NEW OPPORTUNITIES OF TIMBER BRIDGES IN LATVIA

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Abstract. Historically, timber bridges always have played an important role for crossing the water barriers, depth valleys or other obstacles. The history of timber bridges in Latvia begins in 9th century and continues until nowadays. Golden age for timber bridges in Latvia was the period from the end of 19 centuries until the II World War. At that time in Latvia had been high qualified bridge engineers who could design and build outstanding bridge structures. Today's achievements in timber protection systems, new joining methods, the possibility to produce the glued timber structures with clearly indicated properties, will return the timber as structural material in bridge construction industry. The aim of this study is to present the historical and nowadays achievements in the timber bridge building in Latvia.

Keywords: glued laminated timber, bridges, design, durability.

1. Introduction

In the last decades, the interest about the designing and using of timber bridges has increased in many European countries. This could be explained with a new and innovative use of timber – in form of glulam, stress laminated timber, advanced protection systems, new joining methods, a possibility to produce the laminated glued timber structures with clearly indicated properties, etc. The glulam as structural material has many excellent characteristics: high strength to weight ratio, it can be easy to handle. It is widely available natural resource, and it is aesthetically attractive material. By using new methods of chemical and structural protection against environmental actions, moisture and biological damages, for the timber bridge elements will be ensured fifty till eighty years-long lifetime. That will be comparable with service life of bridge structures designed from the concrete and steel.

2. Short historical overview

The first historically documented timber bridge in Latvia is the Araisu lake village bridge discovered by archaeological expedition in 1976 (fig.1. and fig.2). The lake village was populated from 9 until 10 centuries. On the photo taken during the archaeological excavation is clearly seen the bridge piles and longitudinal beams. The pavement consisted of a round timber deck.

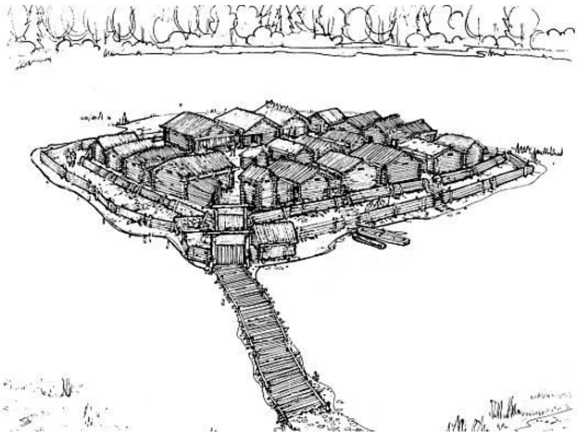

Fig.1 Visualization of Araisu lake village (by architect Dz. Driba).

Fig.2 Bridge structures discovered by archaeological expedition.

Many timber bridges were built in Latvia between the end of 19 century and middle of 20 centuries. Till 1939 in Latvia was built and maintained 3151 timber bridge (Vecvagars, 1994). Most of them were simple timber beam bridges with span length not exceeding 6 – 9 metres supported on pile piers. However, some of them were bridges with considerable lengths and innovative constructive solutions.

Some examples are - strut system timber bridge with 106 m long span over Gauja River in Valmiera built in 1934 (Fig.3), or 115 m long Town's lattice system truss bridge over Musa River in Bauska built in 1885 (Fig.4), or 193 m long Howe system truss bridge over Gauja River on road Riga-Ainaži built in 1924 (Fig.5), or 546 m long Langer system bridge over Daugava River in Riga, built in 1944 (Fig.6).

Fig.3 Bridge over Gauja River in Valmiera built in 1934

Fig. 4 Bridge over Musa River in Bauska built in 1885

Fig.5 Bridge over Gauja River in on road Riga-Ainaži built in 1924

Fig. 6 Bridge over Daugava River in Riga, built in 1944

The lifetime time of timber bridges rarely exceeded 25 years. They were damaged by rot, fungus and insects. The short service life reduced advantages compare to steel or concrete structures and it number quickly decrease. On Latvian rods in 1960 were maintained 3633 timber bridges, but in 2015 only 7.

