

Customized industrial halls in France

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1. Domestic Waste Treatment Centre / Fos-Sur-Mer

1.1. Wood as an alternative to steel

Former company Fargeot Lamellé-Collé, now part of Arbonis, asked our engineering office Arborescence to perform an alternative solution to a European call for tenders which included 80 000 m² industrial halls and office-buildings for the domestic waste treatment centre of the Marseille urban area, located in Fos-Sur-Mer. The specifications provided a steel framework only and we figured that about 54 000 m² could be efficiently replaced by various solutions of wooden construction.



Figure 1: 3D rendering of the project, S'PACE architectes



Figure 2: Aerial view of the construction

Then, Arbonis takes care of studies for the many areas where posts and beams solutions make the job for a total surface of 42 000 m², such as the "train station" covered by a roof 540 meters long and 40 meters wide.

Arborescence focuses on the «MAT-PRE» hall (Maturation and Pretreatment) along with a footbridge connecting office-buildings and industrial halls for the visitors for a total surface of 12 000 m². The design of these structures is based on wood trusses.

The hall is 200 meters long, 50 meters wide and 13 meters clearance below the roof and its structure. The architectural pattern includes a roof with a saw-teeth shape in order to maximize natural daylight in the hall through the vertical parts of the roof. The complexity of the industrial processing chain allows very few intermediate posts inside the hall.

The footbridge draws a square path between different buildings for a total length of 460 meters. It spans roads and is suspended to the hall's façade 9 meters above the ground in order to give interior views of the industrial processing chain.

1.2. Wood truss design for main girders, long spans and façade

Truss design is developed on every main wooden structure of the «MAT-PRE» hall and footbridge with the aim of cost reduction by optimising the members cross sections and minimizing their connections, all the same type multi-pinned through metal sheets.

Intermediate posts are settled every 18,75 meters beside the processing chain. As an exception, one post has to move 0,60 meter on one side due to the machinery occupancy. This has to be treated on elevation to recover the 3,75 meters main spacing. The solution for this only exception is to sit the main truss on a custom welded-steel profile.

The main trusses span isostatic on top of intermediate posts. They are half-inside half-outside the hall. Top-chord is outside and only covered with zinc works while bottom-chord is fully inside the volume, including the braces. For static concerns and efficiency in the connections, the chords are axially released at their free end and attached to the post at the other end where they meet the brace (see detail n°36 et n°37).

[illegible]

Détail 36

Assemblage Poutres treillis inter sur poteaux inter continus

Passage pour axe M30
Fe 49 et 50
poutres treillis 1 et 2

3 Boulons M12/250

Erous M36
Contre écrous

2x F117
Broches ø12/120
Tirefonds M12/160

F101

2 Appuis néoprène LB n°40

Détail 37

Assemblage Poutres treillis inter sur poteaux inter continus

This technical drawing illustrates the assembly of a truss beam on a continuous column. The assembly includes a horizontal truss beam with a top chord of angle iron (F116) and a bottom chord of channels (2xF127). The beam is supported by a vertical column. The connection details are as follows:

- Top Chord:** F116 (Angle iron).
- Bottom Chord:** 2xF127 (Channels).
- Fasteners:** 3 Boulons M12/260 (3 M12/260 bolts) are used to secure the top chord to the column.
- Welds:** Ecrous M36 (M36 nuts) and Contre écrous (Lock washers) are used to secure the bottom chord.
- Support:** 1 Appui néoprène LB n°1 (1 neoprene support LB n°1) is used to support the beam on the column.
- Additional Components:** 10 Broches Ø12/260 (10 Ø12/260 pins) and 2 Boulons M12/250 (2 M12/250 bolts) are also shown in the assembly.

