

# Schwerverkehrsbrücken in Norwegen

Heavy traffic bridges in Norway

Les ponts à trafic lourd en Norvège

Ponti per traffico pesante in Norvegia

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## 1. Introduction

### 1.1. Historic background

Norway has a relatively long tradition of building timber bridges to cross rivers and streams. Before the 20<sup>th</sup> century hundreds, or possibly thousands, of timber bridges were built all around the country. Most of these bridges were small, and just a few remain intact today. In the beginning of the 20<sup>th</sup> century, when the supply of steel and cement was good, timber lost its position as the main bridge building material.



At the beginning of the 1990s a new era for timber bridges started. With the Winter Olympics in Lillehammer in 1994 as the accelerator, new techniques for the use of glulam were developed. A new type of connection technology with slotted-in steel plates and dowels made it possible to handle larger forces and thus create larger spans. The first big timber road bridge built in Norway in modern times was built over the river Glomma in 1996. After this more than 150 modern timber bridges have been built, of which about 50% are designed for full traffic load.

Some of the most known bridges are:

- *Tynset Bridge*. Built 2001. 126 m long. 2-lane road bridge with sidewalk. The 70 m main span is regarded as the longest timber road bridge span worldwide
- *Flisa Bridge*. Built 2003. 196 m long 2-lane road bridge with sidewalk. This is one of the longest timber road bridges in the world
- *Kjøllsæter Bridge*. Built 2006. 158 m long 2-lane military road bridge. Designed for a convoy of tanks each weighing 109 tons.

Confidence in timber bridges is high in Norway. Recently the Norwegian Public Roads Administration initiated a feasibility study for a gigantic timber bridge across the lake Mjøsa in Eastern Norway. This motorway bridge is about 1,5 km long, has 4 lanes and is planned to be finished by the year 2020. It was presented at the International Conference on Timber Bridges in Lillehammer September 2010 [6]

### 1.2. NPRA

The most important bridge owner and bridge builder in Norway is NPRA (Norwegian Public Roads Administration). NPRA is open-minded to all types of bridges as long as they fulfil NPRA's requirements to functionality, maintenance, service life and costs.

NPRA is playing an important role in establishing alternatives to steel and concrete bridges, and has put a lot of effort into developing timber bridges. This is probably the main reason why approximately 10% of new bridges being built in Norway are made of timber.



**Statens vegvesen**

Based upon about 15 years of experience the NPRA has learned the following:

- Short to medium span timber bridges are cost competitive. Usually a timber bridge costs slightly more than a concrete bridge, and slightly less than a steel bridge.
- Timber as a structural material can handle high forces occurring in road bridges
- Timber bridges built so far do not need more maintenance than other bridges
- Timber bridges are aesthetically pleasing
- Timber bridges are popular among the public

NPRA requires 100 years service life for all bridges. The Norwegian approach to this has been to use chemical treatment (copper or creosote) in combination with constructive protection and careful detailing. This has been a successful approach for Norway.

The use of chemically treated timber is considered to be environmentally sound since it ensures that the bridge components can be used for a very long time. NPRA has initiated research projects to search for alternatives to chemically treated timber in future projects. These have not led to any major breakthroughs so far.

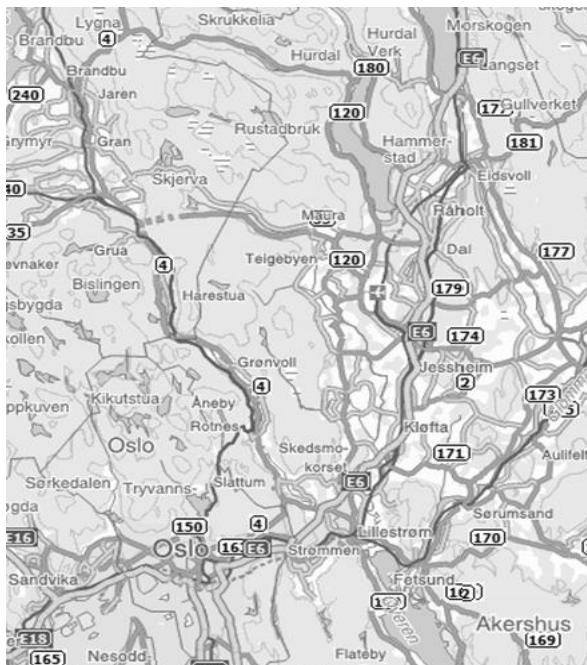
### 1.3. The E6-project

The main north-south connecting motorway E6 in Norway is currently under a huge construction program increasing the road from two to four lanes.