The new evolution of timber bridges has started after development of glued laminated wood (glulam) production technology. For production of glulam is used good quality wood, without insects and fungus damages and low moisture content. As adhesive is used high-quality glue with high resistance to water penetration and low impact on the environment. The use of glued laminated timber increases it application opportunity because from relatively small timber boards is possible to produce long span lightweight structures. By using structural covering and impregnation of glued timber structures with preserving agents it is possible to increase their lives time up to 50 – 80 years.

3. Investigation project

For development of design, construction and research opportunities of laminated glued timber structures in Latvia, in a framework of the European, Regional Development Fund (ERDF) program "Entrepreneurship and Innovation" project "Development of infrastructure for investigation of large-scale timber structures" in Jelgava were built and in 2015 opened a new experimental plant "Innovations in timber bridges and structures (IKTK)" for the production and investigation of large scale glued timber structures. Experimental plant is founded by construction company "Marko KEA Ltd.", Riga Technical University and research institution "Forest and Wood Products Research and Development Institute Ltd.". The plant can produce glulam beams with different forms and dimensions - until 32 m length and until 2 m height.

Within the framework of the project "Modern and Sustainable Wood Construction Research" administered by the "Investment and Development Agency of Latvia" in cooperation with "Forest Industry Competence Centre" Ltd., "Forest and Wood Products Research and Development Institute" Ltd. and consultant company "Inzenierbuve" Ltd. was designed, built and investigated the experimental pedestrian overpass made from glued laminated timber.

4. Pedestrian overpass

4.1. Structures

The pedestrian overpass over regional road P103 Dobele-Bauska serves as an attractive gateway to Nature Park near Tervete village. The design of the overpass was developed as an experimental project for studying of the performance of laminated glued timber structure in natural conditions.

The overpass consists of 30 m long central part, made from glulam frame with steel portal frames on both ends and two 34.20 m and 22.50 m long approach ramps, made from glulam slabs (fig.7). The total length of an overpass is 87.0 m. The width of a walkway is 3.20 m. The pedestrian clearance of the frame is 3 m.

