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FIBREGY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952966.

Technology, validation and demonstration

D6.4 (WP6): CONSTRUCTION OF THE W2POWER REAL SCALE DEMONSTRATOR

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Executive Summary

This deliverable deals about the production of a section of the column D of the W2POWER windmill.

It explains all the production process for this large part.

It enlightens the challenges faced and the process improvement revealed by the building to scale 1:1 of such a large part.

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1. INTRODUCTION

This document is introducing the building of the column D demonstrator. This demonstrator is a scale 1:1 part of the offshore platform on which the windmills are set. The red square on the picture hereunder represents the demonstrator in its context.

Figure 1 : context of the column D

2. DESIGN AND TOOLING

2.1. Studies

The process of building starts with the studies for the building method. The inputs are the design drawings from WP4. It's important to underline that this demonstrator is a ¾ slice of the real part. A second important issue is that this demonstrator is to be visited by about 50 persons during the industrial day. So the first step was to ensure the safety of the visitors by integrating a structural squeleton.

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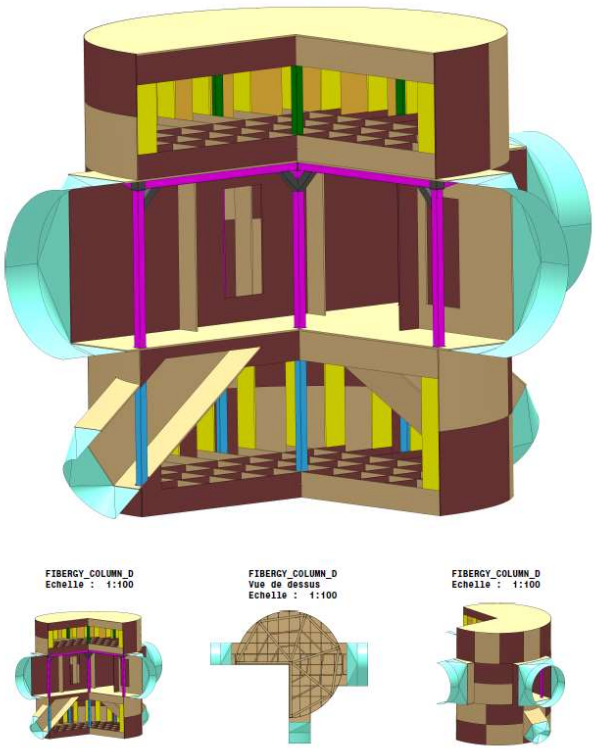

Figure 2 : 3D model of the demonstrator

This integrity of this structure was checked by finite element calculation to be sure that the weight and the vibration generated by the visitor cannot make it colapse.

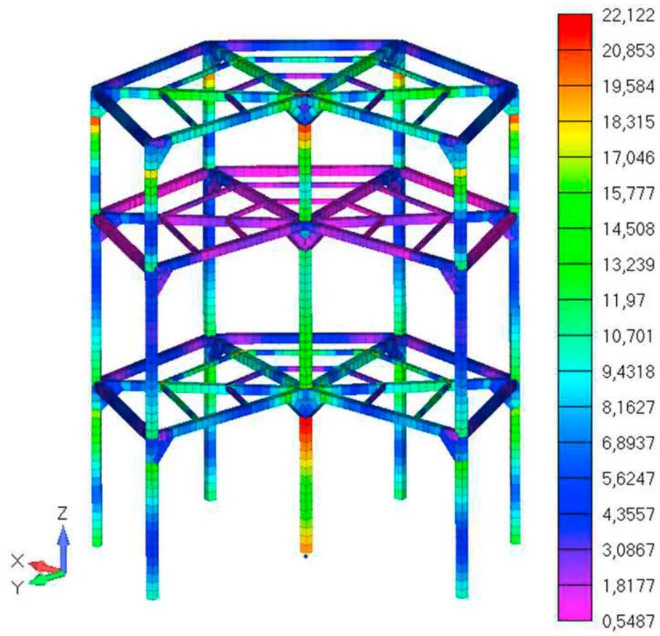

Figure 3 : Finite element results

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Once this step was validated, the building process and the assembly of the parts have been set. The connections lines between the parts known, the mould design could start.