The engineering companies Sweco and Cowi were hired to do the bridge design work for NPRA. On the initiative of the NPRA's project manager it was decided to give five selected bridges crossing over the E6 within a distance of not more than about 10 km a spectacular look to catch the attention of the passing drivers. The idea was that such unusual and eye-catching structures along the route would cause drivers about to fall asleep due to fatigue to wake up simply by pure surprise of what they had seen.

The two road bridges presented here, The Sundbyveien Bridge and the Sletta Bridge are part of this program.

### 1.4. Location



The two bridges are marked on the map shown in **Fehler! Verweisquelle konnte nicht gefunden werden..** Both bridges are serving secondary roads crossing the E6

Sundbyveien Bridge [1] is about 60 km north of Oslo and 15 km north of Oslo Airport.

Sletta Bridge [2] is about 65 km north of Oslo and 23 km north of Oslo Airport.

To locate the bridges simply follow E6 north of Oslo and you will easily spot the bridges as you drive under them.

Fig. 1: Map showing the location of the bridges

## 2. The design process

The design of the timber bridges was developed during a period of four years, and the planning process started in the winter of 2005. The architectural and structural innovations of the bridges are the result of a strong intention of the project manager Jørn Reinsborg and his team to build a new motorway with outstanding technical and visual quality. The overall intention was "a beautiful road". Reinsborg had previously experienced that eye-catching structures kept drivers awake on the roads in this monotonous wooden part of Norway.

This perspective resulted in a design of special structures in a metamorphic visual language. The planning started with informal meetings discussing how to build a beautiful and a safe road. In this process the design of both bridges and other structures were developed from simple and rough sketches expressing various ideas. The informality of the process and the meetings kept at small mountain lodges were important for both the creative process and the result. The participants dared to think freely about road planning and design, and this is something rare in this kind of planning structures. A chaotic expression was strived for, and one idea was to create a bridge from the conception of a timber jam. The first sketch of a metamorphic truss structure was made incidentally. Fig. 2 shows a sketch that became the mother of all the truss bridges of the area.

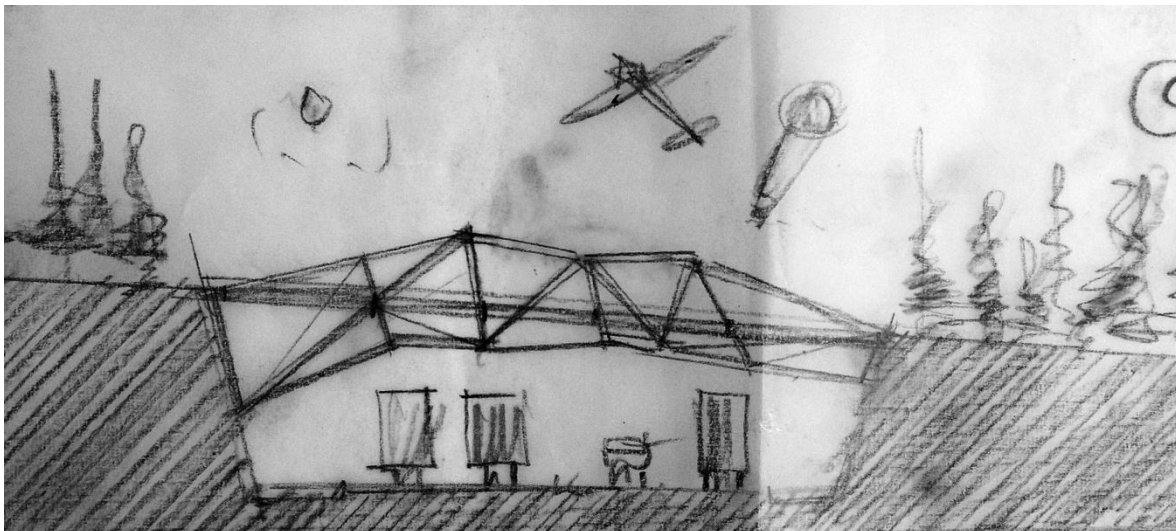


Fig. 2: The "mother" of the truss bridges

The most important in this process was perhaps the equality between engineers and architects in a common design process that lasted for years where a great number of truss structures and similar structures were analyzed. These bridges are therefore primarily engineering structures with the architecture as a consequence of advanced engineering. No engineer and no architect would have developed such structures alone.

