NEW TIMBER BRIDGES IN CROATIA

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Summary

The paper presents two timber bridges designed in 2007. The first one is a bridge for pedestrian and light traffic across the river of Bednja close to Ivanec and the other is for pedestrian traffic only and is be made in the centre of the town of Samobor across the stream of Gradna. Bridge spans are 23.8 m and 11 m respectively. For principal bearing elements, European spruce tree glulam timber will be used. Glulam timber for bridges originates from Slovenia and Norwegian melamine adhesive will be used for adhesion.

Details are presented of CosmosM modelling and large span bridge calculation. Orthotropic wood features have been discussed, and in addition to a static analysis, a buckling analysis and bridge frequency analysis have been done. The calculations are based on the applicable standards for bridge loads in Croatia. For a small beam structure bridge, basic information is provided as well as details of the architectural design of the bridge.

The planned lifespan of the bridges is 50 years with adequate protection of wood and steel structure elements. In case of the arched bridge of a larger span, the arch will be protected by galvanised metal sheet from the upper side.

1. Introduction

Construction of timber bridges in Croatia has gained on significance in recent years. This particularly refers to pedestrian bridges and light traffic bridges across small barriers.

The two bridges presented in this paper are part of a plan of incentives for construction of pedestrian and light vehicle traffic bridges of timber on small spans that allow it. Of course, timber bridges are made in large spans as well, but their application according to the author's experience is optimal on spans up to 30 m.

Photo 1. An old timber bridge across the Odra river

In Croatia, there are several dozens of standard small timber bridges that are during their reconstruction replaced by modern timber bridges.

A standard timber bridge across the river of Odra is presented in Photo 1.

The bridge was made in 1985 and is currently in quite bad condition for lack of appropriate maintenance.

Such bridges are very rarely made.

Presentation of new bridges in this paper shows that the situation is changing in positive direction.

2. Timber bridge over the Bednja river near Ivanec

The bridge near Ivanec is a three-hinged arched structure with suspended cross girders on a steel suspension. The axial span of the bridge is 23.80 m, which is the distance between the supports on reinforced piers on the river banks. The static structure is a three-hinged arched one so that the axial arrow of the circular arches in the mid of the span is 502 cm.

Arch radius along the axis is 16.61 m. Cross sections of the arches are 20/60 cm and are made of I class European spruce glulam timber, according to EC5 class BS 14. On the arches, at an axial distance of 260 cm there are suspended steel elements of 60/60/6 mm rectangular pipe sections connected according to the details in the design project to the transversal glulam girders of 18/40 cm cross section. In the lower tensile zone, the transversal girders are connected at the arch level by steel pipe elements of 80/80/8 mm rectangular cross section, from one bearing to another. The transversal girders and the steel elements in the tensile zone jointly with the steel cross diagonals form a bracing in the lower zone providing the lateral stabilisation of the walking and carriageway structure. The carriageway structure is formed by continuous beams of 16/16 cm cross section supported by cross girders and connected by screws according to a detail in the design project.

The walking surface of the carriageway from one bridge railing to another is of 356 cm clear width and has been adjusted for width of combine harvesters, up to 310 cm, which is 46 cm less than total carriageway width. The bridge has no special pedestrian lanes as they are not necessary. The carriageway surface of 16/16 cm small beams is made by leaving 1 cm distance between the beams. This is done primarily to achieve a higher durability of the bridge structure where by application of protection agents the expected bridge lifespan would exceed 50 years.

