MODERN TIMBER BRIDGES

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Summary

This paper provides details on the status of timber bridges in Canada and presents findings from a recent technical tour focusing on timber bridges technology and design in Norway. The tour was organized by FPInnovations' Advanced Building Systems program as part of an exploratory study looking at developing information to support strategies and decisions to facilitate increase market share for wood and wood-based products and systems in bridge applications in Canada and the US. Advanced and innovative technologies have been developed in Norway that are facilitating the design, construction and maintenance of timber bridges. A large number of innovative modern timber bridges have been constructed in Norway during the last twenty years or so. The majority of those bridges, with lengths ranging from 50 to over 150 meters, are used as overpasses on major highway and traffic roads with some being used as the actual highway bridges, especially on newly-constructed roads. Key findings from the technical tour of Norwagian timber bridges are presented.

1. Introduction

The North American wood industry is currently exploring new opportunities to expand the use of wood in non-traditional construction markets. In addition to mid-high rise and large wood buildings, timber bridges have been identified as an alternative market opportunity that the industry should explore. Preliminary market studies in North America have shown that the construction market for bridges is undergoing a change which has the potential of positioning wood as a viable alternative in the choice of building materials. A recent study on timber bridges was carried out by Marshall Leslie of M. Leslie, Inc. titled "Opportunities for Timber Bridges" commissioned by the Canadian Wood Council (CWC) on behalf of the Timber Bridges Working Group (Leslie 2012). The report provides valuable information on the number and potential for short, medium and long span timber bridges by location, type and use.

There are over 780,000 bridges on public road networks in Canada and the U.S (approximately 70,000 in Canada and 710,000 in the U.S. – and an untold number on private lands) (Leslie 2012). Few of those bridges, however, are fabricated with timber (i.e., less than 2% of U.S. bridges). A recent study on the potential total wood demand in North America of 1-2 lanes timber bridges, less than 50m long, was carried out by FPInnovations (Crespell 2013). The study concluded that the total annual opportunity for wood decking is estimated at 0.5-0.9 BBF based on last decade's levels and that 45% of all wood bridges are obsolete or deficient in some way.

Timber bridges are expected to offer the same standard of structural performance and lifespan as bridges made of steel and/or concrete for the different types of bridges, be it pedestrian, railway or highway overpasses. However, only limited technical information is available on the various performance attributes of timber bridges to support the use of wood-based products and systems in bridge applications in Canada. This document provides a summary of findings from the technical tour of timber bridges in Norway organized by FPInnovations' Advanced Building Systems program as one milestone activity under the current project on timber bridges at FPInnovations. Norway was chosen for this tour as advanced technologies have been developed recently in the country, which are facilitating the design, construction and maintenance of spectacular timber bridges. In addition, a large number of innovative modern timber bridges have been constructed in Norway during the last twenty years making it one of the leading European countries in this area. The key tour objective was to explore type of generic and advanced wood-based materials used in timber bridges, advanced bridge designs and technologies and type of preservative treatments and other means of wood protection adopted and to learn about the Norwegian experience. A detailed report that provides specific details on all timber bridges visited in Norway is available from FPInnovations (Mohammad *et al.*, 2014). The long-term goal of the timber bridges project at FPInnovationis to develop information to support strategies and decisions to facilitate increase market share for wood and wood-based products and systems in bridge applications in Canada and the US.

2. Methods

Mr. Erik Aasheim of Treteknisk developed the technical tour program in close coordination with FPInnovations staff and the rest of the Canadian delegation. An invitation brochure was drafted and circulated to key stakeholders to participate in the technical tour. A list of questions was prepared by the delegation and was shared with the wood industry and with some of the Canadian provincial ministries of transportation for input. The compiled questions were developed to facilitate discussions and gathering of relevant technical and market information for the various stakeholders. The full technical tour program is given below. More than 12 bridges of various types were toured over a period of 3 days. Technical information was collected from the various stakeholders involved in the design, construction, monitoring and long-term durability of those bridges. Some engineers and contractors were present at the construction site and were able to provide some valuable information on the design and construction of those bridges. A list of timber bridges visited is given in Table 1 below.

Table 1 Technical tour program

Bridges Visited	Locations
Sletta	Eidsvoll
Skogsrud	Tangen
Tretten	Tretten
Håmårstad (Hans Erik Sandvoll)	Harpefoss
Evenstad	Evenstad
	Rena
Kjøllsæter (See Figure 1 below)	Rena
Åsta (Trond A. Stensby, Hanne Saug Lie)	Rena
Flisa	Flisa
Lukmo	Skarnes
	Oslo
Klemetsrud	Oslo
Leonardo (Lone Ross Gobakken)	Ås
Nesoddveien	Drøbak
Måna	Drøbak

Figure 1 Kjøllsæter hybrid timber bridge in Rena with a concrete deck

3. Results and Discussion

The following provides a summary of the key findings tour.

