Fifteen years' experience of design, production and assembling of prestressed Bridge decks in Timber

Eisenbahnbrücke in Holz

Un pont de chemin de fer en bois

Ponte ferroviario in legno

PeterJacobsson
Martinsons Träbroar AB.
Skellefteå, Sweden

Fifteen years' experience of design, production and assembling of prestressed Bridge decks in Timber

1. Introduction

Martinsons Träbroar AB is a producer of superstructures for bridges with wood as the main material. Around 40 to 50 superstructures each year leave the factory outside Skellefteå, in the Northern part of Sweden. Approximately half of them are designed as pre stressed decks. Other possible types are beam, boxbeam and trusses. Also cable stayed, arc and other type of additional primary superstructures are done. Example of such on-going projects is GC bro in Skellefteå and a road bridge crossing Nätraån, both can be seen in the figures below.

Figure1: Pedestrian Bridge, Skellefteå
Illustration by Kjell Magnusson

Figure 2: PhotooflocationPedestrian Bridge Skellefteå

Figure 3: Road Bridge Nätraån, Bjästa
Illustration by Björn Andersson WSP

Figure 4: ProductionofroadbridgeNätraån, Bjästa

Martinsons Träbroar has a focus on functional bridges, the volume market, rather than big, sophisticated timber bridge solutions. We want to offer the market an esthetical attractive and cost effective solution in timber as an alternative to other materials.

The production consists of pedestrian bridges as well as road traffic bridges. Around 90 % of the turnover is today related to the Swedish market. Customers are municipality, Swedish Transport Administration, local road authorities and private companies such as forest industry and ski centres.

This paper presents some examples of some performed bridge projects and an overview of Martinsons Träbroar:s opinion and conclusions of advantages, detailing, maintenance and some desired developing issues considering pre-stressed bridge decks in timber. Studies of possibilities to perform railway bridges have also been done and will be described later in this paper.

2. Some performed projects

2.1. Concept Bridges for road traffic over railway

Several identical pre stressed decks, span 22 m and width 5 m, have been built along a new railway. The owner is Swedish Transport Administration. Instead of a solution with signal system where road and railway traffic cross each other in same plane a road bridge is placed above the railway. This bridge solution is more cost efficient than the signal system.

Figure 5: Road Bridge Hataträsk, veiwedfromrailroad

Figure 6: Road Bridge Sandviken, wiewfromroad

These bridges are often located out in the back countrywith rather low traffic intensity where a cost effective function is highly valued. The wearing surface is of asphalt and gravel and the railings are in steel. The road Traficant will not see much of the timber. The deck is performed of glue lam in spruce without impregnation. Pre stressed with steel bars and covered with wood panel along the deck. The bottom surface and the sides of the deck are painted. Water sealing consisting of 5 mm bitumen based carpet are melted to the timber deck. The same sealing material and method as on concrete bridge decks are used.
Amount of work on site for assembling the superstructure is around 3 days and then another day for the water tight sealing layer.

Two methodsfor assembling the bridge are used. One, the preferable one, is the delivery of around 1 m wide elements lifted from trailer directly to the foundations and stressed together to a deck in it's finally position. The second assembling method is to press the elements together beside the final bridge position and then lift the whole deck on to the concrete supports. This method requires more time on site, a larger crane and high precision on the foundations, but has the advantage of short time for stop of train traffic.

2.2. Iggesund

A 122 mlong continuous bridge deck in timber with 7 spans, each span 17,5 m, width 5 m. Owner Iggesund Paperboard Industry.

Figure 7: Road Bridge Iggesundduringassembly

Figure 8: Road Bridge Iggesund in use

Due to its design with 122 m continuous deck it was built by placing beam by beam directly on the final concrete supports for the superstructure. A temporary piled bridge where built parallel with the final bridge. Main purpose of this temporary bridge was to build the supports but was off course also used when assembling the superstructure. Assembly time of the superstructure where 4 weeks with 3 men working in average.