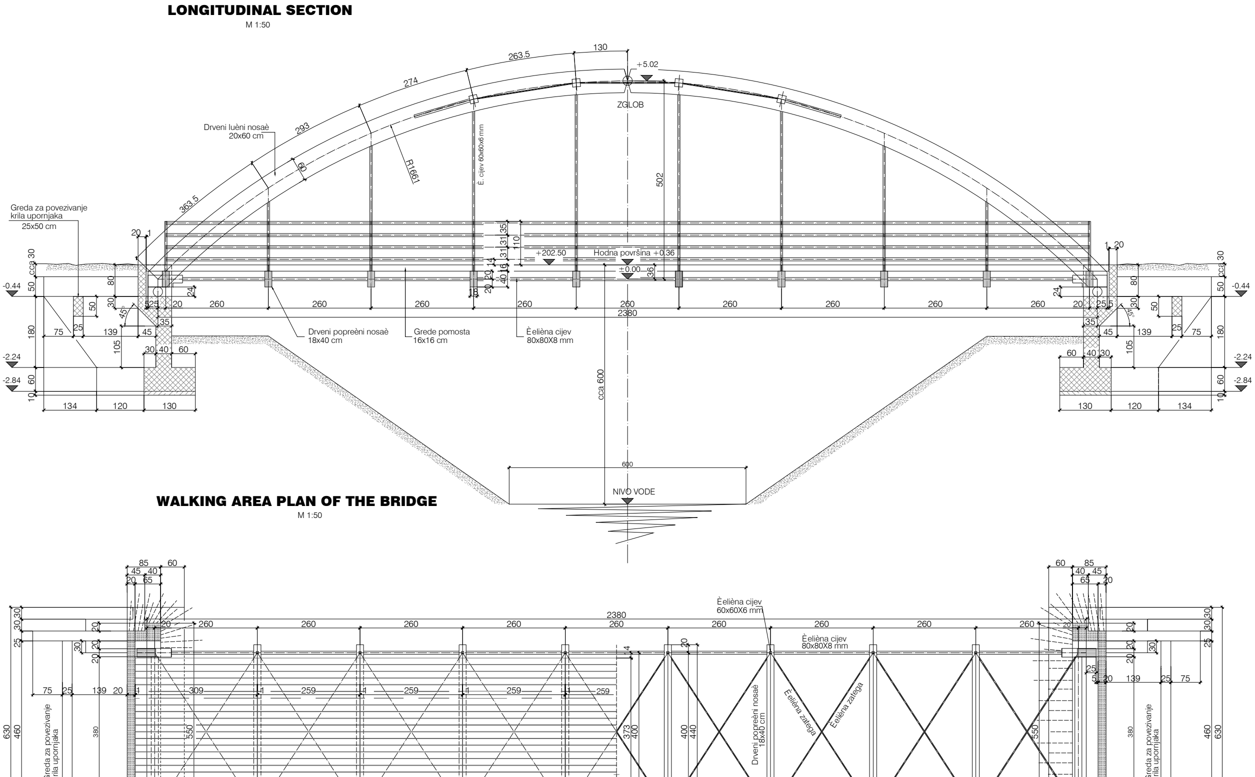

Fig 1. Presentation of bridge based on design documents

In the upper zone, the arches are connected by a grid structure of timber verticals and steel diagonals for the reason of lateral bridge stabilisation that was required due to a rather high load and overall lateral stability. The clear height of vehicles that may cross the bridge is 420 cm.

Total bridge weight is approximately 20 tons. The proposal is to install the bridge from the river bank side and place it on the designed site of piers by the use of crane.

Protection and durability of bridge is particularly attended to in order to achieve as long lifespan as possible. The planned lifespan exceeds 50 years, and with the regular maintenance it may be increased significantly.

Timber arches will be covered with galvanized metal sheets from one side to another, along the upper side. The timber will be protected with insecticide and fungicide coatings for timber structures. The final coating must be scumble with UV protection.

The carriageway structure will be made of S10 class oak wood. Protection of oak wood with a single-layer impregnation and minimum double Chromos-Megaton scumble with UV protection.

Photo 2. Presentation of the future bridge in 2008

All steel elements must be made of S235 steel for steel structures on open, i.e. temperatures ranging to -20^{o} C. All steel connection elements, screws and alike, must be hot-dip galvanized.

