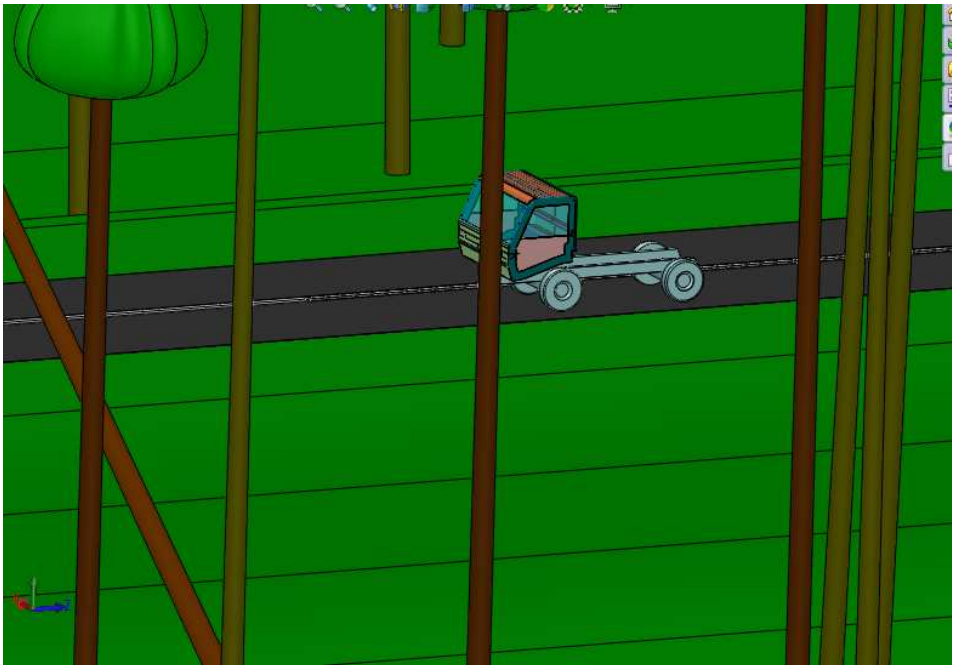


Figure 59. Truck in the bush

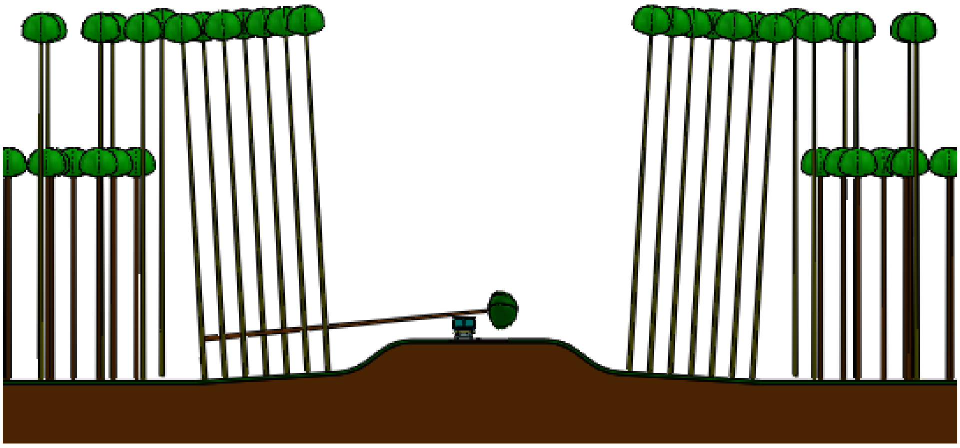


Figure 60. Showing fallen tree

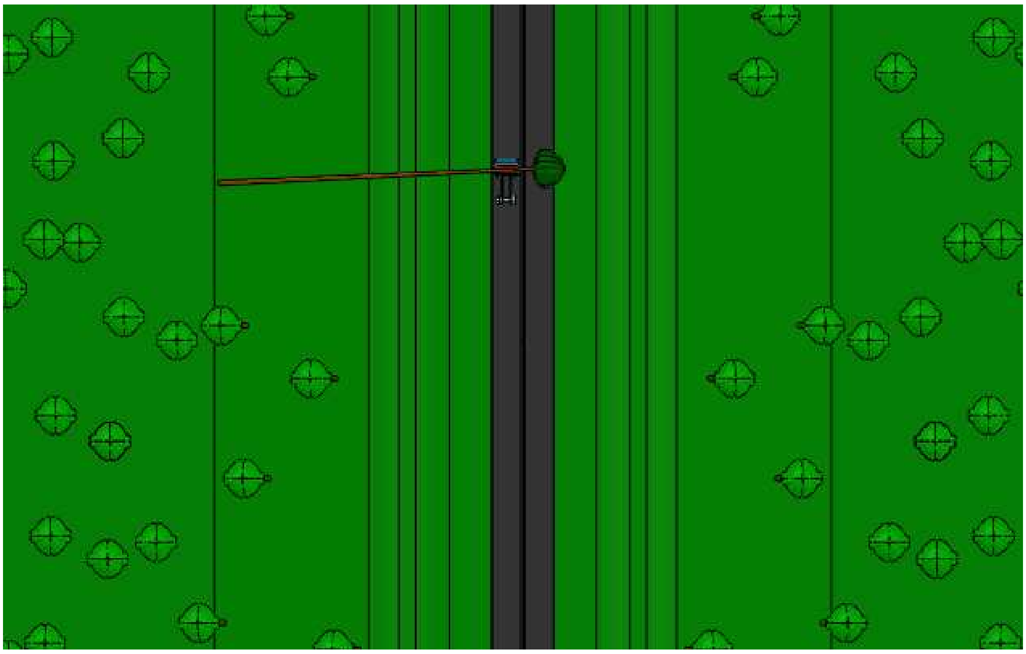


Figure 61. Top view

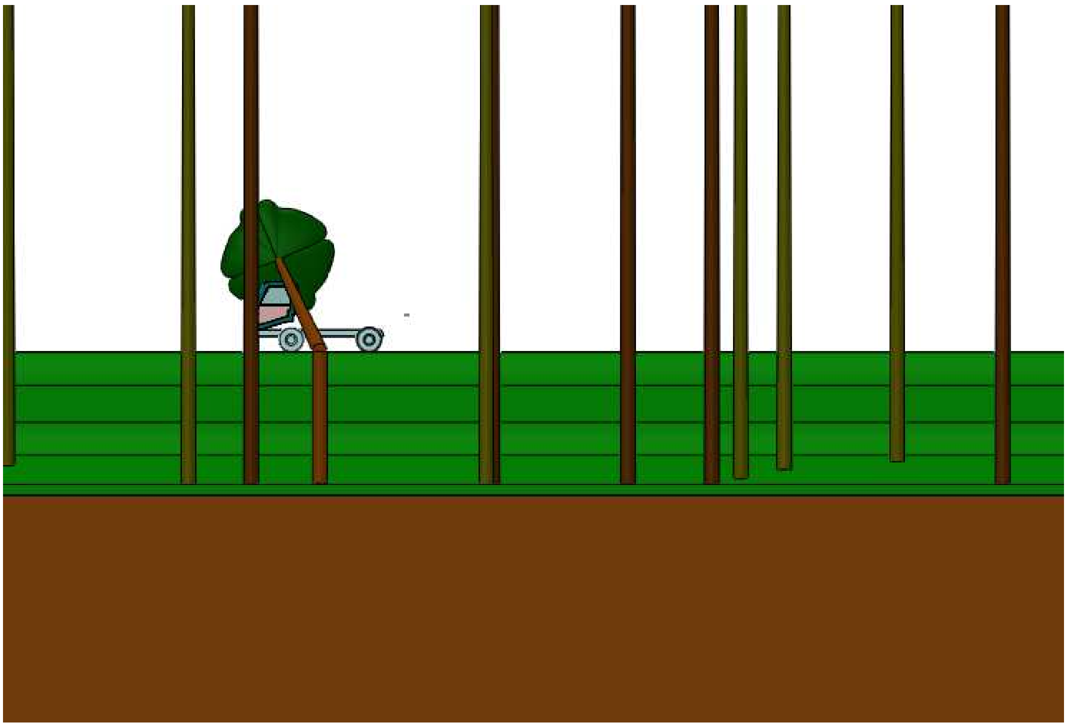


Figure 62. Side view

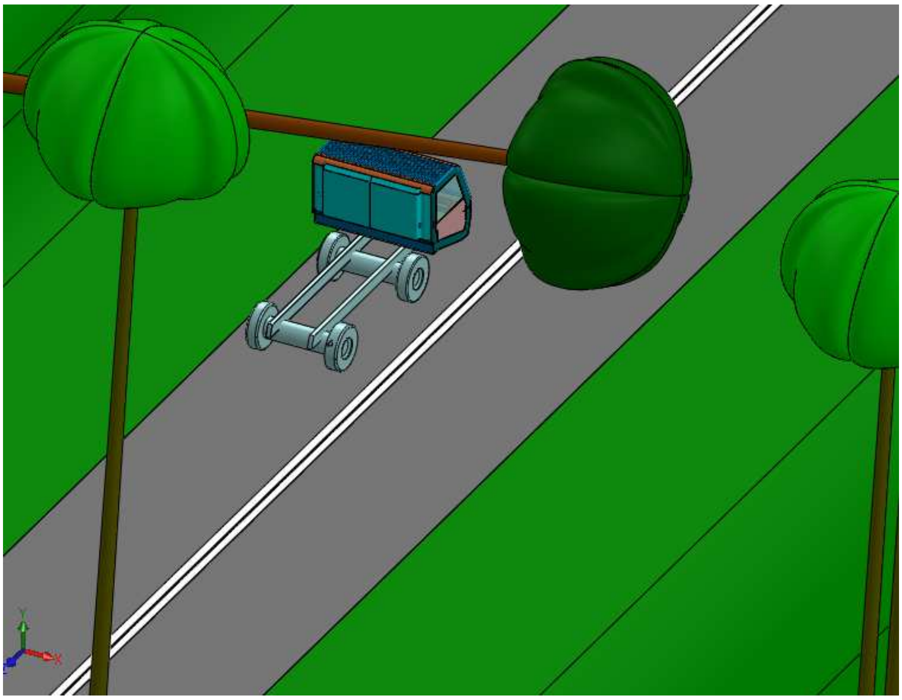


Figure 63. Fallen tree back view

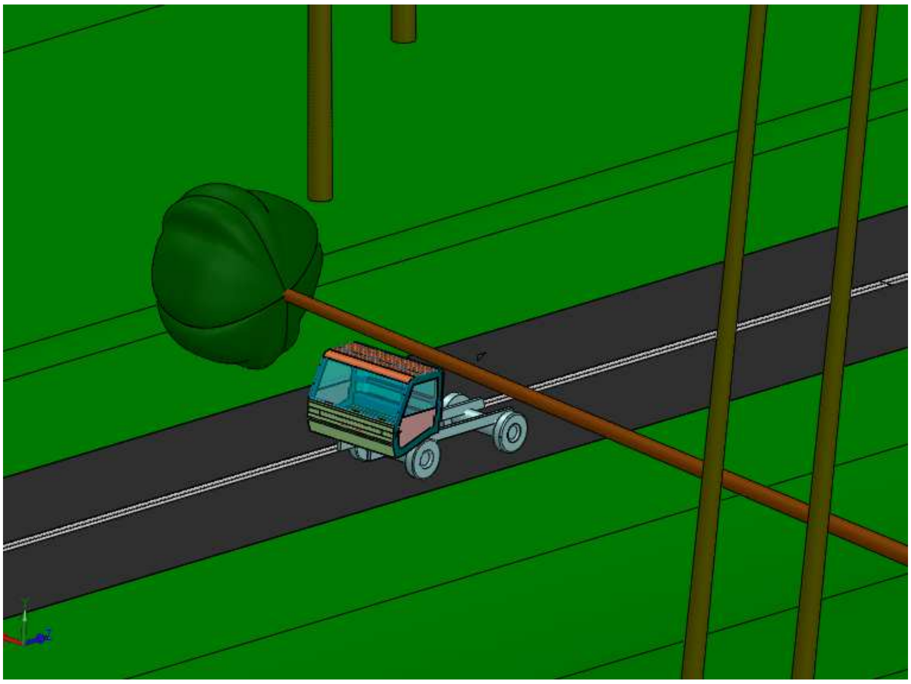


Figure 64. Fallen tree front view

8. **FEM SOLIDWORKS**

8.1 FEM Description

Using the final model, the next stage is an FEM calculation. We used the SOLIDWORKS Simulation module to that calculation.

Some problems with that model were encountered, so we changed the geometry several times until intersecting bodies filled, and we could create the mesh without any problem.

Details of the mesh that we have used.

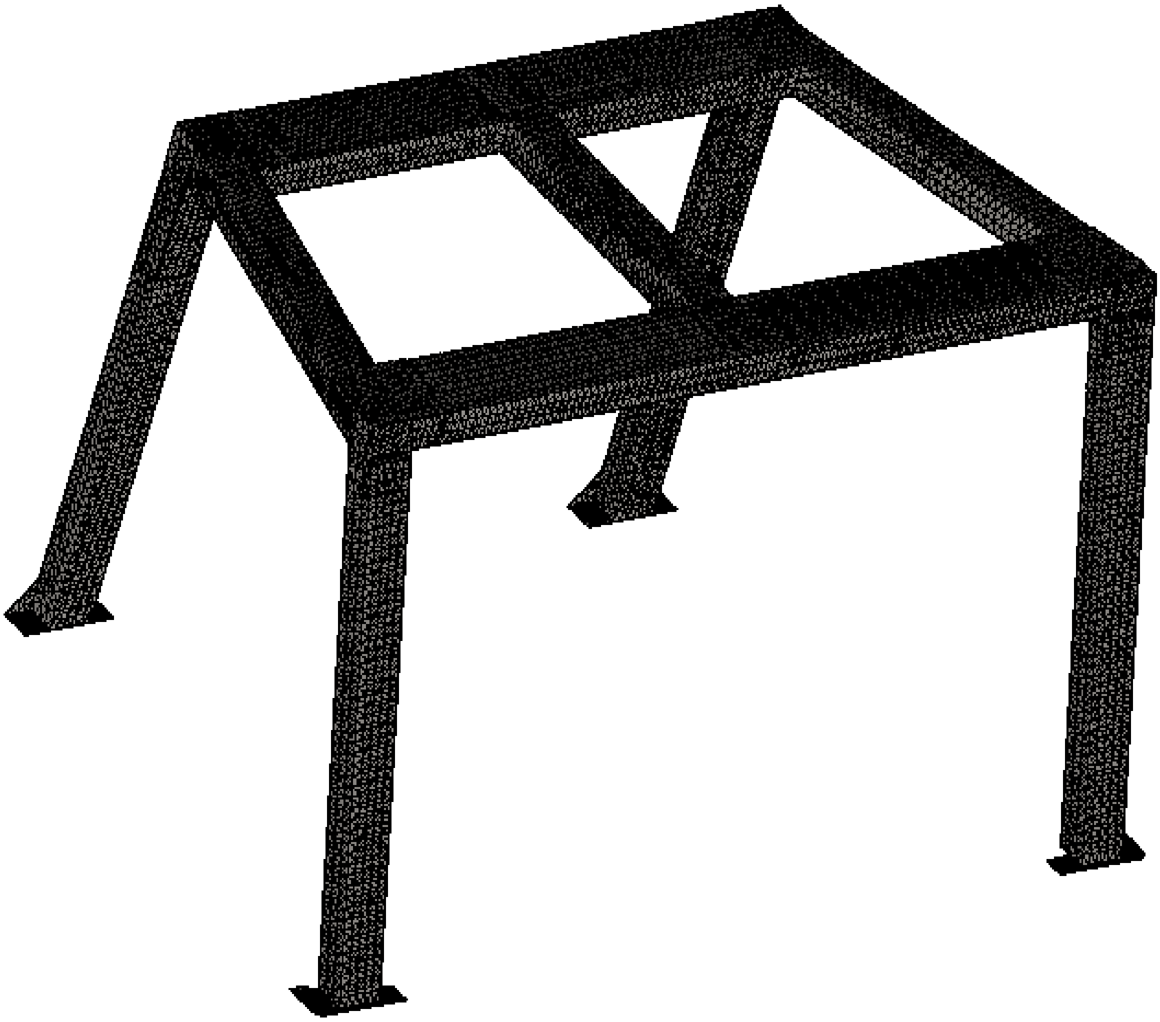


Figure 65. Mesh ISO view

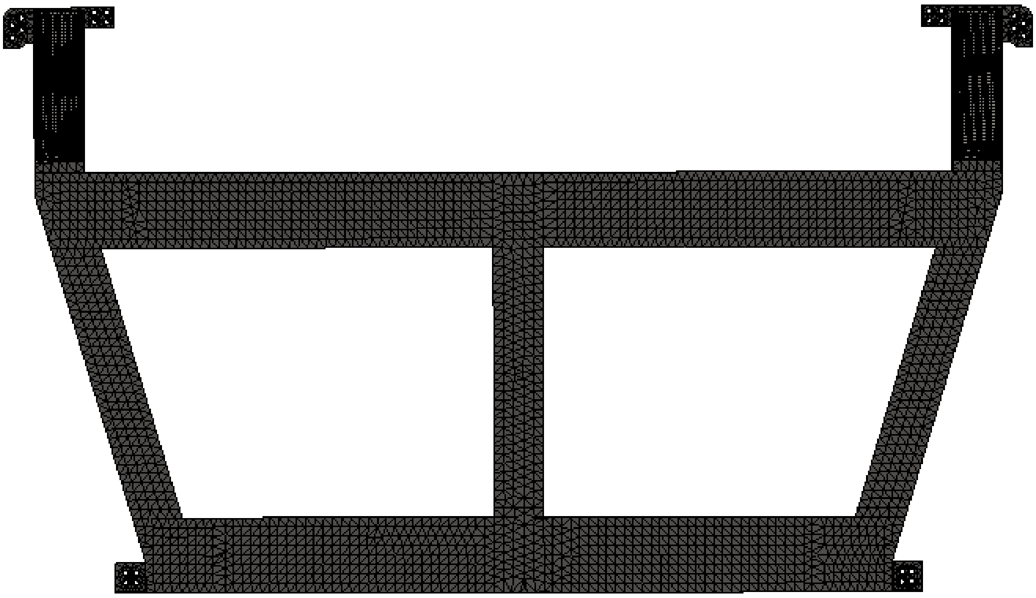


Figure 66. Top Mesh view

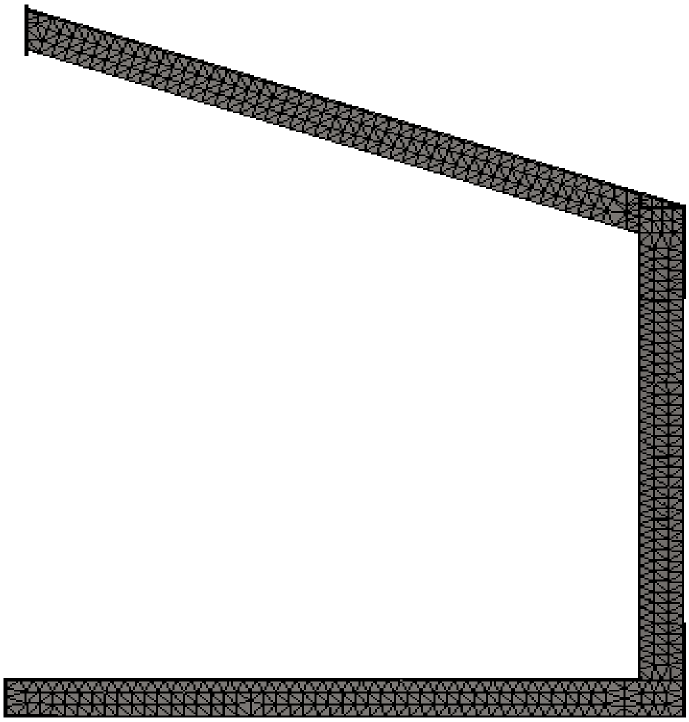


Figure 67. Back Mesh view

Figure 68. Front Mesh view

An important aspect is the mesh continuity. We repeated the meshing process several times until we checked that the mesh was continuous, and each filled.

Below is shown the continuity of the mesh.