2.2. Mould design

iXblue has worked with female mold. Regarding the number of composite parts to be done, the type of mold chosen was simpler than production molds, which are long and expensive to build. This simpler version doesn't need master part to build the mold.

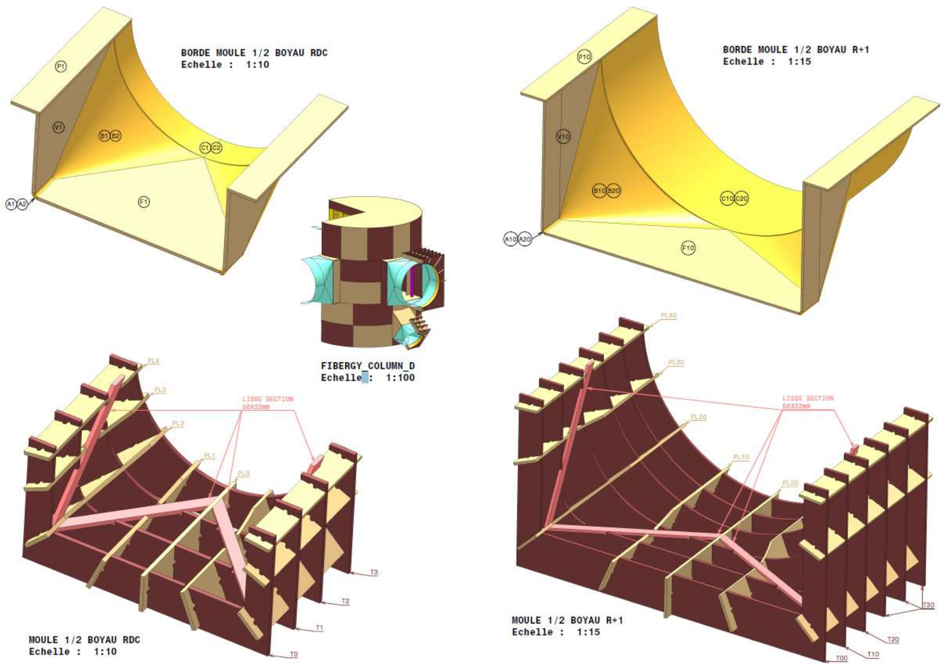

Figure 4 : Mold design

All the molds are designed with 3D software. The 3D files are following all the steps of the production.

2.3. Mould building

Once the mold is designed in 3D by the design office, the file is forwarded to the computer numerical cutting department. The 3D files are converted and coded into files that can be read by the numerical machines. Moreover, the design should be post treated to be adapted to the dimensions of the raw material. For example, the flat parts should not exceed the standard dimensions of plywood panels. For larger parts, it should be an assembly of "small ones".

Figure 5 : 3 axes CNC cutting machine

Once all the parts of the “puzzle” are ready, the building of the mold structure can start.

Figure 6 : Mould structural panels

The design was made to have a self blocking geometry of the structure. Each part is participating to the general stability of the mold.

Then the mold structure is covered with several layers of soft ply wood. The orientation of the wood fiber is very important to ensure a smooth surface. The wood surface is laminated to give more strength to the mold and allow a production of several parts using the same mold.

Figure 7 : Structural part of the mould

The finish step is made of fairing to erase the local defects, primer and paint to have an air tight mold. Then the surface is polished to erase the orange skin. In the case of parts made by infusion it is mandatory to have an air tight mold.

Figure 8 : Mould finishing

Once the vacuum test is validated, the mold can be waxed. The waxing system depends on several parameter such as the temperature, the type of resin, the type of process…

For this project, semi permanent liquid wax was used in 5 steps.

3. COMPOSITE PROCESS

Several composite process can be used to realize the parts. Each of them has advantages and constraints. They are detailed in the next lines.

