

Timber Bridges in the Nordic Countries

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Abstract

The Nordic Timber Bridge Programme is a co-operative programme for Sweden, Finland, Denmark and Norway, with the head of the working group and the chairman from Norway. The participants in this programme come from the Timber Industries, the Timber Research Institutes and Public Roads Administration in the various Nordic countries. The paper will describe the most essential points in “why and how” this Timber Bridge Programme was established. The objective was to increase the knowledge of timber used in bridges, and timber bridges vis-à-vis architects, engineers and politicians regarding material and construction preference and disadvantage, environmental aspects, construction costs and service life costs. The aim is to construct more timber bridges at the sacrifice of steel and concrete bridges.

Background

Bridges in a historic perspective started with different forms of natural bridges, see figure 1.

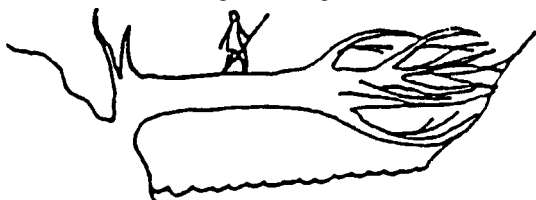


Figure 1-Historical bridge.

In the Nordic countries, as in most part of the world, timber and stone were common constructing materials for bridges in the past. The most common timber bridge types were probably:

- Beam bridges
- Cantilevered timber bridges
- Strut frame bridges
- Suspended frame bridges
- Truss bridges

These bridges could also be covered.



Figure 2-Bridge from the Viking period.

In Norway the number of timber bridges increased during the last part of the nineteenth century, but around the turn of the century the building of timber bridges stopped almost completely. Most likely because steel bridges became cheaper and simpler to construct.

During a period in the 1960's we constructed in Norway a number of glulam bridges for pedestrians. These bridges were competitive concerning cost and aesthetics. After a period of 15 years we almost stopped constructing these bridges because of the supposed service life not being as expected. It seemed

that the bridges decayed much sooner than anticipated. But this was only an assumption.

In connection with the design of the indoor arenas for the 1992 Olympic Winter Games in Norway there was a competition between steel and timber for the roof constructions. Timber was chosen because of the cost and the aesthetics. These arenas are huge constructions compared to previous Norwegian timber constructions. The roof structure consists of several truss girders. The largest span is more than 100 m and the load carrying capacity of two such girders is high enough to facilitate a two-lane road bridge.

If we construct big halls in timber, why don't we also make timber bridges? It was decided to establish a timber bridge group with participants from the timber research centre, the timber industry, and the Public Roads Administration. The task was to work out a conceptual design for timber bridges in Norway with emphasis on aesthetics, service life, design rules and competitive economics. The result of the conceptual design was satisfactory regarding these issues and the work with timber bridges continues. However, the report is written in Norwegian.

About the same time groups from all the Nordic countries worked on or had the intention to start working on national timber bridge projects. This led to a study trip to the Forest Products Laboratory in Madison, Wisconsin, USA. The laboratory was chosen because it is well-known that it possesses the engineering environment and experience to produce research work and to construct timber bridges. On this study trip the whole Nordic group decided to make an effort in establishing a project for timber bridges with financial support from the Nordic Industrial Fund, the timber industry, national timber research institutions and the national Roads Administration.

The Nordic Project in General

During the visit the delegates decided to co-operate in the production of relevant facts to encourage timber bridge structures in the Nordic countries. The Nordic countries are Sweden, Finland, Denmark and Norway.

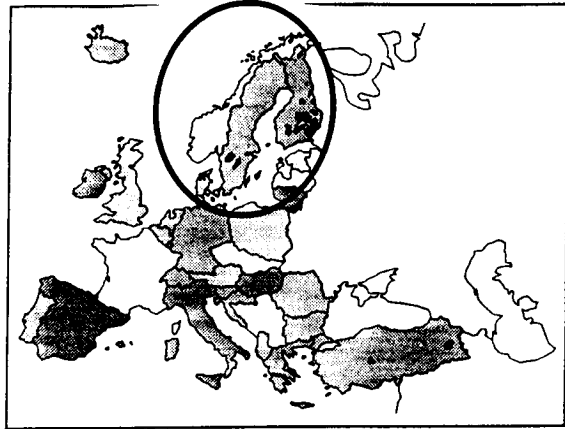


Figure 3-Map showing the Nordic countries as a part of Europe.

