Renewal of old existing small road bridges with modular system – CASE STUDY Mânărău BRIDGE

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Abstract: Romania has a highway network of approx. 154 000 km on which there are over 3300 bridges. The usual range of these bridges is situated in the field of medium spans and was dominated in the past by concrete bridges. At the same time more than 50 % of the total number of bridges is designed for the loading class I (Lorries A 13 tones, S 60 tonnes). For them the National Administration of Roads proposes (in a long term program – Romanian Highway Administration Report 2003) their rehabilitation and upgrading to Loading class E (Lorries A 30 tones, V 80 tonnes). The European RFCS project ECOBRIDGE *or Demonstration of ECOnomical BRIDGE solutions based on innovative composite dowels and integrated abutments* [1] started in 2010 and has the principal objective to continue the research, demonstration projects and accompanying measures for the promotion of knowledge gained by the two pilot projects: INTAB – "Economic and Durable Design of Composite Bridges with Integral Abutments", 2005 – 2008 and PRECOBEAM – "Prefabricated Enduring Composite Beams based on Innovative Shear Transmission", 2006 – 2009. The main conclusion of the two pilot projects was that the composite dowel strips combined with the integral structure concept find a wide application in bridges. The article presents the first Romanian proposed project for the European RFCS program in which the composite dowel strips together with integral abutments in terms of construction details and economic aspects are implemented.

1. Introduction

Rehabilitation and maintenance of existing steel constructions, especially steel bridges, is one of the most important present problems. During service, bridges are subject to wear. In the last decades the initial volume of traffic has increased. Therefore many bridges require a

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detailed investigation and control. The examination should consider the age of the bridge and all repairs, the extent and location of any defects etc.

The research program of the European RFCS project ECOBRIDGE was split in three working groups: one partner was from Germany (Aachen University, SSF Ingenieure AG, TWT Sanierungsgesellschaft), another one from Poland (Wroclaw University, Europrojekt Gdansk and Energopol Szczecin companies) and one from Romania ("Politehnica" University from Timisoara, SSF-RO s.r.l., D.R.D.P. Timişoara). Arcelormittal coordinates the activities of all working groups.

The propose of the RFCS research project ECOBRIDGE was to design, construct and have a monitoring period for three composite bridges in Romania, Germany and Poland with integral abutments and / or composite dowels – an innovative form of shear transmission. The main objective of the first task was to identify a proper bridge site by considering socio-economic as well as technical conditions.

At the beginning, Romania has chosen for this European project an existing bridge at Mânărău. During service, the integrity of the bridges can be influenced by many factors like the increase of the initial traffic volume, the existence of an inadequate maintenance process or a total lack of it, natural disasters, the oldest of them could even be subject of world wars. The imprint of those factors on a structure can be pointed on the appearance of fatigue defects, contingent deformations, corrosion levels, behaviour due to traffic loads or the bearing condition. All these aspects are valid for the Mânărău Bridge, chosen to be deconstructed [2].

The answer to the question "why this structure?" is the following: this structure has been chosen because it was established that is in a very bad condition and doesn't offer safety in operation anymore and also because many other similar small bridges, built in the same period of time are still in use with relevant problems as well.

Moreover, the existing bridge was proposed to be replaced and there has been a technical project that included a classical filler beam deck solution. The technical proposal stipulated for the renewal works to be executed on the initial location of the bridge, while the continuity of the traffic was to be assured during the entire working period by setting up a bypass with a single traffic lane and traffic lights. This temporary traffic variant implied the introduction of a temporary steel bridge with a span of 15 m. The total length of the variant was to be of 130 m and the speed limit would have been of 15 km/h.

Taking these aspects into account, within the applied research programme a modular structure was conceived, which could have been executed on one traffic lane at once under the protection of small longitudinal supporting structures, thus eliminating the costs for the traffic variant. At the same time, the settled objectives were to also minimize the investment costs whilst keeping and assuring the structural robustness. Thus, by using compound dowels it was possible to reduce the steel quantity in the external rigid reinforcement embedded in the concrete and by using the solution of an integral bridge on abutments made of sheet piles one could guarantee a 100% modular structure, which could be easily and rapidly executed.