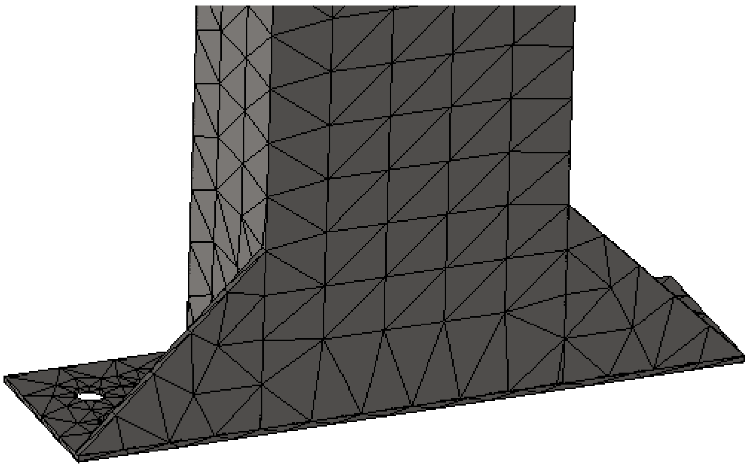


Figure 69. Mesh detail Back support 1

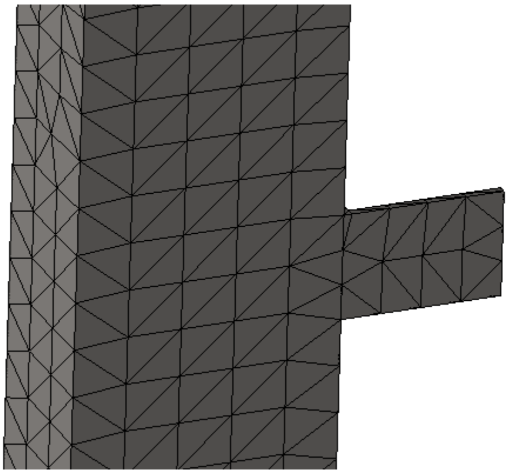


Figure 70. Mesh detail Back support 2

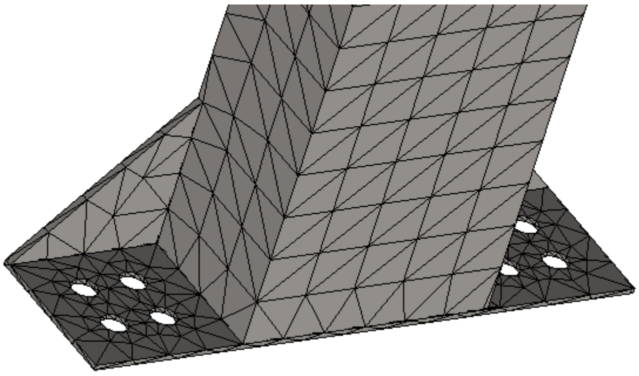


Figure 71. Mesh detail Back support 3

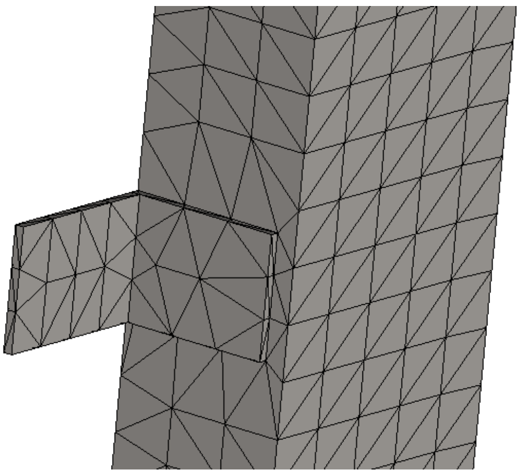


Figure 72. Mesh detail Back support 4

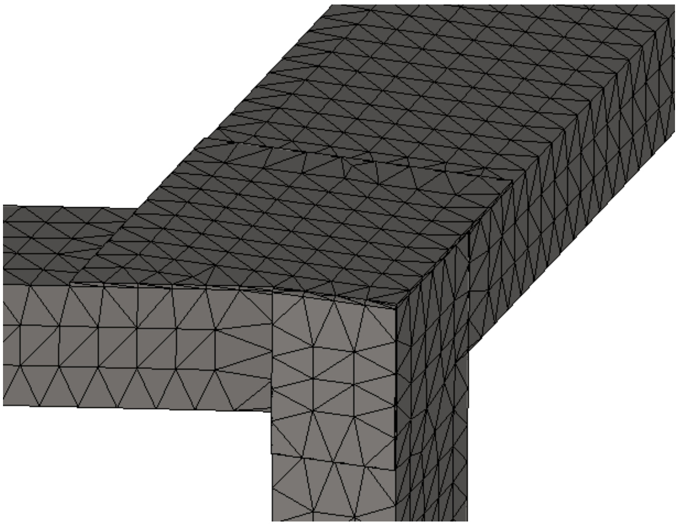


Figure 73. Top connection mesh detail. Back

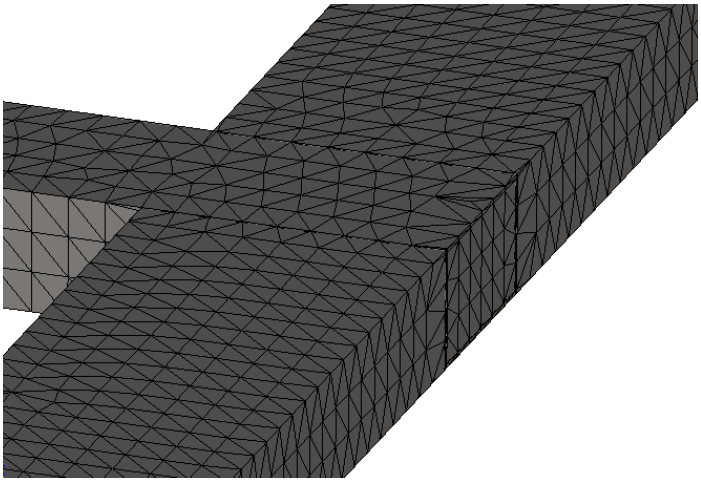


Figure 74. Top connection mesh detail. Middle 1

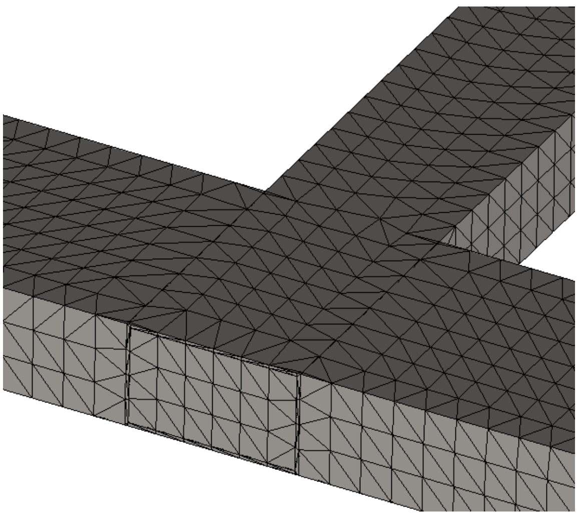


Figure 75. Top connections mesh detail. Middle 2

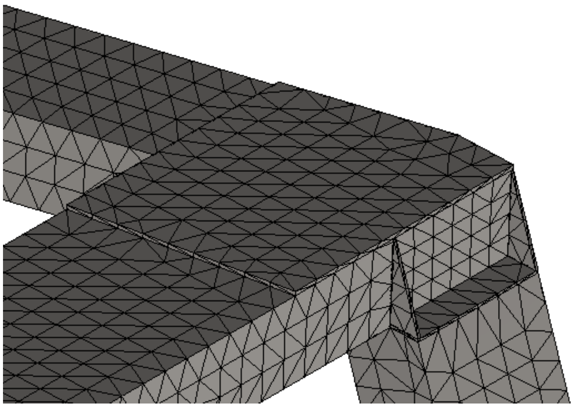


Figure 76. Top connections mesh detail. Front 1

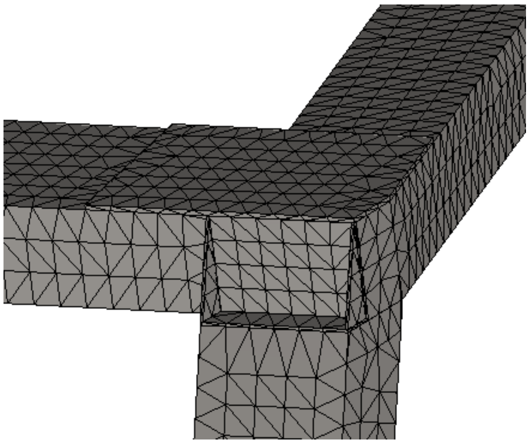


Figure 77. Top connections mesh detail. Front 2

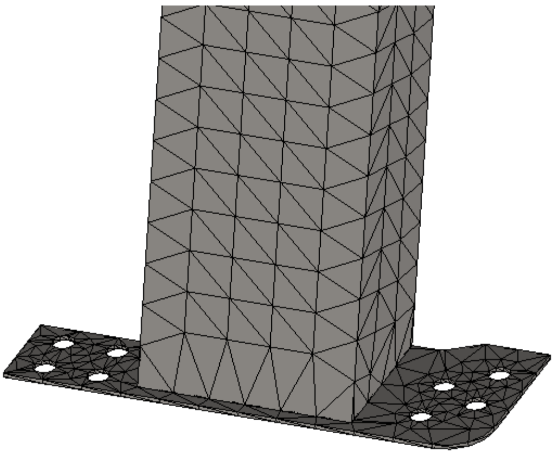


Figure 78. Front support mesh detail

As we can see, there is continuity in all models. We have used a standard mesh, triangular elements, length 0.0181963m.

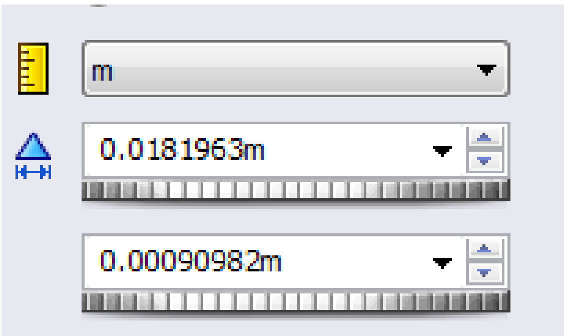


Figure 79. Element length detail.

8.2 Material specifications

We have used for the whole model S 355 JR steel. The average minimum yield for this material is 355 N/mm², hence the name S355. It has a 7850Kg/m3 density.

Analysis

Carbon	0.20% max	Phosphorous	0.025% max
Manganese	1.60% max	Sulphur	0.025% max
Silicon	0.55% max		

8.3 Boundary conditions

There are three different parts where our model is restricted. In each part, displacement and twist are both restricted in X, Y and Z direction. Below we can see the three different restrictions.

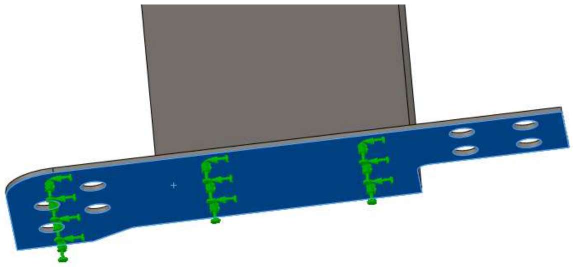


Figure 80 a. Front restriction

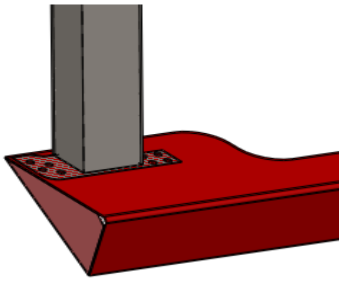


Figure 80 b. Front restriction detail

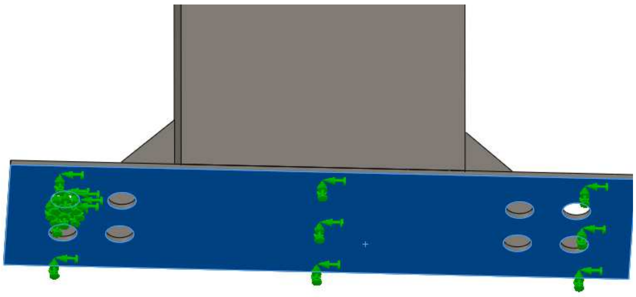


Figure 81 a. Back restriction 1

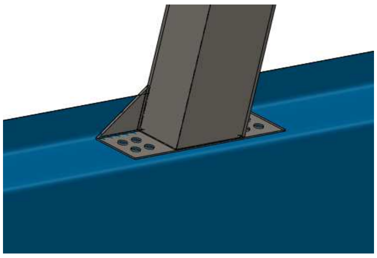


Figure 81 b. Back restriction detail 1

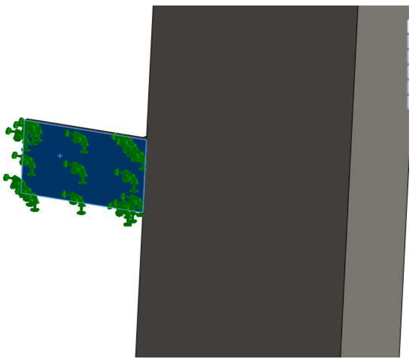


Figure 81 c. back restriction 2

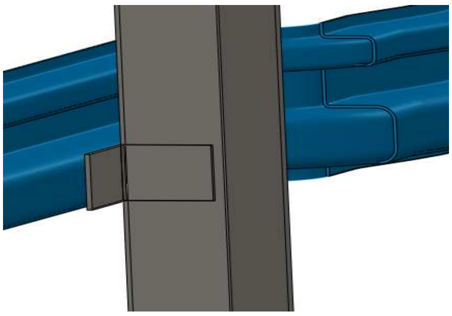


Figure 81 d. back restriction detail

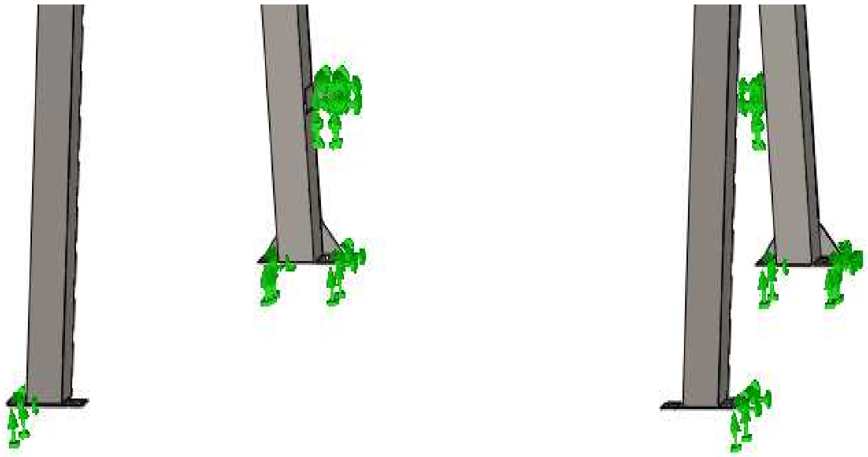


Figure 82. Restrictions 1

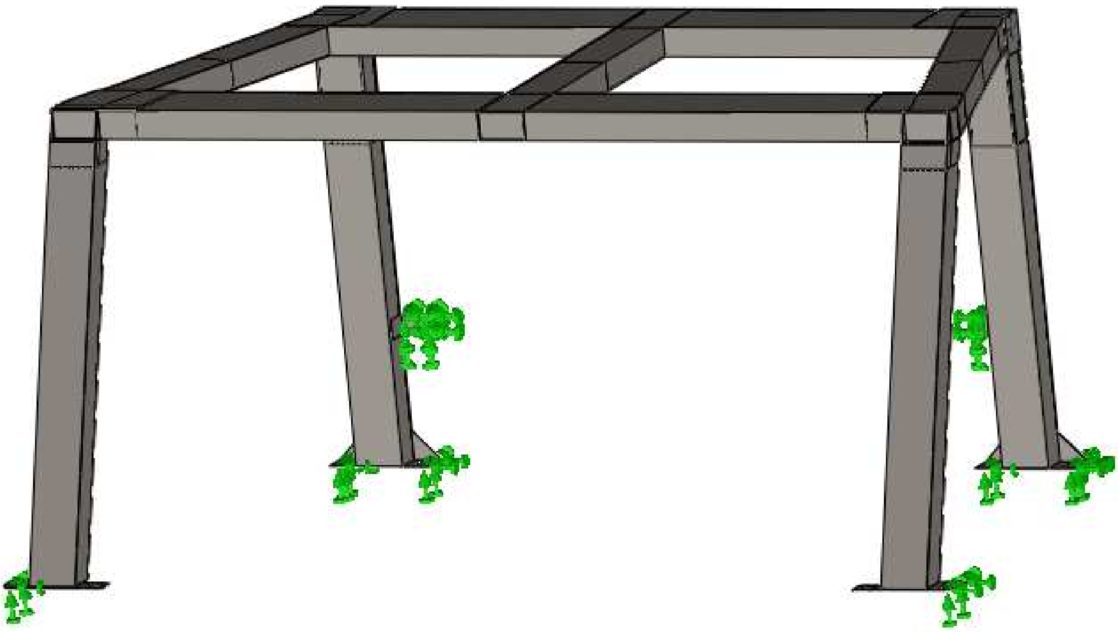


Figure 83. Restrictions 2

8.4 Loads cases

The impact force obtained is about 10932 Kg (we have considered an impact load of 110000N). There are four different load cases depending where the tree fall.

Load case 1

The tree impact exactly from one of the sides, an impact in the three top beams, the load is equality distributed in all of them.

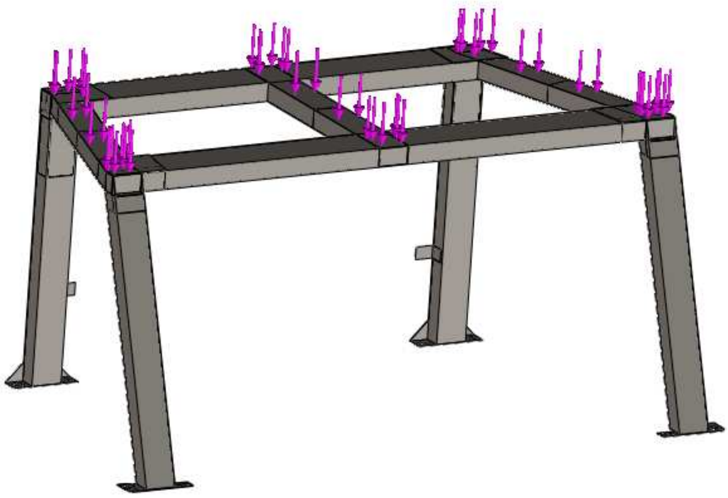


Figure 84. Load case 1. ISO

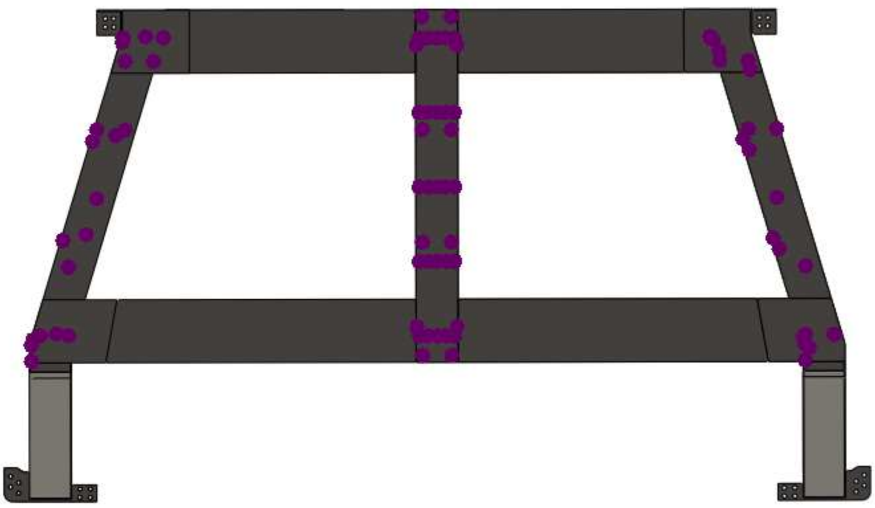


Figure 85. Load case 1. Top

<u>Load case 2</u>

Is the same case as before, but now we assume that the impact is only on two beams, increasing stresses and displacements. The load now is the same (110000N) distributed equality in two beams.

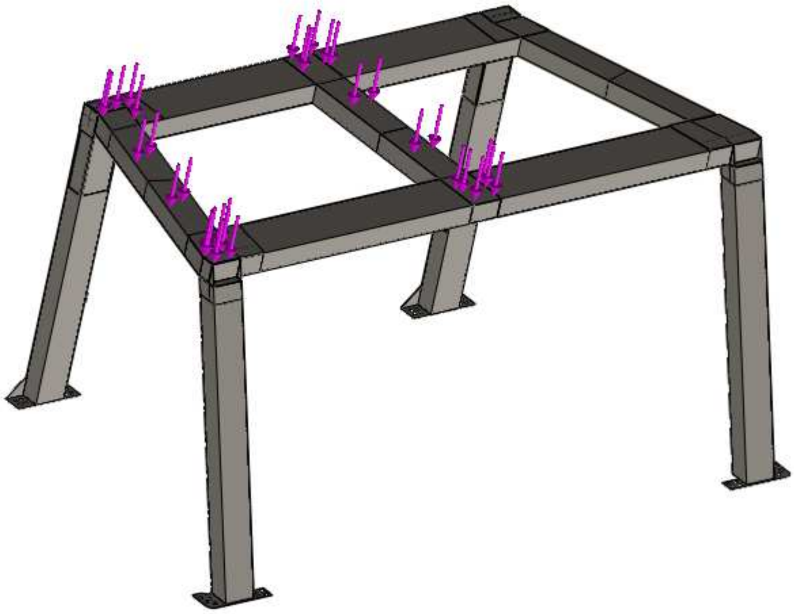


Figure 86. Load case 2. ISO

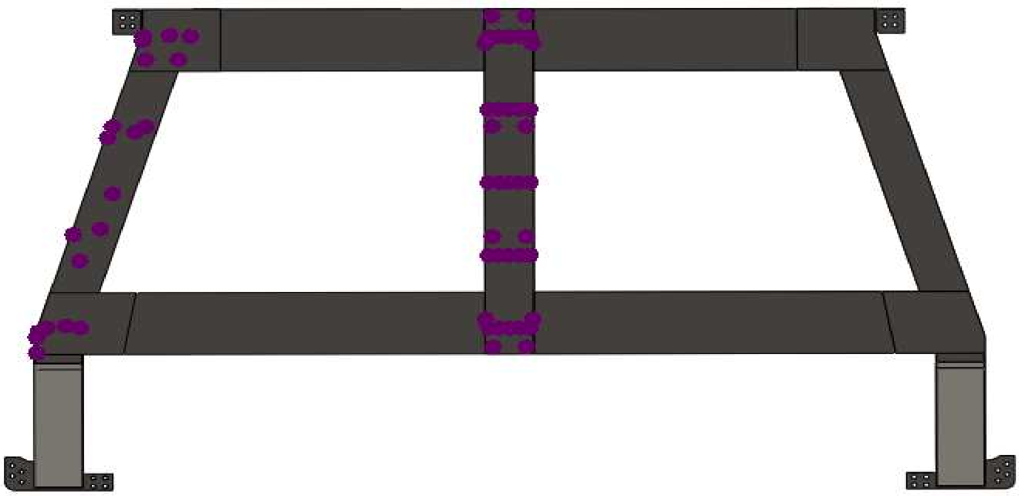


Figure 87. Load case 2. Top

Load case 3

In that case, we consider that the load impacts on one of the beams, and the 110000N is distributed in that beam.

