Integral bridge using the VFT-WIB technology for a three-spanned structure

Edward Petzek[1], Elena Meteş[2], Luiza Toma[3] & Radu Băncilă[4]

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Abstract: Alongside Romania's main focus direction of the past years regarding the transportation system, the motorways, which are part of the Pan-European corridors, the entire road network has to be considered. This is the case of the local road which crosses over the Bistrița River, in the village Frânceşti, via a provisory bridge, used as permanent solution. The bridge does not ensure the safety of its passengers, nor the required clearance. The conducted expertise concluded that the structure must be replaced. The new bridge to be built was chosen to be part of the European research project ECOBRIDGE [1]. It is an three-spanned integral bridge using the VFT-WIB® technology for its superstructure. This technology referring to the German "Verbund-Fertigteil-Träger – Walzträger im Beton" or "prefabricated composite beam – filler beam" was introduced to the market in the last years. A key feature of the solution is the use of composite dowels for the steel-concrete connection. Important European research programs such as INTAB [2] or PRECOBEAM [3] have shown the use of such dowels is efficient and that VFT-WIB® is suitable to be used in case of integral bridges, combing the advantages of both technologies.

1. Introduction

The European research project *Demonstration of ECOnomical BRIDGE solutions based on innovative composite dowels and integrated abutments* with the short name ECOBRIDGE [1] has the objective to construct three composite bridges in Romania, Germany and Poland with integral abutments and/ or composite dowels – an innovative form of shear transmission. This is a possibility to apply the newest techniques and developments in each participating country. The bridge at Frânceşti was the second proposal, made by the project members from Romania, to be part of ECOBRIDGE.

1 *Assoc.Prof.Dr.Ing., Politehnica University of Timşoara and SSF-RO Ltd. Spl. T. Vladimirescu 12/6, Timişoara, Romania, epetzek@ssf.ro*

2 *Dipl.Ing., Doctoral student, Politehnica University of Timşoara and SSF-RO Ltd. Spl. T. Vladimirescu 12/6, Timişoara, Romania, emetes@ssf.ro*

3 *Drd.Ing. Politehnica University of Timşoara and SSF-RO Ltd. Spl. T. Vladimirescu 12/6, Timişoara, Romania, ltoma@ssf.ro*

4 *Prof.Dr.Ing., Politehnica University of Timşoara and SSF-RO Ltd. Spl. T. Vladimirescu 12/6, Timişoara, Romania, radu.bancila@ct.upt.ro*

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The bridge is located in the village Frânceşti and crosses over the Bistrița River. The existing bridge is a provisory structure ("Fig. 1"), not ensuring the safety of its passengers, with a total length of 75,00 m, having 10 spans each of approximately 7,50 m length and a width of 2,40 m. It is the only crossing possibility of the river for the local communities and in urgent need of renewal. Bridges are one of the main founds consumers and an important investment for a small community. The economical factor is important in terms of material consumption, environmental impact and structure costs. Efficient solutions have to be elaborated in order for the structures to be both durable and economic.

Figure 1: Existing bridge over the Bistrița River at Frânceşti

The replacing structure was designed as a three-spanned integral bridge with VFT-WIB® superstructure. Each span has a length of 21,10 m, with a total length of 64,50 m, the width is 5,20 m, with a carriageway of 4,00 m ("Fig. 2"). The design is based on the experience gained at the Vigaun road bridge over ÖBB track Salzburg – Wörgl at km 23,135, Germany built in 2008 [4].

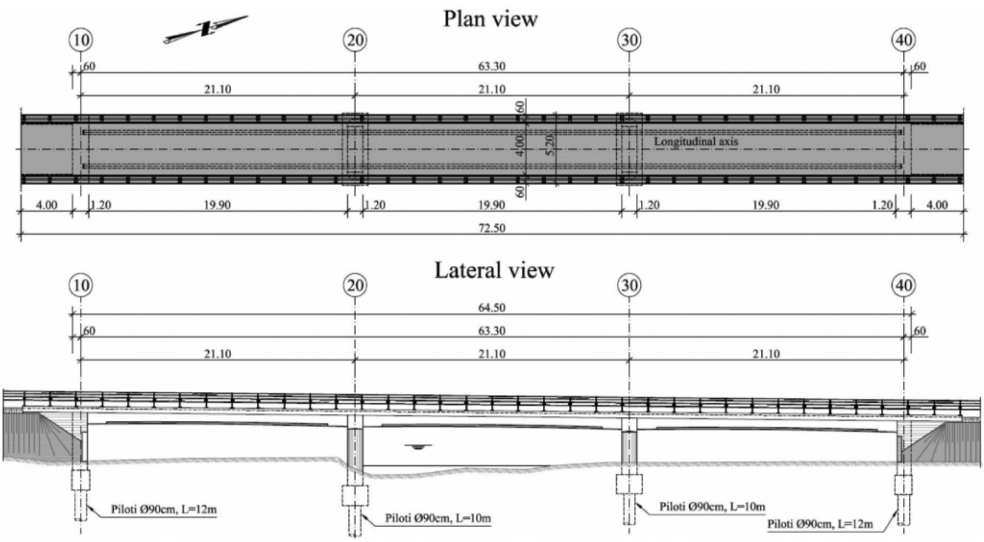

Figure 2: Plan view and lateral view of the new bridge at Frânceşti

The construction of the bridge at Frânceşti began in 2012 when a large part of the infrastructure was executed. Due to lack of founds, the construction process was interrupted. At present the local administration works towards finding the necessary means to finish the structure.