In the later stages of the process and after the project had been given a final "go", five individual bridges were developed and adopted to the situation of the different sites although originating from the same basic idea

### 3. Sundbyveien Bridge

The Sundbyveien Bridge is the largest of the 5 metamorphic bridges. The special thing about this bridge is that the two trusses are mirrored. That means that the two trusses are identical, but rotated 180 degrees to one another. The effect can be seen in Fig. 3.



Fig. 3: Sundbyveien Bridge as seen when "driving" in the 3D model

The Sundbyveien Bridge is part of a local road system crossing the E6. This road serves about 1400 vehicles every day, and the speed limit is 80 km/h. The length of the bridge deck is 61,4 m and the traffic area is 6,3 m. On one side is a 2,4 m wide side-walk area. The distance between the trusses is 10,5 m, and the main span is 42 m, see Fig. 4 and Fig. 5.

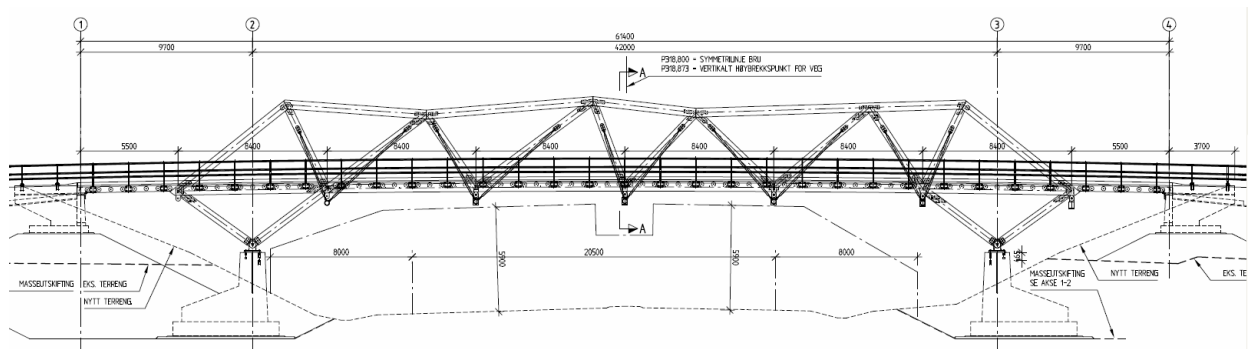


Fig. 4: Side view of Sundbyveien Bridge

The main truss members have typically a cross-section of  $b \times h = 560 \times 500$  mm, while the diagonals have typical dimensions of  $b \times h = 460 \times 433$  mm. They are joined by a group of 12 mm steel dowels and 8 mm slotted-in steel plates.

The inclined steel struts, see Fig. 5, connects some of the diagonals with the cross beams and stabilize the diagonals from warping out of their vertical plane. Through the bending stiffness of these diagonals, the joints of the upper cord of the trusses are prevented from buckling out of the vertical truss plane. The stability of this system has been verified by a 2.-order 3D-analysis.

The bridge deck is a stress-laminated wood plate, made from glulam members with dimensions  $119 \times 333$  mm. The height of these members is increased to 533 mm in the sidewalk. At an interval of 667 mm steel rods are prestressed to produce a lateral compression of the deck. As a result of the friction of the members the deck acts as an orthotropic plate. On top of the glulam deck there is a 1-2 mm Polyurea membrane. On top of this there is an 80 mm layer of asphalt. The sides of the deck are covered with thin copper plates. The membrane overlaps 200 mm with these plates.