The objectives of the project were to promote timber bridges by

- removing some of the myths about these bridges that are obstacles in the choice of timber bridges in competition with concrete or steel bridges.
- increasing the participants' knowledge of timber bridges.
- doing research on timber bridges.
- providing relevant information about timber bridges to be announced for decision-makers by means of
 - publishing reports and participating in exhibitions with results from this project
 - announcements aimed directly at the decision-makers
 - presentations at various conferences
 - newspapers and television.

The success rate is not manifested in figures, but in terms which mean that the trust in timber bridges must be re-established, and that construction of timber bridges should increase substantially in specific areas in the Nordic countries and in neighboring countries. Both pedestrian and road bridges are included in this project, but the increase in road bridges is the most encouraging.

We also expect that this project will result in increased knowledge of timber bridges and start a process with continuous improvement of the timber bridge concept.

Table 1-The sub-project each country deals with. * shows the responsible country.

	Denmark	Sweden	Finland	Norway
Market survey	■	■	■	■
Competitive power	■	■	■	■
Design rules	■	■	■	■
Composite bridges			■	
Arch bridges			■	■
Stress lam. decks		■		
Truss bridges				■
Joints	■			■
Accessories		■		
Substructure		■		
Wearing course		■		
Service life	■	■	■	■
Information	■	■	■	■

The Nordic timber bridge program is organised as a partnership with an executive group consisting of two representatives from each Nordic country. In addition the project has a project group which co-ordinates the activity on behalf of the executive group.

The complete project is composed of the thirteen sub-projects as indicated above.

Each sub-project has one national responsible person from one of the countries. The other nations take part in each sub-project as agreed upon. Not all sub-projects have partners from all countries. A few of them are actually individual, national sub-projects. However, they are still managed by the project and the executive group.

For the Nordic timber bridge project NOK 8,000,000 (\$ 1,200,000) is allocated from the following funds:

- 50 % from the timber industry and from national road administrations
- 20 % from national research funds
- 30 % from Nordic Industrial Fund.

The project will be closed in October this year and has at that time lasted for two years.

There are many advantages with a Nordic project like this.

Firstly, the various partners from the Nordic countries have different experience from their own areas. This means that the store of knowledge based on what all partners know about this subject is greater than the individual knowledge.

Secondly, the basic experience that each of the partners has obtained prior to starting the project is

the basis for aiming directly at the problems that this timber bridge project involves.

Finally, the knowledge coming from a varied group of members and the issues which are raised are the bases for being creative in this study and to indicate excellent solutions.

The project has an on-going research programme for fatigue study of dowel connections. About 20 samples of dowel joints were made. These joints were tested in a fatigue testing machine with up to 10^7 cycles. As the test is still in process, I have to come back to the result in the oral presentation.

Examples from Sweden

Klockarbergsvägen

A new road outside the Swedish city Skellefteå was opened in the autumn of 1994. Two glulam bridges are included in this project. Both of them are based on the principle of stress-laminated timber decks, and are designed to carry the normal traffic loads according to the Swedish regulations "Bronorm 88". Bridge number 1 has a total length of 35,2 m and a width of 10,7 m. The main load carrying structure consists of 4 rows of poles with crossbeams and 4 parallel three-hinged arches, as indicated in figure 4. The span of the arches is 15 m. The stress-laminated deck is built up by glued laminated beams with a depth of 360 mm.

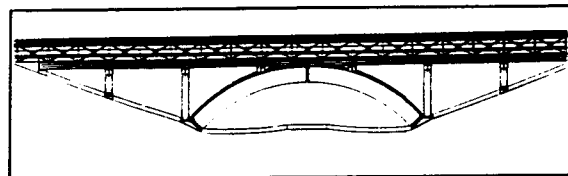


Figure 4-Klockarbergsvägen bridge 1.

Bridge number two has a total length of 16,2 m and a width of 10,5 m. The deck is supported at the ends and by two crossbeams on the top of the poles, see figure 5.