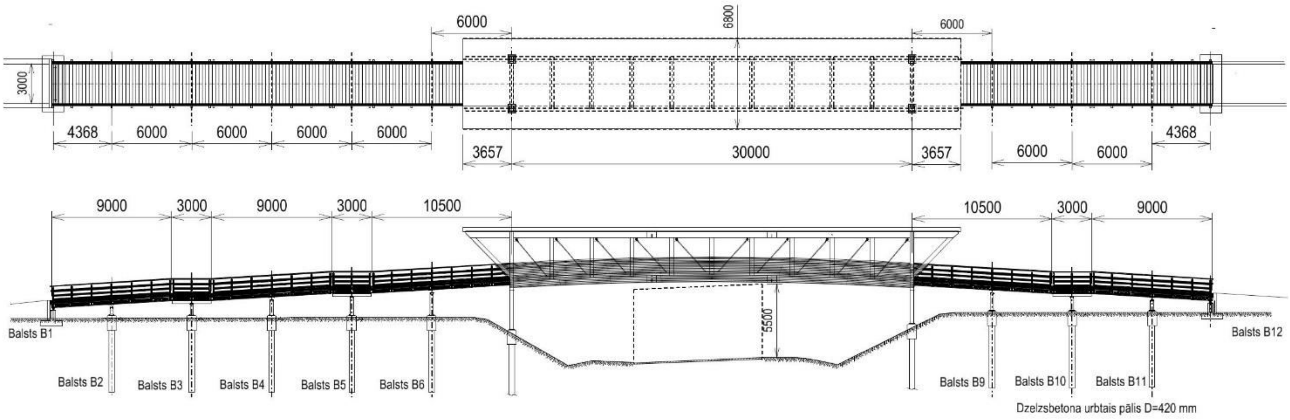

Fig.7 Plan and side view of the overpass

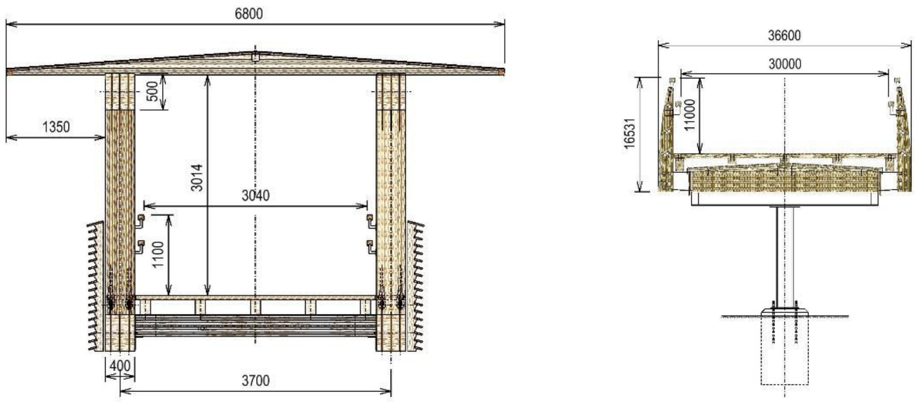

Fig.8 Crossection of frame and approach ramps

The overpass is designed according to pedestrian loads of Eurocode 1. The cross-section dimensions of upper and lower chord members are 400 x 500 mm, vertical bar has cross section 300 x 400 mm. The cross beams between the knots in lower chords have cross section 300 x 300 mm (Fig.9). All truss timber elements are made from GL28h class glulam with density $\rho_{g.k}$ = 425 kg/m^3 , tensile strength $f_{t,0,g,k}$ = 19.5 N/mm^2, compression strength $f_{c,0,g,k}$ = 26.5 (N/mm^2). The diagonal ties and lateral bracing in lower chord level are made from S350-S class steel round bars with a diameter of 36 and 16 mm corresponding and adjustable length. The three-dimensional stability of the frame is provided by installation of portal frames at the ends of the frame. The vertical bars are made from steel class S355J2, double-T profile, HE-B 400, but horizontal from profile, HE-B 300. All elements of portal frame are covered by zinc and coated by green painting.

The truss elements – chords, vertical bars and diagonals are joined by multiple-shear dowel connection with slotted-in steel plates, that form semi-rigid connections. This is one of the most effective connection methods for glulam elements with large cross sections. These connections have high performance that mainly is achieved by use of slender steel dowels and a tight fabrication's tolerance. The load-carrying behavior of dowel-type joints loaded parallel with the grain is based on Johansen's yielding theory (Johansen, 1949), that assumes the rigid-plastic behavior of both the timber and the steel dowels.

