The new footbridge in Arquennes – One of the lightest deck per m².

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Abstract

In Arquennes, the disappearance after the second world war of the old railway bridge crossing river Samme, marked a break on the RAVeL, forcing pedestrians and cyclists to mix with automobile traffic to cross the village. The municipality of Seneffe entrusts bureau greisch with the mission of designing a new footbridge.

In order to respect the original structure and to integrate it as respectfully as possible into this remarkable site, the sketch developed translates a contemporary structure in metal latticework, whose grids (350 mm²) recall the characteristics of the old railway bridge. The materials considered (corten steel structure and exotic wood decking) offer a good color match with the existing masonry and an excellent durability.

The cross section of the metallic latticework is around 30 mm² which gives the structure an extraordinary transparency and a weight of approximativily 75 kg of steel per square meter of decking, which is really low !

Keywords: Footbridge, corten steel, lattice, environment, Arquennes.

1 Introduction

Figure 1: General view of the structure

On the site of the old viaduct occupied by railway line n°141, the municipality of Seneffe wanted to build a footbridge. It extends over two spans of more or less 27 m.

The primary purpose of this footbridge is of course to create a link between the two banks of the canal allowing RAVeL users (pedestrians, cyclists, horse riders, people with reduced mobility) to travel in a comfortable and safe way in order to discover rural areas and preserved natural areas.

Once this link is effective, users of the RAVel (or "pre-RAVel") will be able to cross the village of Arquennes without mingling, as is the case today, with car traffic (see red line instead of yellow line in Figure 2).

Figure 2: Route of the RAVel Line 141 in the Arquennes crossing

1.1 Gateway Design Principle

The mission entrusted to Greisch in February 2018 is nevertheless much broader than the creation of a link.

Interspersed at the junction of two remarkable sites that are also classified as heritage sites (the listed site of the Arquennes swing bridge and the listed site of the former Charleroi-Brussels canal), the following objectives were to guide the project designer throughout his design mission:

- Promote soft mobility;
- To recreate a remarkable viewpoint open to the perspective offered by the canal;
- Preserve a legacy of the past by documenting the multiple construction/demolition events that led to them;
- To allow the different users to be able to cross paths, to meet each other without compromising the good enjoyment of the place.

The consultation of the archival documents compiled by the project manager made it possible to visualize the site at different times in its history. The railway viaduct present before the war is illustrated in the Figure 3. Its elevation shows a lattice beam at a constant height (more or less 2 meters) and with a 45° inclined mesh.

Figure 3: View of the railway bridge before the war 40-45.

The new footbridge is to be supported by the old abutments and piers of the railway structure. In order to minimize the interventions on these elements, for economic but also heritage purposes, it seemed wise to work with a structure with a thickness similar to that of the old structure.

Figure 4: View of the site before the construction of the new footbridge

Figure 5: Zoom on the structure of the projected deck (integration image)

The structure of the footbridge simply needs to fit into this remarkable site. It did not seem appropriate here to work with a superstructure that attracts the eye. The attention of both the user of the footbridge and the person using the quay below must remain anchored in the beauty of the site.

With this in mind, and always with the idea of preserving an image of the past, the idea was to work with a contemporary lattice structure. The latter takes up the idea of 45° mesh meshes like the deck of the railway bridge. It shows a respect for the past, a reinterpretation while keeping the spirit, the memory but without being a pastiche.

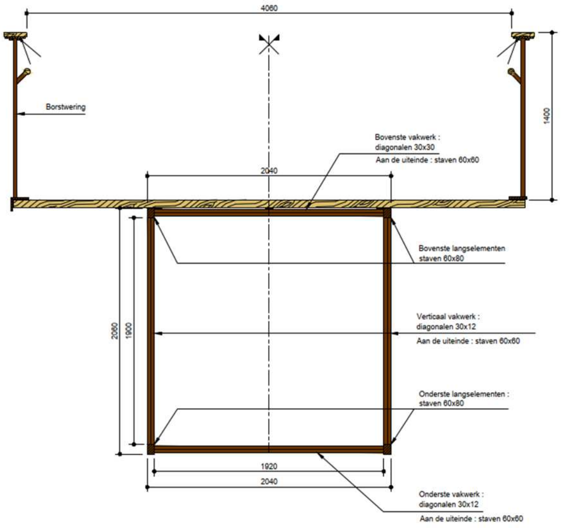

Figure 6: Typical structural section of the deck

1.2 Choice of materials

The design of a lightweight structure that recalls the rich past of this site led to the use of steel for the construction of the structure's deck. In order to minimize the cost and periodicity of the maintenance of the structure, self-weathering steel (Corten) is used.

The forced surface corrosion on this type of steel makes it possible to withstand atmospheric conditions without the need for an anti-corrosion paint application that has a limited lifespan.

