Tretten Bridge – Timber and Steel in Harmony

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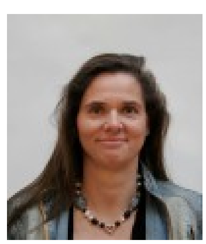

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Summary

The County's Hedmark and Oppland have a tradition of building timber bridges. Tretten Bridge is the last large bridge built suitable for traffic loads. The bridge is intended to have a 100 year life expectancy. This is achieved by creosote impregnation, constructive protection, detailing or a combination of these actions. As for the people at Tretten, a new bridge had long been anticipated and this bridge stands as a landmark not only to the locals but for everyone traveling in the area. The combination of timber and steel made it possible to give the truss a new and unconventional shape, which also improved the traffic situation considerably.

Keywords: Timber Bridge, slender shape, existing foundations, weathering steel.

1. Introduction

The village of Tretten is located in the valley Gudbrandsdalen about 30 kilometres north of Lillehammer, Norway. With the village centre and railway station located on each side of the river Gudbrandsdalslågen, the bridge built in 1894 was the only crossing point for the 900 inhabitants. In the 1980`s the single lane, 3 meters wide truss steel bridge was strengthened with tendons and widened 2 meters for pedestrian traffic. However, the increasing traffic loads, especially vehicles from the industrial area located on the western side of the river, made it necessary to build a new bridge.

2. The concept

As part of the main highway between Oslo and Trondheim, two of the largest cities in Norway, the planning of a 10 kilometres section between Tingberg and Tretten started in September 2003. Initially Tretten Bridge was a part of this development plan, but it was early decided to prepare a separate plan for the bridge only. Several meetings were arranged during the winter of 2003/2004 with the team consisting of architect, structural engineer and representatives from the Norwegian Public Road Administrations, NPRA. The team had to emphasized the aesthetics during the planning as bridge site was strongly exposed both from the highway and city centre.

During this phase several different alternatives were investigated. The Norwegian Water Resources and Energy Directorate, NVE, are restrictive when it comes to establishing new foundations in the river making a normal concrete bridge not an option because of the span length requirement. A combined steel girder and concrete bridge was possible but was excluded because of the aesthetics and the limitations in road geometry below and on the bridge. Remaining as the most obvious option was a truss bridge similar to the existing bridge. Having decided on the bridge system inspiration was gathered from other projects of this time.

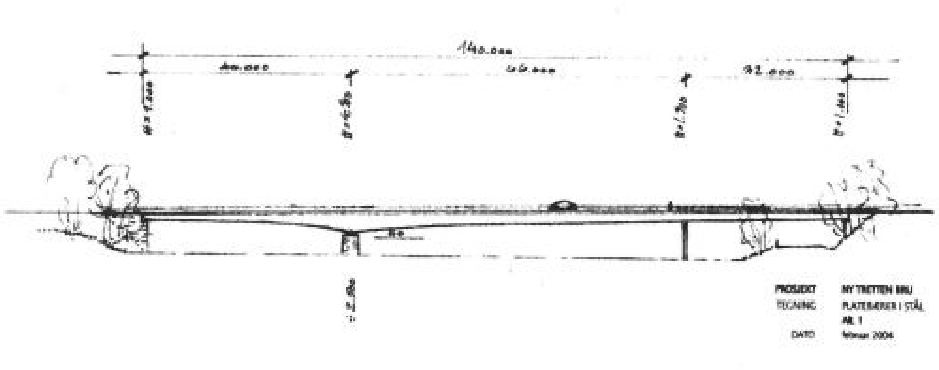

Figure 1 Steel girder and concrete alternative

In June 2003 the new Flisa Timber Bridge was opened for traffic. It was natural to continue the experiences gained during this rebuild. In many ways the two old bridges had a lot in common. They were built during the same period. They were both founded on stone foundations, that showed no signs of settling damages or other damages and were visually in great shape. The superstructure was steel trusses with a relative light timber deck. At Flisa the existing foundations were reused. A premise for reusing these foundations is avoiding an increase in weight of the superstructure and timber is a material often used to fulfil this requirement. Especially a stress laminated timber deck has turned out favourable with its light weight and high stiffness. Based on these experiences it was decided to build a new timber truss bridge on existing foundations at Tretten.