The bridge is situated on the National Highway DN 79A Km 60+627, near to the village Mânărău in the Arad County ("Fig. 1").

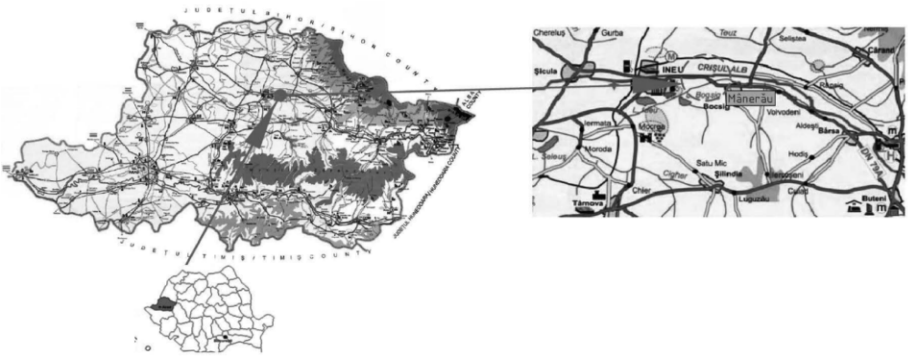

Figure 1: The Mânărău bridge location

Table 1: Technical information of the existing vs. the new bridge

	The new structure	The existing structure
Importance category (HG 766-97)	C	C
Category of construction (STAS 4273-83 art. 2.11)	3	3
Class load	E (A30, V80) and LM1	I (A13, S60);
Bridge length	8,175 m;	9,85 m
Bridge width for the solution 1	10,36 m;	9,00 m
Bridge width for the solution 2	10,08 m;	
Gradient's bridge	0 %;	0 %;
Gradient in the cross section	2,5 %;	2,5 %;
Length of the bridge guardrail	32,2 m	0,0 m
Connection with embankments	connection plates, back walls	back walls
Static structure	frame structure with an opening	simply supported girder
Waterproofing	waterproofing membrane with a protection layer	waterproofing membrane with a protection layer
Access ramps	rehabilitation on 2 x 20 m and will be referred with road verges of 0.5 m;	-
Infrastructure	indirect foundation	direct foundation
Drain water from the bridge	side ditch	-