In addition, the "orange" patina taken on by this material allows a very good architectural marriage with the grey tones of the existing piers and abutments.

Figure 7: Integration of weathering steel into the site

The decking is made of exotic wood with excellent resistance over time and also a very limited maintenance need. The company has been required to use an FSC label for the supply of this wood, which ensures that the forests it comes from are properly managed.

The planks are equipped with an anti-slip system consisting of an inlay of Quartz-filled resin in transverse grooves as recently implemented for the new footbridge in Liège (Figure 8).

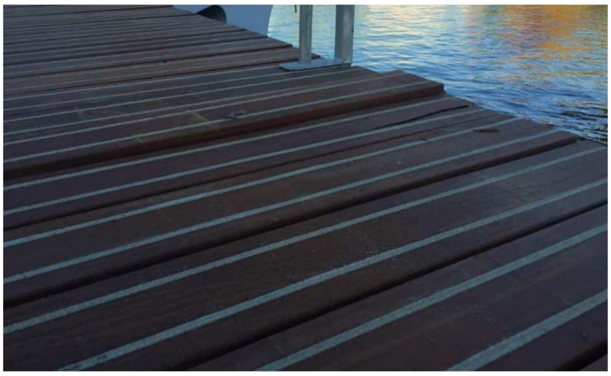

Figure 8: Example of wood cladding with the integration of an anti-slip strip

1.3 Guardrail

As shown at the Figure 6 and in the following figures, the railing was envisaged as a spindle of vertical metal bars (spaced 110 mm apart) and connected at the top by a metal rail. To limit maintenance and to match the main structure, the steel is also of the weathering type.

To improve comfort, the upper rail is topped with an exotic wood piece reminiscent of decking and more pleasant to the touch than self-weathering steel, which can be a little rough. The height of the guardrails being increased to 1.4 meters to make the crossing safer, especially for cyclists, a circular handrail also made of exotic wood is added to the standard height of 1.1 meters.

Figure 9: View of the platale

The vertical uprights are welded to an angle, which is itself attached to the azobe boards that bring the loads applied to the railing back to the main structure. Expansion joints are envisaged every 3 metres in the upper rail railing.

1.4 Lighting

In order to make the crossing safe at night, functional LED lighting is integrated into the two handrails of the railing (see Figure 10). This lighting consists of a hermetic linear profile of opal LEDs with a wide beam (oriented at 45 degrees) and generates a continuous and homogeneous brightness over the width of the deck. The colour temperature used is a warm white at 3000 K.

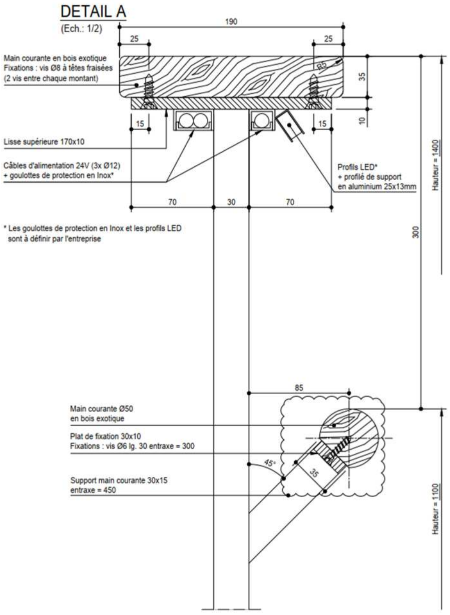

Figure 10 : Transverse cross section of the hand-rail

In addition, to highlight the structure in its environment, 4 adjustable LED spotlights with a symmetrical medium beam are provided in the right of the piers and abutments and oriented in such a way that it gives a luminous halo (diffuse lighting) on the structural mesh of the deck. The colour temperature used is also a warm white at 3000 K.

1.5 Restoring Stacks and Abutments

The overall stability of the pier and abutment assemblies is not affected in comparison with the bearing capacity they had at the time of their construction. The loads that will be brought back on these elements by the new footbridge are also much lower than the loads of the two old railway viaducts, so there is no need to fear the compatibility of the operations.

As part of the work to install this new footbridge, it was nevertheless proposed to restore certain local defects that appeared in the masonry of the pier and abutment assemblies. These restorations mainly include cleaning, sanding, depointing and repointing of the masonry. Some more substantial local repairs have been achieved (tree stumps to be removed, P3 abutment guard walls to be rebuilt on a reinforced foundation, etc.).

Figure 11: Tree root to be extracted

Figure 12: Side wall in P3 to rebuild

1.6 Principle of stability

From a structural point of view, the footbridge is therefore made up of a square metal box, with four frame elements at the four corners of the square (80*60 mm²) and whose box walls are made up of a lattice of square bars of 30*12 mm² every 35 cm (see Figure 6 and Figure 13). These mesh bars are welded to each other at each crossing to ensure stability and are butt welded to the main chord members.