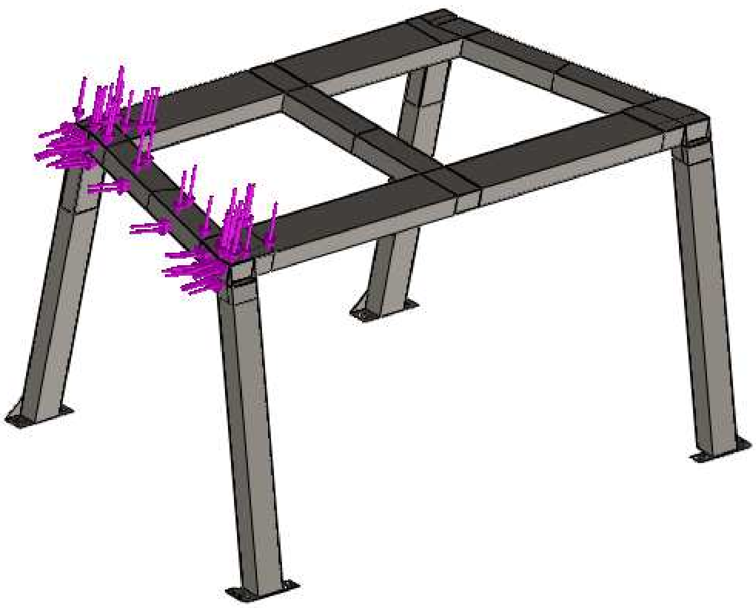


Figure 88. Load case 3. ISO

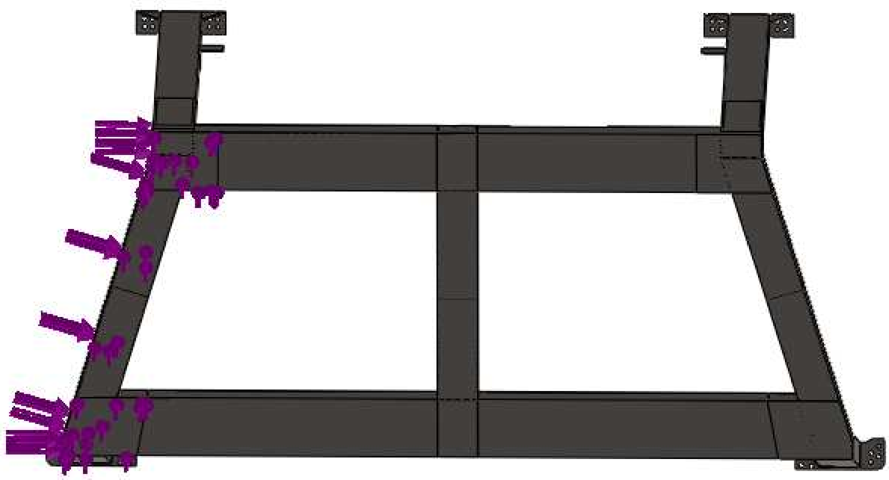


Figure 89. Load case 3. Top

Load case 4

We also need to consider the case where the load impact on the front of the cabin. It is not the most common case, but nevertheless, it needs consideration.

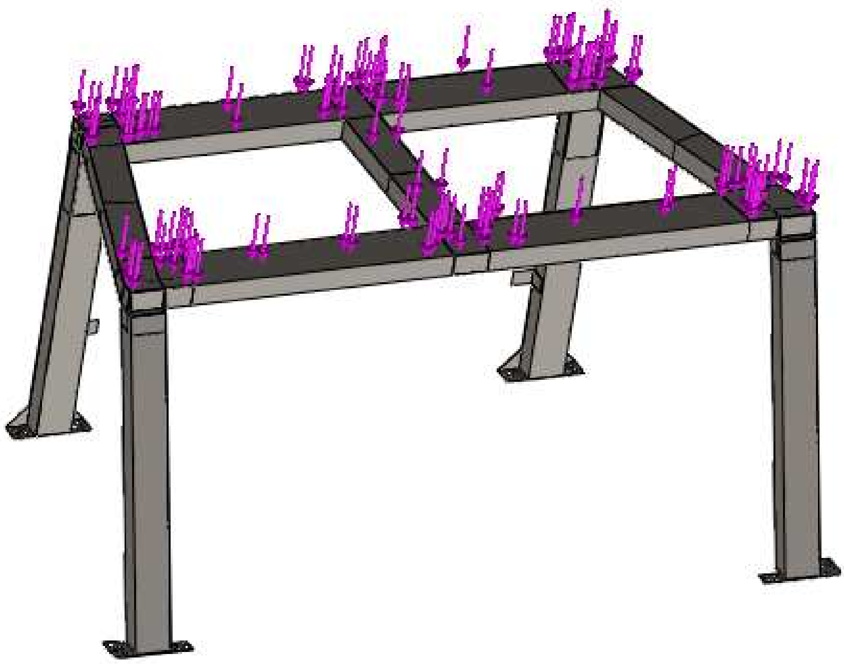


Figure 90 . Load case 4. ISO

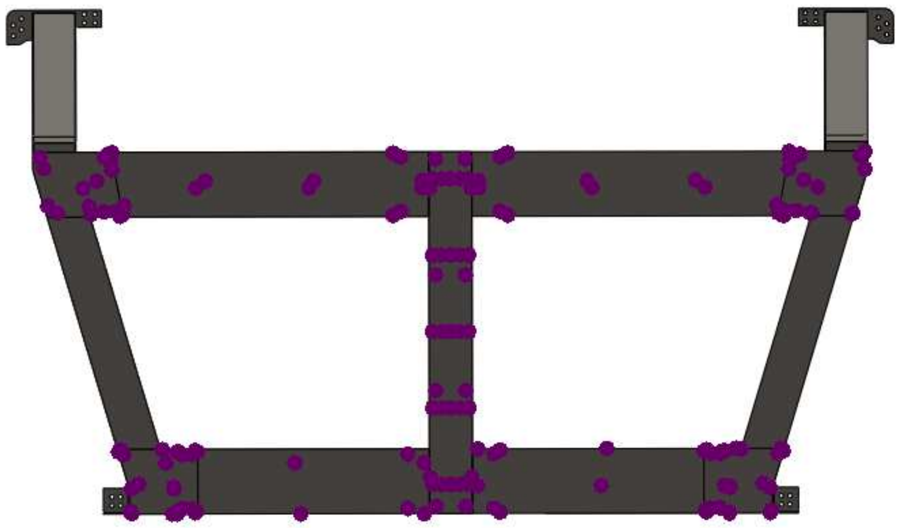


Figure 91. Load case 4. Top

8.5 Results

In this section, we will comment on the results in each load case. Von Mises stresses an displacements are shown.

<u>Load case 1</u>

Von Misses stresses

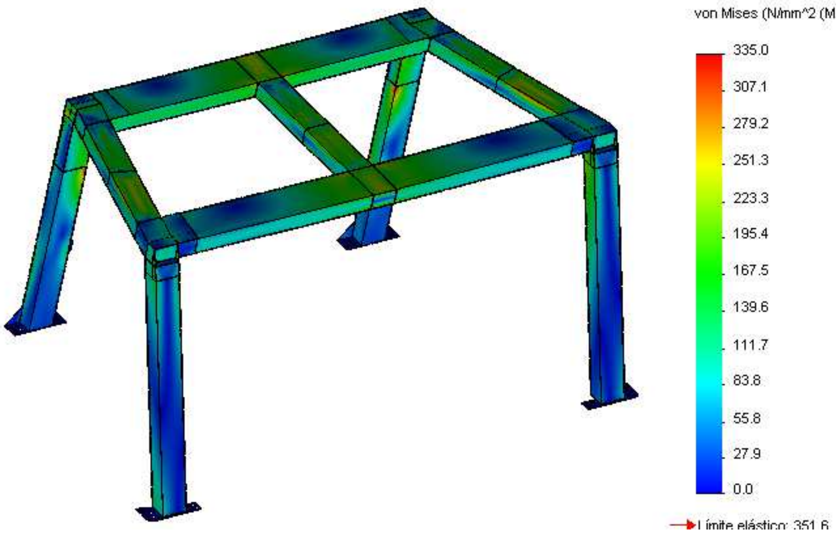


Figure 92. Von Mises Stresses. ISO View

Clipping

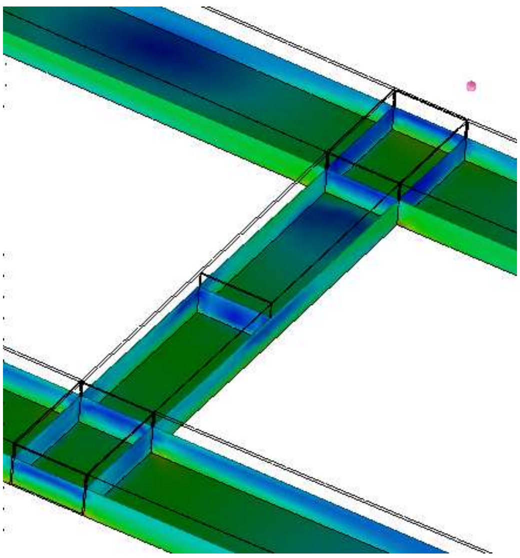


Figure 93 a. Clip 1

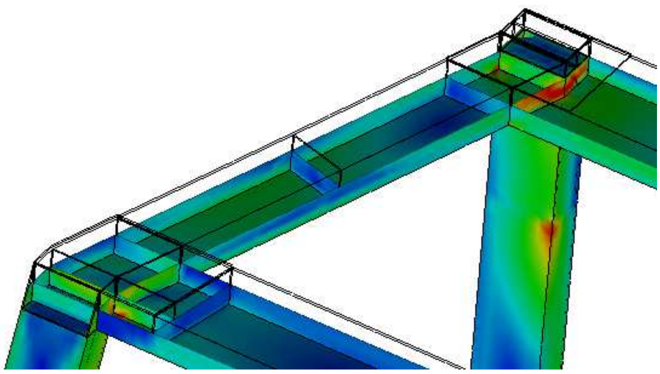


Figure 93 b. Clip 2

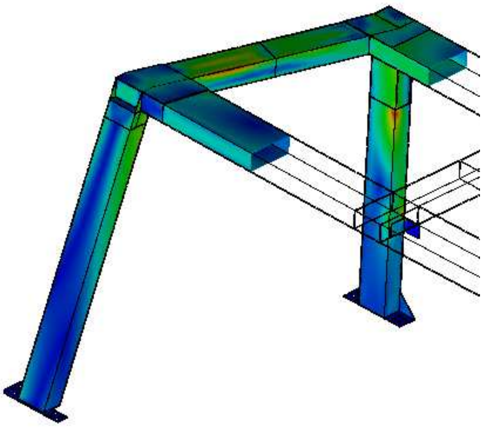


Figure 93 c. Clip 3

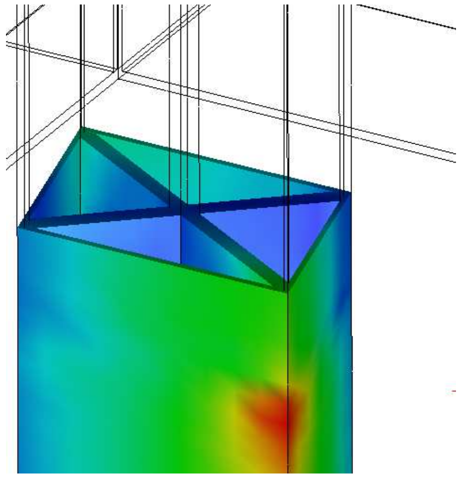


Figure 93 d. Clip 4

Connections

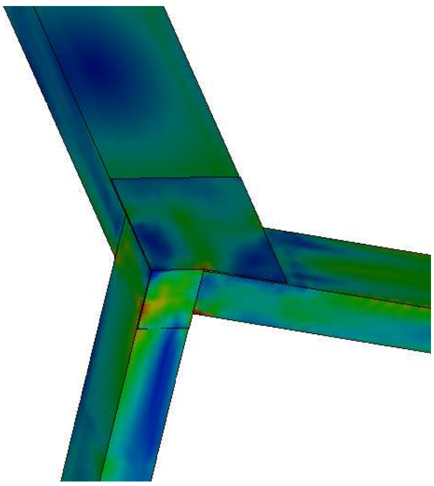


Figure 94 a. Connection 1

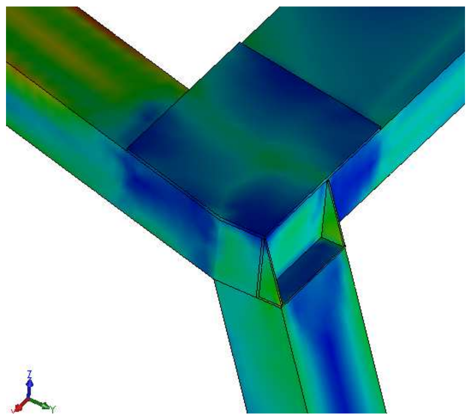


Figure 94 b. Connection 2

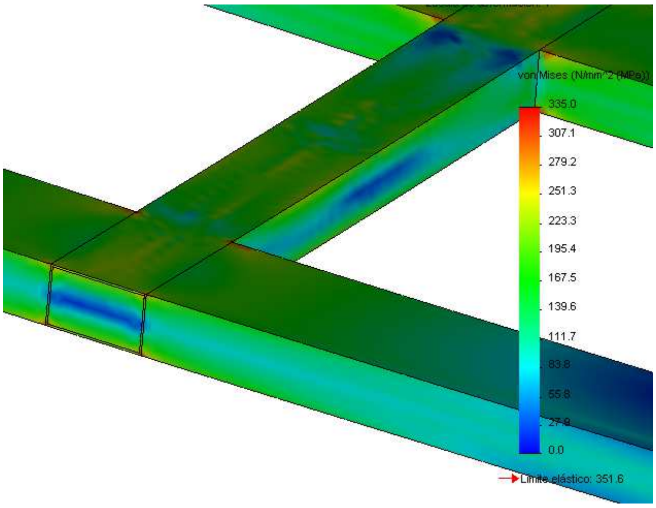
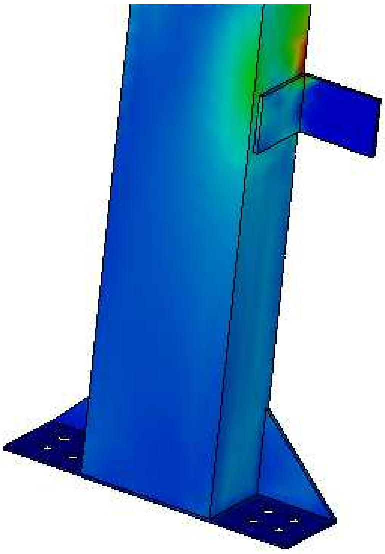