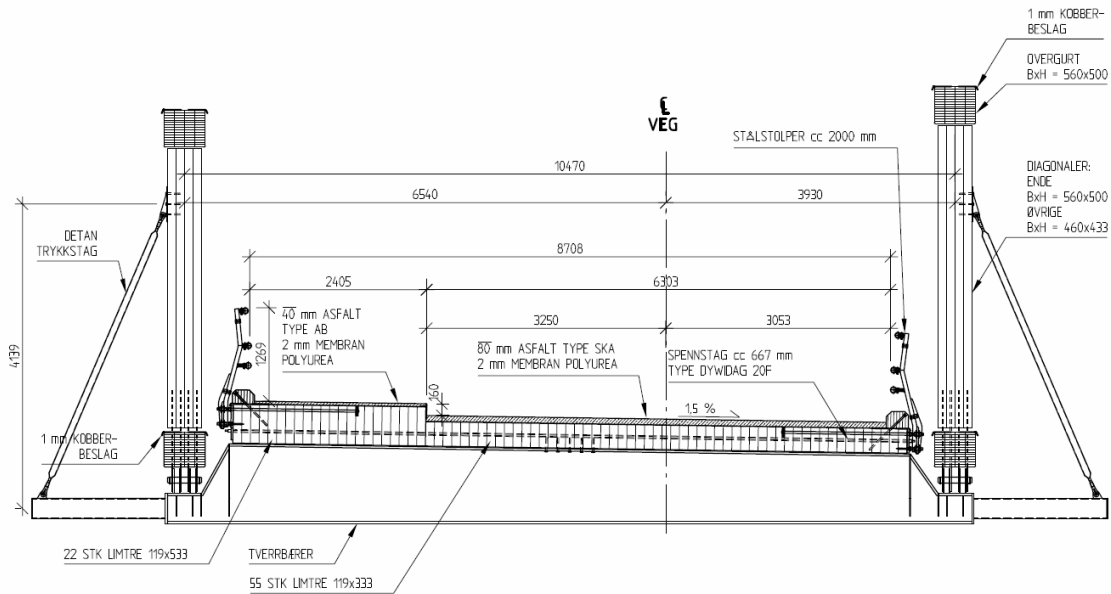


Fig. 5: Cross-section of Sundbyvegen Bridge

All the steel members are made of weathering steel quality. After some years this steel alloy forms a protective rust-like layer that reduces further corrosion. The steel members are designed with some corrosion allowance, and the parts without access for inspection are furthermore protected by powder coating. Thus there are no galvanized or painted steel parts in the bridge.

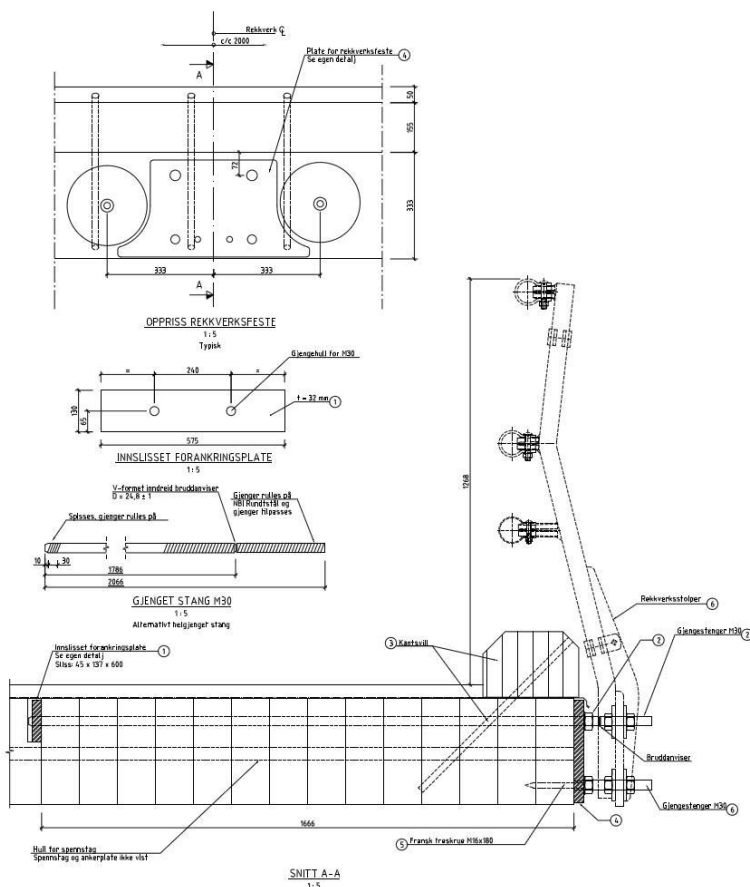


Fig. 6: The traffic barrier system

A traffic barrier system recently developed in Norway for stress laminated road bridge decks is used for all timber bridges in this project, see Fig. 6. The rail is made of steel

instead of timber to give the bridge a more transparent look, since timber rail components tend to get pretty thick. The rail system is tested according to EU-standards using special software for crash testing simulation. The configuration, the requirements and the work done for verification of the system is described in Ref [5].