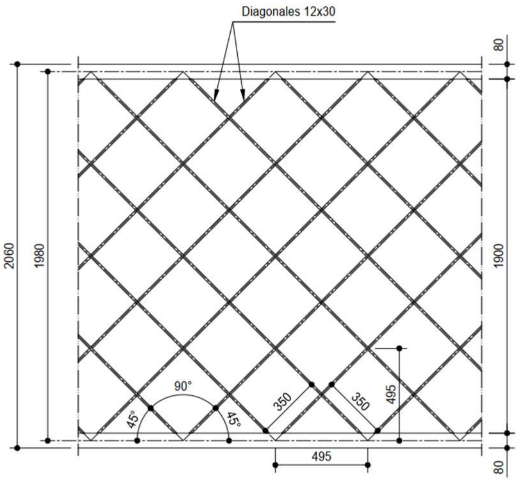

Figure 13: Structural elevation of a truss core

This structure is then covered with a wooden floor whose planks bear on the two members of the chords and ensure stability on the overhang of one metre beyond these frames. The total width of the footbridge is therefore 4 metres.

To avoid leaving the boards free to be fixed for too long, intermediate beams fix the boards together in order to limit the differential movements between boards every 50 cm. This arrangement prevents the boards from becoming misaligned over time given the lively nature of the wood and its tendency to twist according to variations in temperature and humidity.

Figure 14: View underside of the deck

A finite element calculation model allowed the detailed study of the metal structure. Critical load calculations were carried out to define the buckling lengths of the different components of the lattice, and in particular the elements constituting the web diagonals. In order to ensure the dimensioning, nonlinear geometric and material calculations were then carried out under the few cases of main loads.

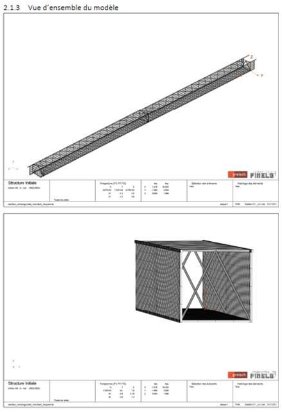

Figure 15: Overview of the calculation model

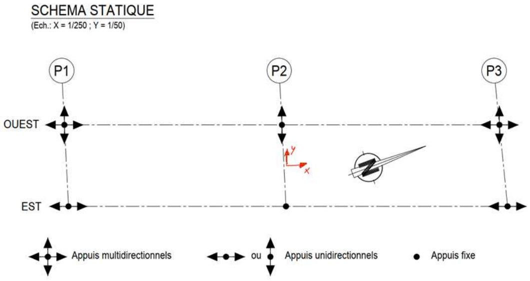

Figure 16: Static Schema

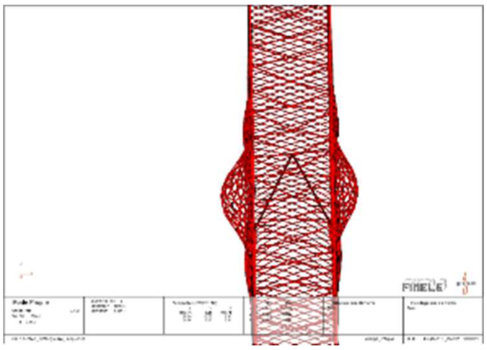

Figure 17: Critical mode of instability of the web panels

On central support, the study demonstrated the need for a support framework. Indeed, as shown by the Figure 18, without a frame, only the diagonals directly above the support take up the loads and transmit them to the diagonals that go back in the other direction once they reach the upper chord. The lattice thus functions like a Warren lattice beam and the material is not well used, leading to the need to reinforce certain diagonals. The frame allows the support reaction to be distributed between all the diagonals it intercepts, which allows for a much better distribution, as shown by the Figure 19. Thus, only the diagonals highlighted in green in this figure had to be reinforced in section 30*30 mm².