Figure 94 c. Connection 3

Supports



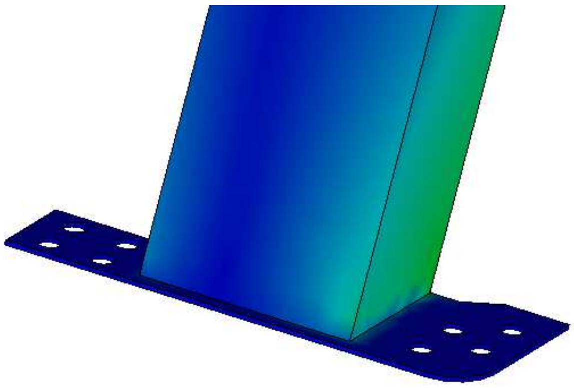


Figure 95 a. Back supports

Figure 95 b. Front supports

Displacements

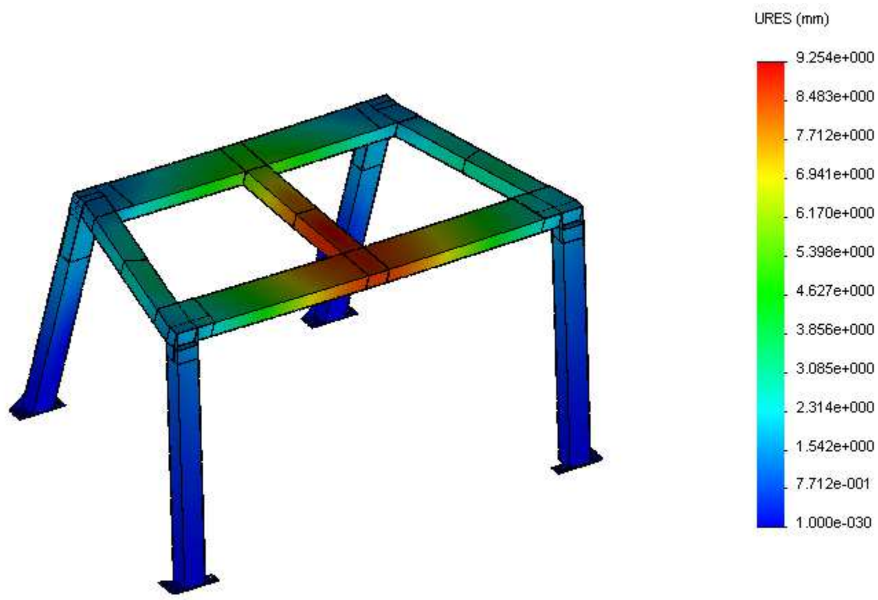


Figure 96. Displacements

Deformed

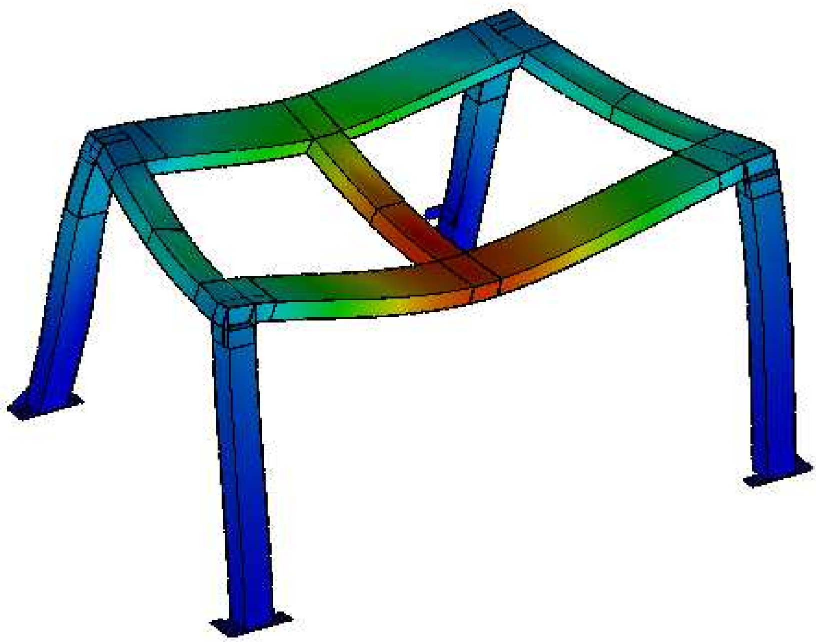


Figure 97. Deformed

Load case 2

Stresses

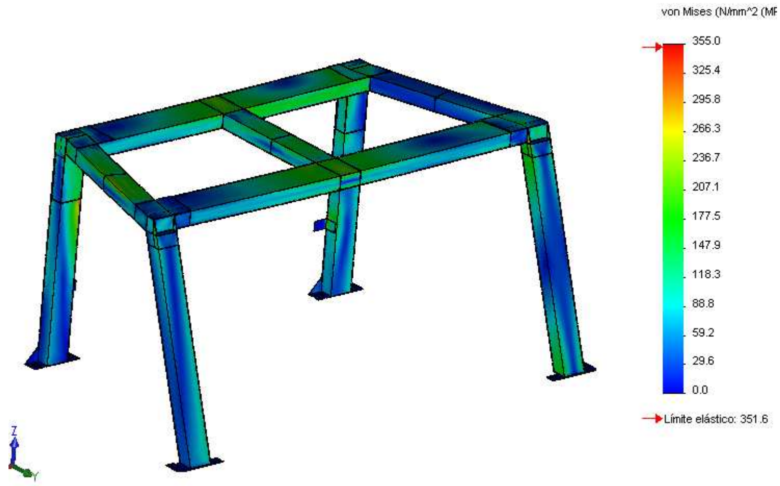


Figure 98. Von Mises Stresses. ISO View

Clipping

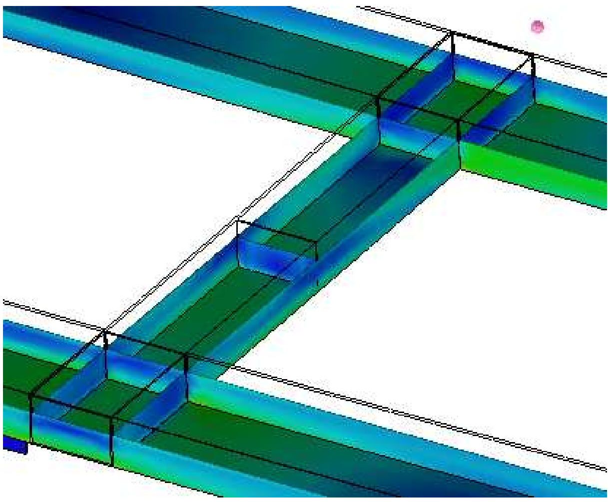


Figure 99 a. Clip 1

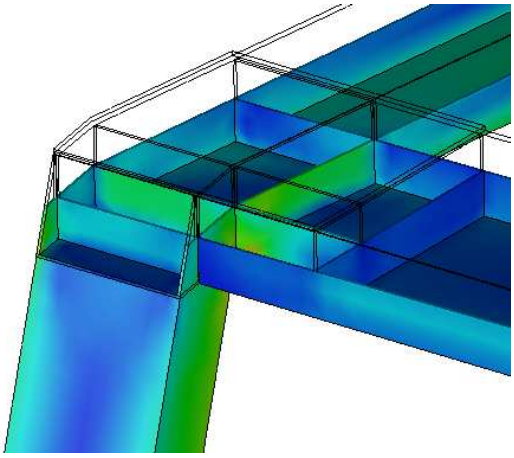


Figure 99 b. Clip 2

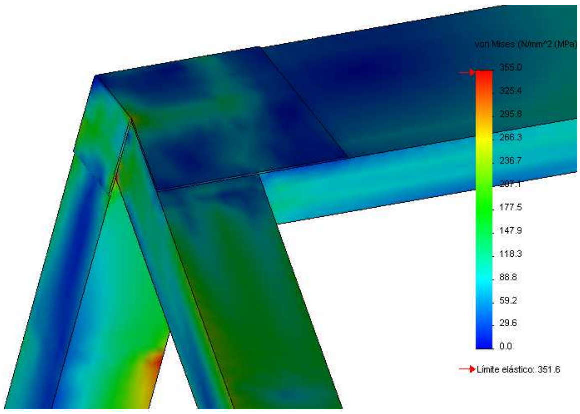


Figure 99 d. Clip 3

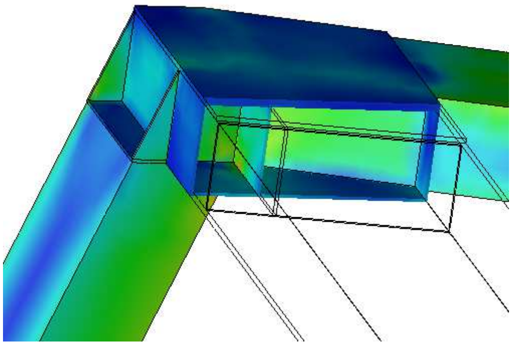


Figure 99 d. Clip 4

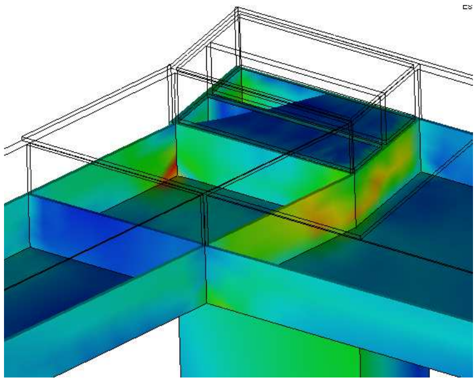


Figure 99 e. Clip 5

Supports

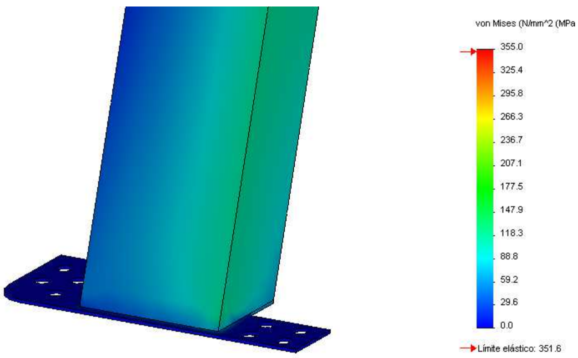


Figure 100 a. Front support

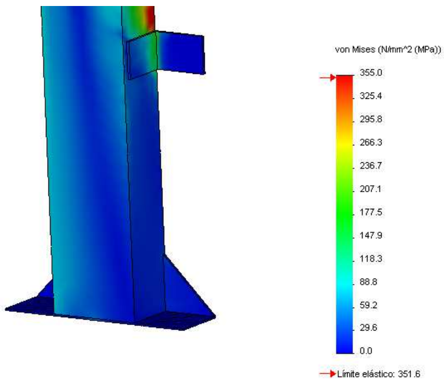


Figure 100 b. Back support

Connections

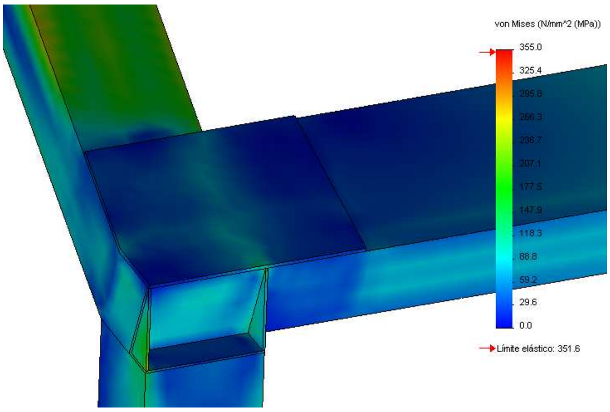


Figure 101 a. Connection 1

Figure 101 b. Connection 2

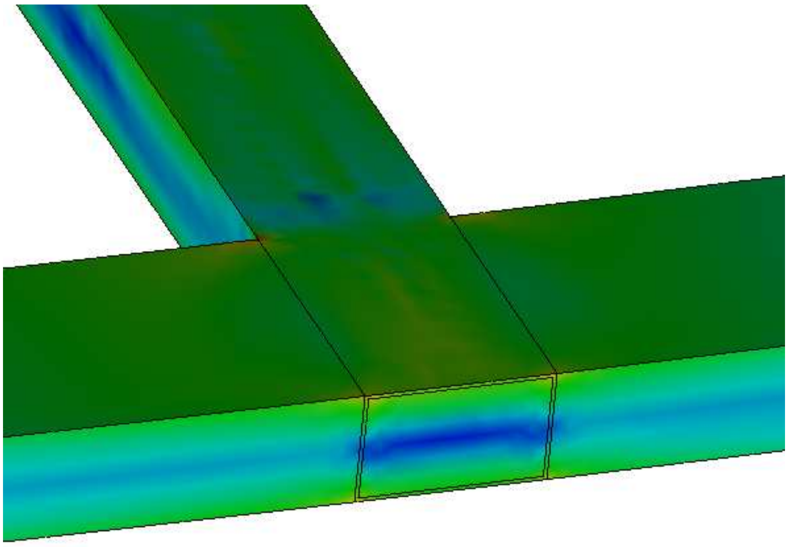


Figure 101 c. Connection 3

Displacements

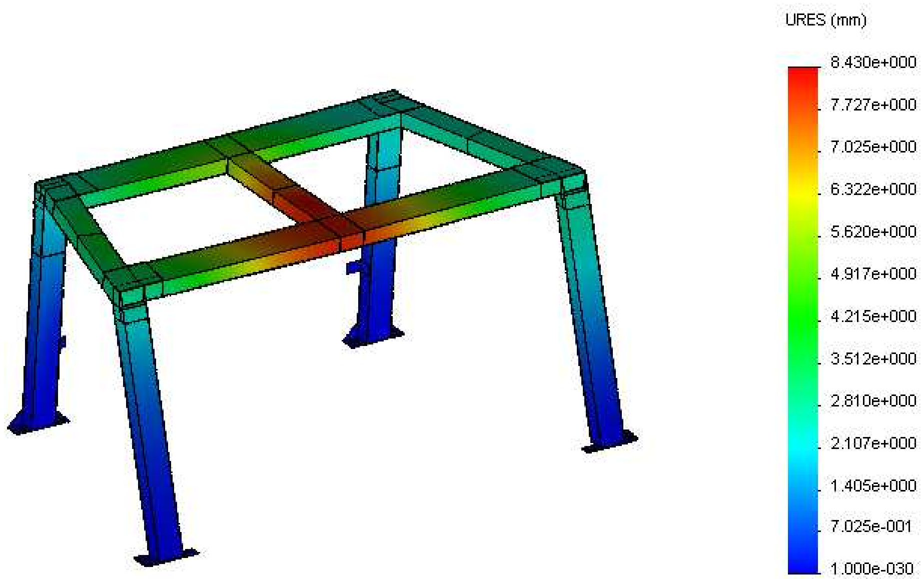


Figure 102. Displacements

Deformed

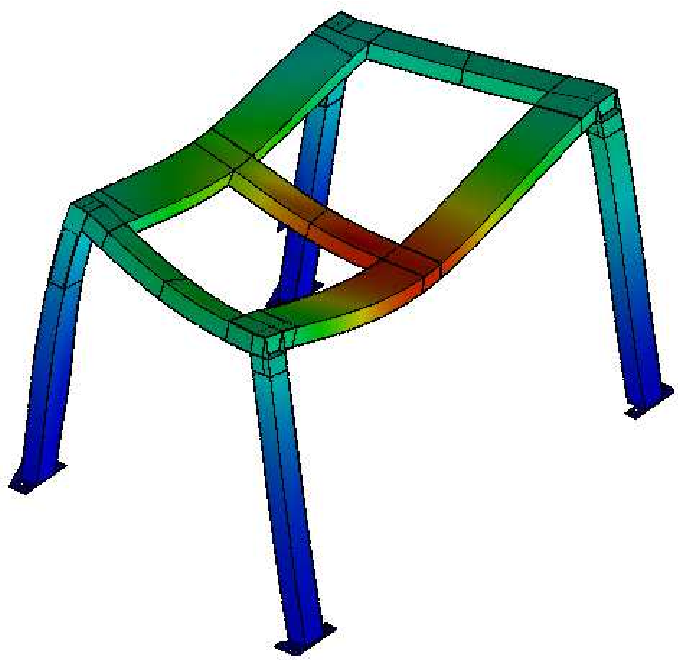


Figure 103. Deformed

<u>Load case 3</u>

Stresses

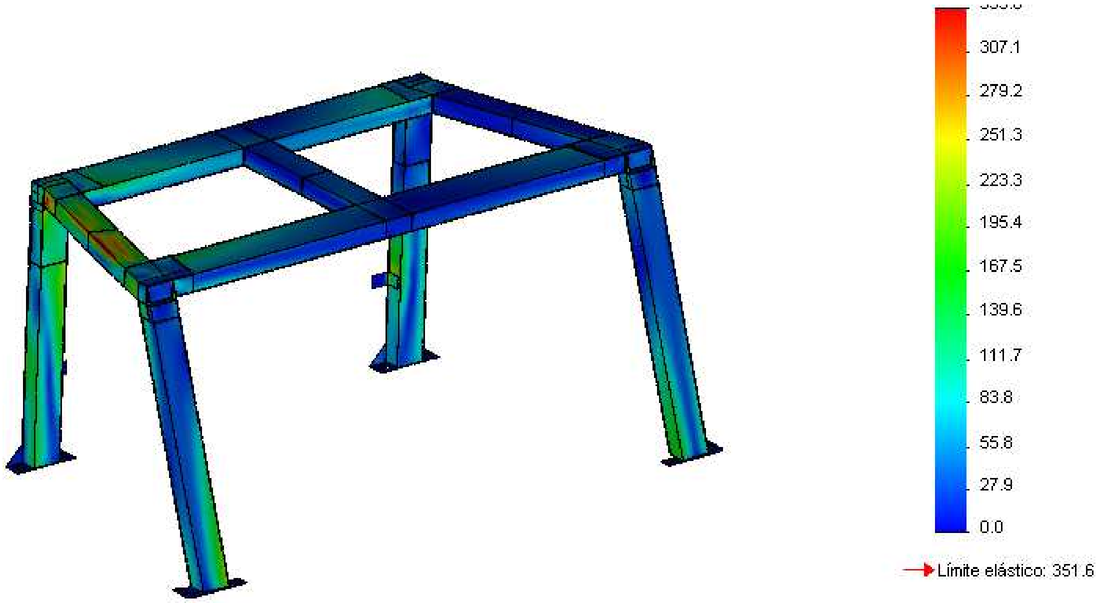


Figure 104. Von Mises Stresses. ISO View

Clipping

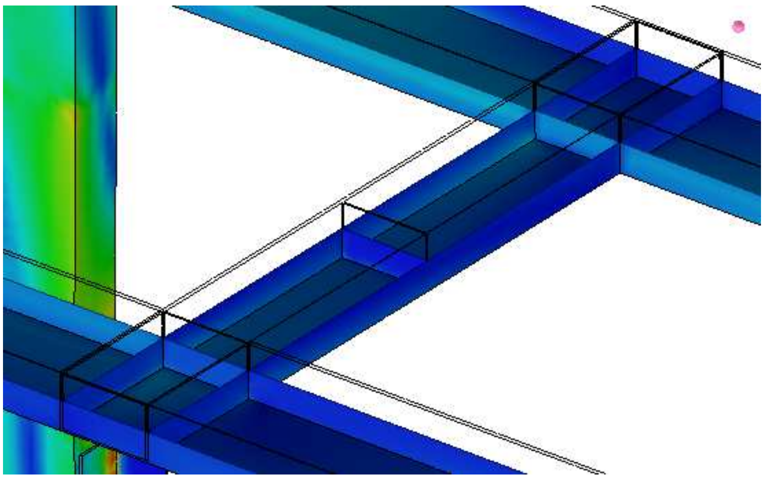


Figure 105 a. Clip 1

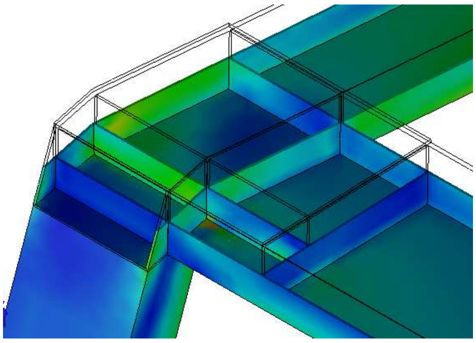


Figure 106 b. Clip 2

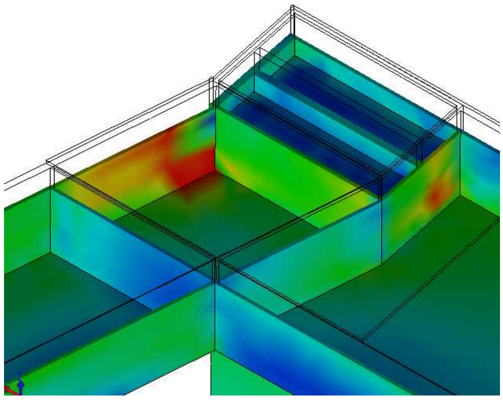


Figure 106 c. Clip 3

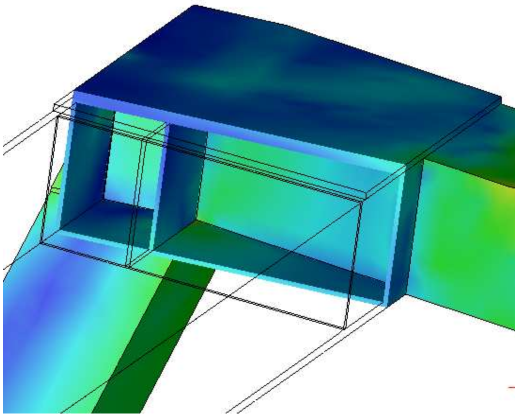


Figure 106 d. Clip 4

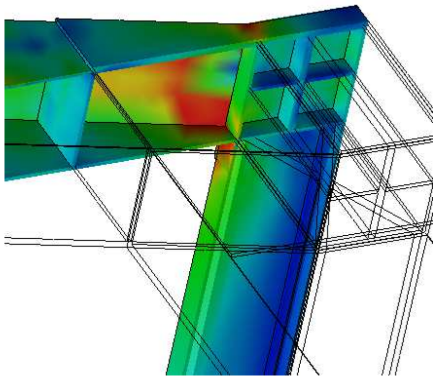


Figure 106 e. Clip 5

Supports

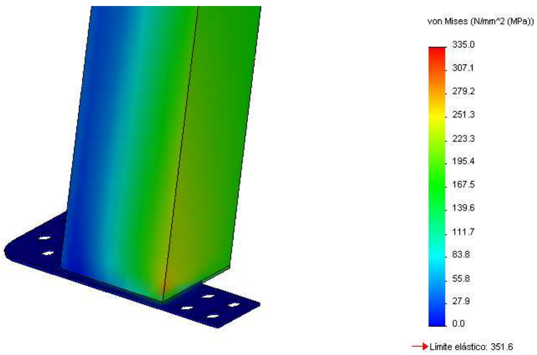


Figure 107 a. Front support

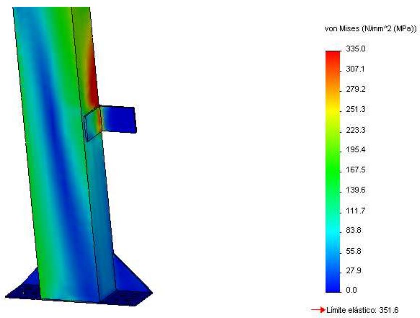


Figure 107 b . Back supports

Connections

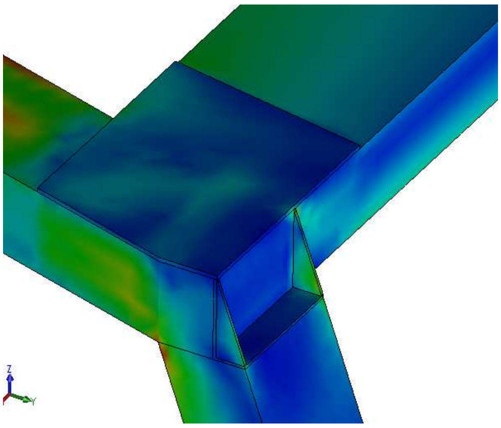


Figure 108 a. Connection 1

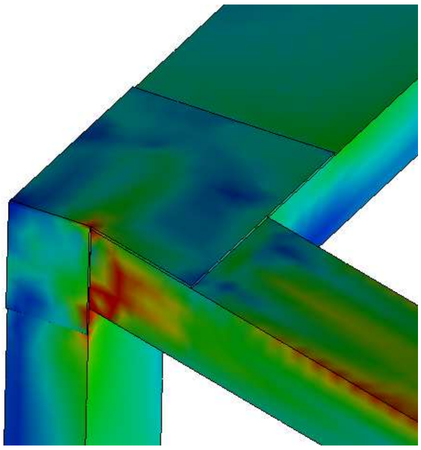


Figure 108 b. Connection 2

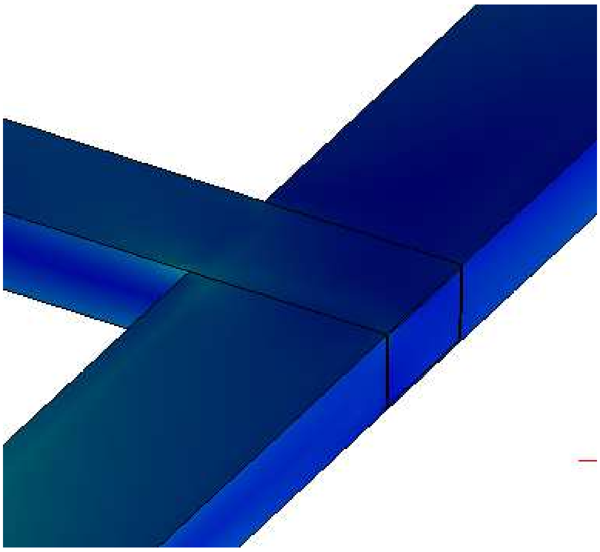


Figure 108 c. Connection 3

Displacements

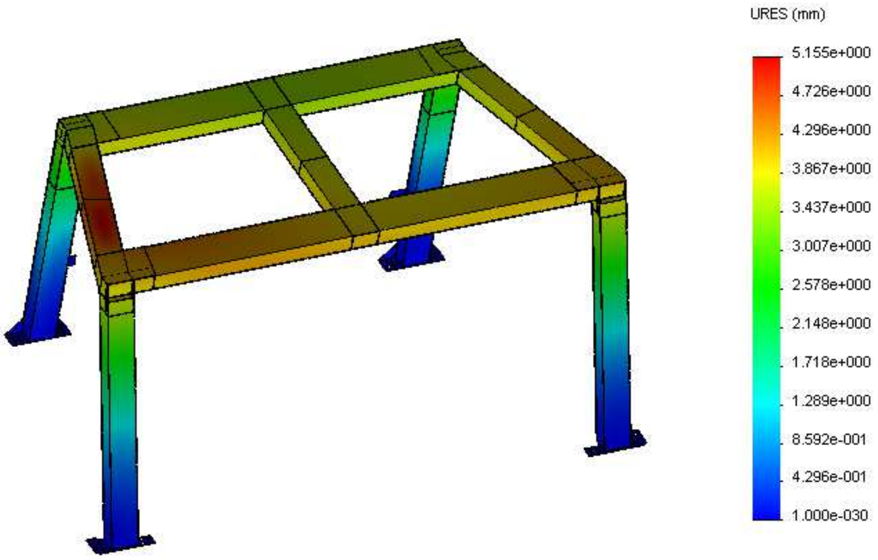


Figure 109. Displacements

Deformed

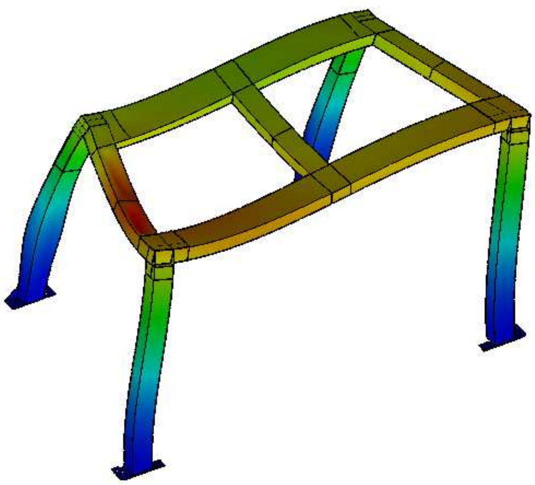


Figure 110. Deformed 1

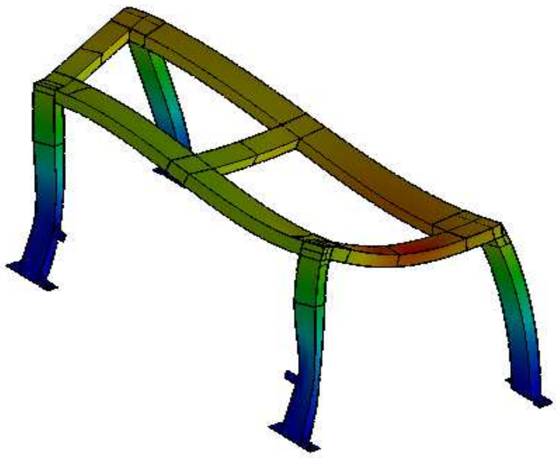