3. COSMOSM bridge structure calculation

Static analysis, buckling and frequency analysis were done by CosmosM software. The entire bridge has been modelled on reinforced concrete piers.
In the calculation, the following finite elements were used:

SHELL4L and SHELL3L for glulam modelling taking into account its orthotropic characteristics
SHELL4 for modelling of isotropic steel elements of the bearing structure
RBAR for modelling of absolutely rigid structural elements such as on bearings due to transfer of force to a single point
BEAM3D elements for modelling of oak carriageway and walking surfaces on the bridge
PIPE elements for modelling of compressive and tensile diagonals of stabilisation in the lower zone directly below the carriageway surface

Features of materials are taken for timber as orthotropic material, value in MPa and density in N/mm^3: MPLIST,1,3,1

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   Label     Name   Temp/BH_Cr        Value
A    1         EX            0     1.150000e+004
A    1         EY            0     6.000000e+002
A    1         EZ            0     6.500000e+002
A    1       NUXY            0     2.700000e-002
A    1       NUYZ            0     6.000000e-001
A    1       NUXZ            0     3.300000e-002
A    1        GXY            0     6.000000e+002
A    1        GYZ            0     6.000000e+001
A    1        GXZ            0     6.500000e+002
A    1       DENS            0     6.000000e-006
A    1    MPERM_R            0     1.000000e+000
A    1         RK            0     8.500000e-001
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Material dimensions are taken based on real constant values. The accounting model of finite elements is presented in Figure 2. Red arrows are visible bearing supports.

