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REHABILITATION OF AN OLD FOREST NARROW GAUGE RAILWAY LINE FOR A SUSTAINABLE DEVELOPMENT OF THE TOURISM

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Abstract: *In Romania, there have been many narrow-gauge railway lines built in the 19th and the beginning of the 20th century - true engineering works, generally built for the exploitation of wood.*
The paper presents the studies made for the recovery of an ancient railway line with narrow gauge for forestry exploitation (in Romanian, "Mocănița"), abandoned in present. Having a total length of 15 km, the major rehabilitation can promote a sustainable tourism, giving a new life for the area situated in the region of the Danube Iron Gate, near to the village of Berzasca. The present technical condition of the railway line is analyzed and proposals for the rehabilitation of narrow railway line are presented. The location of the investment is placed in the area of Berzasca, Caraș-Severin county and Almăjului mountains on the river Berzasca [1].

Key words: *narrow gauge railway, parabolic truss girders, sustainable development, steel railway bridges, tourism.*

1. Introduction

Mocănița is a narrow-line train running in mountain regions. In the village of Berzasca, one of the most southern settlements in Caraş Severin - County, situated at the foot of the Carpați mountains and the Danube river (Figure 1), an old narrow railway line erected at the end of the XIX Century, will be rehabilitated.

With a length of 32 kilometers, the old route of the Mocănița left Berzeasca (Figure 2) and ended in a small village in the mountains. Revitalizing the route is only possible due to accessing European funds, amounting to more than 12 million euros, plus another 15 million euros for the rehabilitation of buildings close to the line.

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Fig. 1. *Berzasca Area [2]*

Fig. 2. *Ancient terminus railway station of the Mocăniţa*

The investment includes the restoration of the Mocăniţa route over a length of approx. 16 km, comprising: departure and arrival, two stops (Moara mare and Ilova), repair and maintenance hall with annexes, the narrow gauge railway (E = 760 mm) and related "*ouvrages d'art*" - retaining walls, culverts and bridges over the Berzasca River. The present paper describes the constructive solutions for the narrow railway bridges, necessary on the route for crossing its intersections with the Berzasca River at km 2 + 430m and at kilometer 13 + 438 m [3].

The topography of the area and the location of the bridges are shown in Figure 3.

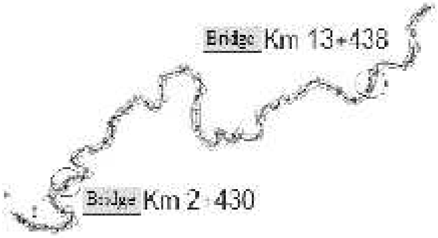

Fig. 3. *The location of the bridges along the route*

Fig. 4. *Mocănița in function*

2. Proposals for the Technical Rehabilitation of the Narrow Railway – line

The line was abandoned for about 15-20 years and the infrastructure was significantly degraded (Figure 4); having some previous damages the rehabilitation is not justified and they will be demolished. As a result, several variants of bridges with single medium span (20-50 m) have been analyzed; they do not need piers in the riverbed (which is advantageous for the extraordinary floods on the Berzasca River) (Figure 2):

- steel plate main girder; this solution would require a beam with a relatively high height of 2.0-2.5 m, which would significantly reduce the clearance under the bridge or would increase the red line (gradient) the elevation of the route. This option has been abandoned.
- trough truss main girder; in this variant, the free space under the bridge sufficient for taking the maximum flow of the river in safety conditions; the structure is economical, easy to be executed and maintained. In addition, a retro-shaped form with the upper parabolic chord (similar to the constructive solutions used in the early years of 1900) can be adopted, which increases tourist interest; this solution was developed in this project.

Parabolic or semi-parabolic (half-parabolic) truss girder bridges were used in most of cases at the end of the 19th century and the beginning of the 20th [4]. Due to the classical advantages of these structures, they covered a large domain, from spans of 30-100 m (for larger spans, in this time cantilever truss girder were chosen). The upper (lower) chord is curved, the diagonals are descending ones (tensioned). Compared to a truss with parallel chords, there is an increase in the fabrication cost, but for medium and large spans the additional cost may be balanced by saving in material. The aesthetic appearance of these structure is pleasant, some of the parabolic truss girder bridges, are monuments of the engineering art.

Fig. 5. *Existent infrastructures [2]*

It is important to mention that, the Eurocode standards adopted as national standards do not refer to narrow railways (with gauge lower than the normal 1435 mm), for the analysis of bridges, the Romanian rules [5], [6],[7], [8] were used.