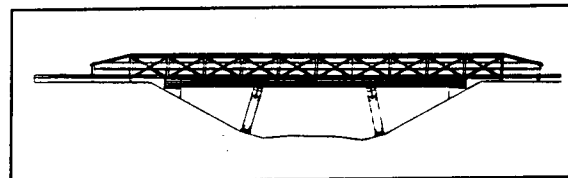


Figure 5-Klockarbergsvägen bridge 2.

The producer of both bridges was Martinsons Trä AB and the design was done by Trätekt in co-operation with Martinsons Trä AB.

Enköpingsbron

In 1995 a new timber bridge for light-weight traffic was opened in the Swedish city Enköping. The bridge has two spans, each 28 m long, see figure 6.

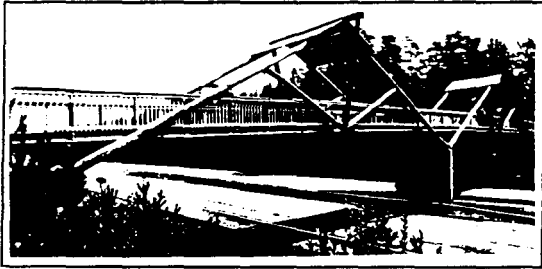


Figure 6-Enköpingsbron.

The deck is supported by a CCA-treated roundwood structure with zinc coated steel parts. The stress laminated deck is built up by CCA-treated solid timber planks and is divided into 5 sections, with lengths of 5 to 6 m. The deck is covered by a membrane and an asphalt top layer.

Examples from Denmark

Pedestrian arch bridge Roskilde

Just outside the Danish city Roskilde a new pedestrian glulam bridge was opened in 1995. The bridge has a total length of 35,8 m and a width of 4,0 m. The main load carrying elements are two three-hinged arches with a span of 32,4 m, as shown in figure 7.

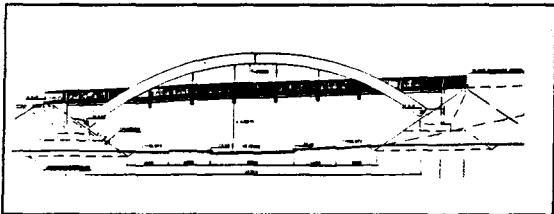


Figure 7-Arch bridge Roskilde.

The arches are circular glulam elements with inner radius of 25 m and a constant cross section area of 300 mm x 1000 mm. The timber deck planks (150 mm x 60 mm) are supported by glulam crossbeams (200 mm x 500 mm) and 7 secondary beams in the longitudinal direction in solid timber (140 mm x 220 mm). The upper surfaces of the glulam arches are protected with aluminium covering.

Pedestrian crossing Hørsholmvej

This timber bridge was built as a temporary bridge in 1955, but is still in service. The total length of the

bridge is 39 m which includes 4 spans with maximum spans of 11,6 m, see figure 8.

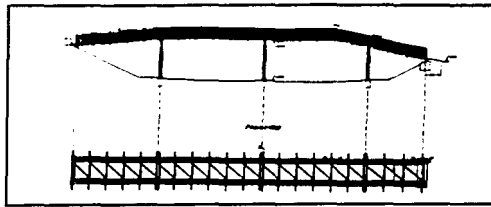


Figure 8-Pedestrian crossing Hørsholmvej.

The main structures are “lattice trusses”. (This system was patented by the US architect Ithiel Town in 1820, and a great number of covered bridges based on “Town lattice trusses” were built in many parts of the United States for railroad and highway traffic.) The cross sections of the trusses are described in figure 9.

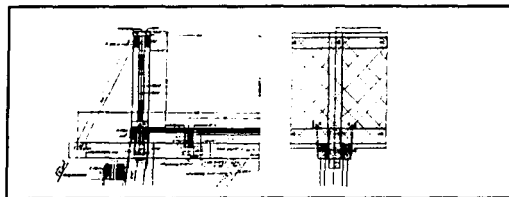


Figure 9-Cross section lattice trusses.

The web members have a cross section of 1,25” x 6”, the lower chord members have a cross section of 3” x 9” and the upper chord members have a cross section of 2,5” x 5” with a horizontal 2” x 8” on the top. After having been in service for 40 years, the bridge is still in good shape with very low maintenance costs.