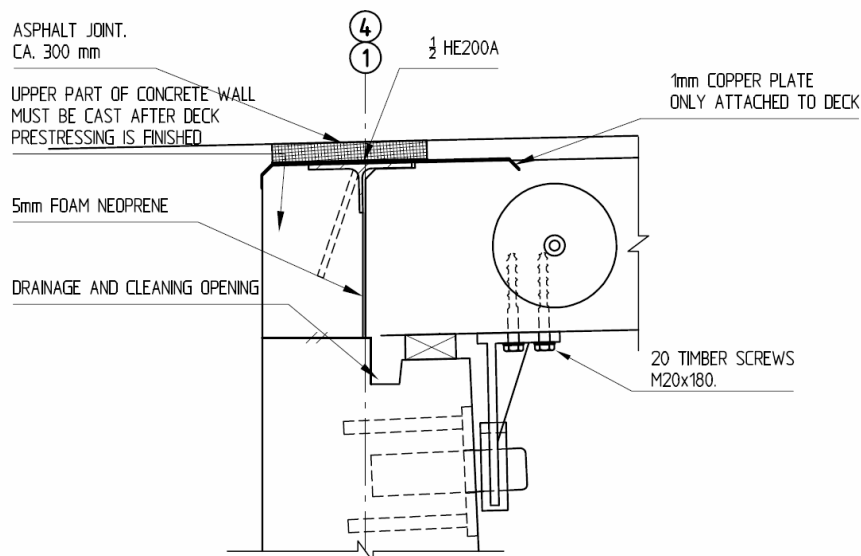


Fig. 7: Typical end detail of deck

Fig. 7 shows the bridge deck end detail for Sundbyveien Bridge. This detail is used for all timber bridges in this project, and is the most common way to do this in Norway. The long time experience with this detail is very good, mainly because of the fact that the timber deck hardly expands or shrinks in the longitudinal direction. The detail is simple and inexpensive, and does not have any special bearings that you normally see in concrete and steel bridges.

All large timber bridges built in Norway so far have been produced by Norwegian glulam manufacturers. These days the Norwegian industry is challenged by foreign producers. A few smaller bridges have been produced in Denmark and Sweden. Now Eastern European producers are eager to enter the Norwegian market. The Sundbyveien Bridge is one of two bridges that are being produced in Lithuania. The company Jūrės Medis won the bid for these two bridges in sharp competition with the Norwegians.

As a result of this the NPRA is putting extra effort into quality checking. NPRA must ensure that they will receive the same quality product from Lithuania as they would have received from Norway.

Sundbyveien Bridge is being produced during winter 2010/11, and is scheduled to be opened for traffic next summer.



### 4. Sletta bridge

The Sletta Bridge is one of the bridges where it was decided to calm down the extreme expression which was the distinctive feature of some of the others. Fig. 8 shows a picture of the just recently finished bridge, and Fig. 9 shows the side view and cross-section of the bridge.

The Sletta Bridge is part of a local road system crossing the E6 main north-south roadway through the south-eastern part of Norway. Although being part of a local road the bridge is designed for full traffic load as are the main bridges in-line the E6 road.