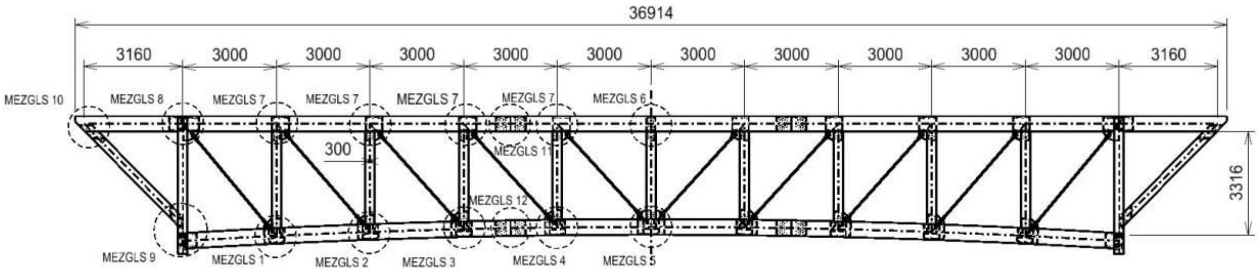

Fig.9. Frame structure

Upper and lower chord of truss is composed of three 10.35 + 9 + 10.35 m long parts, which are connected with four 10 mm thick steel plates and 23 dowel. The vertical bars to chords are connected with three steel plates, and 12 dowel (fig.10). The plates and dowels are made from steel class S355J2. The dowels with diameters 10 and 12 mm, made from S355J2 class steel, and bolts M16 (class 8.8). Such connection method allows to create stiff and correct truss node elements.

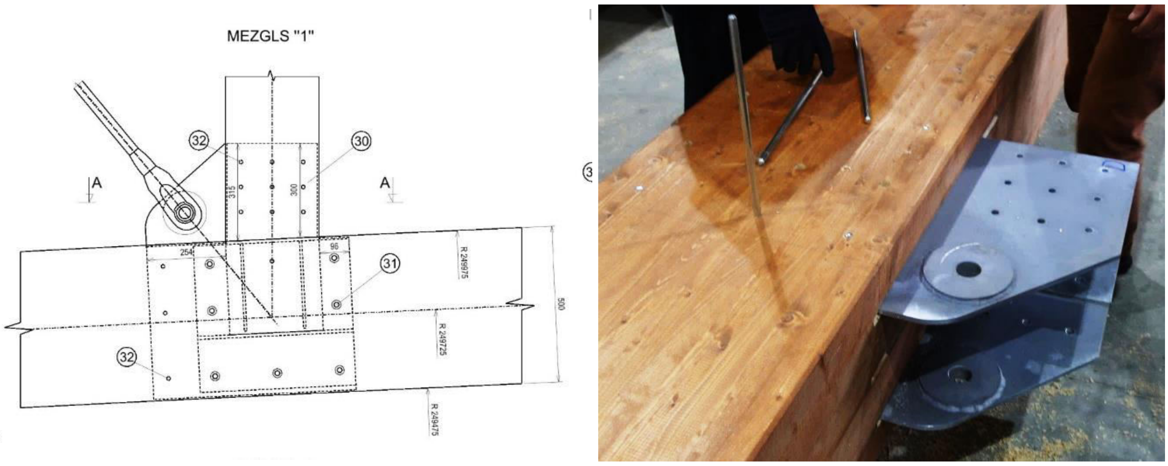

Fig.10 Chord and bar joint structure

The roof structure consists of variable height cross beams GL28h class glulam placed in distance of 1000 mm and covered by moisture resistant plywood and roofing iron. The roof system ensures the stability of truss in upper chord level.

The flooring is made from larch wood boards.

The cross-section of approach ramps is 2700x300 mm and the length changes from 2598 mm in horizontal parts until 10420 mm in skew sections and are made from GL24c class glulam.

4.2. Durability

Durability of timber structures depends from protection systems that prevent the glulam from humidity, since the action of natural deterioration organisms requires the presence of water and warmth. To ensure the long service life the truss structure is covered by roof structure with considerable overhanging in the eaves and all timber elements are covered with water-repellent coating. The bottom chords and walkway from lateral rain are protected by louvered cladding in 180 cm height (see fig.8). The approach ramps are covered with non-corrosive metallic covers and waterproofing system (fig.11). The ramp sides are protected by louvered cladding.