2.3. Ostvik

A 70 meter long and 3 m wide pedestrian bridge with 3 spans and 2 V-formed steel supports between end supports. The bridge crossing over the European highway E4 is made continuous from one end to the other. The continuity made it possible with steel supports that can't handle the accidental hit force from vehicle. If one steel support is accidently destroyedthe superstructure still can carry itself and some traffic load due to the continuity.

During the building time the traffic was going on. Therefore the assembly method was to build it beam by beam beside the final position. When the deck had been stressed together and railing was put in place it was lifted in place during night-time to minimise the disturbance on traffic. The highway was then closed one hour. Time on site to assemble the superstructure was 3 days with 8 men.

Figure 9: Pedestrian Bridge Ostvik,duringassembly

Figure 10: Pedetrian Bridge Iggesund in use

2.4. Developing project regarding railway bridge:

The purpose with this project was to investigate the possibilities to perform a Timber Bridge, superstructure,for railroad traffic. Limitations for the project were a length of maximum 10 m and it did not include the possibility of high speed trains. This is because below the length of 10 m, the breaking and acceleration forces can be neglected according to the Swedish code. High-speed railway was excluded due to limited resources in the project. First other fundamental requirements had to be solved and after that high-speed railway can be studied. With these two limitations it was realistic to reach the goal within the resources, to come up with a suggestion on a railway bridge in timber.

The market for railway bridges in Sweden consists of approximately 3600 bridges with an average length of 13-14 m. So most of bridges are rather short and represent an interesting market segment. Important requirements from the Transport administration on railway bridges where that the bridge should be designed with ballast tray and a width of 7 m. A minimal need of maintenance is especially important for railway bridges due to the disturbance and high costs that occur when the railway need to be shut down.