Figure 7: Top-chord connection

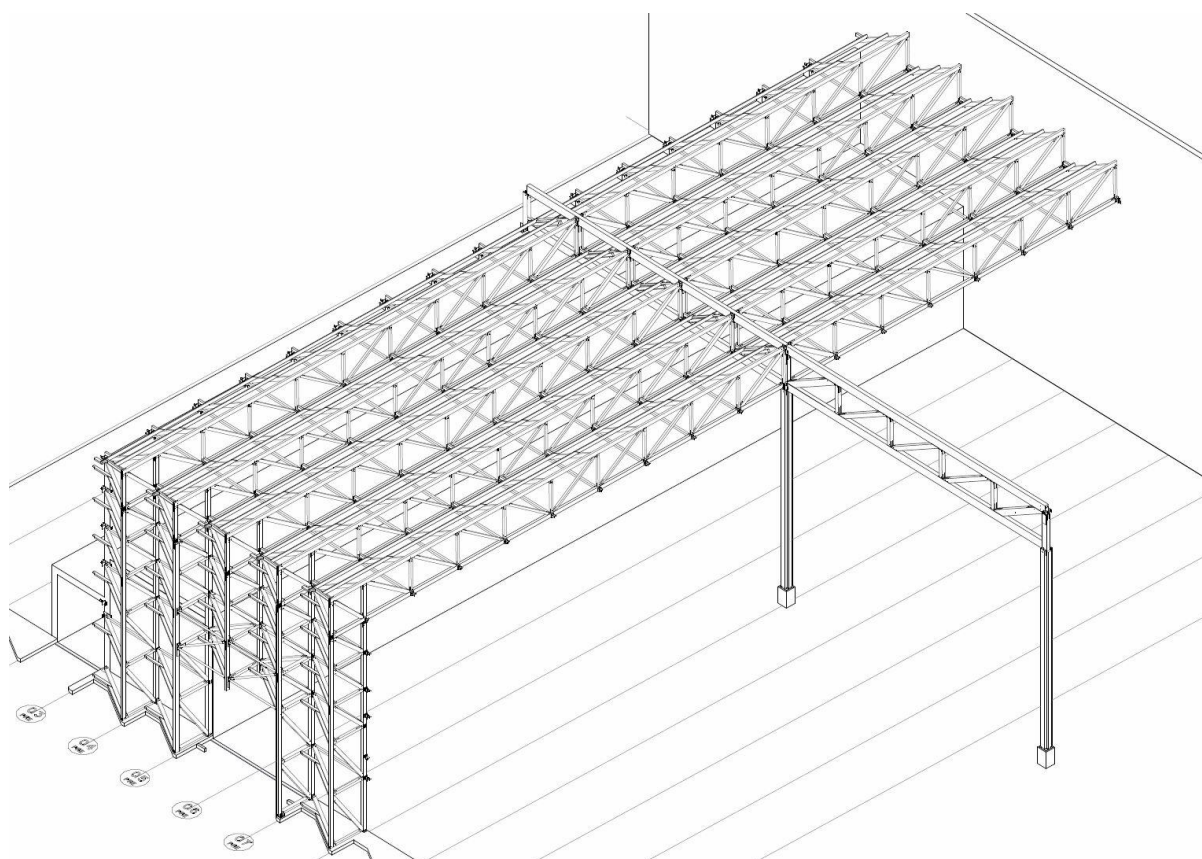


Figure 8: Axonometry – Intermediate posts, Main trusses, Long-span and Façade trusses

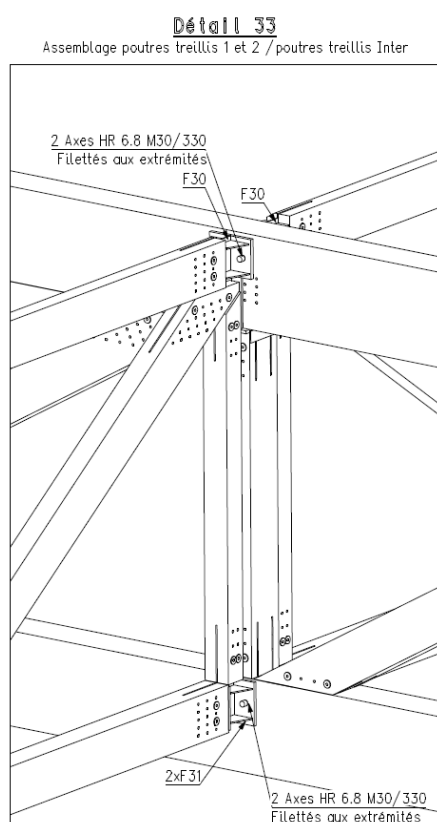


Figure 9: Connecting 2 long-spans through main truss

The long-spans crossing the hall's width are 28,70 meters and 22,60 meters long. The shortest span is attached to the concrete wall at the back. Snow piles up against the back wall and therefore, the shortest the more capable. In order to moderate its deformations, the largest span has to be connected in continuity with the shortest span through the main truss (see detail n°33), and also with the façade-truss.

