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The road to durable bridge design: An experience from Québec

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1 Introduction

In Quebec, forests cover more than half of the province territory, representing over 900 000 km². 92% of these forests are on public land and, therefore, under the responsibility of the Quebec government for managing all activities, including forestry. Access to this forest territory represents 475 000 km of forest roads, and nearly 3 000 bridges. The majority of these forest road bridges, also called bridges on multi-use roads, span between 5 and 30 m [1].

Since these forest road bridges are not located on the public traffic road network, they are not governed by the standards of the Ministry of Transportation (MTQ) [2]. If they are built on public land, these bridges are under the responsibility of the Ministry of Forests, Wildlife and Parks (MFFP), and their design and evaluation must follow its specific regulations, adapted from Canadian Highway Bridge Design Code [3][4][5]. Most of these bridges are built by forestry companies to access the resource. Nonetheless, they may be utilized by various users during their lifetime.

For many years, a steel-wood bridge concept has been often used for this type of structure, due to its simplicity erection and economical aspect. This concept includes steel girders seating on a treated wood box foundation, and supporting treated wood crossbeams and a wood running surface, which can be treated or untreated depending on the context [6].

In the last 20 years, a new solution has been developed to replace the steel girders with locally produced glulam girders, taking advantage of a regional material with a low carbon footprint. These timber bridges are mostly made of straight glulam girders supporting treated wood crossbeams and a treated or untreated wood running surface. Since the beginning of 2000, more than 100 of these timber bridges have been built on the forest roads throughout Quebec [7].

Inspections of existing timber bridges have highlighted some durability issues, often related to discontinuous protection of the main glulam structure. In order to pursue the objective of promoting the use of wood in the realization of these infrastructures, work has been undertaken by the government, the industry and Cecobois to improve the initial concept and develop constructive solutions adapted to the Quebec context [7]. The challenge is to provide high quality glulam bridges that offer the desired structural resistance for a minimum life span of 40 to 50 years, while remaining economically competitive with the current steel-wood concept.

Last year, a technical working committee on the evaluation of the load-bearing capacity of timber bridges, bringing together specialists from the MFFP, the MTQ and the industry, has been set up to promote the development of adequate tools and the acquisition of knowledge regarding timber bridges in order to better understand their long-term behaviour.

2 Glulam forest road bridges

As discussed, more than 100 glulam forest road bridges have been built throughout Quebec since 2000. These timber bridges are mostly made of straight local glulam girders supporting treated wood crossbeams and a treated or untreated wood running surface (Figure 1).

To help the expansion of this innovative solution using local glulam, some issues needed to be addressed. Efficient prefabrication techniques have been developed to ensure the competitiveness of this solution, specific detailing has been proposed to avoid degradation of the glulam girders and limit maintenance, and a new evaluation methodology was established to simplify its design.

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Figure 1: Dalime Bridge - Manufacturing: Nordic Structures – Photo credit: Adrien Williams

1.1 Local glulam

The majority of glulam produced in northern Quebec is made from Black Spruce. This specie is known for its high density and fibre strength, as well as its limited diameter, thin annual rings and small knots. In order to optimize this raw material, a proprietary product, NordicLam, is manufactured by laminating small sections in both directions (Figure 2).

Despite its high strength, black spruce is difficult to treat with chemicals due to the closing of the pit chambers during drying. Therefore, the durability of the infrastructures made with black spruce glulam relies mainly on good design and manufacturing details to avoid the presence of moisture, as well as on effective finishing products to protect the wood against rain and UV rays.

Figure 2: Glulam made of local black spruce (picea mariana) (credit: Nordic Structures)

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1.2 Efficient prefabrication techniques

The fabrication and assembly of glulam forest bridges were optimized in order to be economically competitive. Concepts favouring the pre-assembly of girders in groups of 2 or 3 allow efficient connections between the girders and the diaphragms, a fast and easy construction process, as well as an easier installation of a waterproofing protection on top of the girders (Figure 3).