Fig. 8: The Sletta Bridge

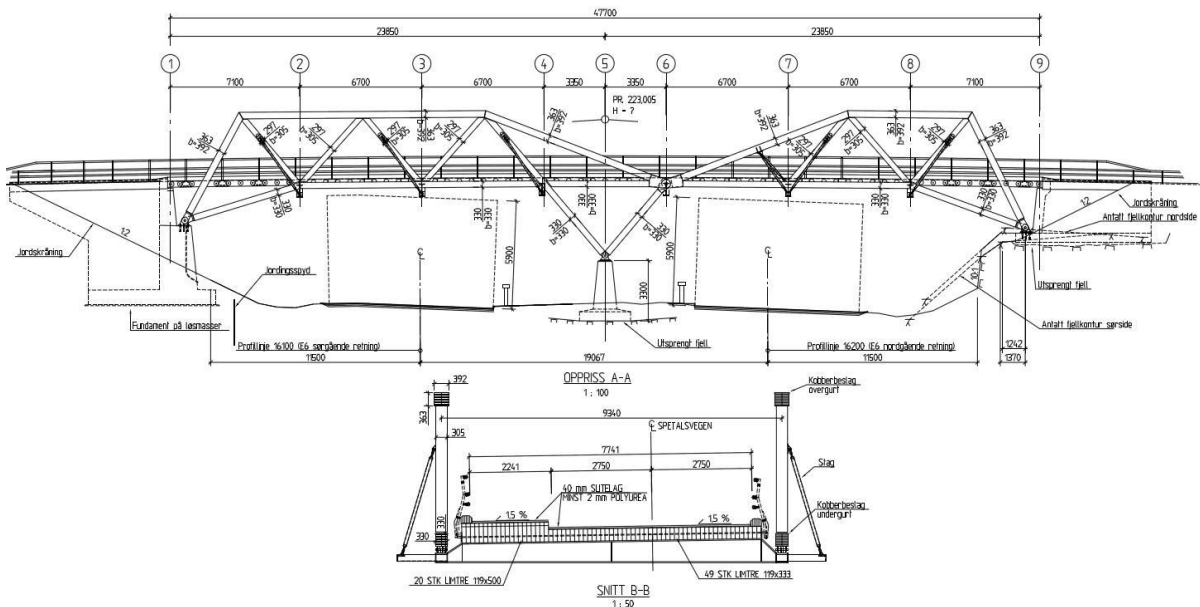


Fig. 9: Side view and cross-section of Sletta Bridge

The length of the bridge deck is 47,7 m and the traffic area is 2x 2,75 m. On one side is a 2,24 m wide side-walk area. The trusses consist of two parts connected by a non-symmetrically located pivoting joint. The span widths of the wooden trusses are 2x 23,0 m.



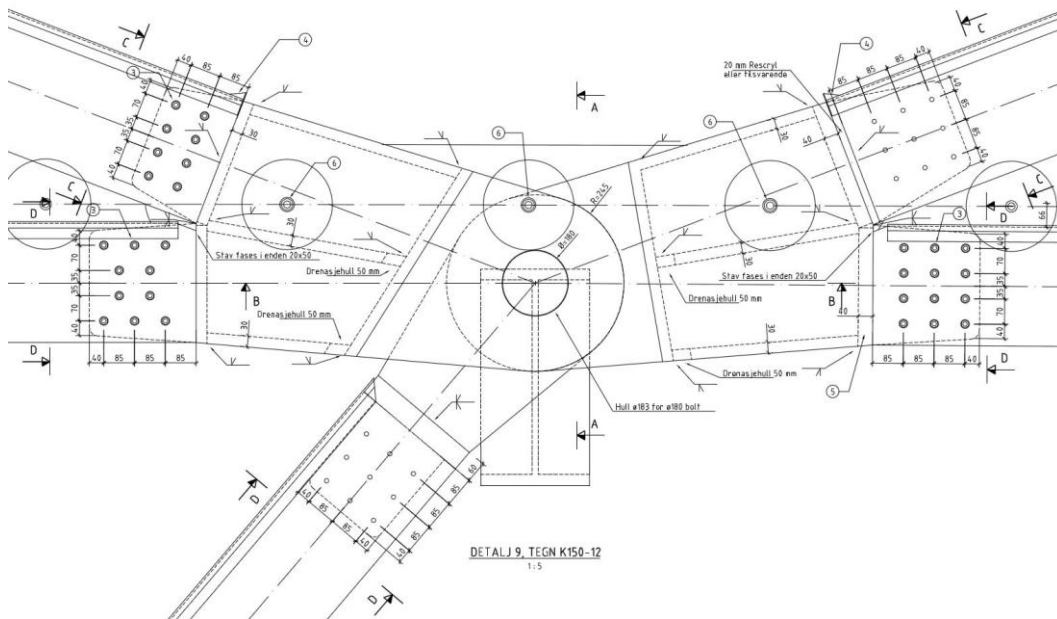


Fig. 12: The central pivoting joint

Fig. 13 shows a side view of this connection and shows how the adjoining steel cross beam is connected to the pivot.