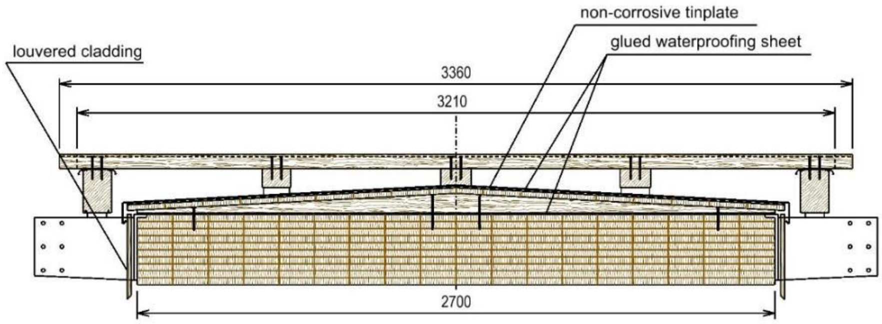

Fig.11 Waterproofing system of ramps

4.3. Construction

The construction process of a pedestrian timber bridge started in July 2015 and finished after five months in November 2015. All glulam structures according to detailed drawings were produced in new timber bridge structure plant. The steel details were made in contractor workshops.

The prefabricated elements of truss were put together in factory assembly area on temporary supports (fig.12). All connections are made during assembly procedure by using stencils for notching's and boring's. The assembled and temporary fastened structure without the roof was transported with the lorry to site and mounted on piers (fig.13). Approach ramps were mounted from prefabricated glulam elements delivered from the factory on site. The view on the finished bridge saw in fig.14.


Fig.12 Bridge assembly on temporary supports in plant


Fig.13 Bridge assemblage on site


Fig.14 View on pedestrian bridge after finishing

4.4. Investigation

After finishing of construction, the truss structure was tested with static and dynamic load, to verify the load carrying capacity and collaboration of all joint's elements. According to the plan, the bridge was loaded with static load of 271.60 kN or 3.35 kN/m^2, evenly distributed over the bridge walkway surface. After setting free from falsework the truss setting was 7 – 8 mm, that pointed to good stiffness of joints. Maximum deflection in the middle of frame span from the full static load was 4.5 mm, and residual deformations compose 39%, that was acceptable for such a type of structure.

The dynamic test showed that the measured 1st mode natural frequency was 5.9 Hz, that is outside of the critical limit proposed in Eurocode 5 (f_0 <5Hz). This mean that there are not risks regarding structural resonance from a pedestrian load.

5. Bridge over Mencupite

The bridge over Mencupite consists of continuous three spans glued and prestressed 11.39 m long (fig.15) and 4 m wide (fig.16) slab with timber safety barriers.