Examples from Finland

Myllysilta bridge in Nurmijärvi

This roundwood timber bridge is a so called “museum bridge” and was built in 1966. The total length of the bridge is 47 m, and the two main spans are 16 m. The main structures are 7 roundwood systems, as shown in figure 10.

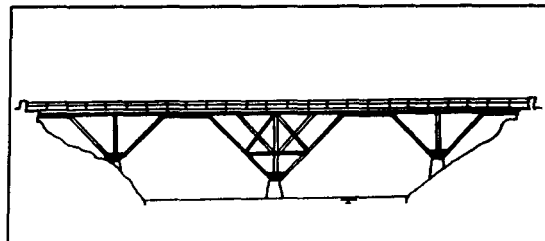


Figure 10-Myllysilta bridge.

The diameter of most of the heavy loaded members are 200 mm, and all the timber pieces are pressure treated with creosote.

Kruununmylly bridge in Hämeenlinna

This bridge was opened in 1993, and was the first Nordic timber and concrete composite bridge. The span of the bridge is 8 m and the width 12 m, see figure 11.

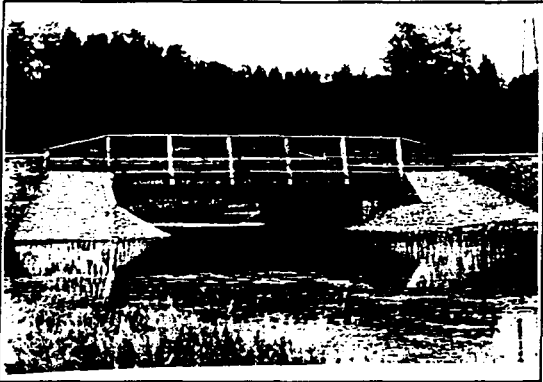


Figure 11-Kruununmylly bridge.

The main structure consists of 11 impregnated glulam beams with cross sections of 140 mm x 630 mm and with a concrete slab as deck structure. The shear connections between the glulam beams and the concrete slab consist of round steel bars. Concreting may be executed without temporary supports, and permanent plywood panels between the girders are the only formwork needed.

Examples from Norway

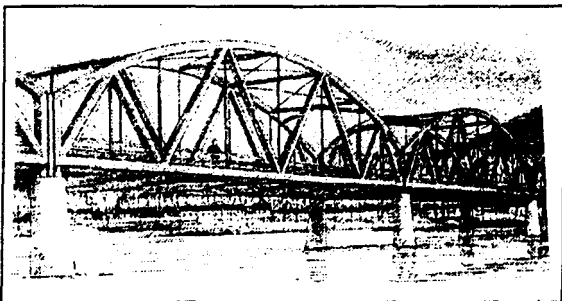


Figure 12-Evenstad bridge.

Evenstad bridge

Evenstad bridge crosses Glomma river in Hedmark county about 250 km north of Oslo.

A preliminary study for the Evenstad bridge was to compare the cost, the aesthetics and the functionality

of one steel, one concrete and one timber bridge in the same situation. Especially for the timber alternative the technical challenge should not be too extensive to handle. The study concluded that the estimated cost for these three alternatives would be about the same, the aesthetic challenge was easier to handle in the timber alternative, and the functionality of the three alternatives would be the same. However, because of the flood condition the superstructure must be situated above the deck. It was decided that a timber bridge should be built. This will be the first modern Norwegian road bridge made of timber.

Technical data and dimensions of the timber bridge

– Evenstad bridge will be 180 m long and the carriageway 6,5 m wide. The bridge will consist of five 35,5 m simply supported spans. The superstructure is composed of two glulam truss girders with a curved upper chord. The girders support the deck by means of crossbeams underneath the truss girders. The substructure will consist of three concrete piers on steel piles and two directly founded abutments. The deck will be a stress laminated timber deck with damp proofing and asphalt.

The project team faces two main challenges for this timber bridge project.