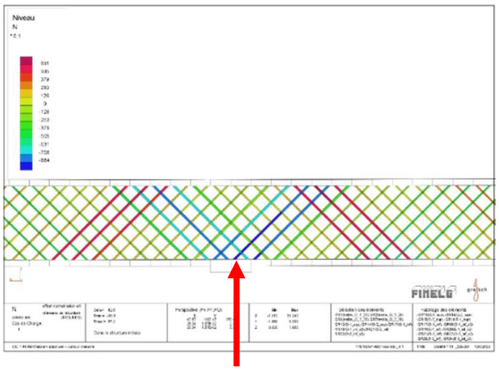

Figure 18: Behaviour of the lattice on a frameless central support

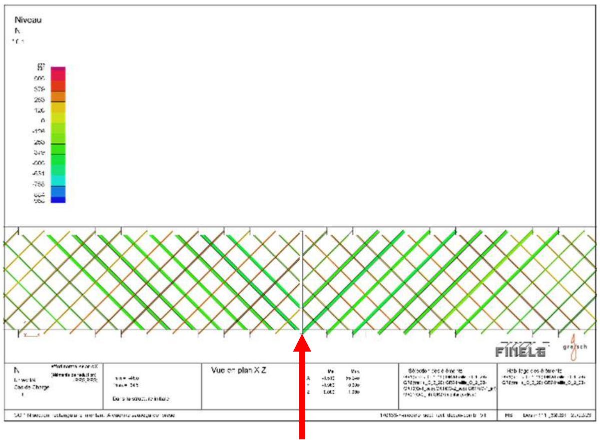

Figure 19: Behaviour of the lattice on a central support with frame

Figure 20 : Zoom on the central support on pier P2

The boom of a span loaded along its entire length with the design overload of 500 kg/m² does not exceed 45 mm, i.e. 1/600 of the span. The vertical natural frequency of the structure is equal to 4.67 Hz while the first horizontal transverse frequency is 3.45 Hz, which allows us to conclude that there is no vibration problem caused by the passage of pedestrians, cyclists or other users.

1.7 Weight per m²

The desire to keep the support structures of the existing bridge as intact as possible has defined a relatively high deck height for this type of structure and span.

Furthermore, the sizing and optimization of the cross sections of the lattice combined with this structural height led to the production of a deck which weighs less than 75 kg of steel per m² of supported floor.

This value is excessively low for this type of structure, which makes it consume very little material and therefore very interesting from the CO2 consumption point of view.

1.8 Mounting principle

As described earlier, the gateway is integrated into a classified site. Access to the site is extremely limited and tenuous. As shown by the Figure 22, the only possible access under the structure is via the Avenue du Viaduc in a cul-de-sac and which crosses the village of Arquennes by taking a particularly narrow section to the right of the area circled in green (see Figure 22– width available ~4 m).

Figure 21 : Road access to the site

Figure 22 : Restricted width available on site

However, the company chose to divide the main framework into four sections, each more or less 13.5 metres long (see Figure 23). These sections were assembled in TMI's workshops in Andenne and transported to the site by truck. Then, two by two, the sections were welded together at the foot of the P3 abutment before being placed in place by crane from the quay.

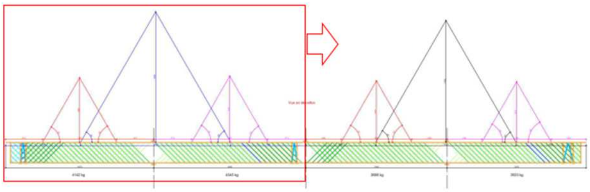

Figure 23: division of the sections of the structure

The Figure 24 illustrates the first two sections assembled at the foot of P3 before being placed by crane on span P1-P2. The next two sections will then arrive to be assembled at the foot of P3 and hoisted into position with a crane.

Figure 24: Assembly of the first two sections on site

In a fairly conventional way, the spans were laid on sandboxes before the final supports were sealed in the concrete (see Figure 25).

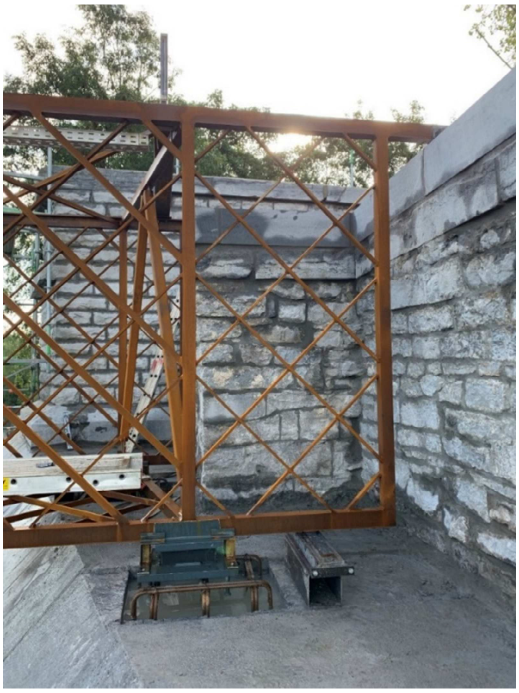

Figure 25: Provisional and definitive support in P1

The last two pictures illustrate the final integration of the structure in its environment.

Figure 26: Setting up the second piece between P2 and P3

Figure 27 : Integration of the structure in its environment