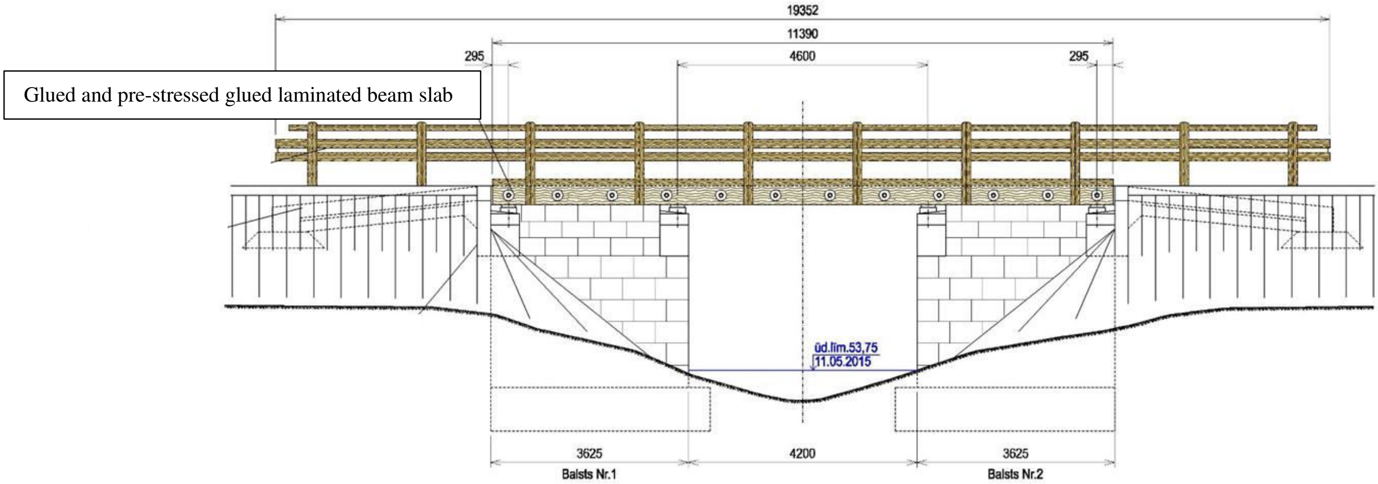

Fig.15 Side view of the bridge

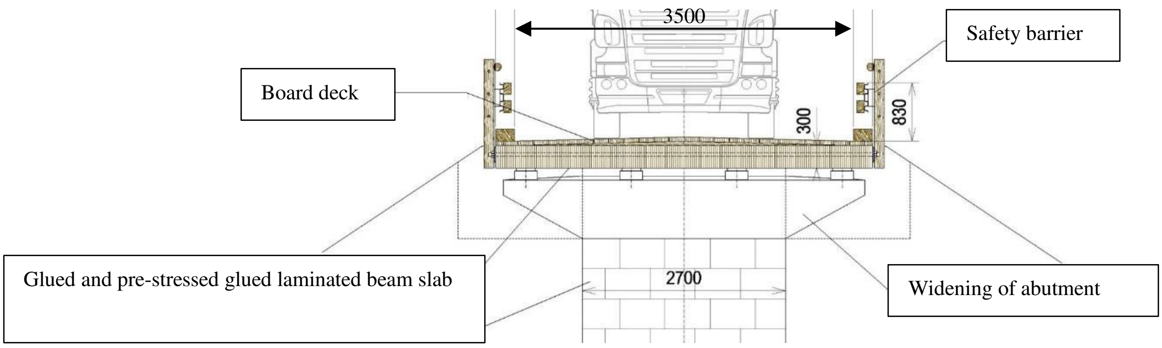

Fig.16 Cross-section of carriageway

The slab consists of 28 glued and pre-stressed glued laminated timber (class GL28c) beams (width 146 mm and height from 300 till 350 mm) (fig.17) pre-stressed with 26.5 mm diameter steel bars (f_{pk}=1030 N/mm^2) with 390 kN (fig.18). The distances between pre-stressing bars were 1.2 m. The deck plate is treated with tar oil and covered by glued waterproofing sheets and board deck above. Bridge side view after finishing is shown in fig.19.

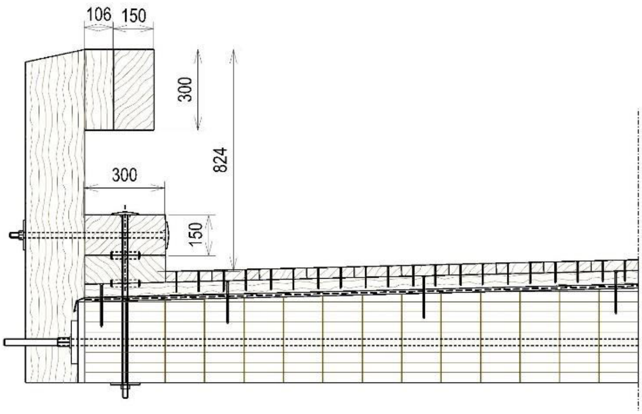

Fig.17 Structures of safety barriers and deck plate

Fig.18 View on pre-stressing bars

Fig.19 View on finished bridge

6. Conclusions

The use of glued laminated timber in transport infrastructure industry has many advantages: it is a friendly for nature, because after the end of the service life timber structures will be easy recycled in environmentally friendly materials; energy consumption during the production process of glulam timber structures is much smaller compare to the steel or cement production; glulam timber structures have a good strength to weight ratio, which allow them to use for the manufacturing of the large bridge span structures. In addition, the glulam timber has a good aesthetic quality that makes it attractive to architectural design of the structures.

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