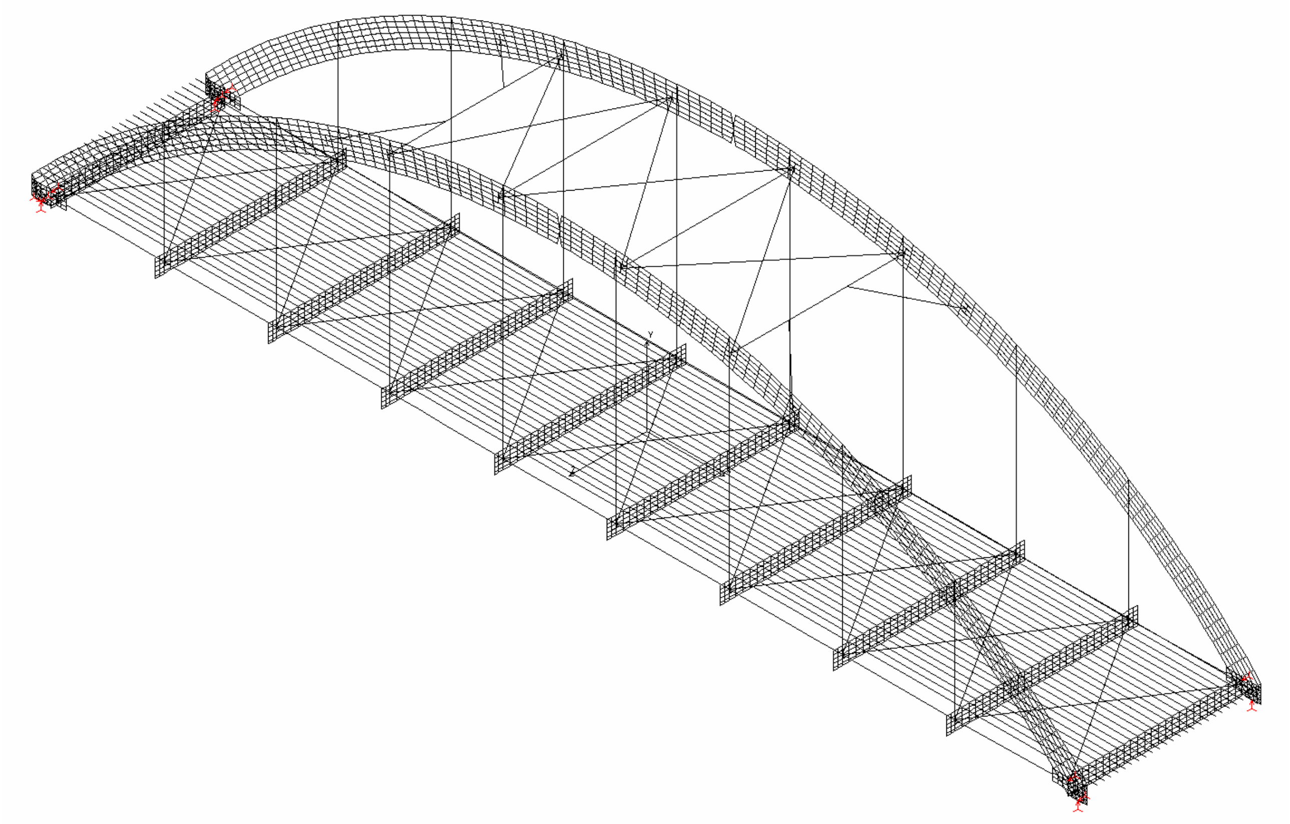

Fig. 2. FEA calculation model

Loads on the bridge were as follows:

1. Permanent load is taken as gravitation load across given density and real dimensions of structure.
2. Mobile load by pedestrians across the bridge of 5.0 kN/m2 intensity of walking surface
3. Mobile load by pedestrians on the bridge mid point of 5.0 kN/m2 intensity
4. Combination of mobile load and combine harvester on the bridge mid point (Position 1)
5. Combination of mobile load and combine harvester on the bridge mid point (Position 2)
6. Combination of loads for buckling analysis.

All calculations have been done of deformations, main and shear stresses as well as (always undesirable) perpendicular tensile stresses. Then the buckling analysis was conducted and the first 5 modes of structural titration analysis.

Lateral stability has been fulfilled with a high certainty. The safety factor is approximately 4.2. Maximum stresses are used up to 90 %.

Frequency modes are as follows:

Mode 1: 1.66 Hz; Mode 2: 2.59; Mode 3: 3.06; Mode 4: 3.52; and Mode 5: 5.22

These values are also satisfactory and acceptable.

Fig. 3 shows the status of structural deformations for load consisting of a combine harvester + pedestrians and lateral wind on the bridge.

Fig. 4 shows the buckling analysis, while frequency modes will be presented at the conference through animations of each specific mode.