Figure 2: General view of the bridge and access ramps

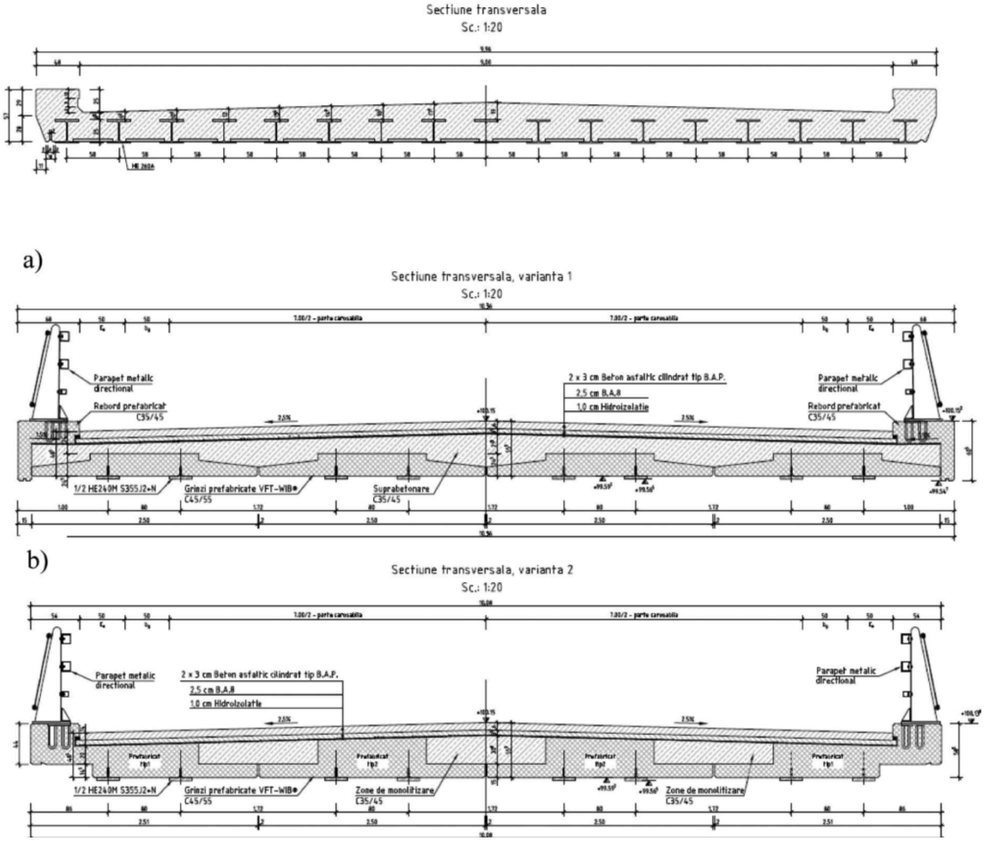

Figure 3: General cross section: Old solution, new solution 1 (a), new solution 2 (b)

The bridge was built in 1967 for the loading class 1 (truck convoys A13 and S60). The general condition of the structure is bad; the maintenance is missing (“Fig. 2”).

The bridge belongs to the Regional Administrations of Roads and Bridges (DRDP). It does not correspond anymore to the present traffic necessities, with trucks of 30 tons (A 30) or even more. There are no footways and no borders. The safety parapet is missing, the traffic participants being in danger. Water discharging devices are also missing on the bridge.

The total length of the bridge is 9,90 m and the width is 9,0 m. The present cross section consists of a reinforced concrete slab of C8/10, having a thickness of approx. 0,40 m (“Fig. 3”). The carriageway, made out of asphalt concrete, presents cracks on extended areas. The infrastructure presents degradations, caused by waters (“Fig. 4”). There is a geotechnical study based on geotechnical investigations, presenting the layers of the foundation ground. The bridge is situated in a seismic zone; according to the Romanian Standards, no measures for anti-seismic protection have to be taken.

Figure 4: Structure degradations

The present viability state of the structure is not satisfactory, which leads to the necessity of replacement with a new structure. The highway bridge presents damages as a result of actions, fatigue and creep. The replacement of the existing structure with the VFT-WIB® solution (developed from the classical WIB composite structure) was proposed.

2. Technical details of the applied solutions

A classical filler beams deck could be an adequate solution for the span and heights imposed for many existing structures especially railway bridges. Going further and taking into consideration also the need of a simple technology and a very short erection time, it leads to the necessity of a modular system with low costs. Using the high degree of prefabrication the possibility of unexpected situations on site is reduced and lower costs are obtained. Simultaneously it offers execution simplicity. The VFT-WIB® solution was obtained from the classical WIB composite structure, considering the improvements mentioned before (“Fig. 5”).

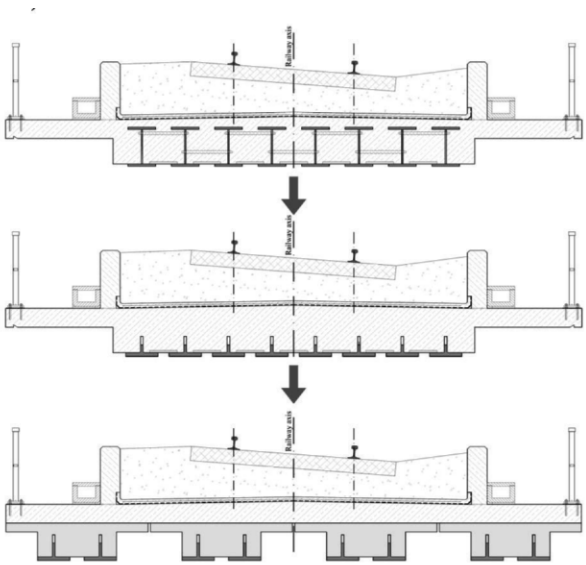

Figure 5: Durability of composite bridges

This new technology has been in continuous development in Europe.

The composite dowels are associating steel T-sections acting as tension member with a concrete top chord acting as compression member. Steel parts are generally obtained from rolled steel profiles that are longitudinally cut in two identical T-sections. The cut is performed with a special shape to allow the shear longitudinal transmission between steel and reinforced concrete ("Fig. 6" [4]). Also a good accuracy of the cutting line is necessary because an imperfection in the geometry can compromise the final resistance to fatigue [5].