3.1. Infusion process

Infusion process has quite a lot of advantages for large parts production. Most of them are the following:

- Very large parts (several hundred m²)
- Low investments (mother nature is making the pressure on the parts)
- Composite with good mechanical properties
- Monolithic or sandwich parts
- Integration of interfaces
- Ratio fibre/ resin constant
- Very short exposure to chemical products for the workers
- low weight of manufactured parts

In regard to the advantages listed above there are some risks. The main one is that the infusion of the resin is a one shot process. If there is a mistake during those critical hours the part can be lost.

The larger the part is, the bigger the risk is.

Many details of the process, like vacuum quality, depends on the workers skills.

Figure 9 : large infusion

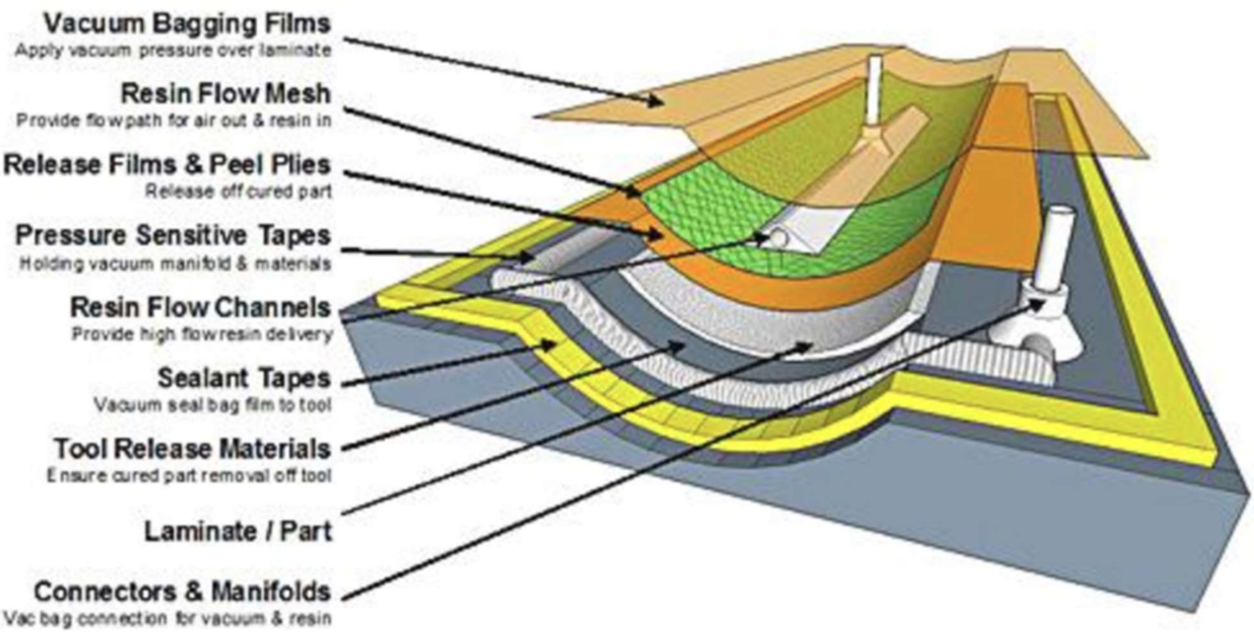

Figure 10 : infusion process

3.2. Filament winding process

The filament winding process is dedicated to parts with a cylindrical geometry due to the fact that the part and its mold are rolling and the fiber deliver system is only making translation. The investment is quite expensive due to the machines and the tooling.

The mechanical properties and the ratio resin / fiber are good. The parts can be done in monolithic only.

Figure 11 : Filament winding machine

This process was not used for the demonstrator because of the consortium was not equipped with this type of large machine.

3.3. Hand lamination

This process, consist of using resin with a roll or a brush and applying directly on the fabric.

The ratio resin / fabric is not optimal as there is too much resin. The quality directly depends on the workers skills.