The façade-truss provides support for the suspended footbridge by adding braces in a wooden frame below the footpath.

When it comes to be suspended above a front-door opening, the entire 3D structure works all together like a torsion-box. 2 additional members create a chord effect within horizontal planes (see front-door opening in Figure 8).

2. Fire & Rescue Station / Bonneville

2.1. Natural bending of LVL plates used for a catenary chord

When the architect draws a curve, the carpenter offers 2 different ways: bending or cutting its material on that curve. When Richard Plottier designs a curved floor plan to wrap the functional and optimum space required, I can see first the support panel for the roofing well cut on that curved edge, and I imagine a way of spanning that panel over the main hall. There is no more efficient way of carrying dead loads and equally distributed loads than the static of a catenary arch. Combined with the inherent tension strength of the LVL, due to its composition of scarfed multi-layers, its capacity to bend laterally makes it genuine for that use.



Figure 10: Inside view of the main hall



Figure 11: Axial view of the catenary chord

The performance of that concept is given with 2 parameters: the ratio $\text{Span} / H_{\text{stat}} = 17,5$ (here 28,00 m span for 1,60 m static height), and the stiffness allows to consider a more flat slope for draining off rain (here 2% construction slope for >1% final slope after snow).

2.2. Design

Hybrid catenary I section girder

The girder is a hybrid design of a catenary bottom-chord combined with a recomposed I section by connecting the support panel as a top-chord through vertical shear panels. This design allows a variation in length for every girder to bear on the curved façade. The length of the vertical shear panel is related with the span. The few connections and their simplicity make the technique cost-effective.

Support panel

The roofing support panel is a LVL-Q plate 63 mm thick in full width 2,50 meters and 14,00 meters long arranged with 2% slope towards the extremities. The side panels are jointed together with a nailed metal band along the edge to create a lateral bracing for horizontal loads, seismic and wind.

Catenary chord

The catenary chord is a LVL-S plate 75 mm thick and 0,40 m wide. The radius of bend is 93,50 meters which is only half the naturel bending of the plate under its own weight. The 2 halves are jointed together with a centre metal fitting including a left-hand thread and a right-hand thread to adjust the geometry of the girder very accurately.

Vertical shear panels

The vertical shear panels at each end of the girder is a pair of LVL-Q plates 69 mm thick and 3,30 meters long for the longest span of 28,00 meters. They are connected to the top-chord and bottom-chord by 4 rows of SFS screws and glued joint.

3D bracings

The round metal tubes Ø48,3 mm offer a distributed support to the top panel, bearing its load on the bottom-chord. The truss effect is very small and appears in case of asymmetric loads over the span. Alternate V parts are prefabricated and connected to the LVL plates with screws through a small metal sheet.

2.3. Static modelling

At the time we developed the project, the girder was modelled under Rstab including 3D to figure the lateral distribution in the support panel with 2 parallel top-chords. The vertical shear panel at each end of the girder was approximated with multi-braces (not shown below). The longitudinal shear between plates is equal to the values of the 3 steps in the axial forces in the bottom-chord, rather linear along the connection.