Figure 110 b. Deformed 2

Load case 4

Stresses

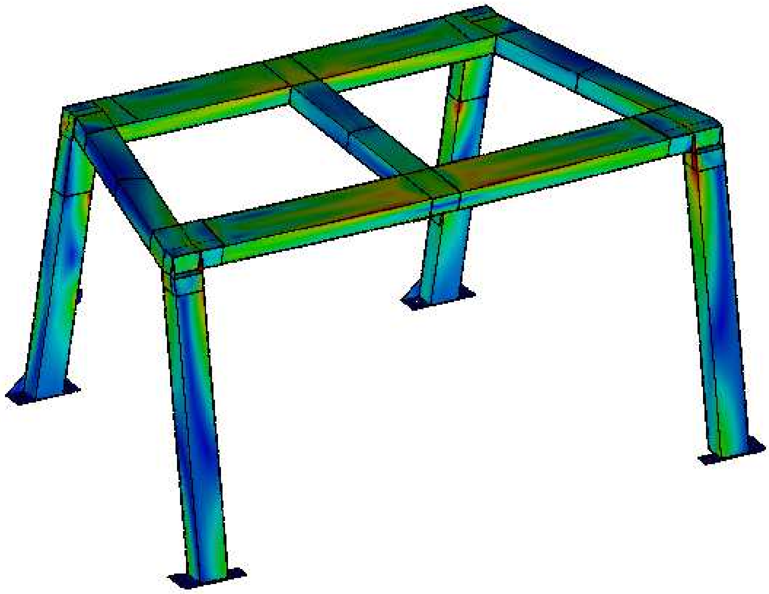


Figure 111. Von Misses Stresses. ISO View

Clipping

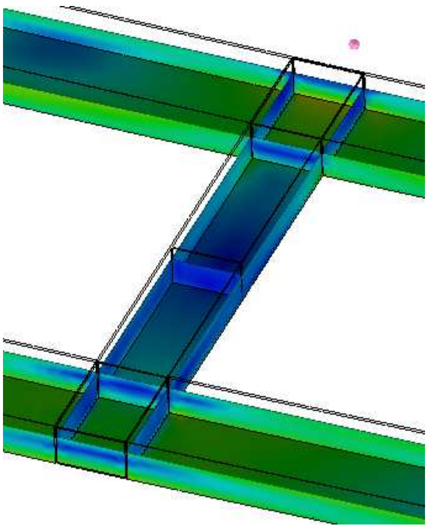


Figure 112 a. Clip 1

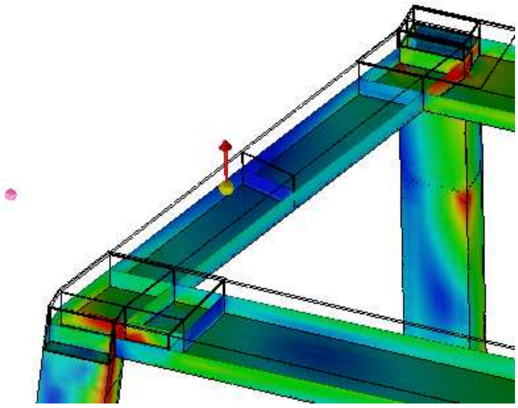


Figure 112 b. Clip 2

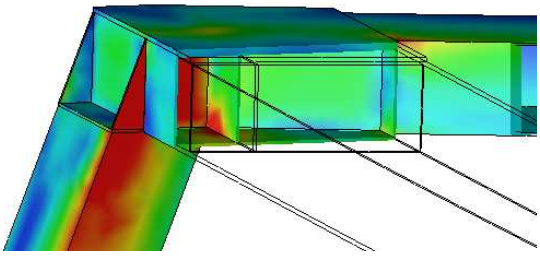


Figure 112 c. Clip 3

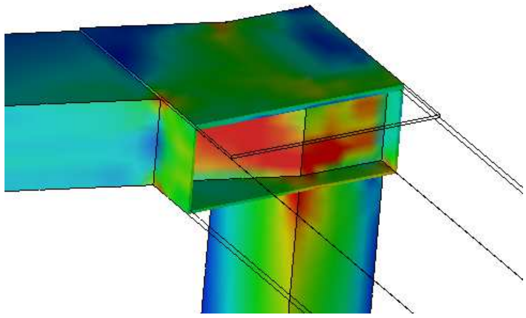


Figure 113 d. Clip 4

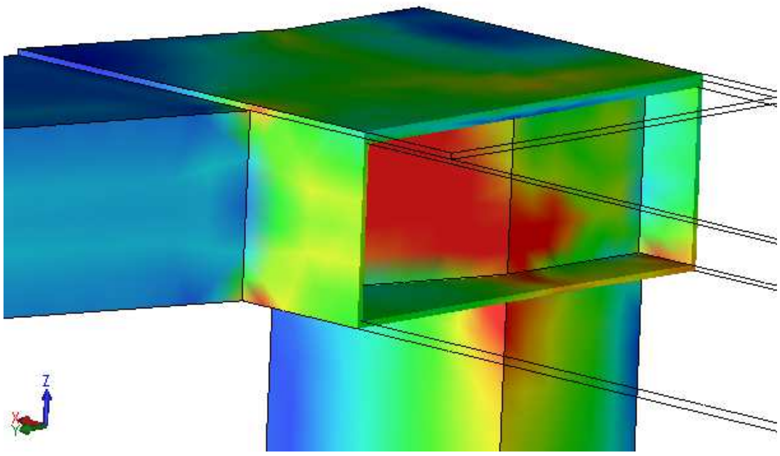


Figure 113 e. Clip e

supports

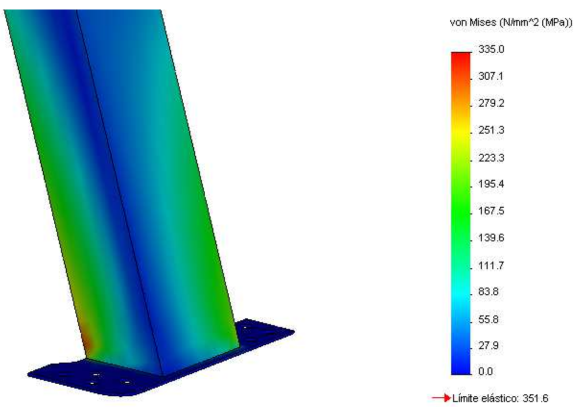


Figure 114 a. Front support

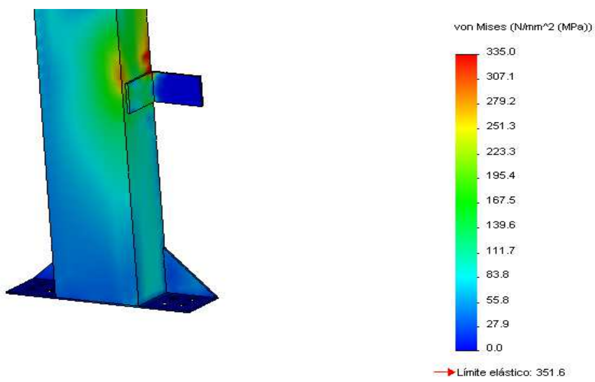


Figure 114 b. Back supports

Connections

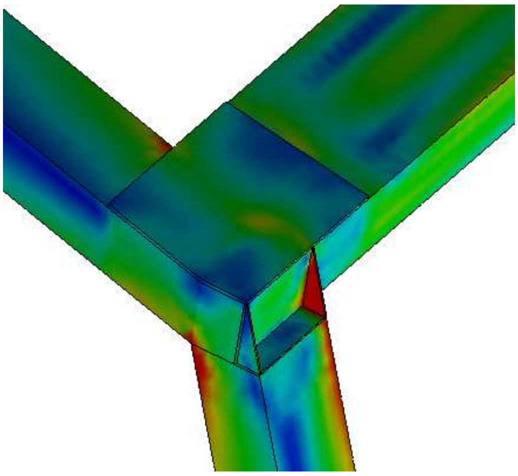


Figure 115 a. Connection 1

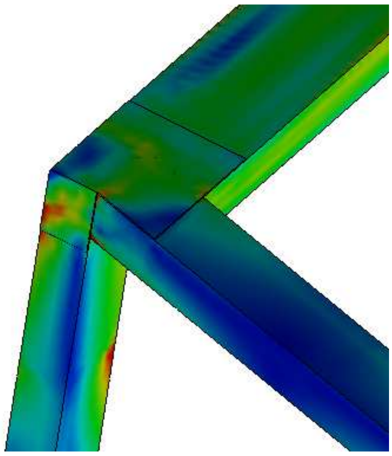


Figure 115 b. Connection 2

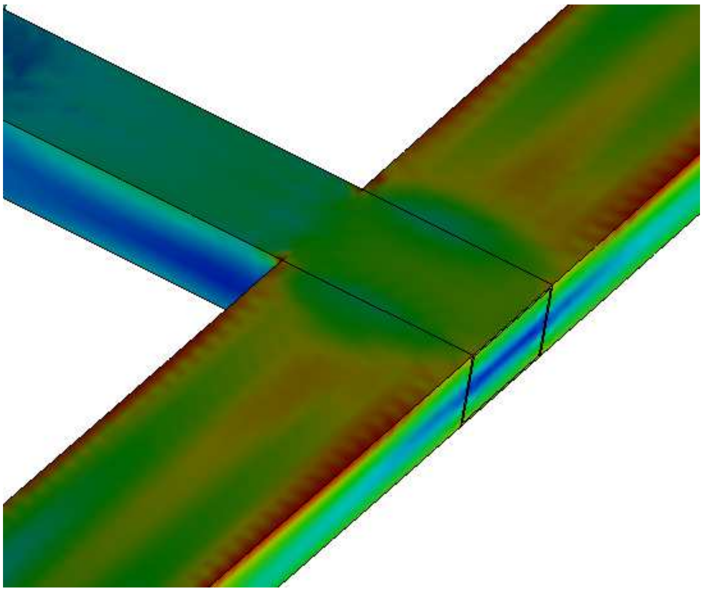


Figure 115 c. Connection 3

Displacements

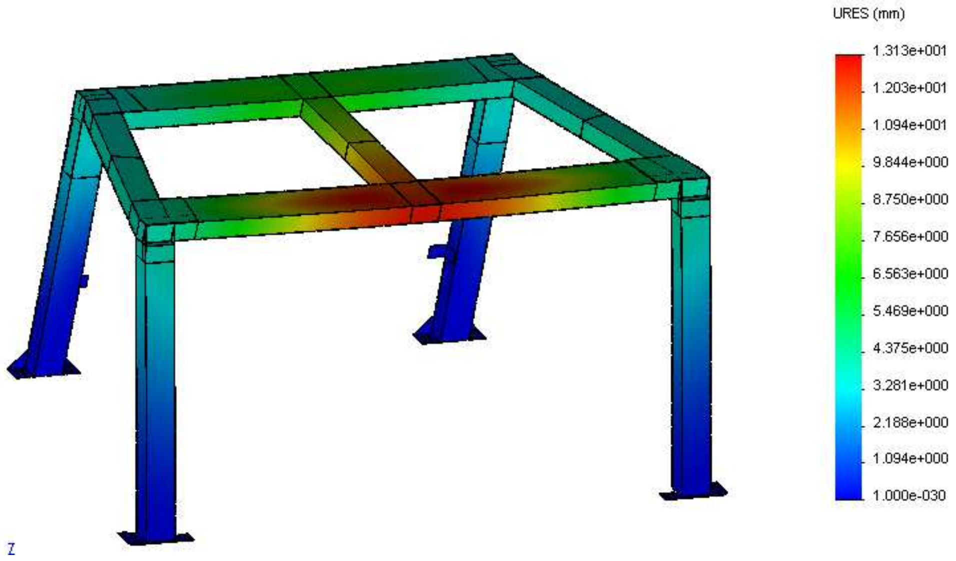


Figure 116. Displacements

Deformed

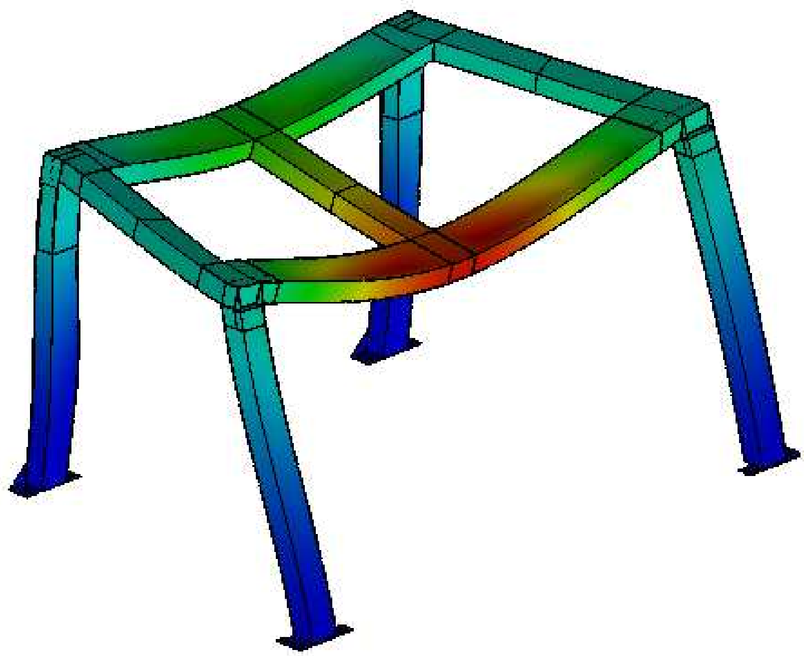


Figure 117. Deformed

9. TOP PART

As an important part of our design, we decided to redesign the top part of our model, for an accurate calculation. The main point is that the deflection under 40 mm. The stresses also have to be less than 335 MPa, but as we can see this is not the problem

That design has been made with the Nastran Patran program, which is specific finite element software.

9.1 Geometry description

We have used shells for this design. It has been important to consider the continuity of the model, through changes in the geometry or where the mesh needed to be different.

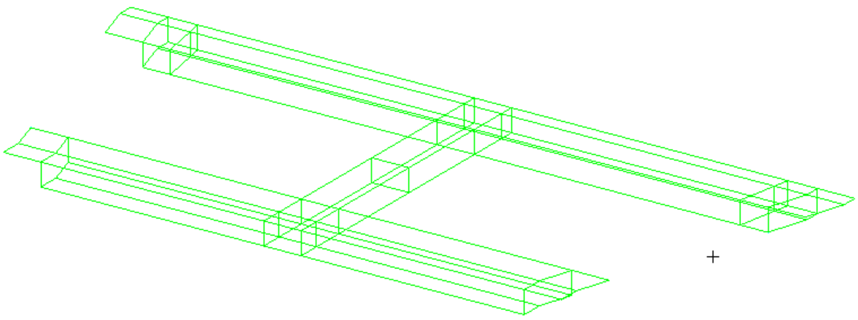


Figure 119. Wireframe model

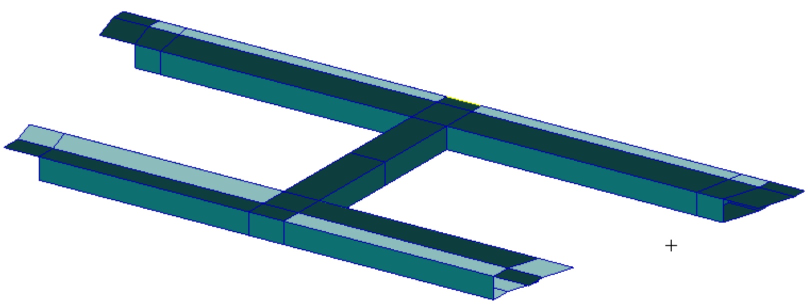


Figure 120. Shaded model

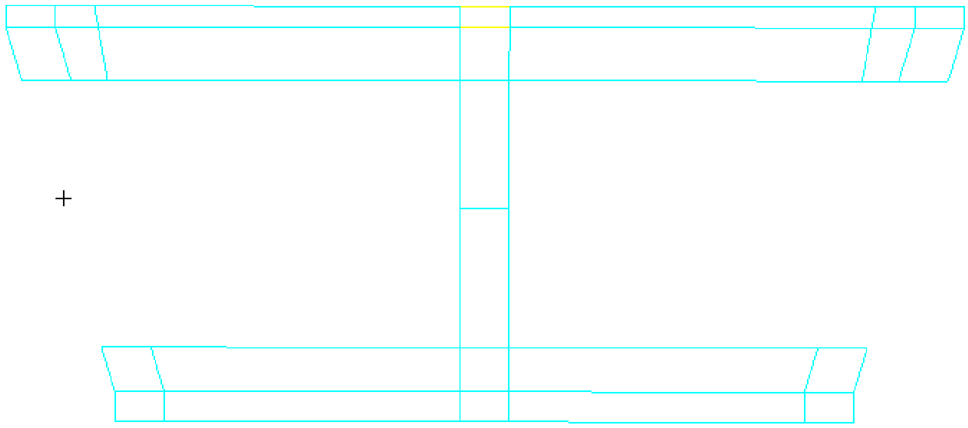


Figure 121. Top view

Figure 122. Front view

As can be seen discontinue, we break the surface where the geometry changes, and this effects to the rest of the model.

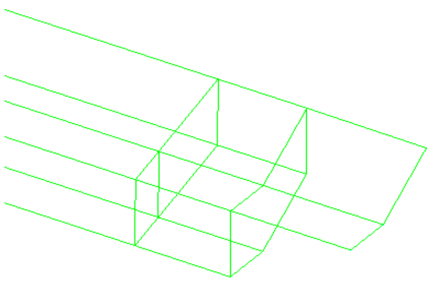


Figure 123 a. Break surface 1

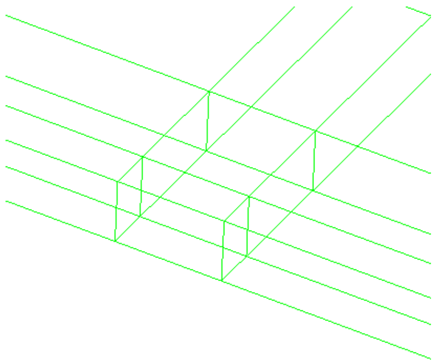


Figure 123 b. Break surface 2

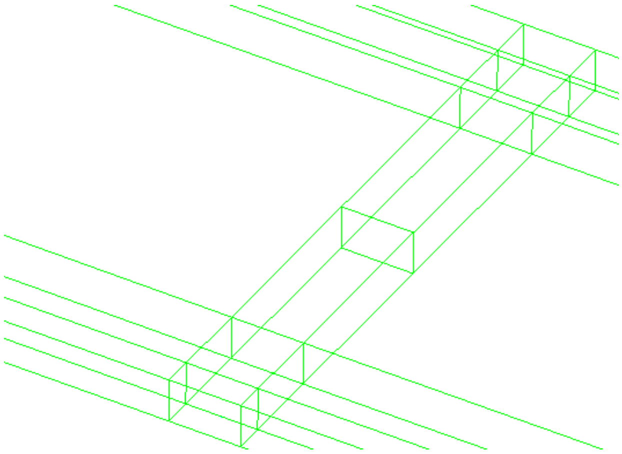


Figure 123 c. Break surface 3

9.2 Mesh description

We have used ISO mesh as basis, with Quad as an element type. The mesh in the model is continuous.