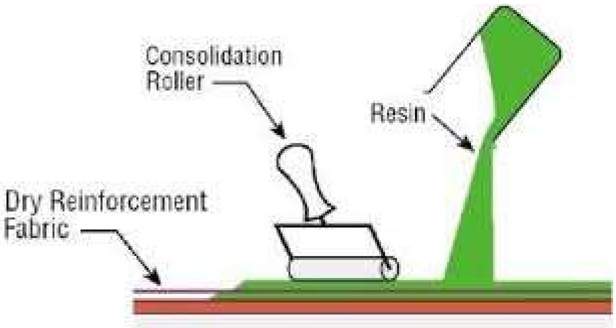

Figure 12 : Hand lamination process

The hand lamination process is used for all the connections area during the assembly process.

4. COLUMN D PRODUCTION :

The first step of the production was to build the representative parts with their scantling.

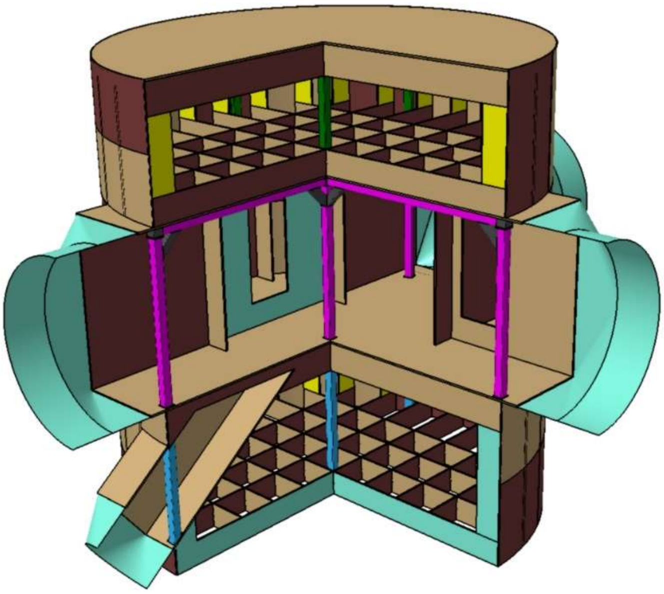

Figure 13 : representative parts

Due to the shape of the demonstrator, the tubes were made by halves. Some of them were assembled to have a full tube where it was needed.

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Figure 14 : Half tube under vaccum

Figure 15 : large tube completed

The safety structure was built first. It ensures a total safety for the workers and the visitors. Moreover, it gives the possibility to the designers to cut a part of the column D to give a full view of the inside without modifying the design.

Figure 16 : safety structure

Then all was hidden in the demonstrator's structure.

All the parts were fitted with the main structure by hand lamination process. The parts are trimmed edge to edge, bonded and then the interior and exterior faces are laminated to ensure a strong connection.

Figure 17 : Tubes connected to module D

The lifting of the parts is done with a crane. The immobilization time of the crane in position is to be considered. For a metal structure as soon as the welding is done, the part can be free from the crane. For a composite structure the curing time is generally about 24 hours. Therefore, during this time the part shouldn't move.

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Figure 18 : Column without finishing

Once all the structure is completed, the last steps are the outfitting with the handrail's integration and painting.

Figure 19 : pad eyes for safety line

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Some outfitting parts were added for the safety. Metal parts can be bonded on the composite or can be bolted. The area for outfitting should have the right density to ensure a good strength. It has to be in monolithic or with a densification for sandwich materials.

Figure 20 : global view of the demonstrator

The demonstrator has access to all the decks. It permits to the consortium to visit all the areas at real scale. Anybody involved in the process can face the reality of the building and the relevance or not of the choices made during the conception phase.

Figure 21 : view of the inside of the demonstrator

5. PROCESS REVIEW

The building of a demonstrator scale 1:1 lead to face the reality to the expectation of the building process. This implies to think about improved solutions.

5.1. Main cylinder

The best solution to produce the main cylinder is to use large filament winding. For the demonstrator it was not the selected technique as the shipyard is not equipped with this type of machine.

Figure 22 : main cylinder 3D and large filament winding cylinders

This type of part should be manufactured by a serial production which fits with the filament winding technique. It would avoid having large junction between two halves like for infusion process. The part would be stronger and faster to build.

Some very large systems are already producing thick monolithic parts. This would perfectly fit.