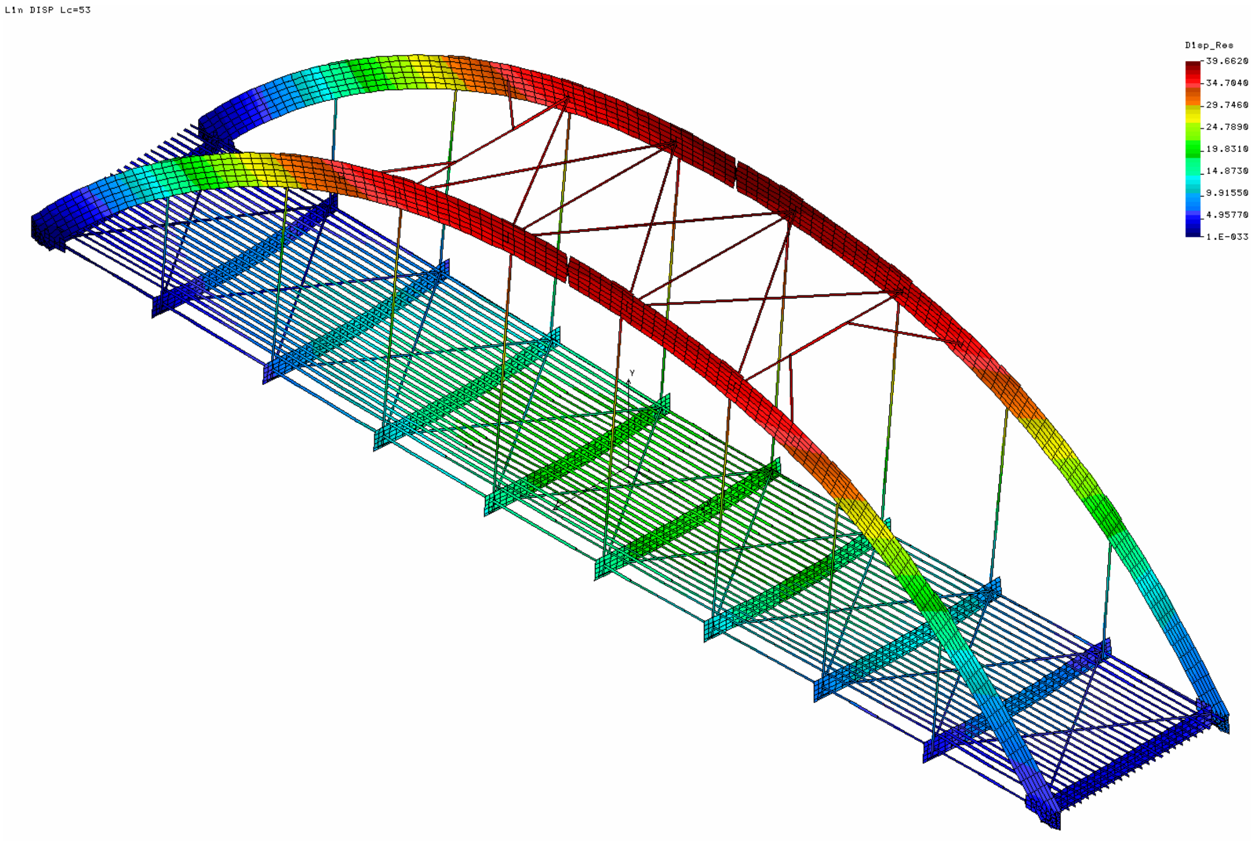

Fig 3. Presentation of bridge deformations for permanent + combine harvester + pedestrians + lateral wind load