Rebuilding the line includes a new train station, two bridges, and the entire narrow railway track along the Berzasca River, as well as a part of the former forestry rail Mocănița.

Bridges on the narrow railway line were made to cross the Berzasca River to km. 2 + 340 km. 13 + 438 m are placed in alignment and horizontal.

The bridges were calculated for the I3 convoy - a train with two 4-axle locomotives with maximum axle load of 80 kN (the total weight of the 32.0 metric tons locomotive) and an unlimited number of wagons with 30kN/m.

For infrastructure and connections, the I 3.5 convoy was chosen (Figure 6).

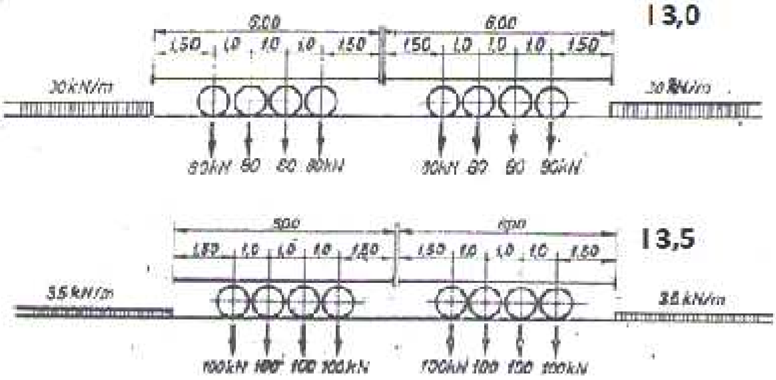

Fig. 6. *Narrow gauge railway convoys I 3 and I 3.5*

For the structural analysis two alternatives for the convoy were chosen (Figure 7).

Fig. 7. *Two alternatives for the convoy used in the analysis of the structures*

The freeway clearance gauge is 3300 mm wide (horizontal) measured symmetrically to the CF axis and 3650 mm height (vertical) measured from the NSS (upper rail level). The maximum speed on the bridge is 50 km/h.

The steel superstructure of the bridges was calculated for the seismic area F (seismicity VI), according to the seismic zoning in [4], characterized by the P100-2006 standard and the coefficients $a_g = 0.12 \cdot g$ and $Tc = 0.7$ *sec*. Snow climate zone: the "*B*" area according to the map of [10], with the characteristic value of the snow load on the ground $S_{0,k} = 2.0$ kN/m^2 [14]. For wind: zone "*D*" was chosen, with the fundamental value of the reference speed 37 m/s and the dynamic pressure $q_{ref} = 0.83$ kN/m^2 [13]. The area is characterized by the strong Coşava wind.

In the following brief description of the two new bridges are presented.

The structure situated at km. 2+430, span L=36.0 m.

The bridge has single main span over the minor and major river - bed and a classical infrastructure (Figure 7). The span of the bridge is 36 m and the total length of the bridge is L_t = 42.40 m. The structure has a number of 10 panels.

The width is 3.80 m measured between the axes of the main truss girders, providing the free bridge gauge (single line, b_{LT} = 3.30 m for narrow rail with 760 mm gauge) and a safety space of min. 100 mm, on each side. The service footpaths, with a width of 0.75 m, are located on both sides and are placed on the consoles outside the main beams. In this way, they can be separated from the free passage gauge for the railway convoy and can also be used as a stopover for tourists when the train is stationed in the zone of the bridge. For the protection, a 1.10-meter-height parapet was provided. The considered live load on the footpath was 3.0 kN/m^2 [3], [4], [5], [6].

Considering the allowable transport length of the main girder, the structure three splices are provided dividing the bridge in pieces with max. 14-15 m long each; they can be transported from the plant to the site without restrictions. Their erection in the site will be carried out an a scaffold. The connection on site are made by high strength bolts, avoiding welding in a difficult area.