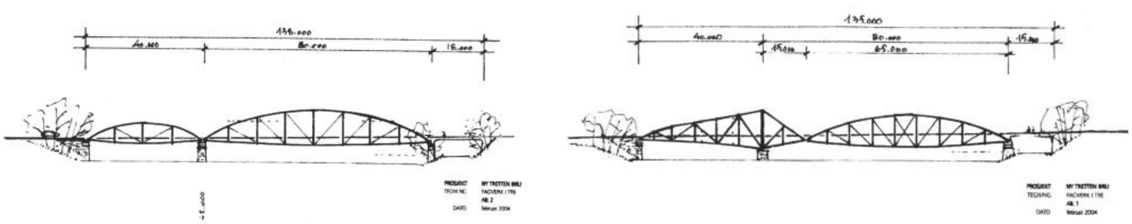

Figure 2 Timber truss alternatives

Traditional truss bridges, like the existing truss at Tretten with elevated wind trusses for each section, often give a tunnel sensation while driving through them. A continuous truss was expected to counteract this feeling, minimizing the need of wind truss. Also, the bridge deck was lifted up from beneath the truss and placed inside the truss. This lowered the height of the bridge without reducing the capacity of the truss.

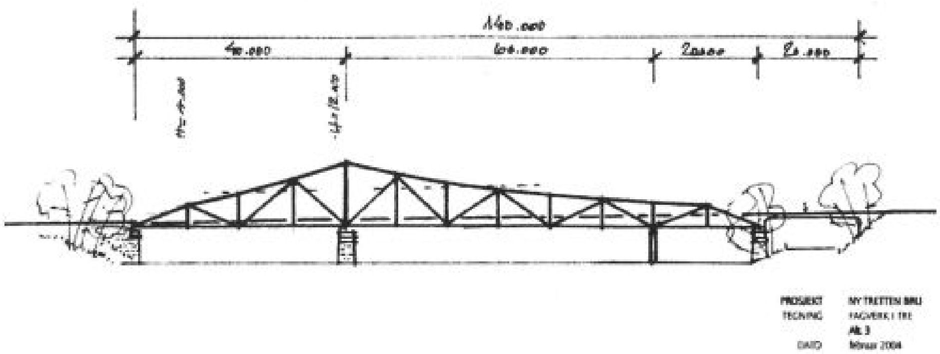

Figure 3 Continuous truss

The bridges also had some differences that influenced the shape of the superstructure. At Flisa all the existing foundations were reused and a similar truss system to the existing truss was designed. At Tretten only the foundations on the western side of the river could be reused. The abutment on the eastern side was partly damaged during a reconstruction in the 1980`s and it was early decided that a new foundation was needed. This resulted in an asymmetry in the foundations, old and "heavy" in the west and new and "light" in the east, and the architect wanted to reflect this asymmetry in the superstructure. The distinctive wing shape is strengthened by the asymmetry in foundations.

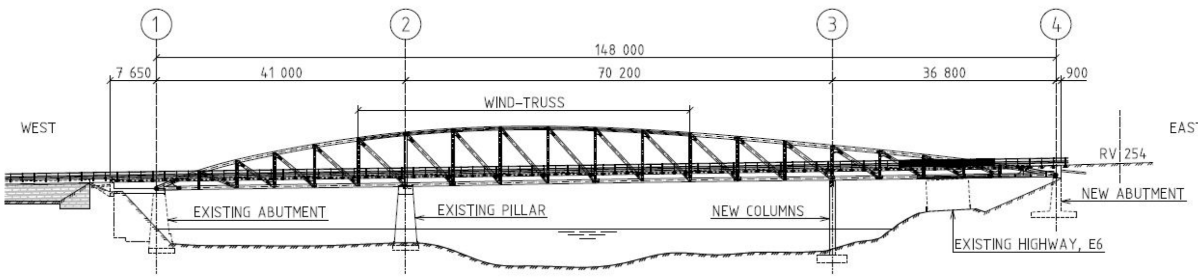

Figure 4 The final shape of the truss

The pointy end in the east was also favourable for the T-intersection at this side. The low height made it possible to start the widening of the carriageway somewhat inside the truss supports strongly improving the tracking for vehicles, especially larger trucks.

Also a big advantage with the truss shape was the lack of negative support forces at the ends. This simplified the detailing of the support as there was need to anchor the bridge.