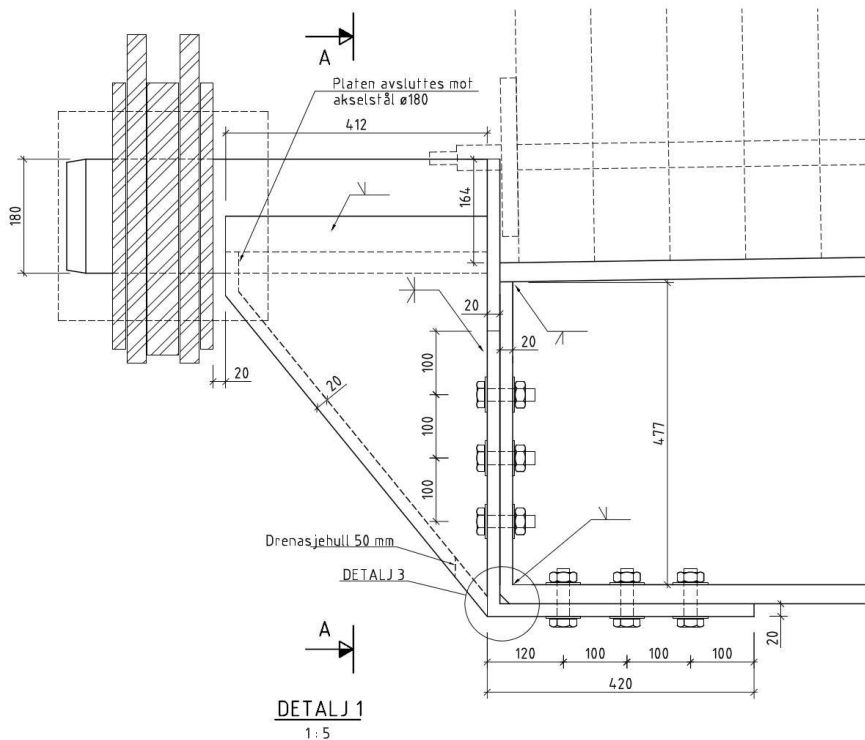


Fig. 13: Side view of pivoting joint and connection to the cross beam

The inclined steel struts, see Fig. 9, connects some of the diagonals with the cross beams and stabilize the diagonals from warping out of their vertical plane. Through the bending stiffness of these diagonals, the joints of the upper cord of the trusses are prevented from buckling out of the vertical truss plane. The stability of this system has been verified by a 2.-order 3D-analysis.

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A traffic barrier system recently developed for stress laminated road bridge deck is used for this bridge, see Fig. 6.

## 5. Acknowledgements

The authors would like to thank all the people and companies that took part in the design and building of Sundbyveien and Sletta Bridges, and in particular...

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Moelven Limtre, Moelv, Norway. (glulam manufacturer Sletta Bridge)

Ecobygg, Norway and Jures Medis, Lithuania (glulam manufacturer Sundbyveien Bridge)



## 6. References

- [1] Norwegian Public Roads Administration. Handbook 184. Load regulations for public bridges and ferry quays. Version 2001-1.
- [2] Norwegian Public Roads Administration. Handbook 185. Design rules for bridges. Version 2001-1.
- [3] Eurocode 1995-1. Eurocode 5: Design of timber structures – Part 1-1: General – Common rules and rules for buildings. Nov 2004
- [4] Eurocode 1995-2. Eurocode 5: Design of timber structures – Part 2: Bridges. Nov 2004
- [5] Lund, B. A. and Pezzucchi, M.S.: Development of a New Barrier System for Stress Laminated Road Bridge Decks, Int. Conf. on Timber Bridges, ICTB 2010, Lillehammer, Norway, 12-15 September 2010.
- [6] Solheim, Ove. : New 4-lane Mjoesbridge in timber?, Int. Conf. on Timber Bridges, ICTB 2010, Lillehammer, Norway, 12-15 September 2010.