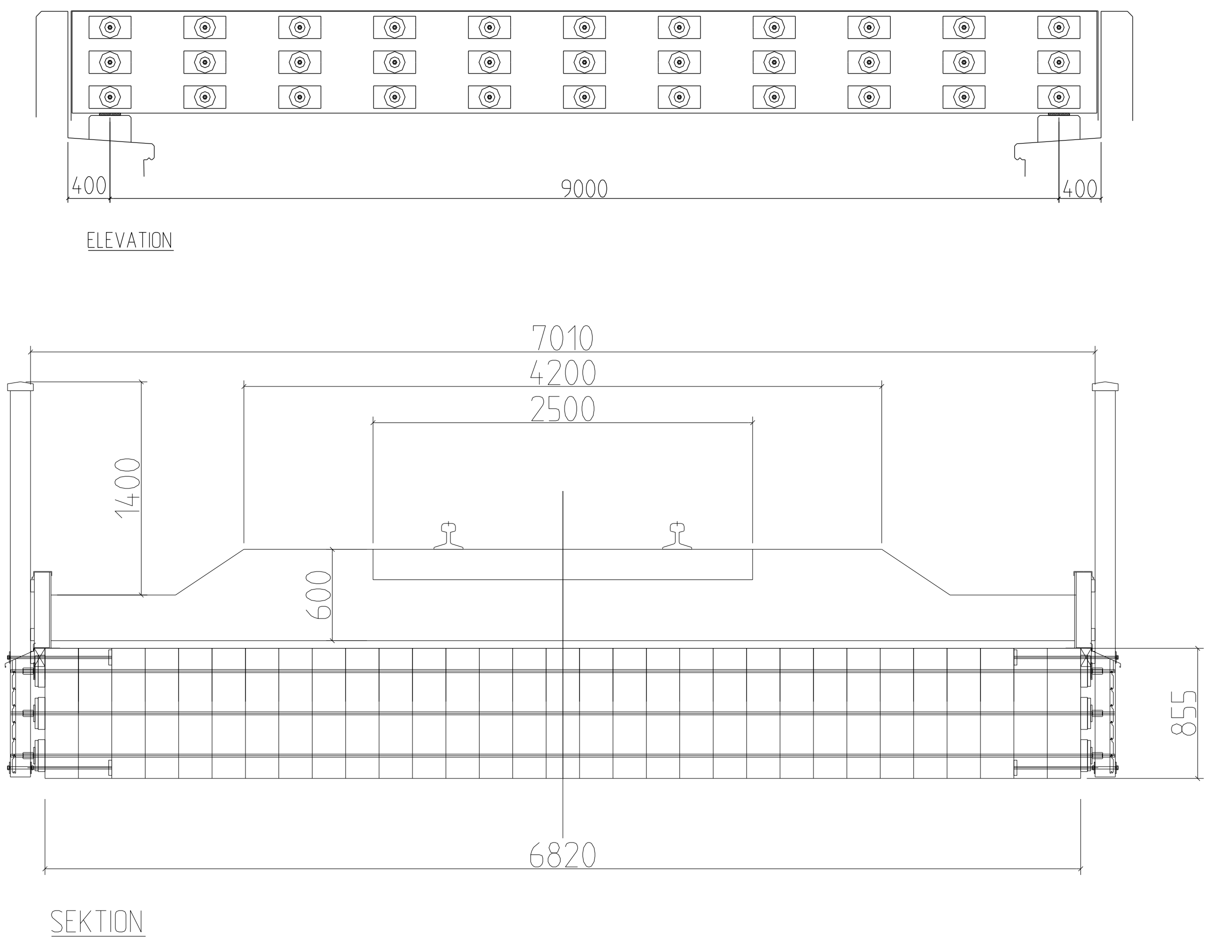


Figure 11: Drawing ofrailroad Bridge

Traffic load from the train is of high magnitude but with help from the 600 mm thick ballast it gives a rather limitied effect on the timber deck. It will be a uniformly distributed load on a main part of the width of deck. Also, it will always be in the same place of the width, centred on midpoint of width.

An easy way to calculate the required height is to just look on the beam under the load width at mid height of the timber deck. With a span of 9 m and a beam height of 855 mm we have according to the Swedish code calculated the following utilizations.

Deflection SLS requirement L/800	82 %
Bending stress ULS,	71 %
Shear stress ULS,	55 %
Bending fatigue	58 %
Shear fatigue	68 %

Calculations with full deck width instead of a beam have also been performed. Calculations with an nonlinear FE tool has shown that a pre stress level of 0,4MPa is sufficient for this bridge.

A prestressed deck has been selected as the most suitable construction type. It's robust and with awell-defined stable volume. It can be prefabricated in an effective way to give short assembling time at the site. On the top of deck surface a water sealing is necessary and a polymer modified bitumen based 5 mm thick carpet of the same type used on road bridges in concrete are suggested. To protect the isolation from wearing from the ballastlayingon top a 50-60 mm thick layer of cast asphalt is suggested. That should give the water sealing a really long lifetime with an eliminated or very small amount of maintenancy. The water needs to be removed from the deck. It can be solved by giving the deck a slopeto make the water flow in the length direction of the deck. Along the sides a railing is attached as protection for railway workers and service personal. Along the sides a board also is needed to make the ballast stay in place.

The presented timber deck solution is most likely to be competitive when there is a need for changing an old bridge deck and keeping the foundation. Due to the low weight of timber, the possibilities for an effective method to replace old bridge decks are deemed to be good.

A railway bridge in timber hasn't yet been built in Sweden yet but our work with evaluating this application for timber will continue together with the Swedish authorities.

3. Advantages with pre-stressed timber decks

During these years work with timber bridges some experience and knowledge about advantages has been identified.

Some of the main advantages of timber bridges are the low weight and high strength of timber that makes it possible for efficient design solutions and also suitable for prefabrication, transportation and assembling of relatively large sections. This makes it possible to have a short time on the site and a small disturbance in traffic for rather large bridges that in the end makes it cost efficient.

The fact that timber is renewable is another important advantage. A natural material that can be lasting and fulfil its function for very long time with the right performance but also can be put back into the natural cycle (carbon dioxide neutral)and in the same time generate energy.

A technical advantage with pre-stressed decks is the possibility to make the deck continuous over several supports that is of great interest for many applications of bridges. The decks height gets smaller and the supports can be made simpler. If a support accidentally is destroyed a collapse of the bridge will not occur due to the continuity of the deck.