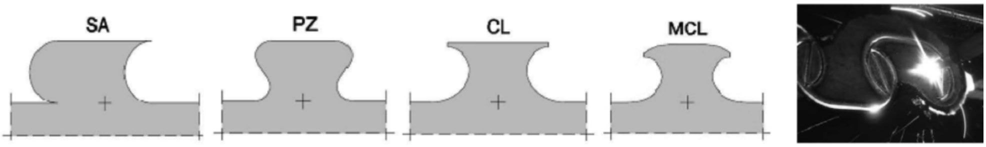

Figure 6: Cutting line types: fin (SA), puzzle (PZ), clothoidal (CL), modified clothoidal (MCL).

Going further by introducing these beams into framed load bearing systems such as integral abutment bridges, it is possible to manufacture hybrid integral structures with concrete shafts and composite crossbeams that can easily absorb the high horizontal forces from impacts or earthquakes. In case of an integral system, due to the absence of bearings and joints, the maintenance costs can be significantly decreased [3]. Also the reduction of the number of construction stages on the site leads to a simple technology and a high quality assurance, during the building process. Those main advantages of the integral bridges turn out to become highly attractive to designers, constructors and road administrations.

Over the last four years, VFT® and VFT-WIB® technology included within frame bridges has been applied in Romania. Unfortunately, as there occurred the same financial problems in case of the bridge over the Mânărău channel on the national road, all the works have been stopped and the project remained only in design stage.

3. Design aspects

With the help of the main dimensions and cross sections of the structural elements from the existing drawings and completed by the present situation on the site, a simple analysis of the structure with the help of a FEM analyses was made. According to the results, the main girders subjected to current Romanian standards exceed the normal values. The conclusion was that the existing bridge needs to be replaced. The new structure was developed and also analysed in a FEM program according to the Eurocode load models ("Fig. 7").

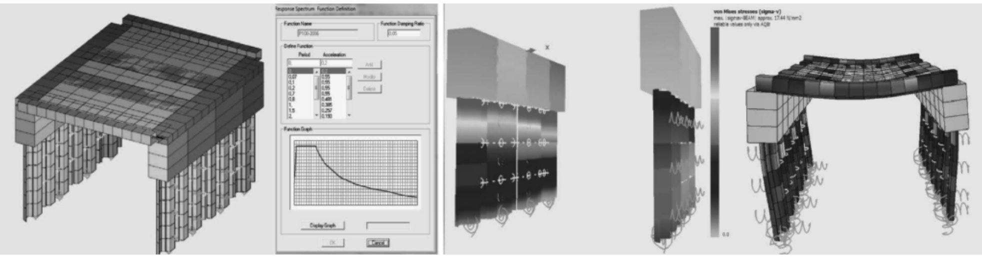

Figure 7: Spatial 3D model and FEM analysis

Therefore, for the new cross section two types of precast elements were proposed. The difference between the two is only the geometry of the elements ("Fig. 8"). Four VFT- WIB® prefabricated composite girders were aligned and linked together by cast-in-place areas. To reduce the usage of the formwork on site to the maximum, precast concrete solutions were also provided for the sidewalks ("Fig. 8").