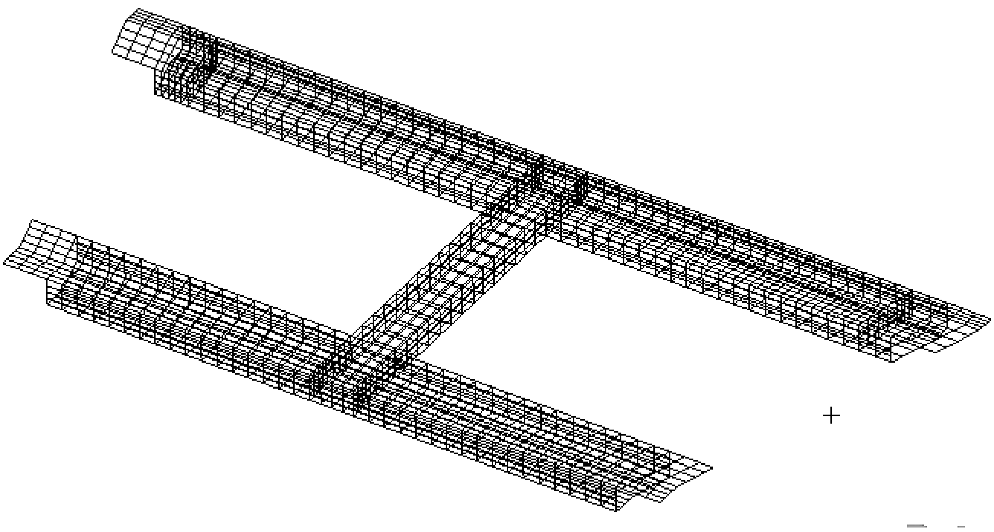


Figure 124. Wireframe mesh

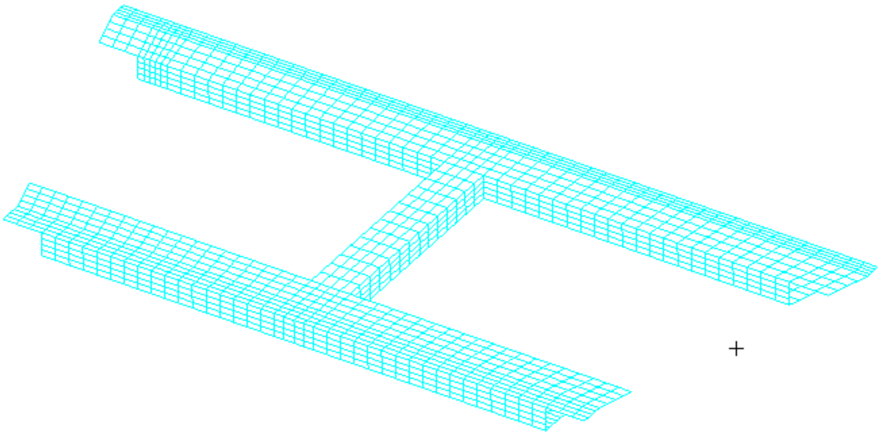


Figure 125. Hidden line mesh

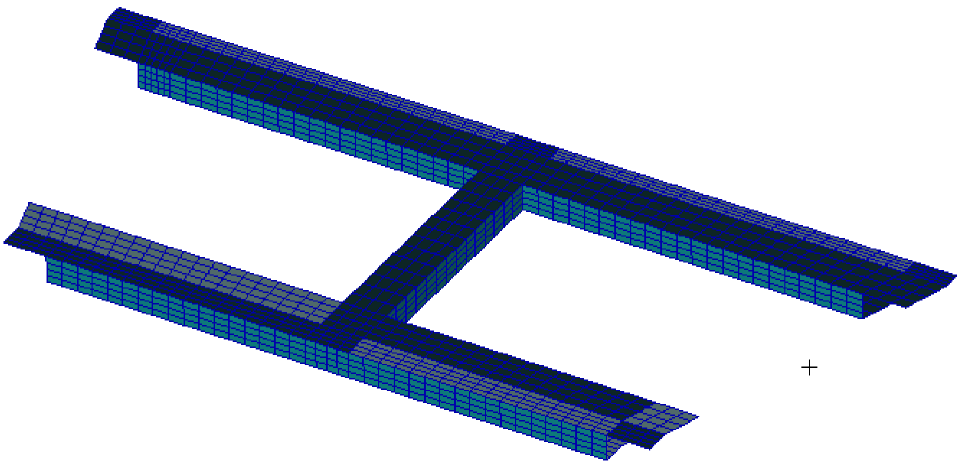


Figure 126. Shaded mesh

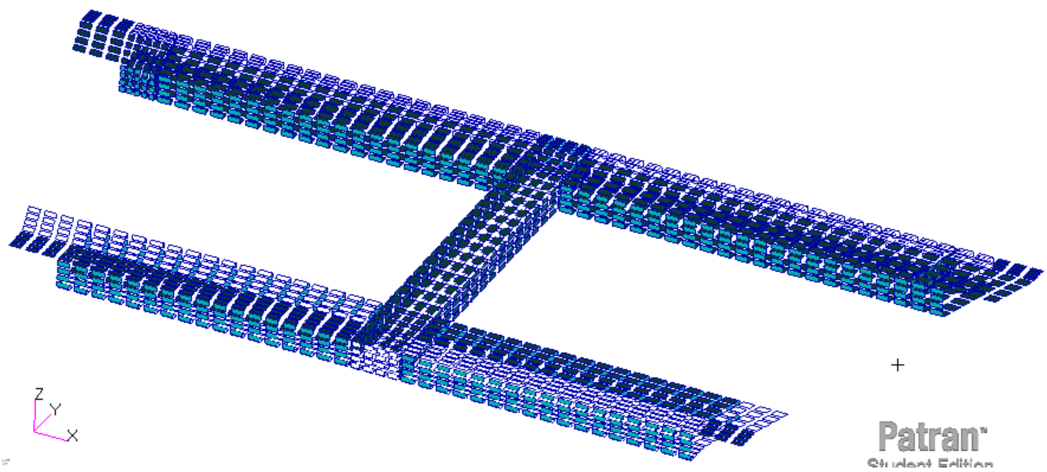


Figure 127. Element shrink mesh

Mesh joint details below.

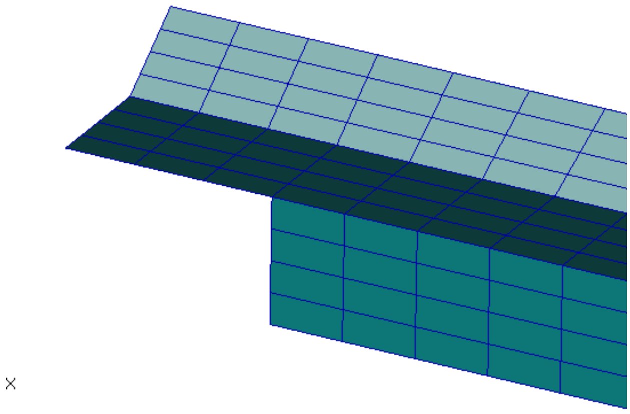


Figure 128. Mesh detail 1

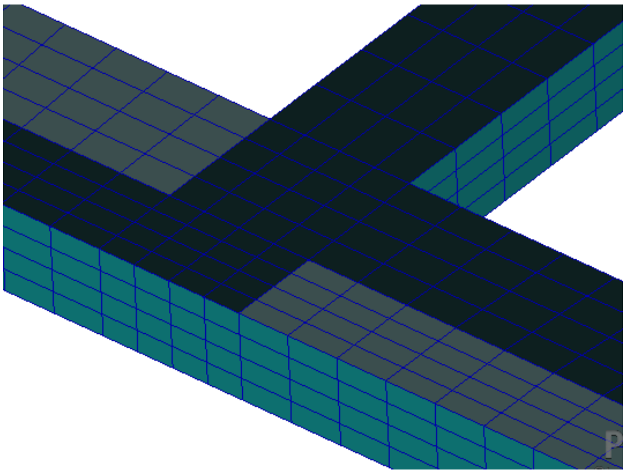


Figure 129. Mesh detail 2

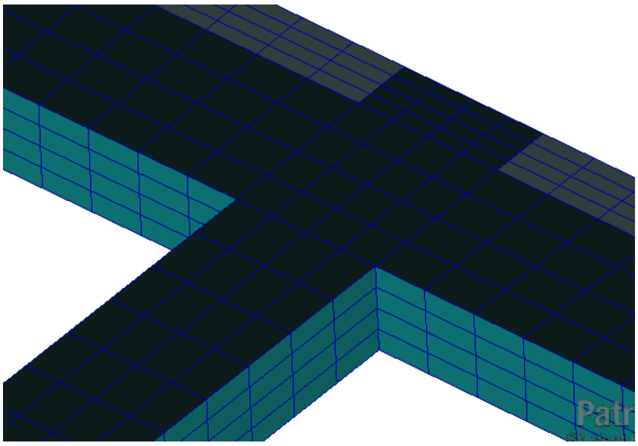


Figure 130. Mesh detail 3

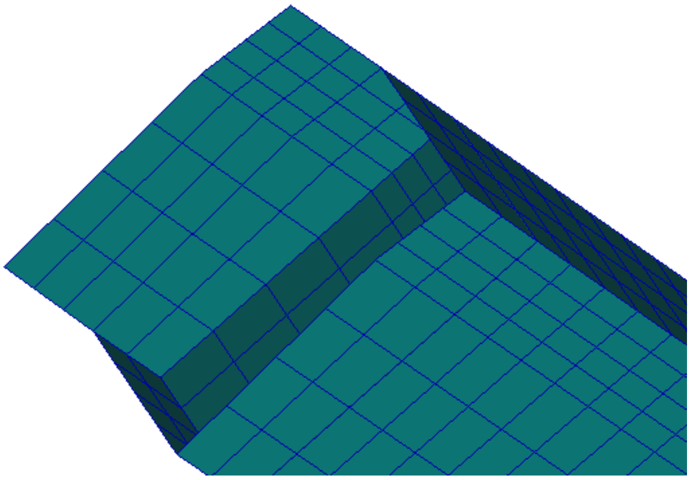


Figure 131. Mesh detail 4

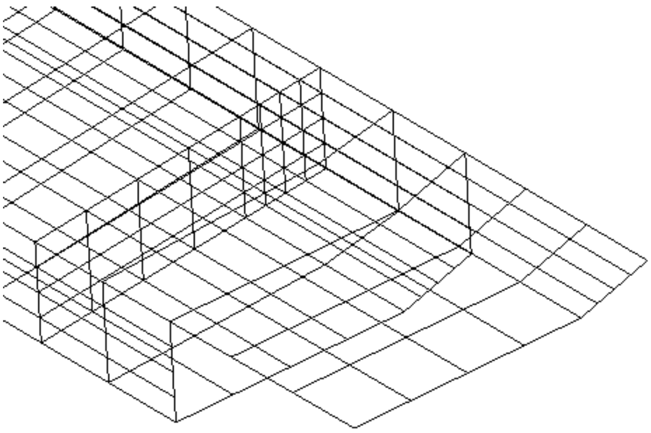


Figure 132. Wireframe mesh detail 1

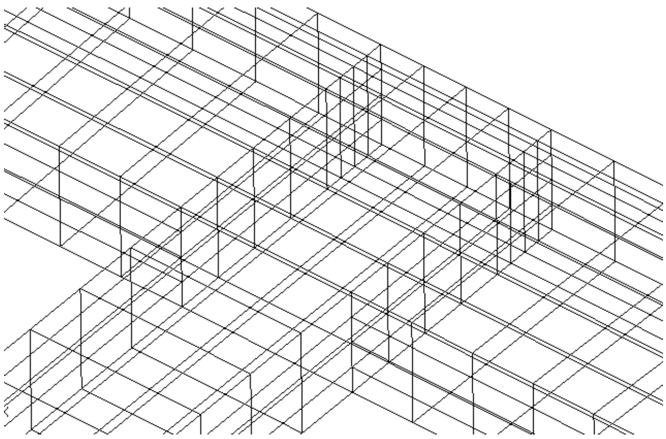


Figure 133. wireframe detail 2

9.3 Loads and boundary conditions

We applied a total load about 110000N, as follows

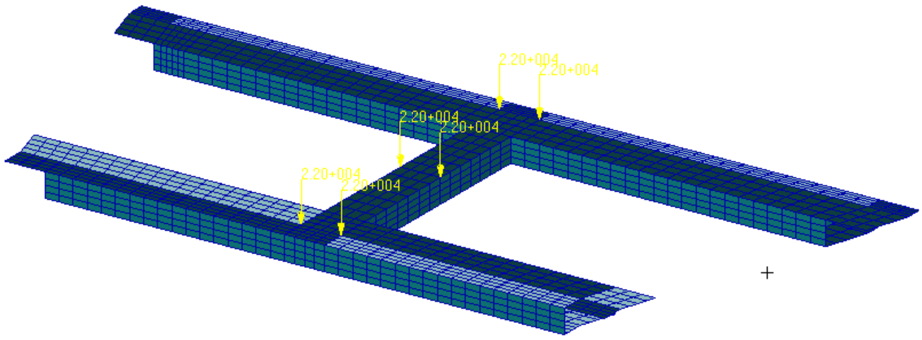


Figure 134. Iso view load

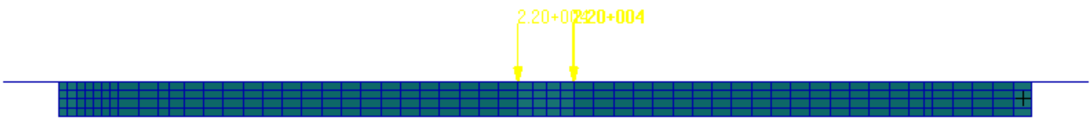


Figure 135. Front view load

We restricted the displacement in X, Y and Z, and also the rotation.