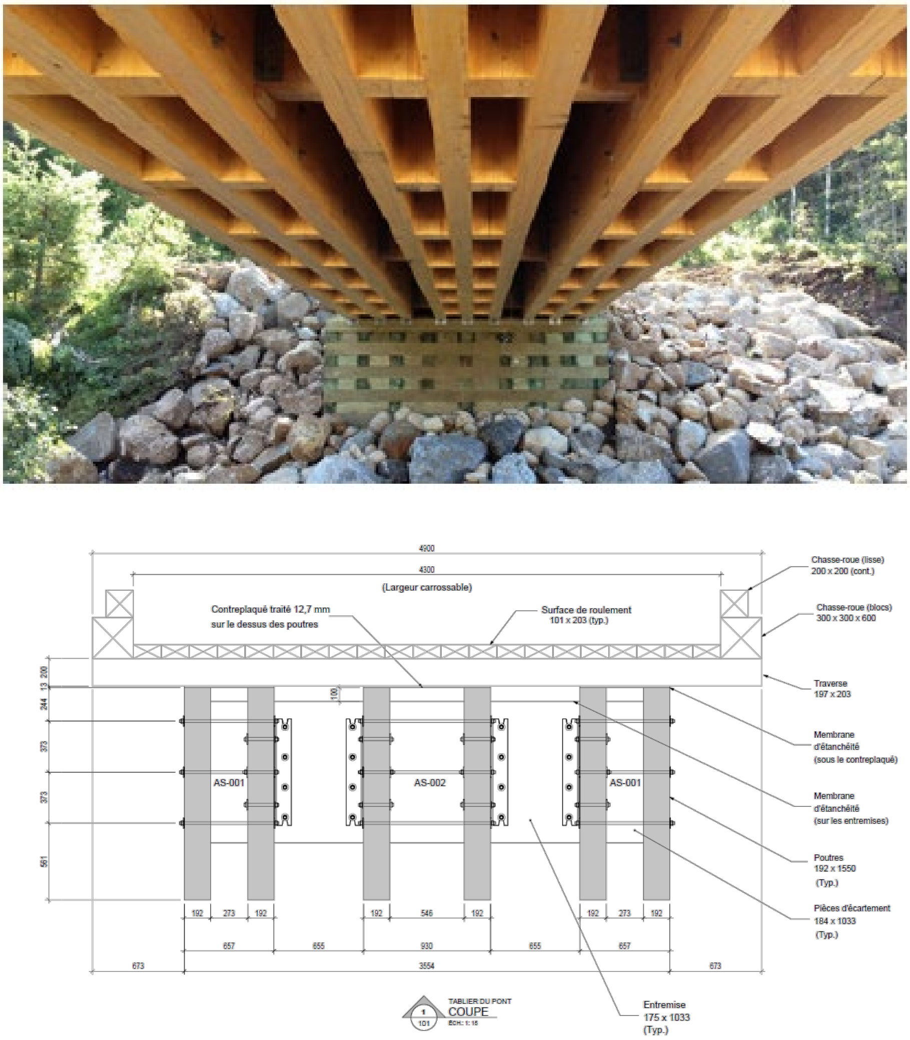

Figure 3: Concept with pre-assembled glulam girders (credit: Nordic Structures)

1.3 Detailing for durability

Several old covered bridges, still in service, demonstrate the durability of timber bridges [8]. Although loads and uses have changed over time, the basic principles of durability have allowed these infrastructures to be in service for years, some for more than a century. Today, without necessarily using a full-bridge cladding, these principles can be used to ensure the durability of modern timber bridges.

In the case of the forest road bridges built in Quebec, the impossibility of chemically treating the local spruce glulam girders requires the development of effective protection solutions. Moreover, maintenance of the bridges built on public land represents a challenge. Firstly, these bridges are often very remote, they can be few hundred kilometres from the nearest town. Secondly, the maintenance of these bridges is under the responsibility of the users, who may change during the lifetime of the bridge. For example, a new bridge may be built to provide access to a new logging area. A few years later, it is no longer required by the forestry company, and remains in place for other users, such as cottagers or hunting and fishing associations.

