A timber bridge across Lake Mjøsa in Norway

Svein Erik Jakobsen
Director
Aas-Jakobsen
Oslo, Norway
sej@aaj.no

M.Sc. from Norwegian Institute of Technology from 1984. Joined the company Aas-Jakobsen in 1985 and is currently Director of the Bridge Department.
.

Trond Arne Stensby
Project Manager
Norwegian Public Roads Administration
Hamar, Norway
trond.stensby@vegvesen.no

Widar Mikkelsen
Project Manager
Norwegian Public Roads Administration
Hamar, Norway
widar.mikkelsen@vegvesen.no

Yngve Årtun
Chief Architect
Plan Arkitekter AS
Trondheim, Norway
yngve@plan.no

M.Arch. from Norwegian Institute of Technology from 1983. Joined the company Plan Arkitekter as a partner in 1996. Specialist in bridge aesthetics and timber bridges.

Per Meaas
Project Manager
Aas-Jakobsen
Oslo, Norway
pme@aaj.no

M.Sc. from Norwegian Institute of Technology from 1974. Joined the company Aas-Jakobsen in 1976 and is Project Manager for several Major Infrastructure Projects.

Summary

Pre-studies are performed on how to cross Lake Mjøsa in Norway for a new 4-lane link on Highway E6 between the cities Hamar and Lillehammer. Preliminary design is also performed for timber bridges in several alternatives. The timber alternatives are truss bridges with two underlay timber trusses composite with a concrete bridge deck. Typical span width is 69m. Main spans are suggested to be cable stay spans with the same timber truss solution and span widths 120.75m. Total length of the bridge is approximately 1650m.

The conclusions from preliminary design in accordance to ref. [1] have been that a concrete extradosed alternative or a timber truss alternative with cable stayed main spans is to be preferred.

A research program was recently launched by the Norwegian Ministry of Transportation in order to investigate critical aspects involved in construction of such a large timber bridge. The research will focus on the large scale aspects, durability and the technical solution.

Keywords: Timber truss, world record, research program.

1. Introduction

1.1 1st Mjøsa Bridge

Fig. 1 Overview of 1st Mjøsa Bridge

The 1st Mjøsa Bridge was opened to traffic in 1985 and is a part of the main north-south highway in Norway, the E6. The bridge crosses the largest lake in Norway, Lake Mjøsa, and is in total 1311m long. It is a concrete box girder bridge with typical span widths of 69m. The bridge is founded on piles, some to rock, some as friction piles. At the bridge site, the lake is app. 30-40m deep, giving a considerable free span in water for each pile. The bridge has two lanes of traffic and a pavement for walking/bicycling. An overview picture og the bridge is shown in Fig. 1.

1.2 Feasibility study 2006

Since traffic is increasing on the E6, plans have been introduced to increase capacity across Lake Mjøsa. In 2006, Norwegian Public Roads Administration carried out a feasibility study in order to investigate if it was possible to cross Lake Mjøsa with a bridge in vicinity to the existing one. The feasibility study report was worked out by Aas-Jakobsen AS. The existing Mjøsa Bridge is situated on a narrow sill formed by ancient glaciers. The feasibility study concluded that it was possible to place yet another bridge at the same sill. The study also identified another possible alignment for the crossing further south, this however requiring deep sea foundations.

1.3 The timber bridge background

The Norwegian Public Roads Administration Region East is responsible for construction and operation of the possible 2nd crossing. This region has been the leading developer of timber bridges in Norway. Through a large number of timber bridge projects, the knowhow and expertise has grown over the years, making this region one of the leading timber bridge environments in the world. Since Mjøsa Bridge is situated in the very heart of this timber bridge society, it is only natural that there are strong interests to consider a timber bridge alternative for the new crossing. The fact that this will be the world's longest bridge of its kind, if carried out as a timber bridge, only strengthen this attitude. In 2010, a timber bridge seminar was held close to the bridge site in order to determine whether a timber bridge alternative was feasible for Mjøsa Bridge. Experts from the whole industry were invited, and the conclusion was positive. The seminar even introduced three different technical solutions as basis for further work.