- Nordic Timber Bridge program made major impact on triggering the interest among designers, engineers and government agencies in timber bridges and led to increasing the number of timber bridges in Norway and other Nordic countries over the last 20 years.
- Timber bridges are currently favoured due to a strong interest/tradition in using wood, cost competitiveness and speed of installation.
- A key driver leading to the adoption of timber bridges in Norway was the efforts of timber bridge champions within the Norwegian Public Road Administration
- Typical construction elements in modern Norwegian timber bridges include: glued laminated members for main structural system (arches, stringers, truss girder), stress laminated timber/glulam decks.Most of bridges visited were hybrid construction in one way or another. Steel cross-beams are very common. Cross-beams are used due to their small depth which maximizes clearance between the lower deck and water or highway below. If glulam cross-beams are used then most likely, a deeper section of beams would have to be used.
- Multiple concealed metal plates and tight fit dowels are very common type of connection system detail used for all wood to wood members and wood to steel in all of the timber bridges visited. Metals plates used for connections are typically galvanized then powder coated. All dowels and bolts are made of stainless steel.
- With the exception of one bridge (Kjøllsaeter) where it has a concrete deck, decking is mostly made of pressure treated stress laminated 2x8 or 2x10 sawn timber planks or glulam. Threaded rods or steel cables (more recently) are used for the stress lamination process combined with circular metal bearing plates. Cables ends are usually protected from the weather with metal caps and are installed within the deck in tubes with lubricants to avoid corrosion. It has been found that expansion joints are not needed in these decks.
- Abutments are usually made of concrete or stone. Arches or truss girders are commonly supported by concrete pedestals through steel bearings plates and hinges.

- "Durability by design" concept has been implemented widely in all timber bridges in Norway combined with wood treatment. Metal (mostly copper) flashing to divert rain water away from the glulam structural members was observed in almost all timber bridges visited. Louvers (or cladding) were used to divert rainwater away from larger or more curved arches that could not fit into a pressure treatment retort to be creosote treated. Considerable attention is usually paid to details to divert water away from wood elements, minimize water trapping and promote drying especially by eliminating direct wood to wood connections using metal plates. In almost all bridges, direct contact between wood elements and concrete has also been minimized through use of gaps and membranes.
- Scots pine is used for most timber bridges because it has a wide treatable sapwood and moderately durable heartwood.
- Dual pressure treatment for structural wood products such as glulam has been adopted in Norway. A copper-based preservative is used for impregnating the individual lamina then after planing, gluing, fabrication of components, assembly and disassembly, a second pressure treatment with creosote. Previously lamina were treated with Chromated Copper Arsenate (CCA). These days it is typically one of the copper-organic-cobicide preservatives. Lumber and timbers tend to be just creosoted. Creosote treatment seems to be quite popular in Norway.
- There seem to be some issues with creosote dripping but this does not seem to be a major concern to local communities. This could be eliminated by process modifications such as those recommended in the Best Management Practices for The Use of Treated Wood in Aquatic and Wetland Environments developed by Wood Preservation Canada and the Western Wood Preservers Institute.
- Environmental impact assessments are done for all bridges of all materials. Recyclability of creosoted wood is not an issue as it can be burnt for energy. However, the concern is related to recyclability of copper-based preservatives in individual lamina.
- Due to concerns over potential ban on the use of creosote in Norway and some other European nations, a new research program called "Creosub" has been initiated between Norway, Finland and UK aiming at developing environmentally friendly wood preservatives that can be used as alternative to creosote for various applications such as timber bridges, railway sleepers and utility poles.
- Typically, Asphalt is a common wearing surface in all traffic roads. Liquid bitumen is added as a bonding agent between the asphalt and the wooden deck. The bitumen acts also as a waterproof membrane protecting the wooden deck.
- Corten steel used for railing supports and guard railing on the new sections of the E6. Elsewhere galvanized steel is used.
- There is a great interest in upgrading existing old steel bridges by replacing old cracked concrete decks with stress laminated decks or CLT. This provides a lot of

advantages as the dead load will be significantly reduced which allows for increased load carrying capacity. This has big potential for Canada and the US.

- All timber bridges are currently designed for an expected service life of 100 years (with the exception of Leonardo bridge which is designed for 40 years due to the use of a light-duty colourless preservative and limited protection by design).
- While, stress laminated timber deck is the most common type of decking in timber bridges in Norway, in Finland, hybrid glulam stringers and concrete decks are quite popular. Creosote treatment is rarely used in Sweden (other treatments may be used). Sweden has a large number of timber bridges.
- Most bridges are owned by the Norwegian Public Road Administration (NPRA) and the design and construction are subcontracted to engineering firms. Occasionally, NPRA designs certain timber bridges.
- Bridges are inspected on a regular basis by NPRA and appropriate maintenance plan is adopted. Regular inspection and maintenance is carried out once every 5 years, with casual inspection every 2nd year. This is the same as for bridges constructed with other materials.
- Four key design firms that designs most of timber bridges in Norway: SWECO, Norconsult AS, Statkraft Grøner AS, Dr. Ing. Aas-Jakobsen AS. Moelven Limtre AS is the main manufacturing and supplier firm of glulam and deck boards in most of bridge projects visited. A crew from Moelven also does the assembly as well.

4. Conclusions

Key findings from this tour indicate that "durability by design"- i.e., good detailing, combined with dual treatments is critical for ensuring the durability of the structural elements of timber bridges throughout its service life. There is also a need to educate and engage the various provincial ministries of transport across Canada to trigger their interest. There is also a need to develop advanced wood-based bridge designs (could be hybrid solutions) to facilitate the adoption of timber bridges in Canada.

5. Literature

Crespell, P. 2013. The Opportunity for Wood Bridge Decks in North America. FPInnovations, Vancouver.

Leslie, M. 2012. Opportunities for Timber Bridges. Report commissioned by the Canadian Wood Council, on behalf of the Timber Bridges Working Group.

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