5.2. Tubes' connections

For the demonstrators, the tubes (in blue hereunder) were connected to roots by hand lamination system.

The aims would be to produce a maximum length of the main tubes inside the column D with filament winding process.

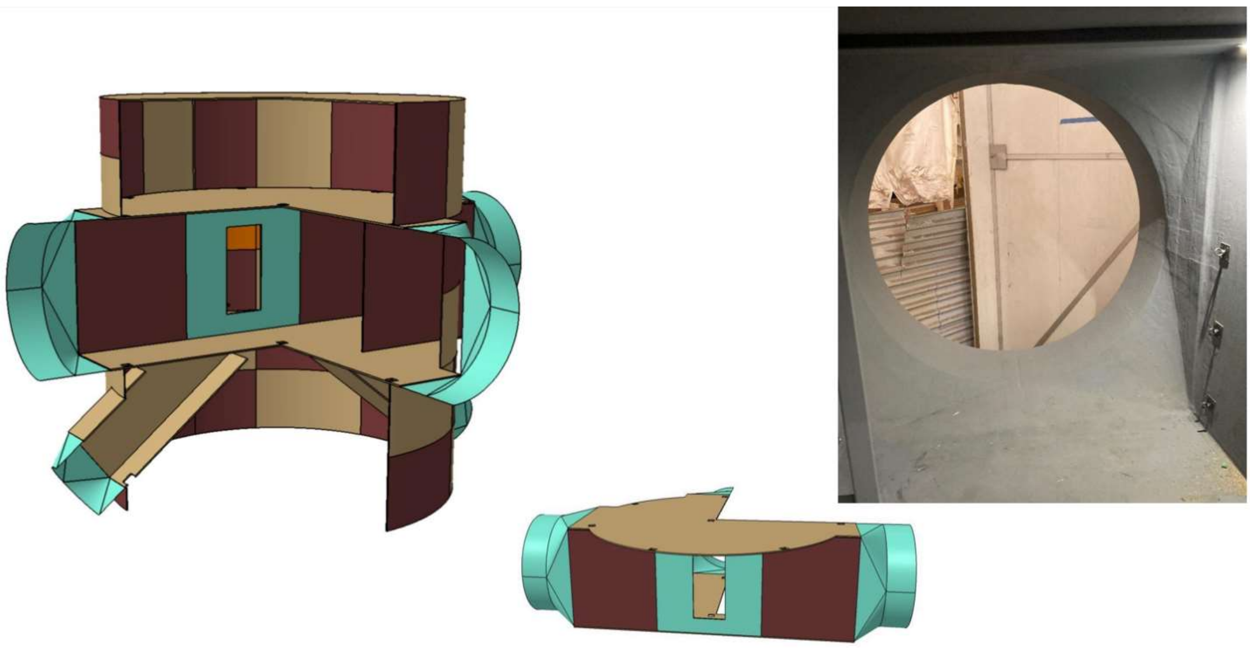

Figure 23 : 3D view the tubes and tube's connection the demonstrator

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We must keep in mind that the scarf process for connections, which is common for edge-to-edge connection, has a length of about 30 times the thickness. In our case this is making scarf of about 1.5 meter. Thus, we have to make less connection as possible, else the column D is going to be full of connection overlapping in all the areas.

5.3. Horizontal tube connections

The roots of the main horizontal tubes are going to be under large stress due to the swell. All the platform will try to twist. One solution to avoid stress concentration is to laminate a foam corner to have a connection smoother and increase the strength of this crucial connection.