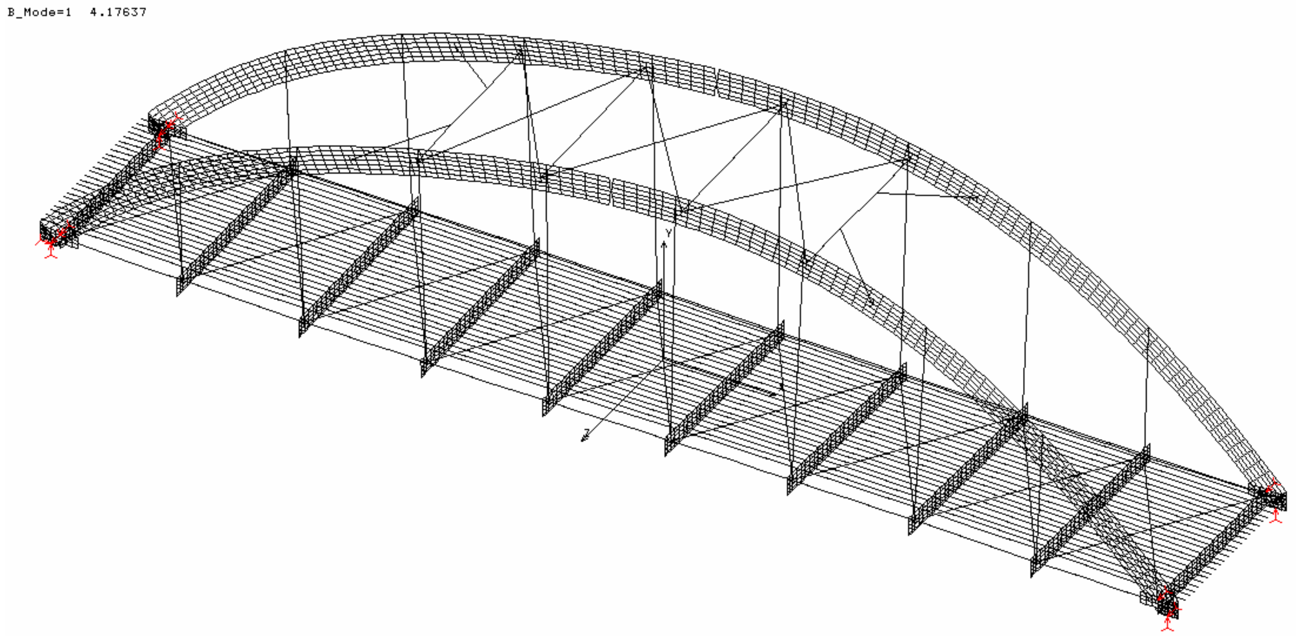

Fig. 4. Presentation of buckling analysis, SF = 4.18

In addition to this interesting bridge that should be constructed in the course of this year, below is presented a pedestrian bridge that is planned for construction in the town of Samobor near Zagreb.

4. Pedestrian bridge in Samobor

The timber bridge will be a glulam beam structure of pine tree or spruce tree of BS 14 class based on EC5. All steel bearing elements will be of S235 steel for structures on open and the handrails will be made of stainless steel 1.4301.

Main girders of 18/60 cm cross section are made at an axial distance of 192 cm. The axial span of the bridge will be 10.2 m from one pier bearing to another. The bridge will have a rectangular ground plan and will be positioned in relation to the axis of the stream of Gradna at an angle of 75 degrees. The direction is selected as a logical direction of movement of pedestrians from the town of Samobor across the bridge to the promenade of Vugrinšćak.

Due to the different bearing heights, the main girders will be made in a very mild circular curve along the radius of 133.17 m (Fig. 5).

On main girders at the axial span of 92 cm, transversal girders of 10/14 cm cross section will be placed that will support secondary girders of the same cross section, parallel to the main girders at an axial distance of 58 cm.

A grid of main, transversal and secondary girders will form a basis for the walking surface of water-resistant 9 mm wide veneer boards placed across a 25 mm wide water-resistant OSB board. The water-resistant veneer board will have a roughly treated anti-sliding surface as a walking surface.

Special attention has been paid to the bridge railing as the aim is to have an attractive and recognizable new bridge in Samobor. The railing will have columns with the central part partially made of steel console elements fixed on the lateral sides of the main girders. The sides of the columns will be coated with glulam elements, and the area between them will provide space for installation of LED lights that will through transparent Lexan provide diffuse lighting of the bridge by night. There will be 6 columns on each side. Between the columns, there will be 5 fields with a glass railing installed. From the upper side, there will be a wooden handrail up to 1 m height, and from there up to the height of 1.1 m, a round stainless steel handrail Ø 50 mm will be mounted.