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This particular context explains the importance of providing efficient durability detailing anticipating the possibility of irregular maintenance service. In 2020, Cecobois wrote a guide on the durability of timber bridges in order to present design details that would promote the durability of these glulam forest bridges [7]. In collaboration with several specialists from the government and the industry, design and fabrication details were developed to provide adequate protection of the glulam structure against frequently observed sources of moisture, such as frequent exposure of the edge girders to rain and accumulation of wet sand at the footings.

These recommendations had to consider the use of a semi-waterproof wood deck over the main structure and the impossibility to add a waterproof bituminous surface on these remote bridges. Nonetheless, the continuity of the deck, a sufficient overhang over the side girders and a watertight and durable protection above each girder showed to be efficient to ensure the protection of the girders. In addition, a flashing to protect the end-grain of the crossbeams was recommended. Various solutions were also presented to protect the support of the glulam girders, including the use of a nylon pad to raise the support and prevent rising moisture as well as the extension of the running surface on top of the abutments to prevent the passage of debris.

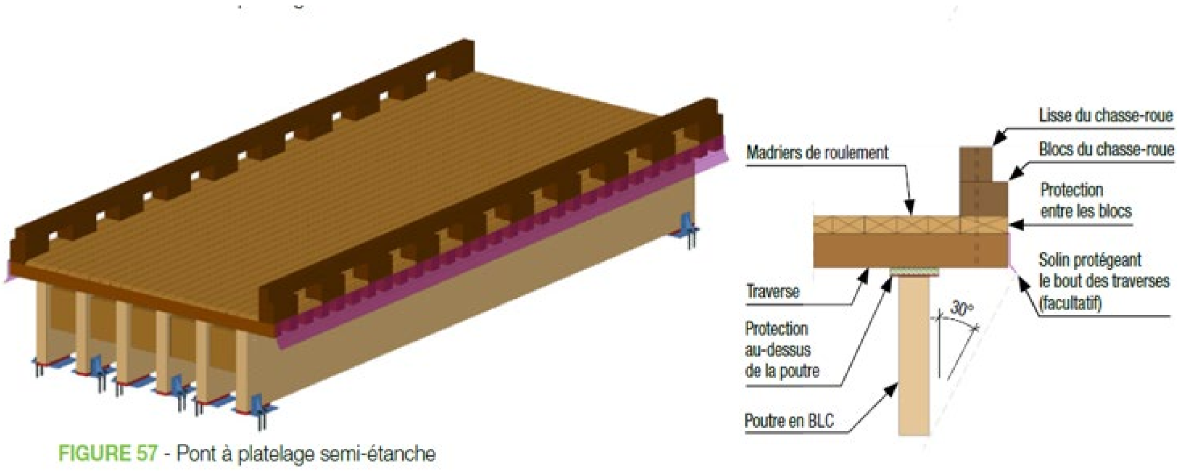

Figure 4: Examples of detailing for protection [7]

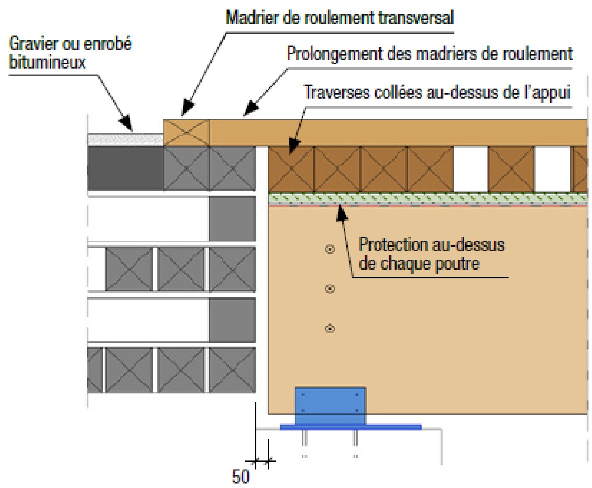

Figure 5: Continuity of the decking to prevent debris accumulation [7]

A new bridge was built recently respecting the recommendations of the Cecobois guide, including the use of a dark opaque finishing product to protect the wood against rain and UV and flashing to provide a 30° angle protection to the main glulam side girders (Figure 6).