4. Detailing, maintenanceand some desired development issues

4.1. Important detailing, performance

Due to timbers relation with moisture it's very important with the detailing. The detailing doesn't necessary have the greatest influence on the initial load bearing capacity but will to a high degree decide the lifetime, function and required maintenance. One of the most important parts in a pre-stressed deck is the water sealing on top of the deck beneath the asphalt. How the sealing is completed along edges and at the ends is very important. For a pre-stressed deck with high concentrated loads from steel bars with anchor plates into the side of deck it's especially important. If the sealing doesn't function correctlythedecks increasing moisture content followed by the fibres being crushed and the anchor plates being pushed into the wood will result in a loss of the pre-stressing force. High requirements and competence on the personal performing the water sealing, clear instructions/drawings of performance and a control program is recommended.

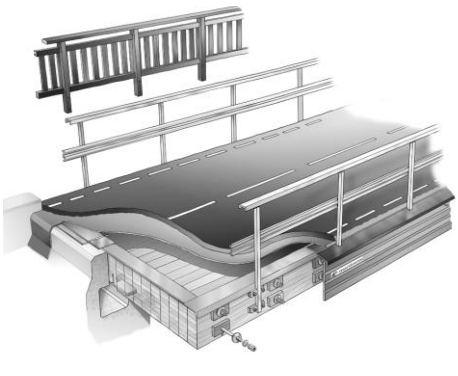


Figure 12: Illustration prestressedtimberdeck

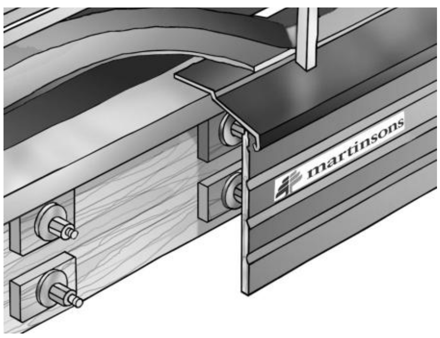


Figure 13: Illustration timber deck, detailsealingat deck edge

Figure 14: Watersealingat deck edge

Figure 15: Watersealing on top surfaceof deck

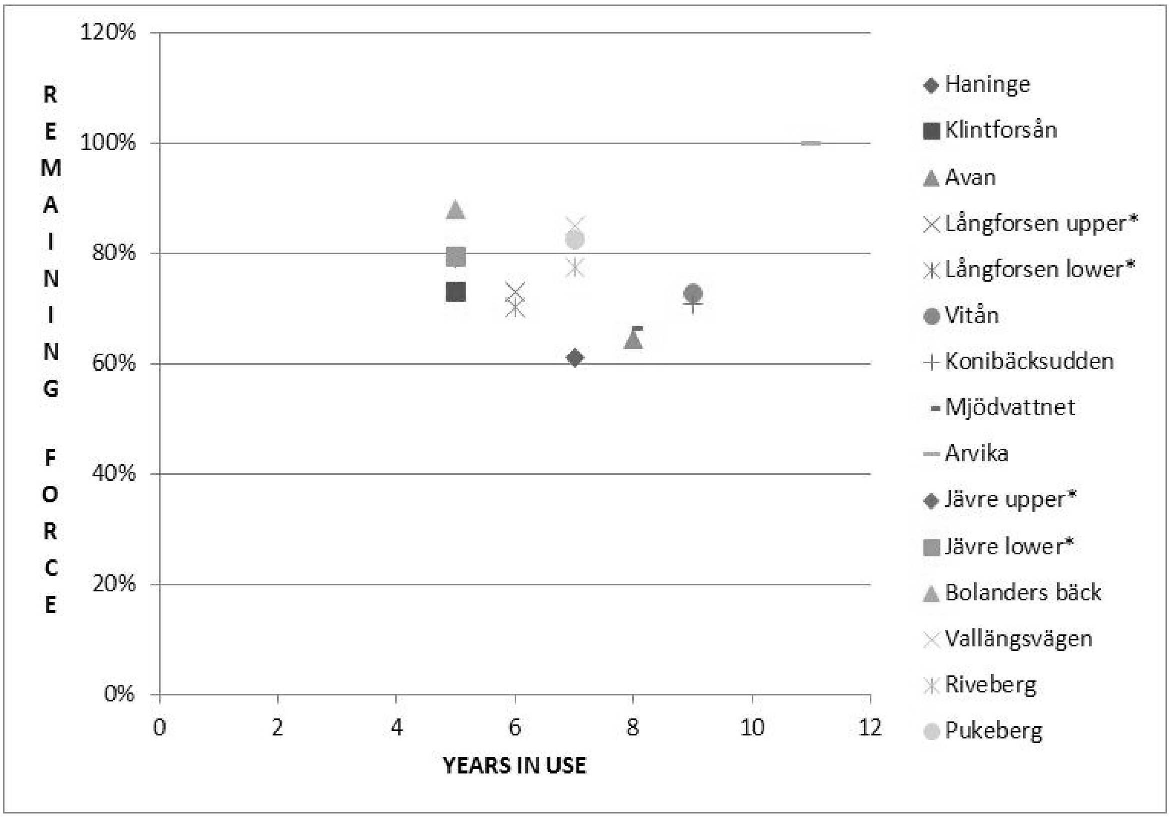
A panel cladding on the outside of the beams are also an important detail. To just paint a weather exposed beam can instead of protect the beam shorten its lifetime. Cracks will occur in beam and water leads deep into it. The paint decrease the drying out speed and the moisture content gets high and risk for fungi attack increase. A cladding with an air-gap to the beam surface gives a very good protection of the beam.