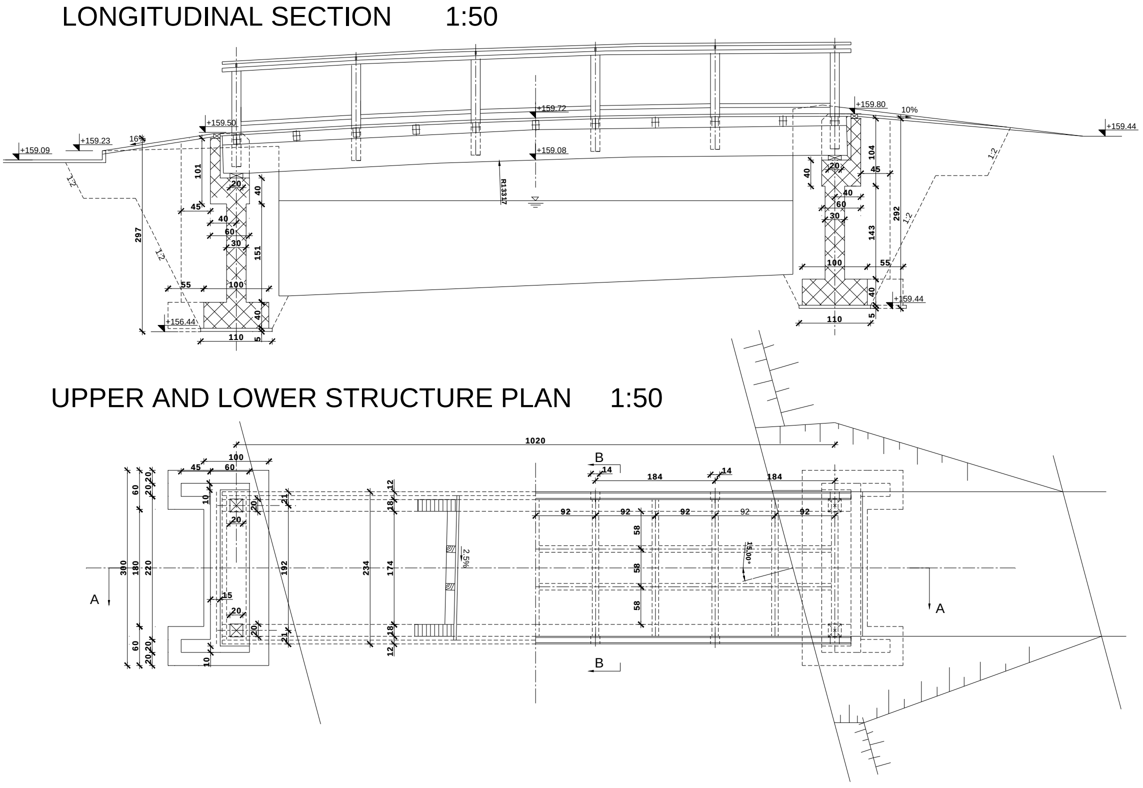

Fig 5. Ground plan and design of the timber bridge in Samobor

The bridge will be supported by light-weight reinforced concrete abutments. The abutment wall dimensions will be 30 cm.
Maximum water level in the stream according to a 28-year average projected on 50-year term is 127 cm, which is about 50 cm lower than the bottom edge of the new pedestrian bridge.

The bridge will not have any special bracings for lateral structural stabilisation as it will be stabilised by a hard walking surface connected by screws to the main and secondary timber sub-structure.

The expected lifespan of the bridge exceeds 50 years for the main bearing elements and lateral supports, and far more for all steel elements that will be protected by hot-dip galvanisation or made of stainless steel.

The bridge structure is planned in the centre of the town of Samobor and special attention has been paid to the architectural solution and fitting of the new structure into the environment. It is also important to make the bridge look as attractive as possible by night when the play of lights installed into the railing columns would provide appropriate visual effects. As the environment is well lighted, no special lighting by lamp posts and lighting at the height of several meters is planned.
The plan is to complete the bridge in 2008.
Photo 3 shows the vision of the future bridge by night at the planned site.