1.4 Conceptual design 2012

In 2012, Norwegian Public Roads Administration launched a conceptual design phase involving evaluation of all consequences of realization of the project for the 2nd crossing of Lake Mjøsa. The project was awarded Aas-Jakobsen AS. One of the basic boundary conditions of the project was that at least one timber bridge alternative should be investigated.

The first part of the project was dedicated to evaluations of road alignments as defined in the feasibility study. Along this work a broad spectre of bridge alternatives was evaluated for the different alignments. The recommendation from this part of the project was that even if the southern alignment has technical challenges from deep sea foundations, it is preferable to traffic and to public considerations.

Given the recommended alignment, it was concluded that both from technical aspects and from aesthetical aspects, the bridge should have increased mid span lengths compared to side span lengths. This lead to the conclusion that the bridge type should either be a concrete box girder type with extradosed main spans, or a timber underlay truss type with main spans supported by cable stays.

This paper further describes the latter.

2. Technical challenges

2.1 Technical description

The proposed new bridge has a total length of 1650m and span widths typically 69m. The middle four spans have span widths 120.75m. The bridge is founded on rock in two axes, on piles to rock on 13 axes and on friction piles on the remaining 8 axes. Deep sea foundations in the five main span axes are friction piles up to almost 110m length, with a 40m portion in soil and a water depth of 70m. The free spanning through water is restricted through a concrete caisson solution acting both as guides and as buckling constraints to the piles. The piles are steel piles with diameter 1220mm. A side overview of the bridge solution is given in Fig. 2.

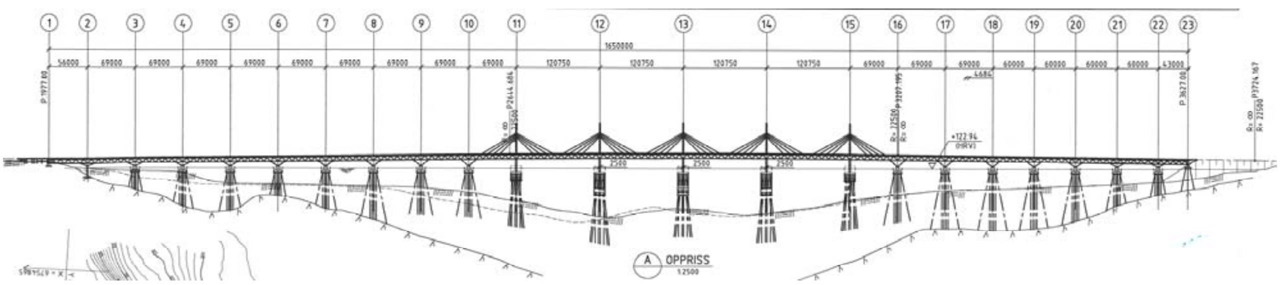

Fig. 2 Side overview, timber bridge

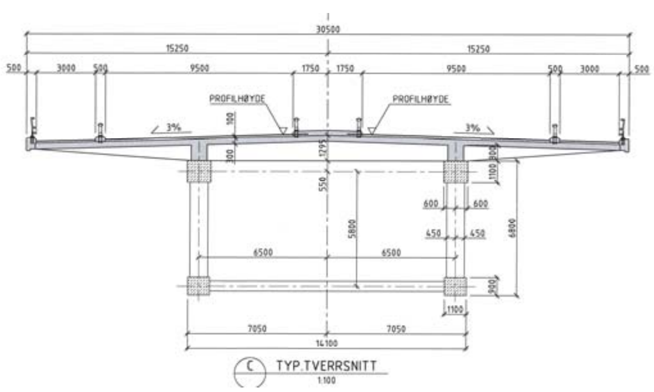

Fig. 3 Typical cross section

The bridge carries four lanes of traffic, with free space between railings of 2 x 9.5m, one pedestrian lane of 3m and one service lane on the opposite side of 3m, giving a symmetric layout og the bridge as can been seen on Fig. 3.

The superstructure is a two plane timber truss with a height of 6.8m proposed in composite action with a concrete bridge deck. The timber truss members have typical dimensions of 1100mm x 1100mm, 1100mm x 900mm and 900mm x 900mm, and with steel nodes.

Fig. 4 View beneath the bridge

Typical columns are V-shaped in side spans to reduce effective span widths and W-shaped in main span to transfer the large vertical forces to the foundations. This can be seen in Fig. 4.