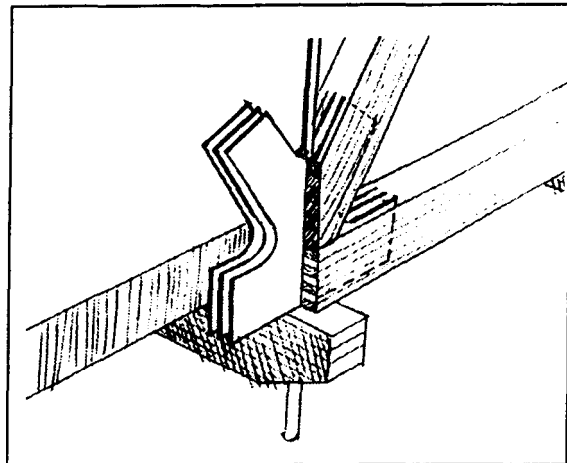


Figure 13-Timber truss girder with joints of multi-section dowel.

The joining of big glulam structures is both feasible, economical and practical to do by using multi-section dowel joint. This will also be the case here, as shown in figure 13. The evaluation is based on experience gained both from the construction of the Olympic Arenas in Norway and from Switzerland in particular. As mentioned, some fatigue studies for this joint are in progress in the Nordic timber bridge project.

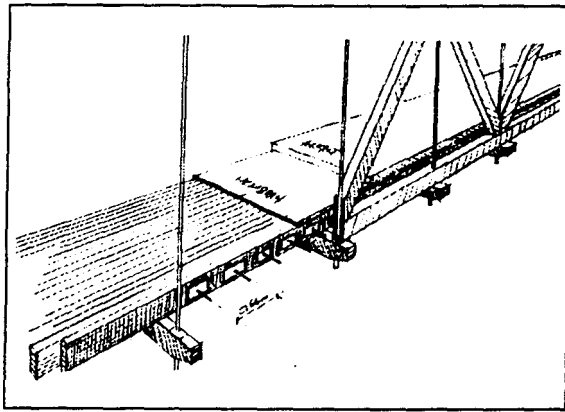


Figure 14-Stress-laminated timber deck.

It will be the first time stress-laminated decks are utilised in a large bridge in Norway. Other nations as Sweden, Switzerland, Australia, Canada and USA have used them for several years. *On* the topside of the deck will be placed a membrane with an asphalt layer top, se figure 14.

Protection system — For this bridge a preservation treatment with MT Creosote with BAP less than 50 ppm will be used. This product is assessed to be the best long-term treatment also in relation to the environmental aspect. Creosote with low benzopyrene used for wood preservation is no longer classified as a carcinogenic product according to EU-classification.

The first timber bridge for road traffic in many years in Norway will be instrument to monitoring moisture content and stress.

From a **maintenance** aspect the use of timber should not be problematic in such a structure. Both the experience from countries that have used modern timber bridges in the last decade, and the use of timber in outdoor constructions show that the maintenance cost for timber structures is very low during the first 40-70 years. The reason for this is both the pressure-treatment with creosote and the fact that the wood itself, with its good characteristics as a bridge construction material, is able to resist impact and shock load.

I will now mention some recently constructed pedestrian bridges.

Stien bridge, Rogaland county.

Stien bridge is a pedestrian bridge crossing the highway about 15 km south of Stavanger leading into the city. It was constructed in 1993.

Stien bridge is 31 m long and 3.4 m wide with a 3 m carriageway. The bridge consists of two glulam

arches with 24 m span which support a deck of wood and steel grating. All timber is preserved with CCA and mordant of oil.

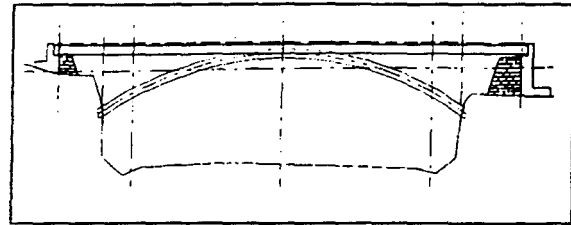


Figure 15-Stien Bridge.

Holmen bridge, Nord-Troendelag county

Holmen bridge is a pedestrian bridge crossing Namsen river in Nord-Troendelag county. It was constructed in 1994.

Holmen bridge is 60 m long and 3.65 m wide with a 3 m carriageway. The bridge consists of two glulam arches with 40 m span supporting a deck of wood and steel grating.

All timber is preserved with creosote. The only problem up to now is that some creosote leaked from the wind bracing to the pedestrians on the bridge. The problem was solved by removing redundant creosote.