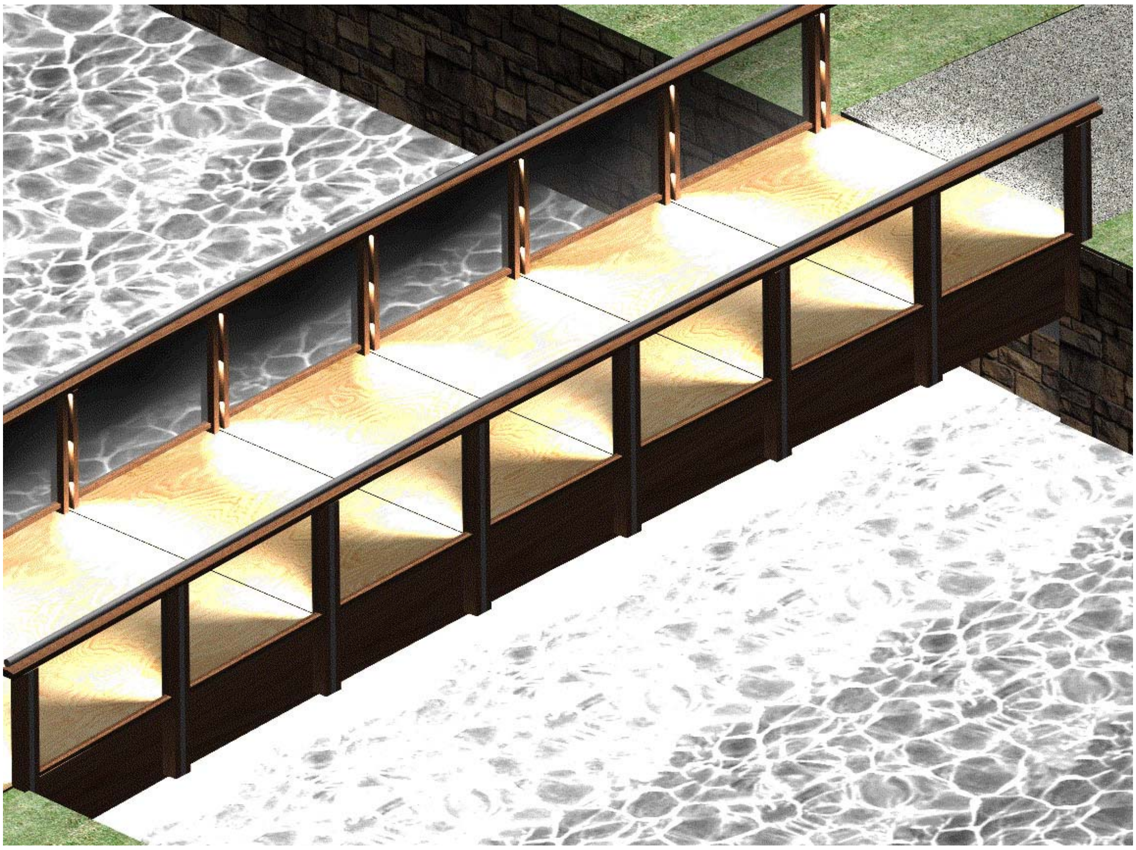

Photo 3 Bridge in Samobor by night

The calculation of the bridge has been done by means of a simple static analysis of the beam girder. The glulam girders will be supported by neoprene rubber bearings on a reinforced concrete base. Secondary bearings will be connected to the main bearings by means of the usual steel hangers connected with crews through the timber of the main structure.

5. Conclusion

In Croatia, timber structures are gaining on significance. These two recent examples show a change in perception and abandoning of the previous practice of constructing all bridges, even small ones, out of reinforced concrete.

There is primarily a well known fact that timber bridge structures are very acceptable on small spans for pedestrian and light traffic as it has been shown from the practice of other countries. Such bridges are easily made in a factory, easily transported to the site of installation, and after the expiry of their lifespan they are easily replaced and the traffic across them is immediately in function.

Their maintenance is simple and wood is a high-quality recyclable structural material.

Also in the winter, there are no aggressive adverse effects of defrosting salts, as opposed to reinforced concrete structures, where chlorides destroy the reinforcement.

Finally, I would like to refer to a statement by the authors of the paper (3):

«In the construction of small road and pedestrian bridges, timber is the structural material of the 21st century».

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