4.2. Maintenance

The maintenance of pre-stressed deck consists primarily of inspections with regular intervals, we recommend each 6 year. Measuring moisture content and forces in pre-stress bars, checking bearings, asphalt layer and vegetation, soil etc. are usual inspection activities.

A pure pre-stressed deck for road traffic often has asphalt and steel railing meaning that only timber seen is the panel cladding at side of the bridge. Necessary maintenance varies due to usage, localisation and requirements from the owner. Inspections made indicates following

- Bottom side of bridge deck that isn't weather exposed seems to be nearly unaffected after 10-15 years. Based on that the repainting interval seems to be rather long, aestimation / guess is 15-30 years, maybe even longer.
- For weather exposed wooden parts such as panel cladding and wood railing the repainting interval is often between 5-10 years. The panel cladding can also be without paint and then there isn't any maintenance until it shall be replaced by new one. Time for that is most likely connected to esthetical requirements. An estimated lifetime for panel cladding is around 40 years.
- Re-stressing the pre-stressed bars is also something that can be required during the lifetime of bridge. The force in the pre-stressed bars is decreasing with time and the knowledge regarding rate of change is limited. The rate of change varies a lot. Influencing factors can be surrounding conditions and the performance of the pre-stressing system, primarily anchor plates. Some follow up studies and inspections have been made were barforces have been controlled. Results are shown in diagram below.Normally the pre-stressed decks are designed so a decrease of pre-stress force down to 40% is allowed.



- The water sealing is also a part that needs maintenance. The interval of replacement are probably depending a lot of traffic intensity. During our 15 years of delivering timber decks we haven't replaced any water sealing with bad function related to wearing or time. It is also difficult to find generalised replacement intervals for the sealing on concrete bridges, but an often mentioned interval is approximately 25 years.

4.3. Some future desirable develop issues.

4.3.1. Lifetime

Today it is usual with definition of technical lifetime of 40 or 80 years for timber bridges in Sweden. But what does this technical lifetime say? What maintenance and amount of changing parts is allowed to be classified for a certain technical lifetime? It's desirable that choice of bridge type is made from cost during lifetime instead a definition of just technical lifetime.

4.3.2. Design model

Design model for deciding the height and performance of pre-stress system is desirable. The method used today is a semi empirical beam theory model that has some uncertainties and lack of traceability. Work with developing new design model is going on in a research project that we are engaged in.

4.3.3. Weather protection

A difficulty in assembling phase with larger timber decks are the weather protection. To have god quality of the water sealing a dry top surface of the timber deck is needed. It can be seen as a trivial technique question but is of great importance. It's not so easy to solve without getting to much costs and still have good function, reliability and to be easy to work with. Today the most common is wraps put out on deck when all beams been are put in place. A method with higher reliability and efficiency is desirable.