A third longitudinal beam is required in main spans to transfer the horizontal compression force from the stays into the bridge deck.

The stay plane is placed in the centre, implying the introduction if single towers in between the traffic lanes. The towers are preferably wooden with steel anchor attachments.

The bridge deck is a concrete deck with typical thickness of 300mm supported by longitudinal beams above each truss plane and transverse cross beams every approximate 7m, situated above the truss nodes.

2.2 Structural behaviour

The overall length of the bridge requires careful considerations on global behaviour and force transfer of for instance creep, shrinkage and temperature effects. In the preliminary design performed, the bridge is proposed to be a composite bridge with regards to the timber truss and the concrete deck, and with full force transfer between these elements. The superstructure therefore will be a continuous beam from abutment to abutment. The bridge is fixed at the central pylons and has sliding bearings in side spans. This requires large expansion joints at the abutments.

The vertical forces in the main span are partly transferred through the stays to the central pylons, while the transverse forces are transferred through the bridge beam to the same pylons.

2.3 Aesthetics

The idea of the truss timber bridge was developed from the requirement of relatively large spans. This requirement was agreed to be vital both from aesthetical and economic reasons, to avoid costly foundations and to avoid the common barrier look that the long strait crossings with small spans often tend to have.

It was also agreed that the introduction of longer mid spans was beneficial to the overall looks of the bridge. These spans underline the bridge as an icon, and also emphasize the proposed ship channel areas. It was also a discussion of how many towers should be introduced. The common opinion within the project group was that a number of 3, 5, 7 etc. would be better than 2, 4, 6 etc. This is demonstrated in Fig. 5.

Fig. 5 Example of a 3-tower configuration

The final decision was to introduce 5 towers as this also minimizes the number of deep sea foundations.

2.4 Large scale challenges

The bridge will be the longest timber bridge in the world if chosen. Hence it has been vital to the project to identify what challenges this introduces. A list of topics has been outlined as follows:

- Composite behaviour with concrete (internal force transfer, different material characteristics)
- Deliverance capacity (manufacturing, transportation, assembly)
- QA (certificates, guarantees)
- Durability (large scale effects)

2.5 Durability

The bridge will be designed for a 100 year life. The project must however make sure this is feasible in reality for such a large scale project. For normal size bridges it is more relevant to do repair and rehabilitation on exposed parts of the structure, but with the size of the Mjøsa Bridge it is of vital importance to ensure durability through technical solutions, treatment and planning.

To place the timber trusses beneath the wide concrete deck as proposed will make timber less exposed to sun, temperature differences, rain, salt treatment, etc. The environment should therefore be the best to increase durability. In addition, the experience from the many neighbouring timber bridges will constantly improve the durability, giving the best state of the art design available as a reference.

3. Further development

3.1 Goals

The project will now enter the next phase doing extended preliminary design of the chosen concepts before entering a future detail design phase. As per now, the time schedule for further work is however uncertain due to the political situation in Norway, with a parliament election this autumn.

It is however the goal of the project team to design and construct this prestige bridge in near future, making it an iconic symbol for both the region and the country. To make it into the largest timber bridge ever built would in addition be a valuable achievement for the whole industry.

3.2 Research programme

The Norwegian Department of Transportation has recently launched a research programme to make the timber bridge alternative for the 2nd Mjøsa Bridge competitive to other solutions with regards to the technical challenges involved. The research programme will focus on the following aspects:

- Large scale effects on timber bridges
- Cable stay solutions on timber bridges
- Large spans on timber bridges
- Temperature effects on timber bridges
- Material specifications on timber
- Preservation of timber
- Composite behaviour between timber and concrete

4. Conclusions

The conclusion of the feasibility study and preliminary design of the 2nd Mjøsa Bridge is that a timber truss alternative is recommended as one of the alternative solutions. The bridge will have a total length of 1650m. A research programme is now being launched in order to bring this alternative up to level of other recommended alternatives. The program will focus on large scale aspects, durability and technical solution.

5. References

[1] Statens vegvesen: “Kommunedelplan. E6 Gardermoen-Biri. Parsell Moelv-Biri. Rinsaker og Gjøvik kommune. Konstruksjonsrapport”. B003 (Aas-Jakobsen), ver. 14.06.2013.