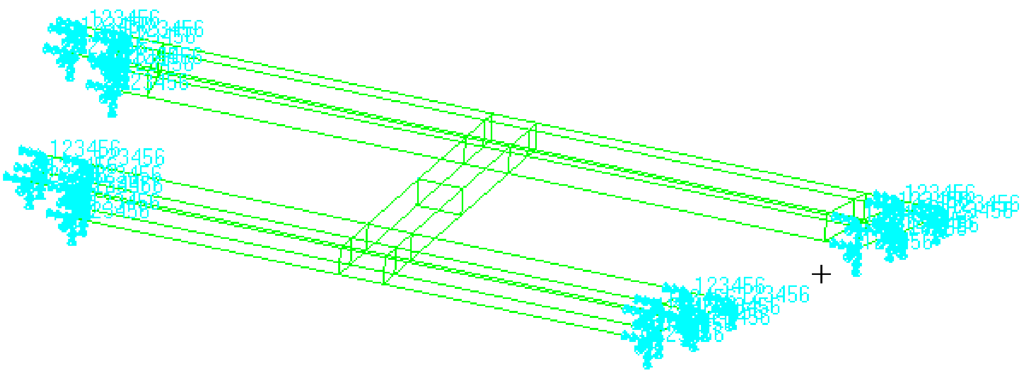


Figure 136. Iso view boundary restrictions

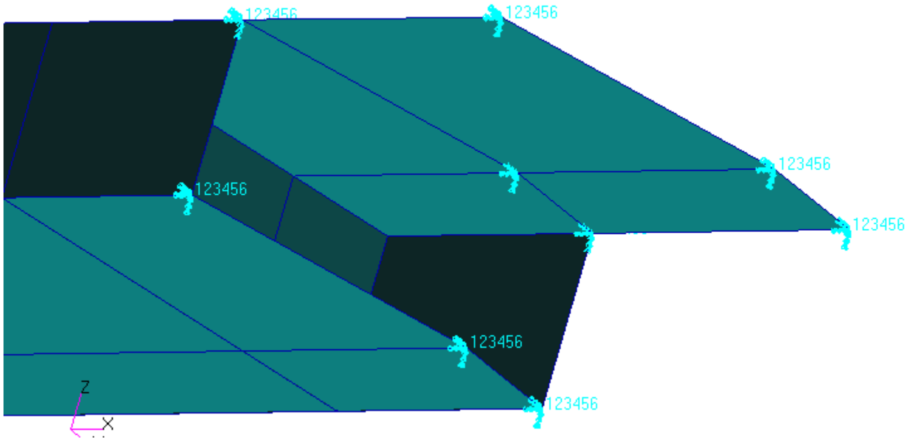


Figure 137. Restriction detail 1

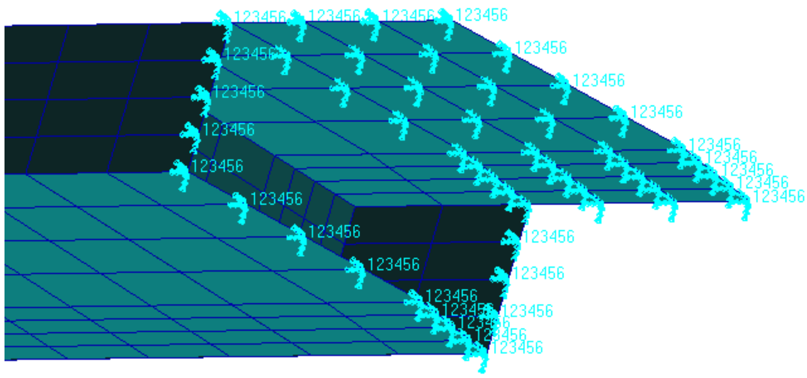


Figure 138. Restriction detail 2

9.4 Results

Stresses

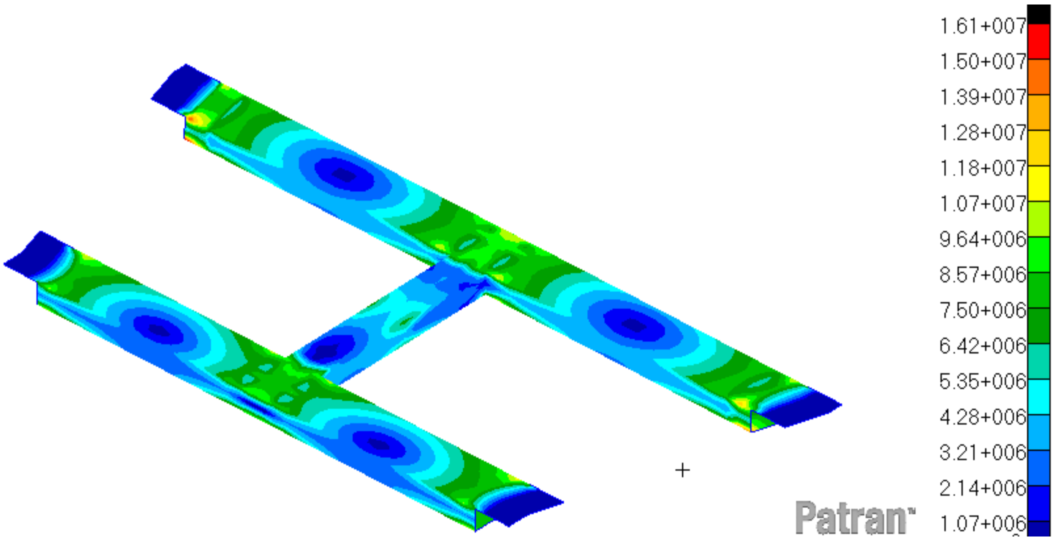


Figure 139. Max Von Misses stresses 16.1 MPa

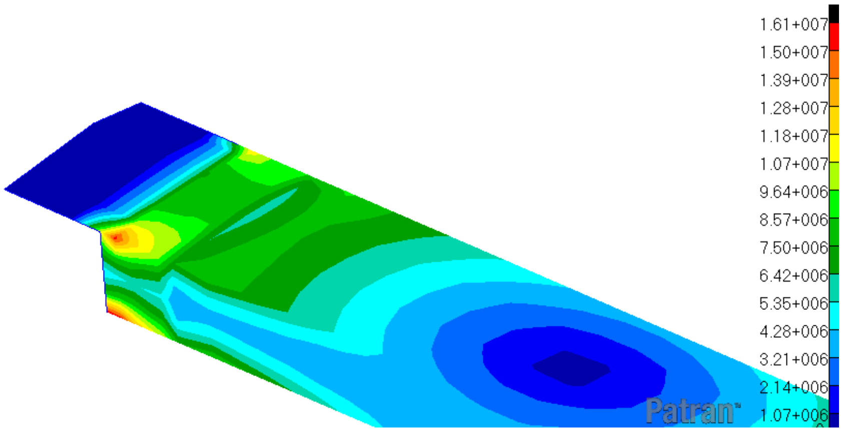


Figure 139. Detail Max Von Misses stresses 1

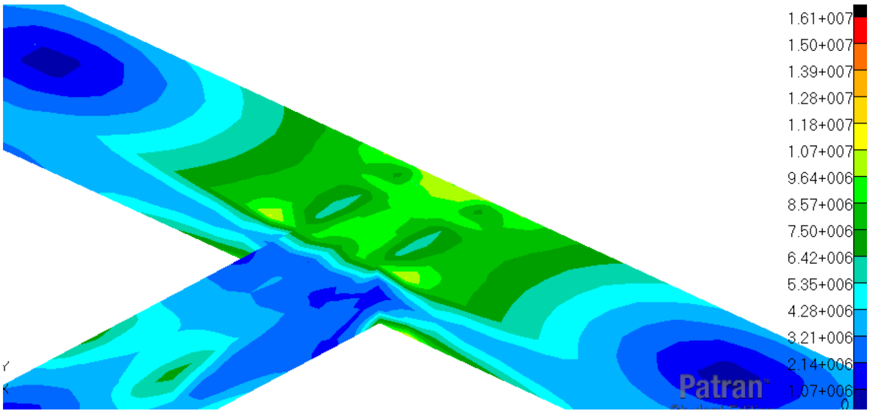


Figure 140. Detail Max Von Misses stresses 2

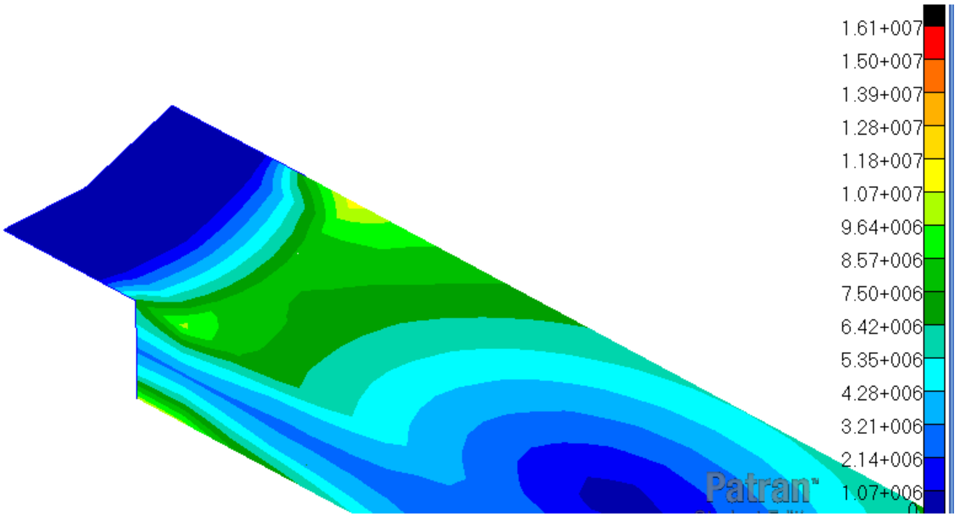


Figure 141. Detail Max Von Misses stresses 3

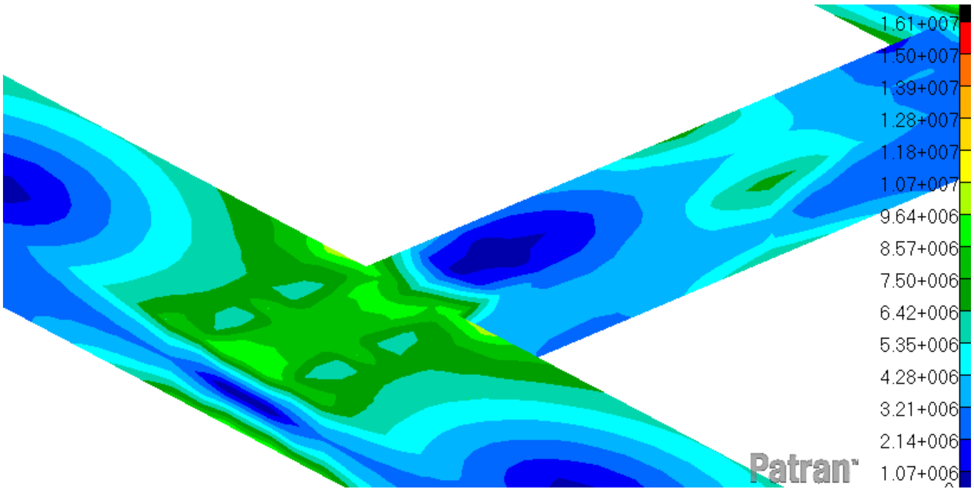


Figure 142 Detail Max Von Misses stresses 3

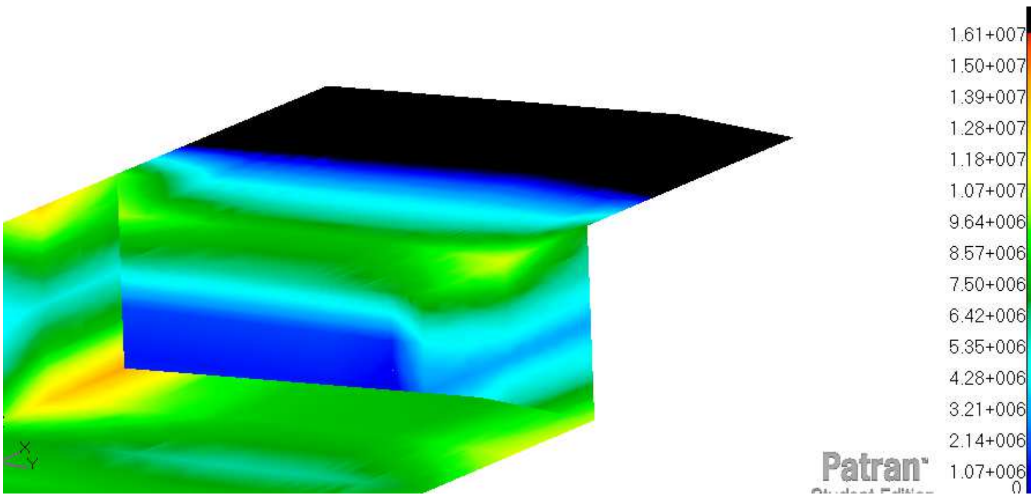


Figure 143. Detail Max Von Misses stresses continuous

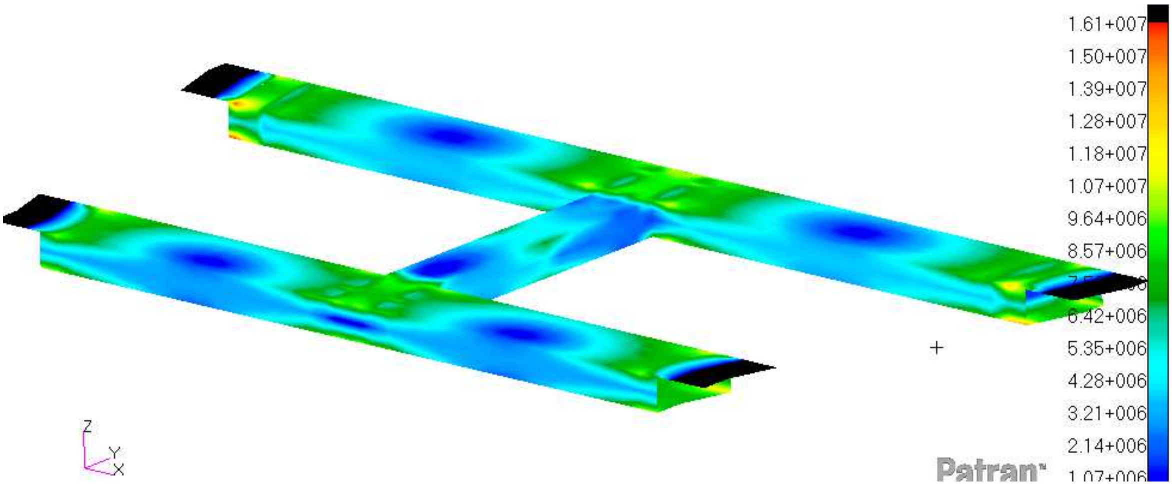


Figure 144. ISO view Max Von Misses stresses

Constrain forces

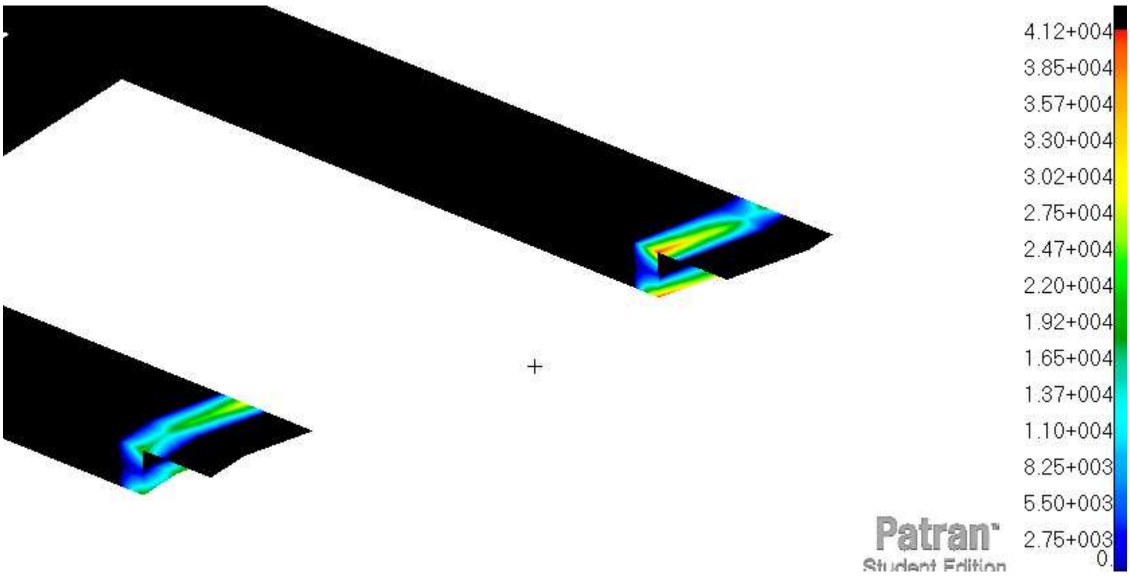


Figure 145. Constraint forces

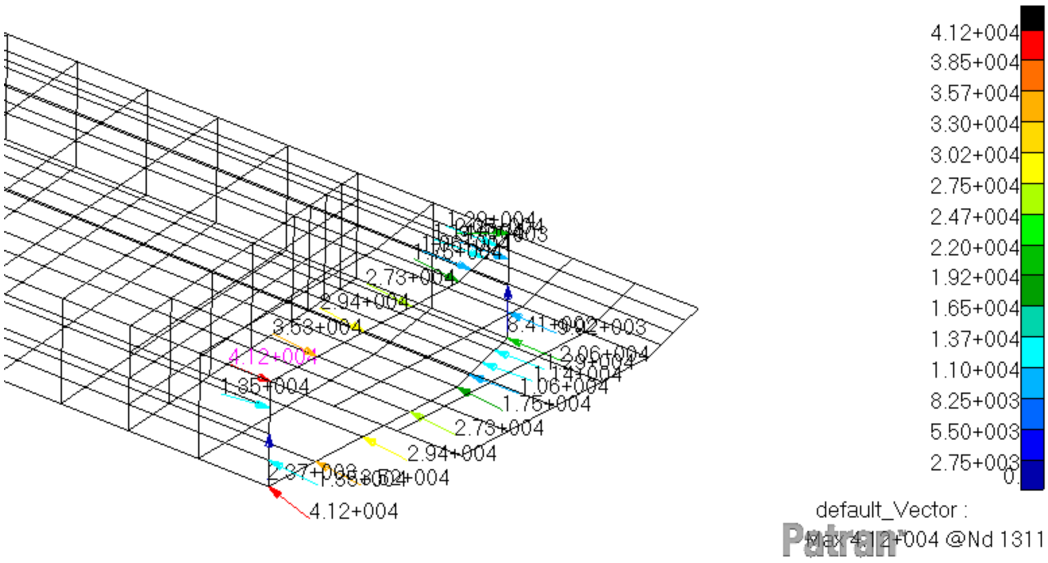


Figure 146. Vector constraint forces .Back Support

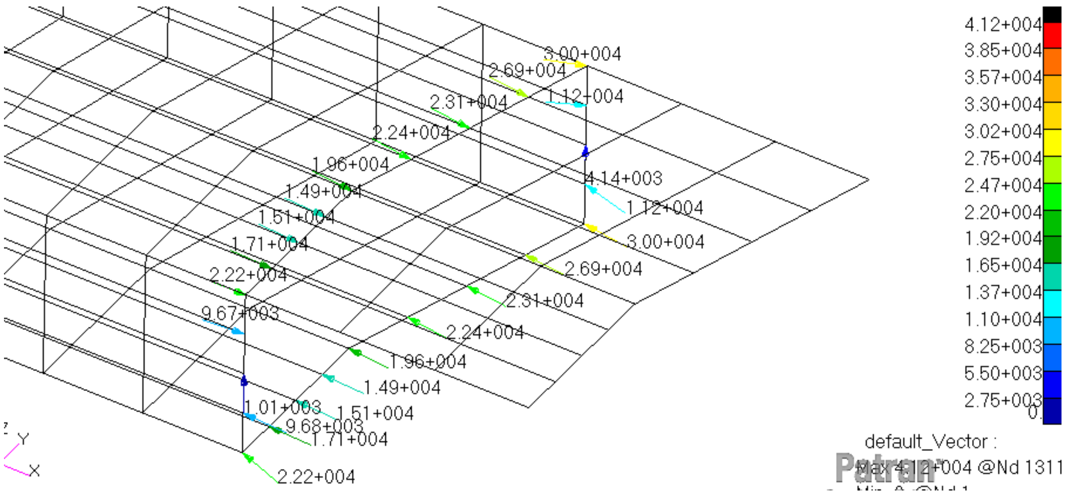


Figure 147. Vector constraint forces .Front Support

Deformation

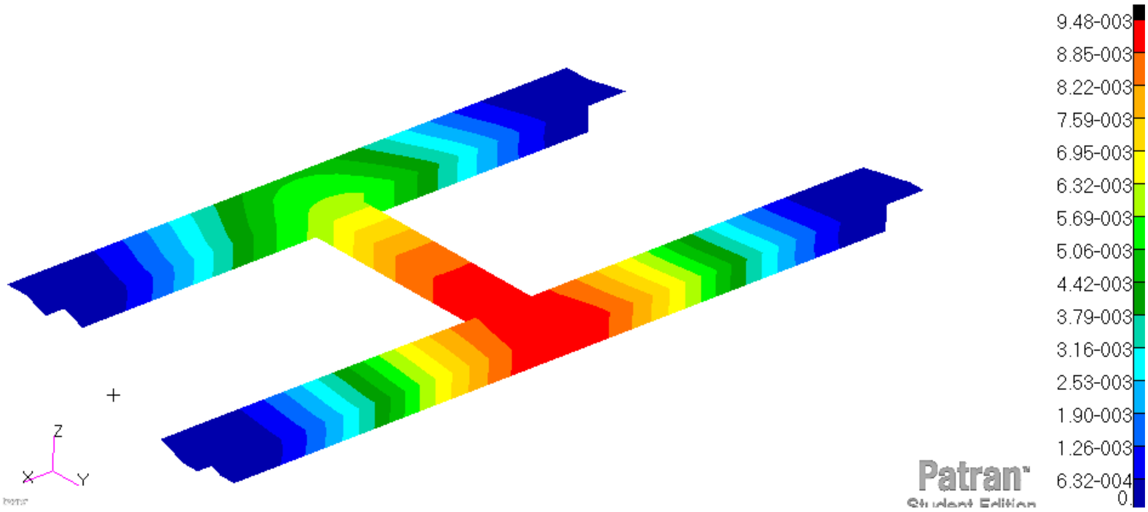


Figure 148. Displacements ISO view (9.48mm)

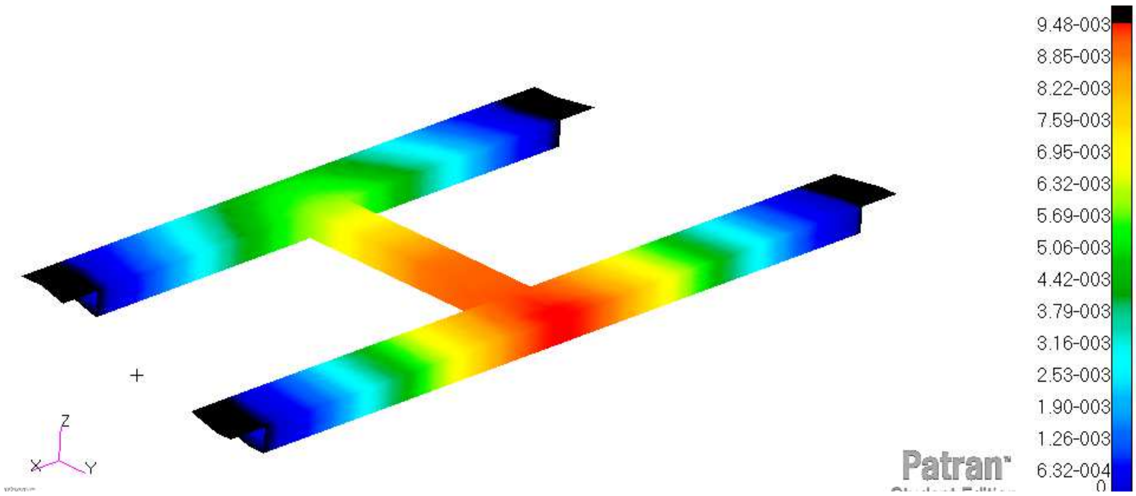


Figure 149. Displacement ISO view continuous

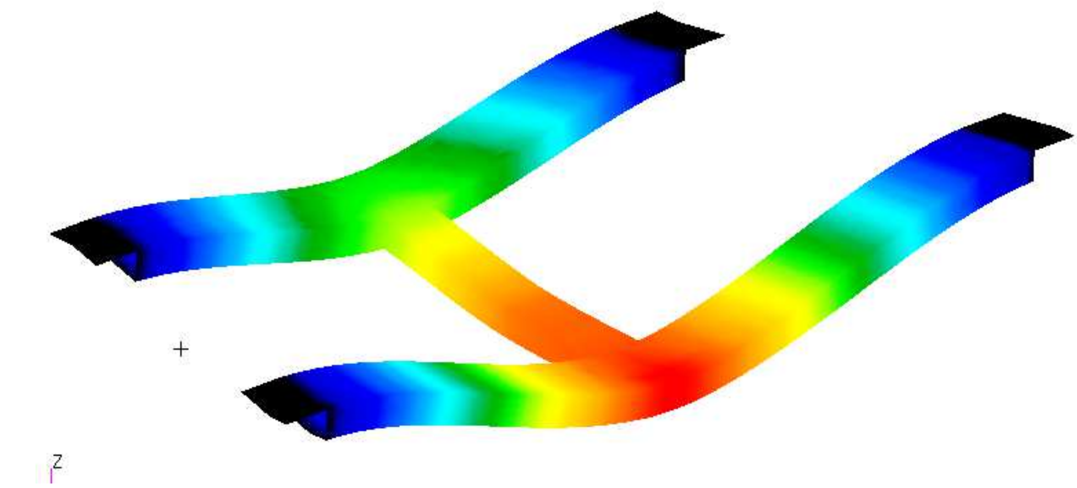


Figure 150. Displacements on deformed structure

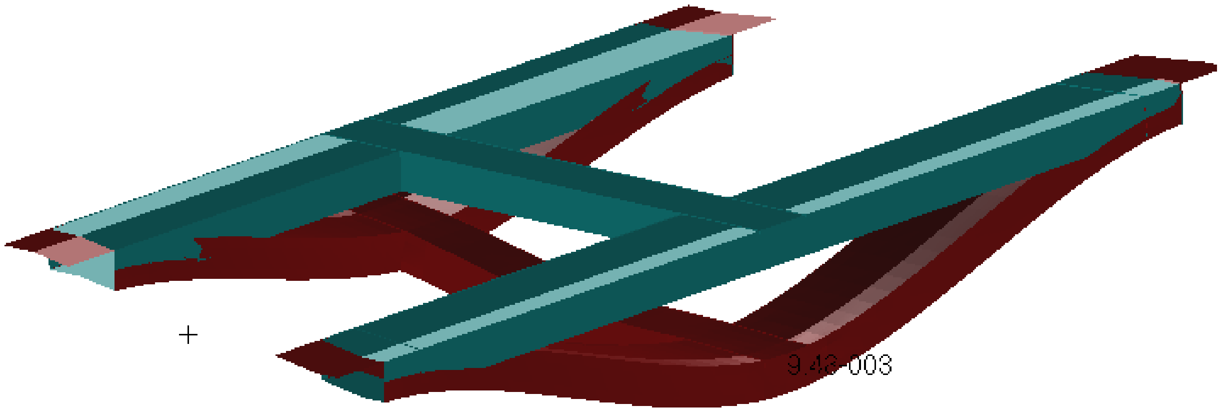


Figure 151. Deformed and original 1

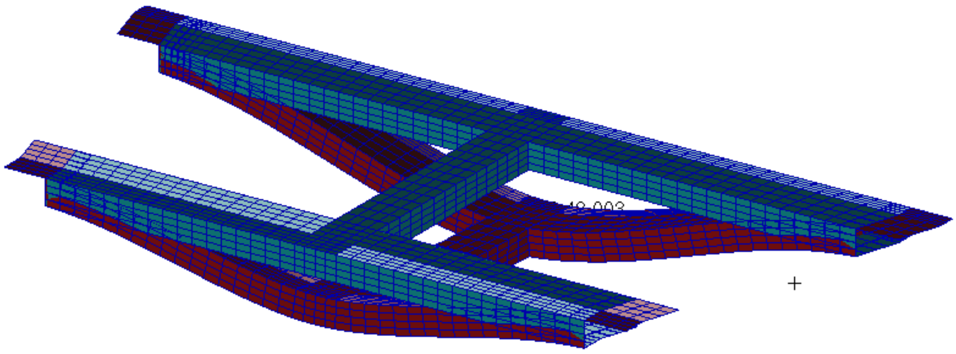


Figure 152. Deformed and original 2

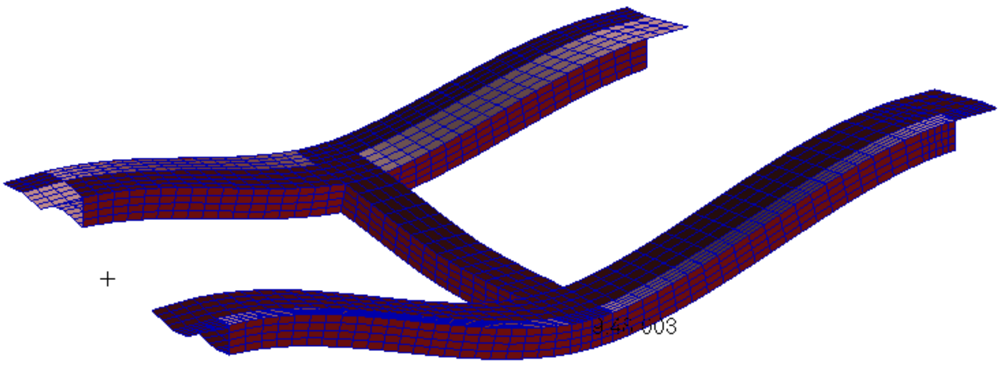


Figure 153. Deformed

10. ASSEMBLY

An important requirement was the assembly into the cabin. It is divided of the structure into three different parts, the right and left side assembly, and the top assembly. The right and left side assemblies are symmetrical.