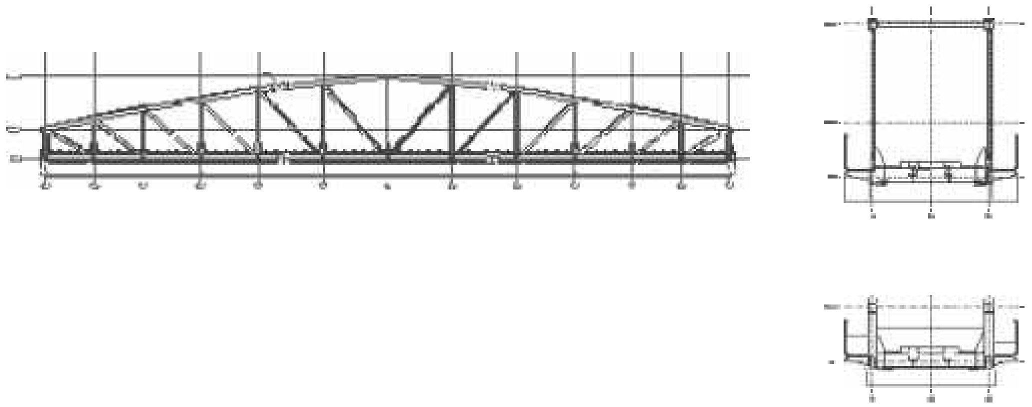

Fig.8. *General view of the bridge km. 2+430*

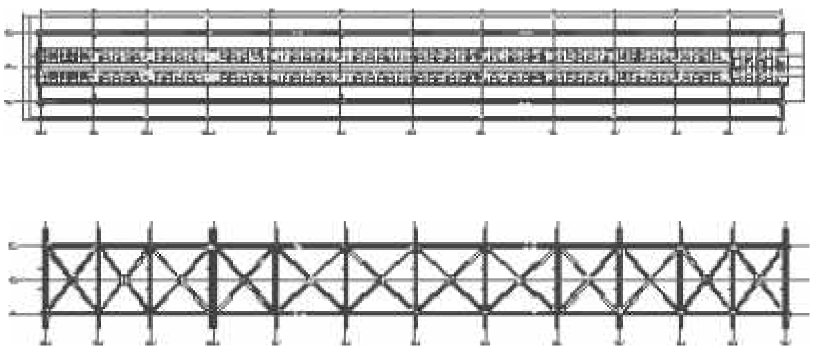

Fig. 9. *Characteristic view of the bridge L=42.0m km.13+438*

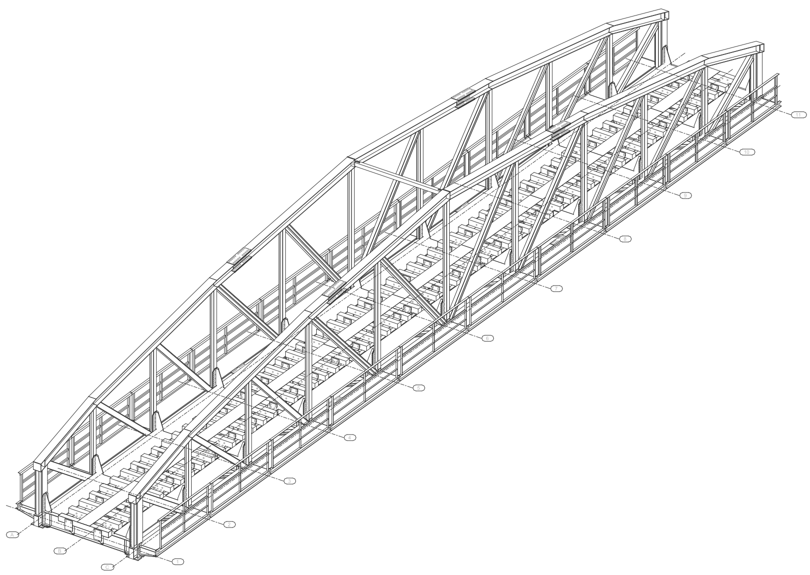

Fig. 10. *Space model of the bridge.*

The composition of the bridge is classical: stringers, cross girders and wind bracings.

The structure situated at km. 13+438, span L=42.0 m

The bridge has the same composition, only the span is different. The span of the structure is L= 42.0m and the total length is L_t = 48.60 m. (Figure 8).

The analyzed space model of the structure is shown in Figure 10.

A space analysis of the structure was performed: the resulting cross section of the elements were: for the upper chord HEA240; lower chord IPE330; Diagonals = rectangular hollow section 200x150x8; Verticals = square hollow section 150x8 [7], [8], [9], [10].

3. Conclusions

In Romania in the past, existed many railway narrow gauge railway lines. Unfortunately, during the communist time and immediately after they were neglected, dismantled and sometimes sold as scrap iron.

We firmly believe that the rebuilding of these technical miracles (Figure 10) [12] can contribute to the revival of tourism in general and would bring out anonymity many regions that otherwise depopulate and fall into oblivion.

The authors of this paper had - some years ago - the same attempt to save an old railway line near to Hunedoara, without any result. A guide for the bridges verification on narrow railway lines was conceived [11].

The rehabilitation of the present railway narrow railway line can promote a sustainable tourism, giving a new life for the area situated in the region of the Danube Iron Gate, near to the village of Berzasca.

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