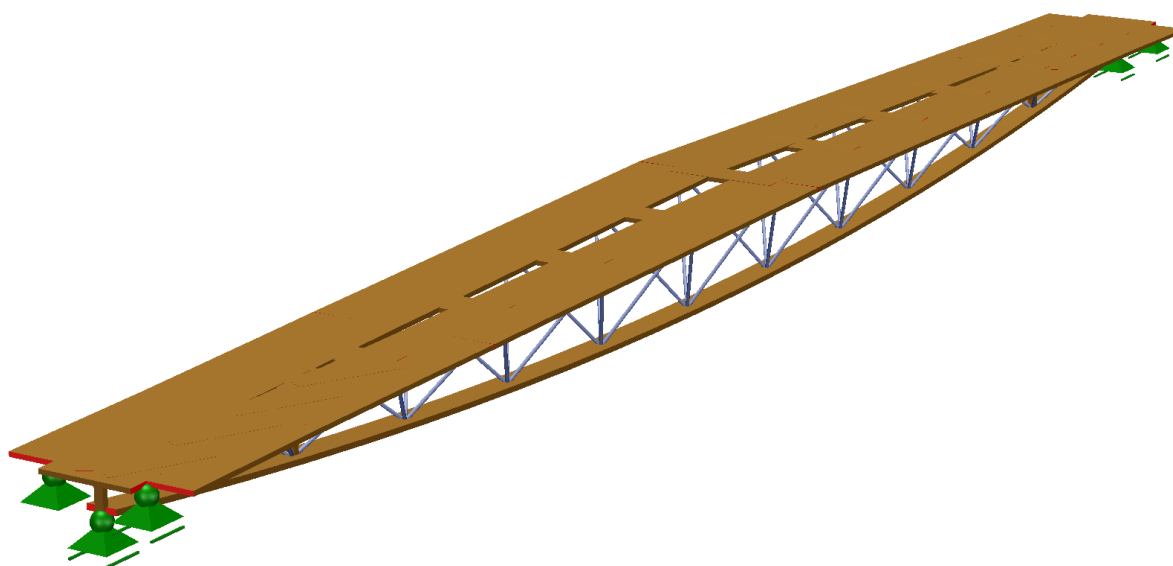


Figure 12: Perspective rendering

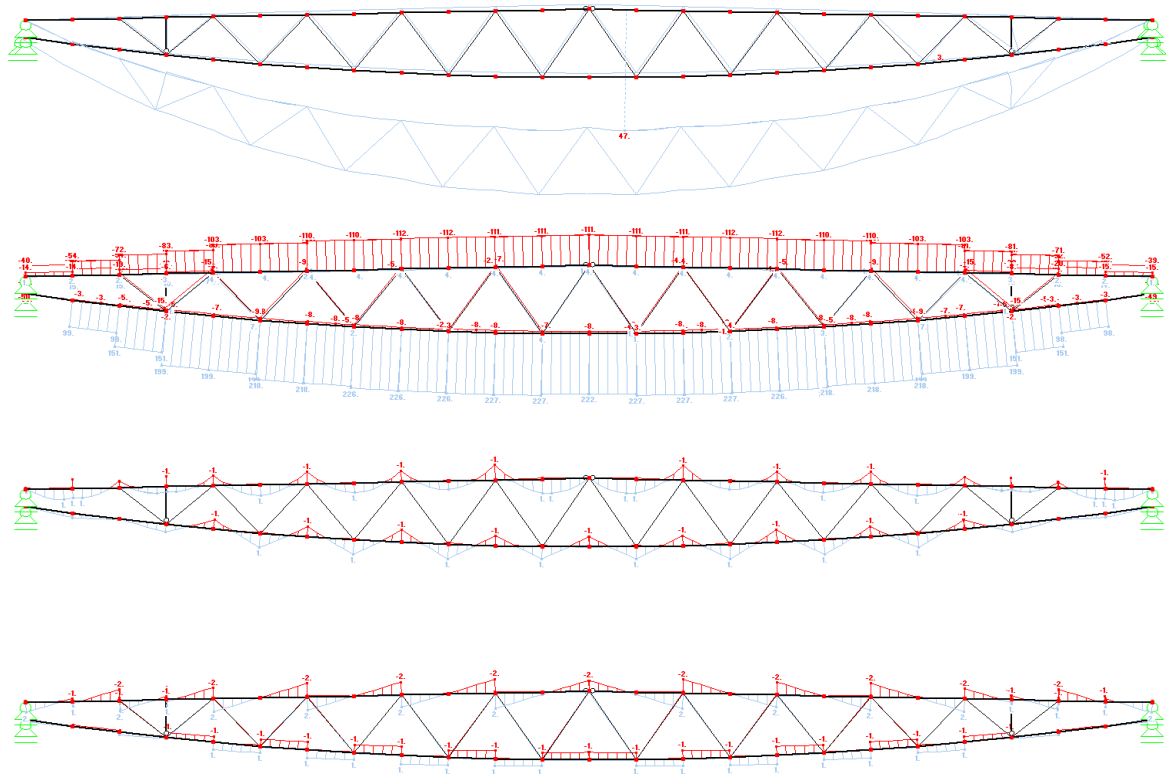


Figure 13: Deformations $< L/500$ – Catenary chord takes it all in Axial forces – Shear and Moments are local