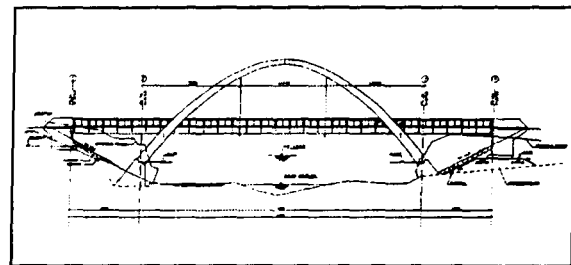


Figure 16-Holmen bridge.

Oeya bridge, Oppland county

Oeya bridge is a pedestrian bridge crossing a small creek in a park in Lillehammer. It was constructed in 1993.

This is a one-span 13 m long and 2 m wide bridge. It is made of one arched glulam girder with steel ribs which also function as parapet. On each post is a timber hand rail. The timber girder and the ribs support a CCA-treated deal deck.

The timber girder is treated with creosote.

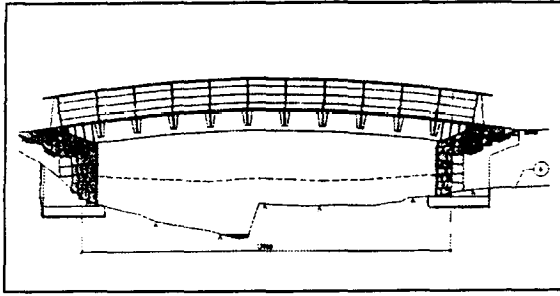


Figure 17-Oeya bridge.

Os bridge, Hedmark county

Os pedestrian bridge is only in a preliminary stage, but is planned as a 80 m long, two-span covered bridge.

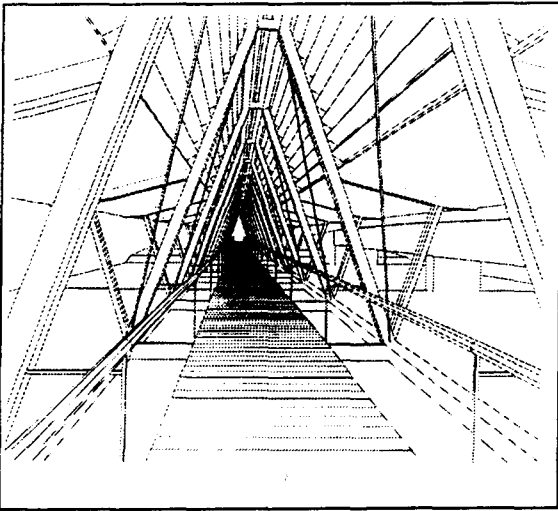


Figure 18-Os bridge.

A dream

Will it be possible to design and build a really big timber bridge? Rune Abrahamsen, a student at the university of Trondheim, questions this in his postgraduate thesis. He concludes that it would be possible to construct a truss arch bridge with a span of 150 m. This is based on experience from the construction of the before-mentioned Olympic Arenas in Norway. The bridge will sustain the traffic load described in the Norwegian Traffic Load Regulation.

The bridge consists of six truss arch timber girders, see figure 19. The top and bottom flange will be 645 x 645 mm and the height of the arch 4 m. The wooden deck will consist of 600 m³ timber and the girders of 1234 m³.

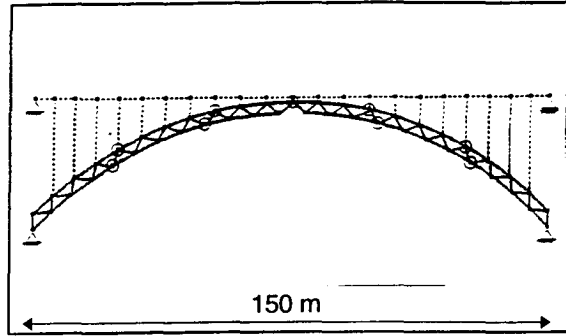


Figure 19-A dreambridge ?

The timber part of the bridge is estimated to about 15 MNOK (M\$ 6.2). At that amount the structure will not be competitive with a similar bridge in concrete or steel.

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