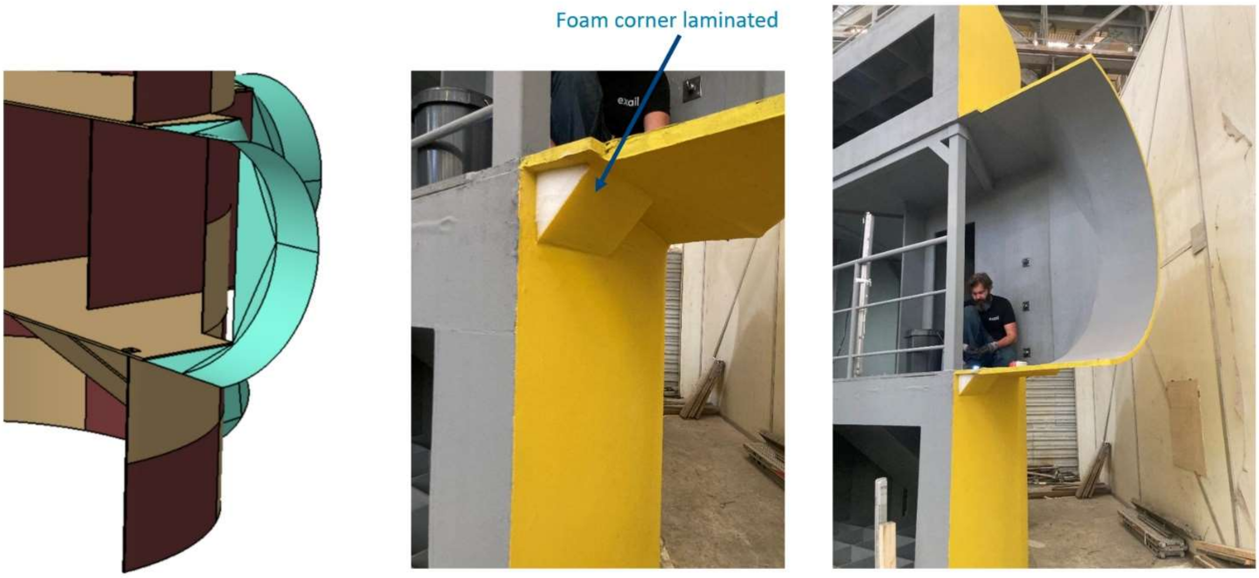

Figure 24 : example of corner lamination at the tube's root

5.4. Vertical structure

The structural priorities of the column D are the following.

- Main cylinder
- Decks
- Main tubes
- Vertical structure

When a structural part is interrupted by another one it creates a hot point regarding the stress transmission. Some structural details should be added.

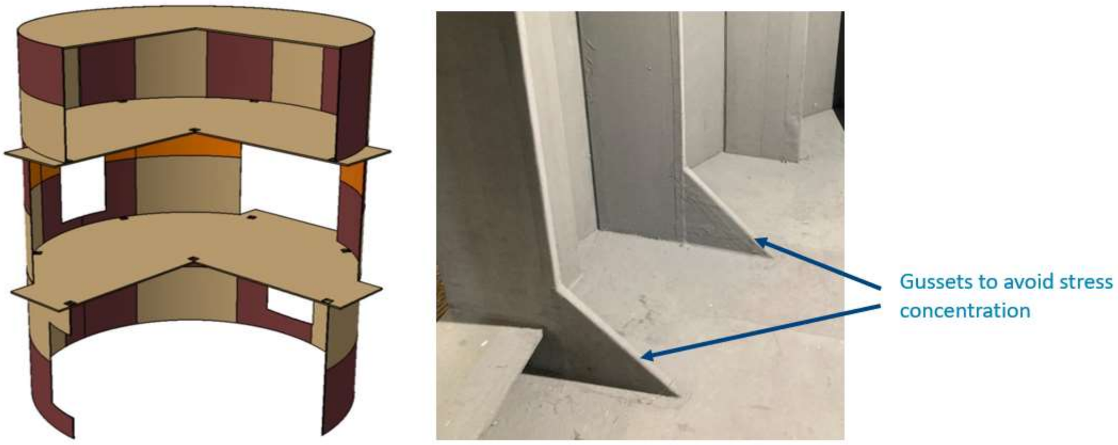

Figure 25 : vertical structure's gussets

Thus, the vertical structure is interrupted when crossing the deck. Gussets should be added to avoid stress concentration.

5.5. Deck crossing structure

Each deck is stiffened by a crossing structure to give more inertia.