Figure 6: Rivière Tachereau Bridge - Manufacturing: Nordic Structures – Photo credit: Stéphane Routhier

1.4 Realistic evaluation methods

As discussed previously, a technical working committee on the evaluation of the load-bearing capacity of timber bridges was created to bring together specialists from the MFFP, the MTQ and the industry. During the work of this technical committee (which is still ongoing), a new evaluation analysis method is being developed to allow a simplified but more representative analysis of forest bridges with glulam girders [9]. This evaluation method would be more adapted to these bridges than the simplified analysis method provided by the Canadian Highway Bridge Code [5], while being less complex than a 3D FEM model.

The proposed evaluation method is performed in two steps: first, a longitudinal analysis and then a transverse analysis. The longitudinal analysis consists in determining the effects produced by a truck load on a lane by treating the bridge as a group of parallel beams. Once the highest load configuration is obtained, the transverse analysis associates the effects of the longitudinal analysis to each girder by considering the transverse distribution of the forces. This distribution considers the flexibility of the glulam girders supporting the deck as spring supports (Figure 7).

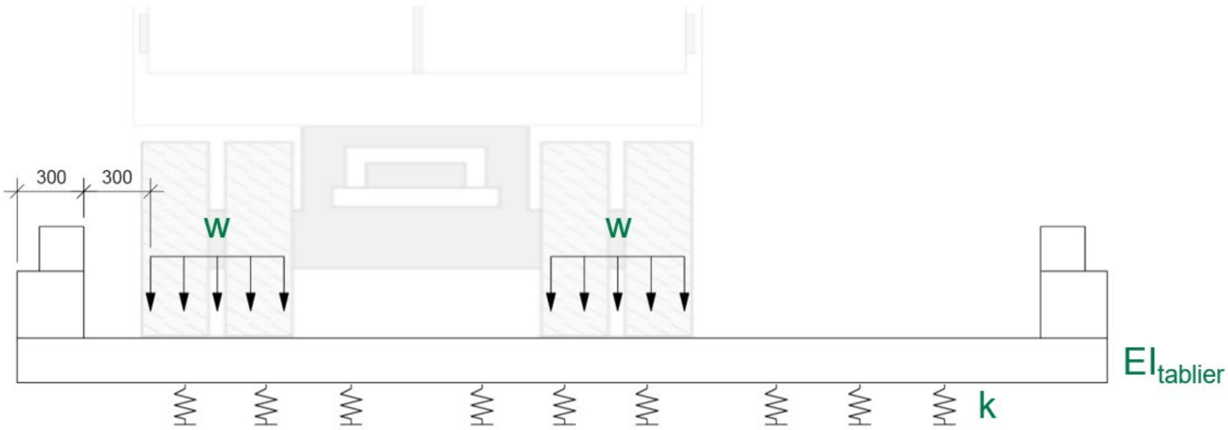

Figure 7: Modelling of the deck as a beam supported on spring supports [9]

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3 Glulam traffic road bridges

In addition to the forest road bridges discussed in this paper, few traffic road bridges have been built in Quebec, and are monitored by the Ministry of Transportation (MTQ) [10]. For these bridges, the glulam structure is protected by a waterproof layer and a bituminous rolling surface. Exceptional timber bridges, such as the 160-meter four span Mistissini bridge built on the Cree nation land in Northern Quebec, also show in opportunities of timber bridges in Canada (Figure 8) [11].

In 2017, the Ontario Wood Bridge Reference Guide provided guidance for the design of timber bridge in the Ontario Province and highlighted the need to update the Canadian Highway Bridge Code regarding new technologies in timber bridges [12]. Since then, an active committee has been working on the section 9 of the Canadian Highway Bridge Code to update this section [13].

Figure 8: Mistissini Bridge - Design: Stantec - Manufacturing: Nordic Structures - Photo credit: Stéphane Groleau

4 Conclusion

The construction of glulam bridges appeared in Quebec's forests in the early 2000s and since then, more than 100 bridges using this material have been built on public forest roads throughout Quebec.

A collaborative effort between government and industry specialists has resulted in the development of constructive solutions to ensure future use and longevity of this bridge concept using local black spruce glulam girders.

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