3. Analysis

The Eurocode Design Code was introduced in November 2010 as the governing code for all new bridges in Norway. However, the design of the bridge started prior to this date and it was decided to continue using the Norwegian material codes, NS3470-1 [1], NS3472 and NS3473. The bridge is exposed to traffic loading defined in the Handbook HB185 issued by the Norwegian Public Roads Administrations, NPRA, [2]. Three concentrated axel loads, each of 210 kN, and a uniformly distributed load of 9 kN/m is applied to each lane of width 3.0 m. In addition, the pedestrian pathway is submitted to a uniformly distributed load of 4 kN/m. The traffic loads are applied both symmetric and asymmetric in the lateral direction on the 7.5 m wide driving area.

The bridge was analysed using the program RM-Bridge [3] and consists of the complete model of the superstructure, including the bridge deck and columns in axis 3. The foundations in axis 1, 2 and 4 were modelled as simple supports.

The predesign phase anticipated steel parts at the truss ends and at axes 2 and 4. However, with all cross beams located above the lower chord every connection between cross beam and vertical member had to be able to transfer moment forces. Common connection design using vertical members of wood or vertical steel hangers could not be used. Hence, all vertical members were carried out in steel.

4. Substructure

Minor modifications were done to the existing foundations in the west. The upper most stone layers were removed enabling space for a new concrete slab working as support for the new cross beams. Expansions of the bridge-width lead to cantilever cross beams used to support the new trusses. The concrete slab, cross beam and truss support in axis 1 is shown in figure 5.

Figure 5 Truss support in axis 1

Calculations showed that the existing foundation in axis 2 had sufficient capacity without further modifications. However, based on experiences gained at Flisa, steel piles under each bearing were installed to give extra capacity as a precaution.

The shape of the new columns in axis 3 was challenging for the architect. Reproducing the appearance of the old foundations was possible, but this construction method is out of date and not an optimal option. The solution was two slender columns diverging from the existing foundations and amplifying the asymmetry of the bridge.

The new abutment in the east was built to take into account for future expansion of E6. Also by widening the bridge deck with a cantilever concrete beam, no widening was done in the timber bridge deck.

Figure 6 Cantilever beam in axis 4

5. Superstructure

How did the shape of the truss influence the design of the superstructure?

All timber connections were done by embedded steel plates in sawn slots. The forces are transferred by dowels through the plates and timber. The timber deck consists of stress-laminated beams clamped together by pre-stressed high strength steel rods. These methods are thoroughly described in the article "Technical Concepts for Long Timber Bridges" presented at ICTB 2010 [4].

The bridge railing used was developed for timber decks solely and is used at most timber bridges built in Norway during recent years. The development was presented in the article "Development of a New Barrier System for Stress Laminated Road Bridge Decks" at ICTB 2010 [5].

Figur 7 Bridge railing at pedestrian side

5.1 Main truss

The main truss was carried out in glue laminated timber. The material properties of the timber are given in [1]. In general timber in strength class GL32c (GL = Glue Laminated, 32 = 32 MPa bending capacity, c = combined cross-section) was used.

The diagonal braces were individually designed with cross sections depending on the loads. Initially it was desired to use the same cross section for all diagonal braces, but the braces closest to the supports needed larger cross section. The difference in dimensions was barely noticeable on the new bridge.

The buckling capacity of the upper chord was expected to determine the dimensions because there was no wind truss over the lower points of the structure. However, timber has greater compression than tension strength and it turn out that the most critical area was above axis 3 where the chord has its maximum tension force. Also, substantial lateral moments occurred at this point as the only lateral stability in this area is given by the U-frame created by the verticals and cross beam. To reduce these moments the cross beams closest to axis 3 were made stiffer to give more lateral stability. Also the timber strength class changed to GL32h (h = homogenous) which has greater tension capacity compared to GL32c by about 15 %.

Figure 8 Crossbeam/vertical connection

At the eastern end the steel part was extended for the lower chord as the capacity of the timber was insufficient. Also the timber was changed to GL32h for the timber next to the steel.

5.2 Weathering steel

Weathering steel, also known under the trademark COR-TEN steel, was used in all visible steel parts. The colour of COR-TEN steel resembles the colour of creosote impregnated timber and this was an important reason for choosing COR-TEN steel in the main truss members.