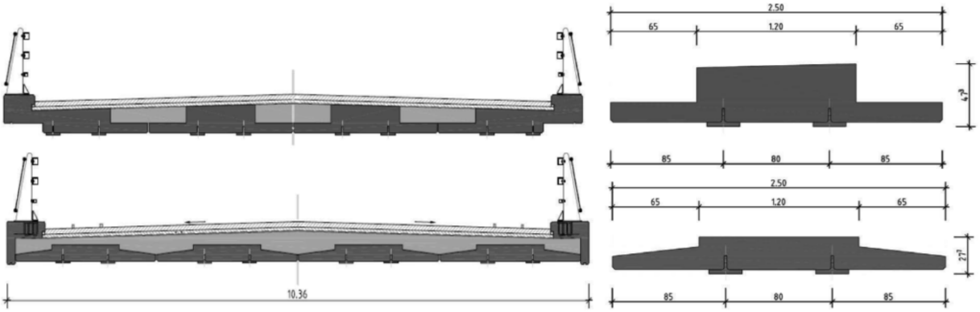

Figure 8: General new cross sections and details with the precast elements

Considering only one precast element, the steel girders should be composed of two rolled girders ½ HE240M at the bottom of the section, made of steel S355 J3+N. A rolled steel girder is cut according to a separation line (corresponding to the modified clothoidal or MCL shape) [3], resulting 2 "T"-shaped steel girders. The resulted halved girders work as external reinforcement, the steel consumption is reduced to a minimum, leading to a very slender and economical composite structure. The MCL composite dowels are suitable for the bridges field, because they allow high bearing capacities and provide uniform and bidirectional transmission of the shear forces in the structure, and can assume also the dynamic loads. They have a good behaviour also in longitudinal direction.

The reinforcement bars are passing perpendicularly to the web of steel profile and through the concrete area between the steel dowels. Achieving its role in the composite dowel, it must also resist to the shear forces (“Fig. 9”).

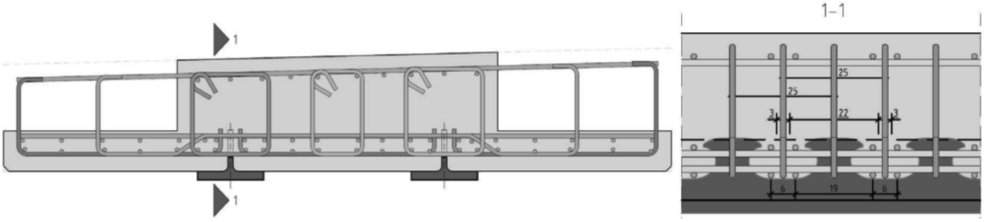

Figure 9: Reinforcement detail of the precast composite girder

4. Technology aspects

Integral bridges require full collaboration between structure and foundation soil. The solution with Larssen sheets disposed in the bearing axis was adopted; they transmit the loads of the superstructure in the carrying soil foundation (“Fig. 10”).

The following technological phases have been proposed:

- The Larssen profile (type 604) having a total length of 9,0 m will be introduced in the soil.
- At the top of the Larssen profiles a bearing seat of reinforced concrete C25/30 with a width of 1,00 m will be provided.
- The abutments will have back walls and connection plates of reinforced concrete C25/30.
- 4 rolled steel girders HE240M of S355 J3+N – resulting 8 steel “T” shaped beams will be prepared; 2 for each precast element – as a rigid external reinforcement.
- Bst500 reinforcement, C45/55 concrete – for the precast elements.
- After 14 days the prefabricated girders will be transported on site and placed in final position. Due to the high degree of prefabrication the influence of the shrinkage and the creep on the structure is eliminated.
- In this phase the structural system is a simply supported girder.
- Finally the precast beams are fixed at the ends with concrete class C35/45 obtaining the frame effect, resulting a frame system (“Fig. 10”).

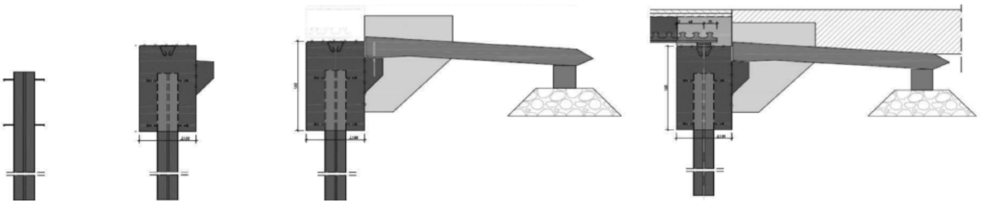

Figure 10: Frame corner technological phases.

5. Conclusions

Combining the advantages of the VFT® girder with the robustness of the traditional “filler beam plate” a very slender, robust, durable and economical structure was obtained due to an optimal usage of materials and short construction times. Due to the absence of bearings and joints, the maintenance costs were also significantly decreased.

By eliminating the traffic variant which included the temporary bridge, the investment costs as well as the execution time could be substantially reduced.

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