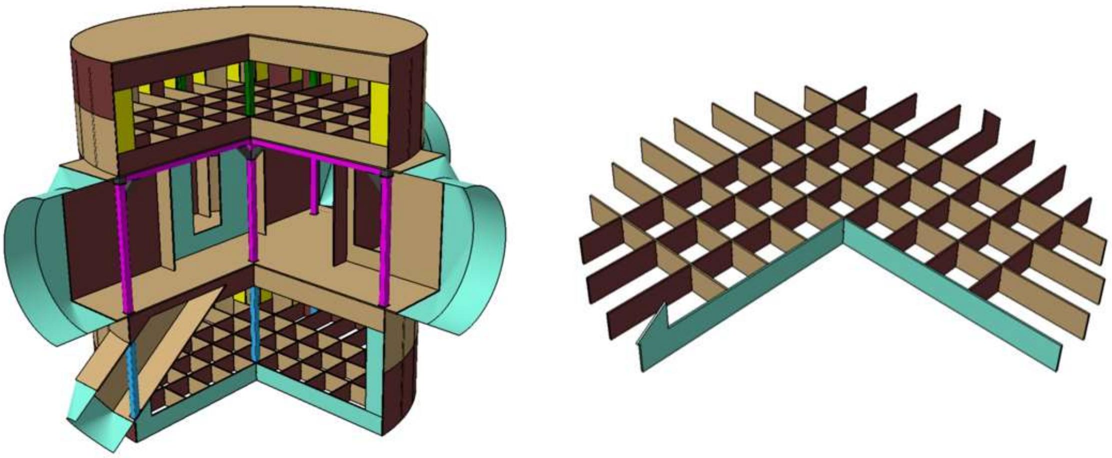

Figure 26 : 3D of the crossing structure

Making this structure with many small parts is not the right way as it would be very complicated to maintain the geometry.

The process developed is to have a CNC cutting of composite stripes. Each stripe has a half cutting to allow a fitting with other stripes.

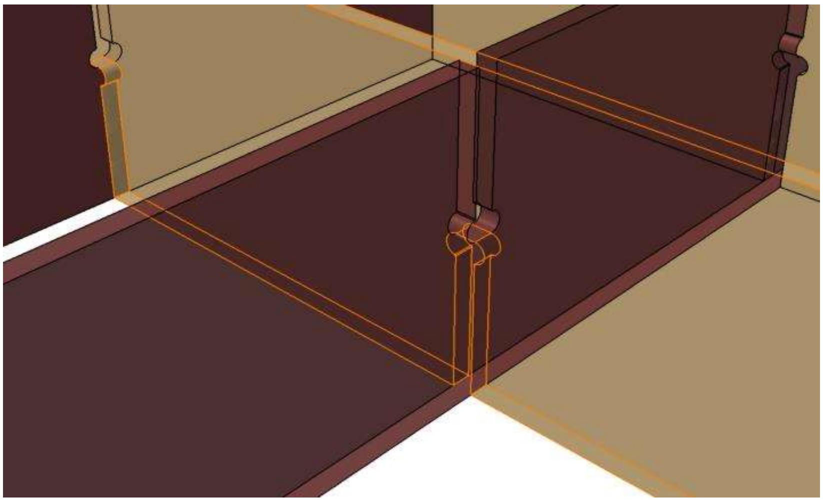

Figure 27 : half cutting 3D view

With this process the geometry is well maintained, and the connection can have a smaller scantling.

Figure 28 : process of fitting

Regarding the connection, two possibilities were set. The first one is to hand laminate the corners, but it could be time consuming, the second on is to bond "L" profiles in the corners.

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Figure 29 : connections possibilities

6. DELIVERY

The second industrial open day took place in La Ciotat and was the occasion to show the real scale column D demonstrator to the consortium.

Figure 30 : attendees of the industrial day in the demonstrator

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7. CONCLUSION

The building of the demonstrator was a challenge as it is an unconventional structure for the composite building. This type of structure forced us to think out of the box for many details and the real building is making the thoughts evolving again.

Finally, the module D scale 1 demonstrator was built and presented to all the consortium.

All the remarks and suggestions araised, such as different process or other designs, could be useful for a future project.