The main advantage with using COR-Ten steel is the reduction in maintenance. As there is no need for surface treatment the construction period will be shortened and simplified. For conventional steel, surface-damages appearing during transport, storage and installation have to be repaired. These small damages are insignificant for COR-TEN steel as the protective patina will be restored on its own.

COR-TEN steel is more vulnerable to moisture and dirt compared to conventional steel. It is therefore important to emphasize detailing, especially avoiding areas where moisture and dirt might accumulate.

The selection in steel quality is somewhat limited for COR-TEN steel compared to regular steel. The best steel quality available is S355K2W, specified in NS-EN 10027-1 [6]. The Norwegian Process Code [7], issued by the NPRA, specifies the maximum thickness of the steel to avoid brittle fractures depending on the minimum temperature at the bridge site. With a minimum temperature of -40°C the maximum thickness is 35 mm. This had to be incorporated in the structure.

5.3 Lightning

The architect wanted to avoid the standard light pylons used to light up the road surface. These pylons would also interfere with the contour of the truss. Special armatures were developed exclusively for this project. These were fitted on the pedestrian side of the bridge and were designed to light up the road surface without blinding the drivers on the road below.

6. Fabrication and installation

October 2011 a new temporary bridge was constructed. This bridge was founded on embankments in the river. The embankments would also serve as construction site for the truss assembly and mobile crane arrangement. At wintertime the water flow in the river is less than during the rest of the year, and especially in the months of May and June when the spring floods arrives. As a consequence, the temporary embankments had to be removed before the middle of April. Early November the temporary bridge was finished and the demolishing of the old steel truss started.

All steel parts were prepared in Denmark before they were shipped to the Czech Republic and assembled. The finished steel parts were then shipped to Norway and the glue-lam factory Moelven AS at Moelv, 60 kilometres south of Tretten.

The size of the timber parts was limited to the size of the creosote impregnation tank, transportation and reasonable truss size during the lifting operation. Thus, the truss was divided into 6 sections giving a maximum timber part length of 23.4 m.

To secure the fitting of steel and timber members all parts were assembled on the floor in the factory in advance. The sections were coupled before they were disassembled and sent to the creosote tank. Finally the sections were reassembled at the bridge site and hoisted into position. The final truss section was installed in the end of April, shortly after the removal of the provisional bridge.

The last couple of months were used installing the parapet, membrane and asphalt, and finalizing other details. June 15th 2012 the new bridge opened, only 7 months after the old bridge was closed.

Figure 9 New bridge in the sunshine

7. Cost

Did the truss shape, with a relative high share of steel, influence the costs of the bridge? Will the price increase along with the amount of steel? As seen in the table below, this seems not to be the case. All prices are adjusted to 2013 values.

	Year	Length [m]	Width [m]	Area [m^2]	[NOK/m^2]
Evenstad	1996	180	6.5	1170	23 238
Flisa	2003	182	10,5	1911	26 297
Rena	2005	158	6,3	995	28 924
Tretten	2012	148	10.5	1554	26 810

Table 1 Compared prices

The difference between Evenstad in 1996 and Flisa in 2003 is thought to be from the increase in steel prices around the turn of the century. During the following years the prices have stabilized.

It is most natural to compare bridges at Flisa and Tretten as these have the most in common. As Tretten Bridge has more steel parts and also two new foundations it is somewhat surprising that the prices in reality are the same. The explanation might be in preparing the steel parts. The number of connections between steel and timber are considerably reduced as there is only one vertical steel member at each cross beam. The detailing and accuracy level at connections is an important cost factor and a reduction of these will compensate for the increase in steel.

The bridge at Rena is designed for heavy military vehicles and was, as might be expected, more expensive.

It is also worth mentioning that timber truss bridges are price competitive in comparison to steel truss bridges.

8. Discussion

The feedback on the truss shape and the amount of steel has varied. Some wondered why the bridge wasn't carried out in steel in its entirety. Others react on the unconventional truss shape with all diagonal braces pointing in the same direction.

As mentioned above the pre-design phase had several guidelines when determining the shape. The team was influenced by other projects at that time and Oppland County is a forestry county where timber has been an important building material. This combined with the benefits of the light deck made a timber bridge the best option.

The combination of timber and steel made it possible to shape the bridge as desired without any additional bracing at the axes, as done at Flisa. A structural engineer might think that the materials weren't utilized to its maximum, but the common person in the street wouldn't think about this.

And who are in majority?

9. References

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