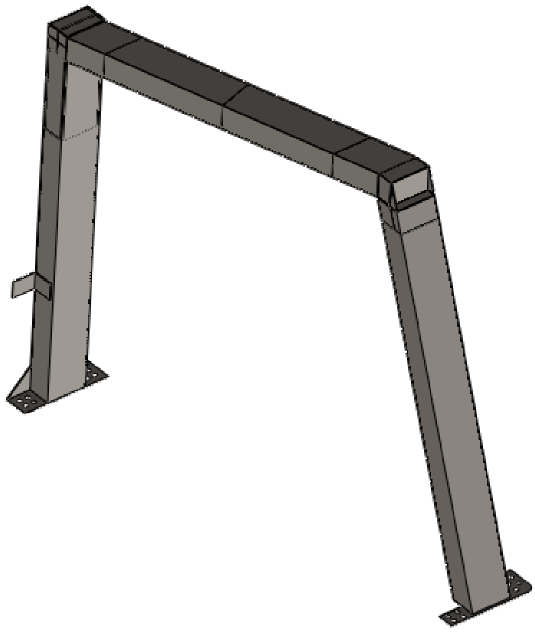


Figure 154. Right side.

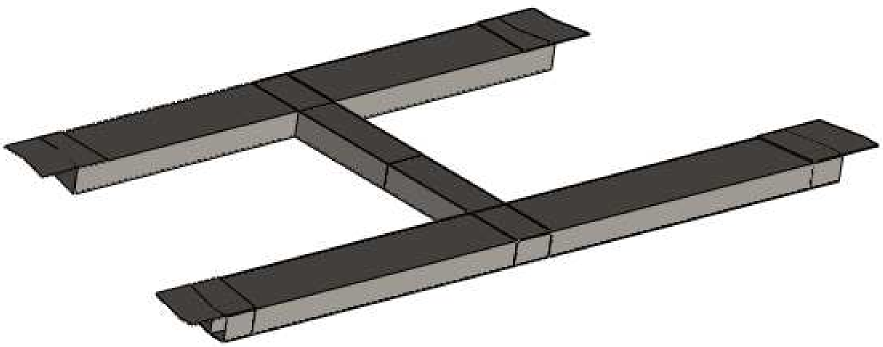


Figure 155.Top part

Initially, we checked that all parts were able to be filled into the cabin when introducing them through the door. Below, are the main measures of the door, and the assemblies, to check that there is no problem when fitting the structure into the cabin.

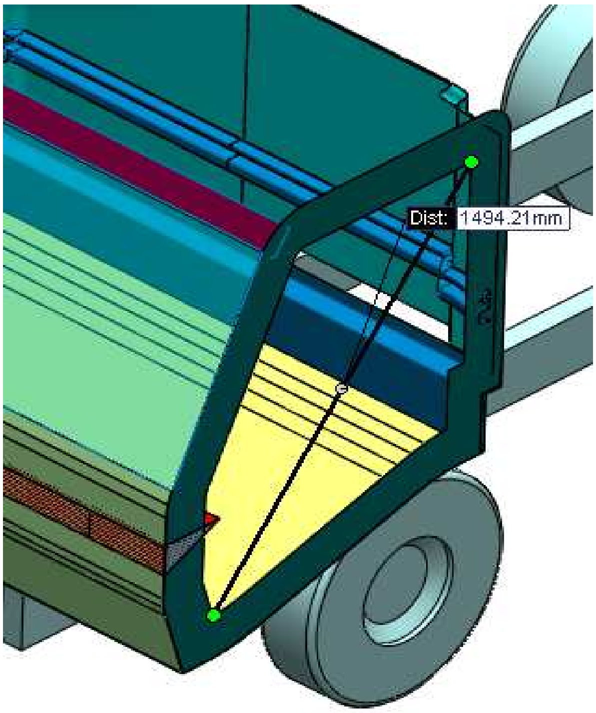


Figure 156. Door measure (1494mm)

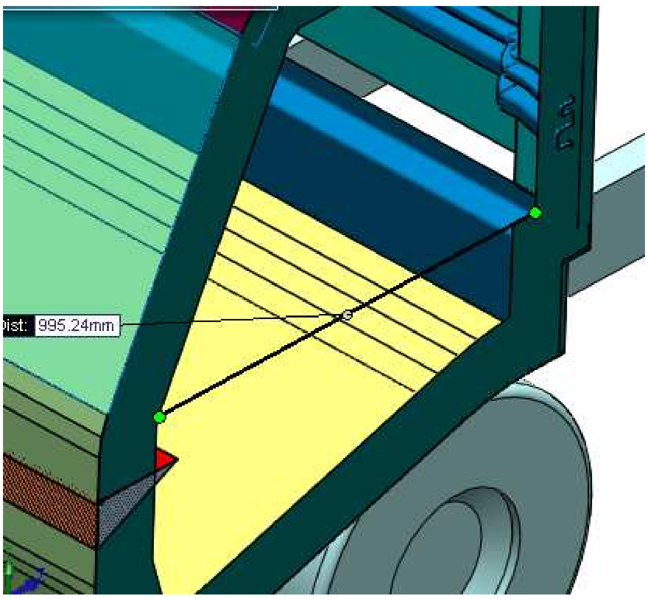


Figure 157. Door measure (995mm)

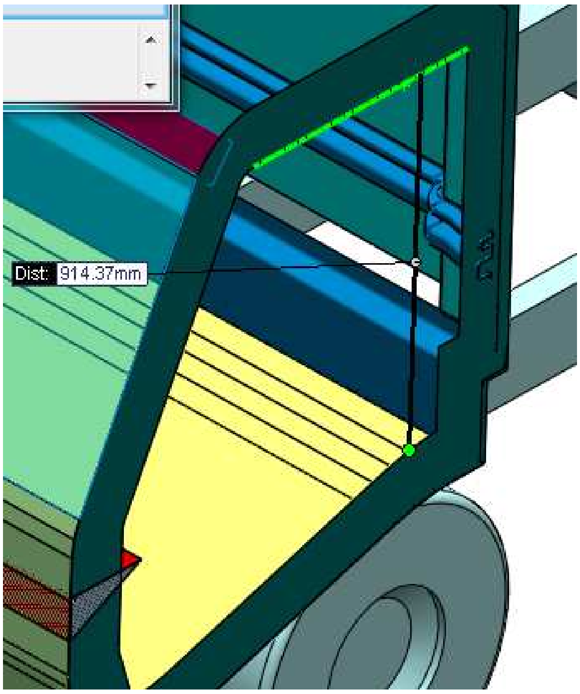


Figure 158. Door measure (914 mm)

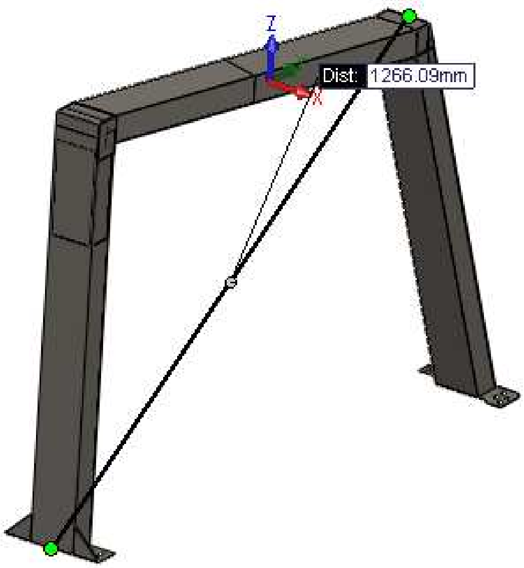


Figure 159. Right side measure (1266mm)

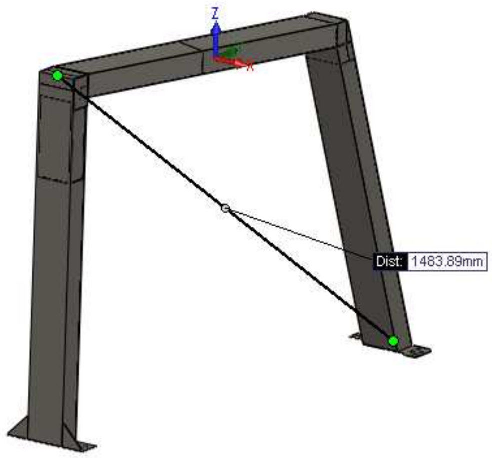


Figure 160. Door measure (1483mm)

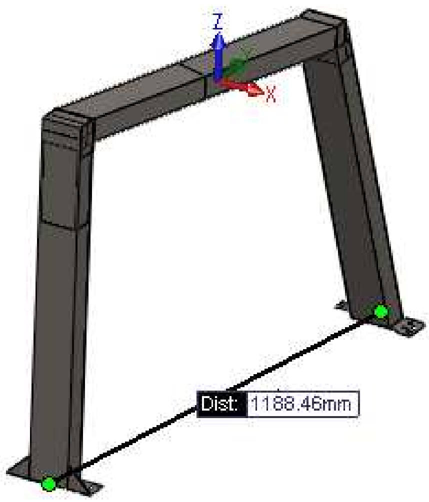


Figure 161. Door measure (1819mm)

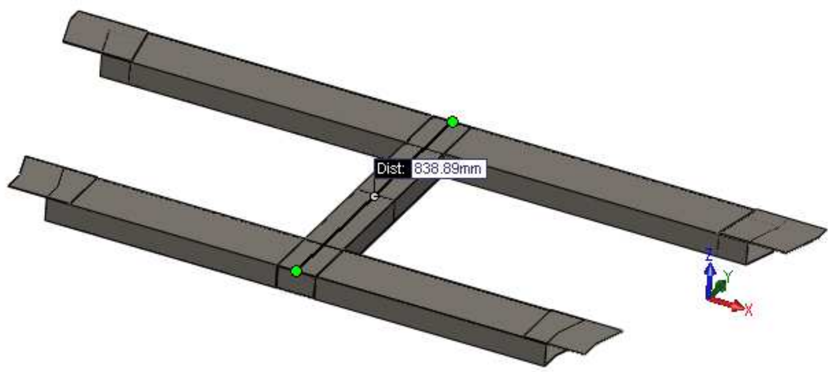


Figure 162. Door measure (840 mm)

As we can see, the main dimension of the right side assembly is 1483mm, which less than 1493 mm that is the longest dimension of the door.

The longest top part measure is 840 mm, under the 1493mm.

First, we fit the right side assembly (or left, it doesn't matter) into the cabin. It is bolted to the back part, as was explained before.

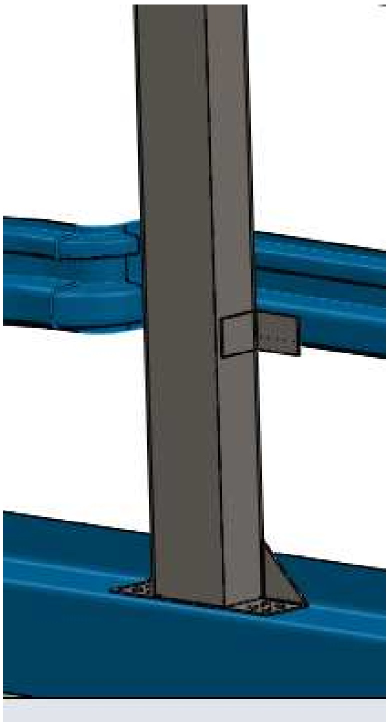


Figure 163. Right side bolted to back part

Once one side is filled and bolted to the top part, the other side is filled into the cabin and bolted to the top part and the back part.

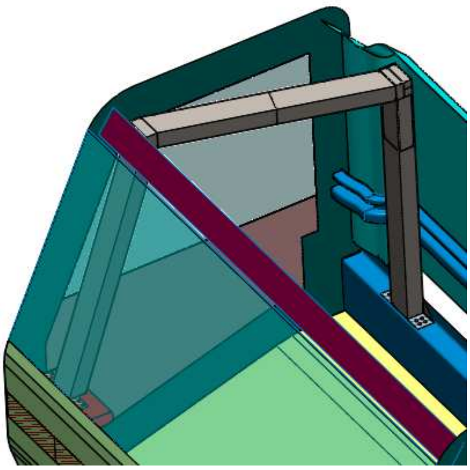


Figure 164. Fit into the cabin left side

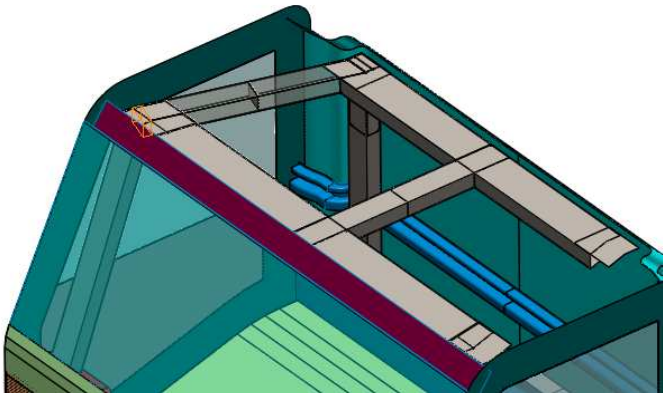


Figure 165. Left side and top side bolted

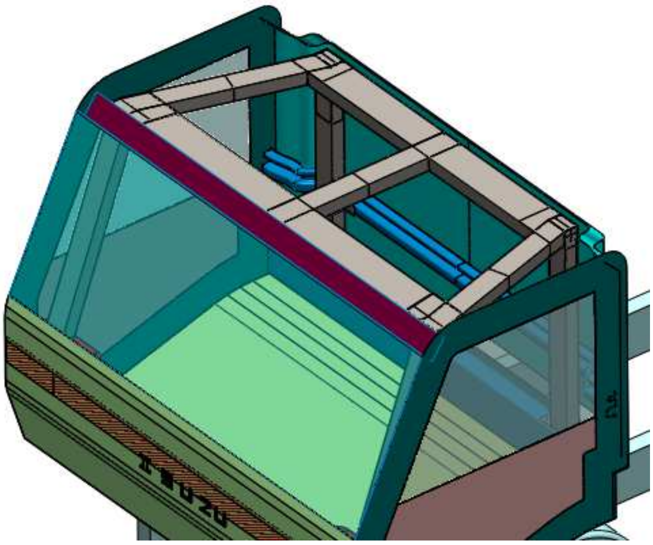


Figure 166. Final assembly

11. STANDARDS

- AS/NZS 1252 High strength steel bolts with associated nuts and washers for structural engineering

- AS/NZS 3679.2 Structural steel. Welded I sections

- AS/NZS 4600 Cold-formed steel structures

- AS 4100 Steel structures

12. CONCLUSIONS

The aim of this project is to ensure the safety of the occupants in the cabin. The maximum deformation allowed in our model is 40mm, so all calculations had to be under this value.

We have been working with two different software's, SOLIDWORKS, and NASTRAN PATRAN. The first one has been very useful for the design and to have a main idea about what is happening in our model. The stresses obtained with this software are not accurate enough, but nevertheless, we can see that the stresses are not over 335 MPa, and also the displacements obtained are less than 40mm.

The maximum stresses obtained with that program are under 355 Mpa, and just in some points the stresses are bigger, but it is something that we don't have to worry about.

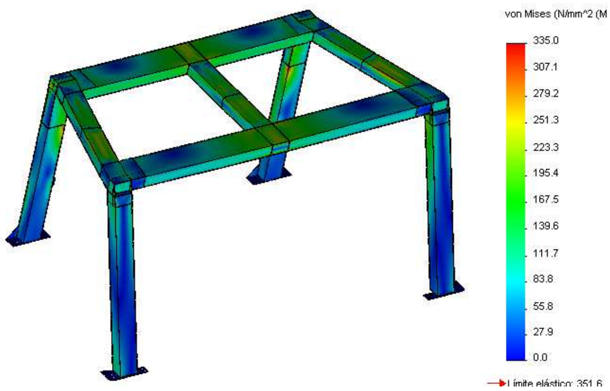


Figure 167. SOLIDWORKS stresses

The maximum displacement obtained is 9.25 mm, in the case that the load collapsed into the cabin from one side.

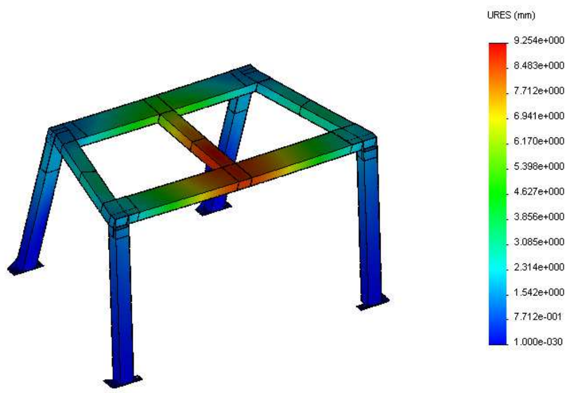


Figure 168. SOLIDWORKS displacements. Side load

The displacement is larger if we consider that the load falls on the front part. It is about 13.13mm.

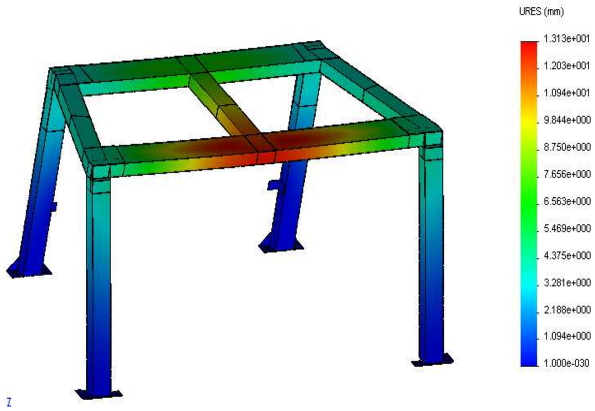
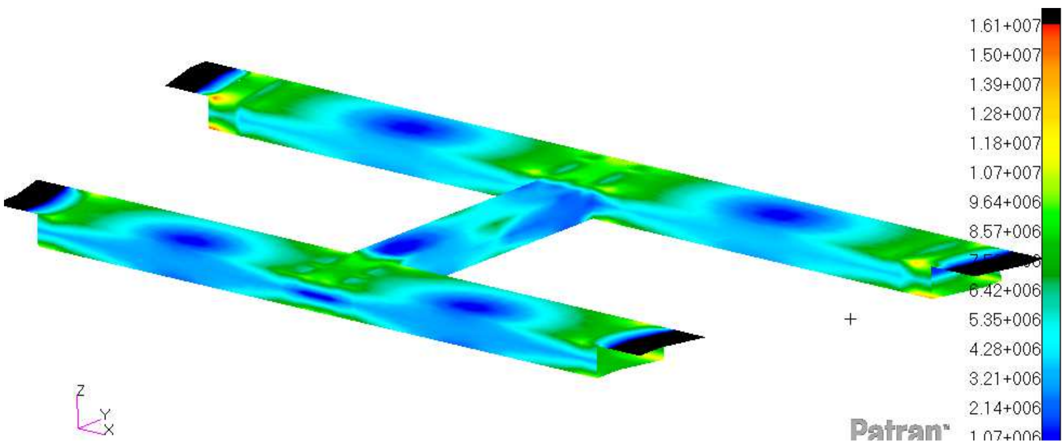


Figure 169. SOLIDWORKS displacements. Front load

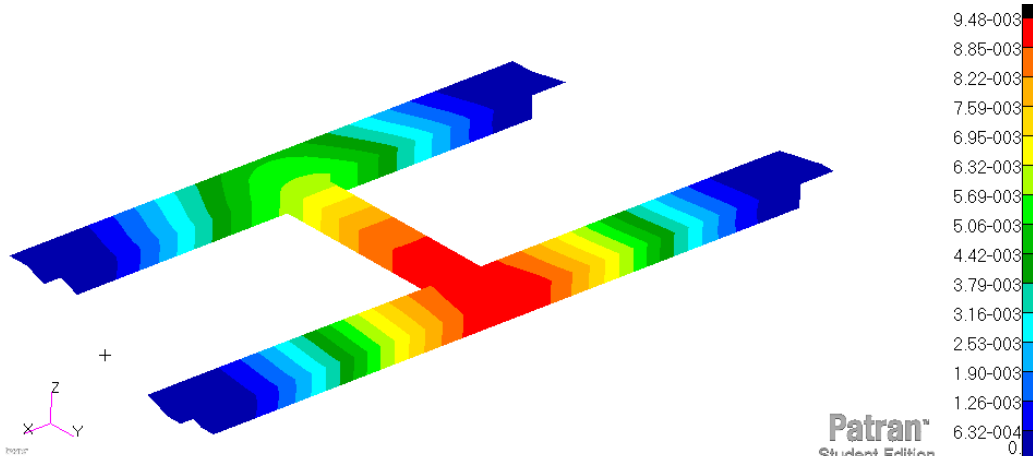
Those calculations have been made with SOLIDWORKS, and we can see the displacements and the stresses obtained are correct.

The second calculation was the top part, as it is such an important part in this model. It was important to check the displacements with an accurate program. We worked with NASTRAN PATRAN.

As we can see, the main stresses obtained by Von Misses are 16.1 MPa.



And the displacements obtained are basically equal to the displacements obtained with SOLIDWORKS. With NASTRAN PATRAN the maximum displacement obtained was 9.48mm



In conclusion, it can be said, that the results satisfy the specifications that were required.