The current paper presents design aspects and structural details of the VFT-WIB® structure.

1.1 Integral bridges using VFT-WIB® superstructure

Integral abutment bridges have by now demonstrated their effectiveness, especially through material consumption and maintenance savings. This type of structure requires special attention in design, considering the frame-type behavior. Modern calculus methods have made it possible for the engineers to evaluate correctly the behavior of static complex structures.

The frame effect, by ensuring smaller positive bending moments in the middle area of the spans in comparison to simple supported or continuous superstructures systems, allows for the superstructure to have a smaller constructive height and reduce the material consumption. At the same time, negative bending moments arise in the joint areas of the superstructure, imposing a strong conformation of the frame nodes, needing reinforcement at the top layers and continuity between the superstructure and infrastructure [2].

By using integral abutment bridges no expansion joints and no bearings are needed. The risks emerging from the great execution precision needed for the disposal of the expansion joint or of the bearing equipments are eliminated. Simultaneously the maintenance procedures are eased and inspection times are further apart.

The frame type structures bring about new challenges to the design as well as to the execution procedure, but do succeed in bringing advantages regarding both total costs and easiness of the montage. Efficient structures can be obtained when for integral bridges prefabricated composite girders with composite dowels are used.

The VFT-WIB® solution, a modern reinterpretation of the filler beam decks, has by now been used in countries like Germany or Poland for small and middle spanned bridge structures. Earlier research projects such as PRECOBEAM [3], focused on the design of so called composite dowels, a main feature of the VFT-WIB® solutions, prefabricated composite girders.

The standard double T rolled steel profiles are replaced by T shaped sections with a bottom flange and a web, while the concrete section is redesigned and reduced. Modularity is obtained by creating prefabricated parts. Individual prefabricated reinforced concrete beams with external reinforcement represented by the T steel girders are created. The two materials are linked together by composite shear connectors [3], with no need of headed studs and hence no need of upper flange for the steel profile. This concept allows many design opportunities and therefore many types of VFT-WIB® sections were obtained: using steel profiles „duo-WIB“ (“Fig. 3a”) and „mono-WIB“(“Fig. 3b”), using welded sections (“Fig. 3c”, “Fig. 3d”); special types VFR-Rail (“Fig. 3f”) and external reinforcement in in-situ plate cross-section (“Fig. 3g”) [4].

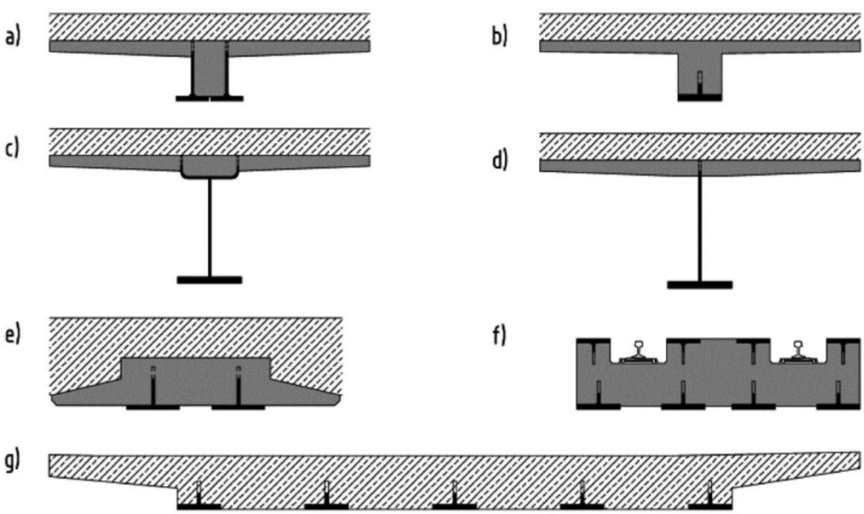

Figure 3: VFT-WIB® section types a) to g) [4]

In case of the bridge at Frânceşti the „mono-WIB“ – design was chosen, suitable for spans with lengths up to 35,0 m. This VFT-WIB® solution uses one or more beam type elements displayed in the bridge’s longitudinal direction, bound together by in-situ concrete decks or by joints filled with concrete and connection reinforcement. These prefabricated girders consist of an upper reinforced concrete flange, a reinforced concrete web and one imbedded T shaped steel profile at the bottom of the section using composite dowels for the shear connection. The T shaped steel sections are obtained by a special cut along the longitudinal axis of the web of a double T rolled steel profile almost without any outcuts. Two individual T profiles result, each having due to the special cut line tooth shaped steel dowels at the free end of the webs. The separation cut has to be performed precise to avoid imperfections and a possible compromise of the final fatigue resistance. The composite dowels represent the interaction between the steel dowels, through-going reinforcement bars and enwrapping concrete.

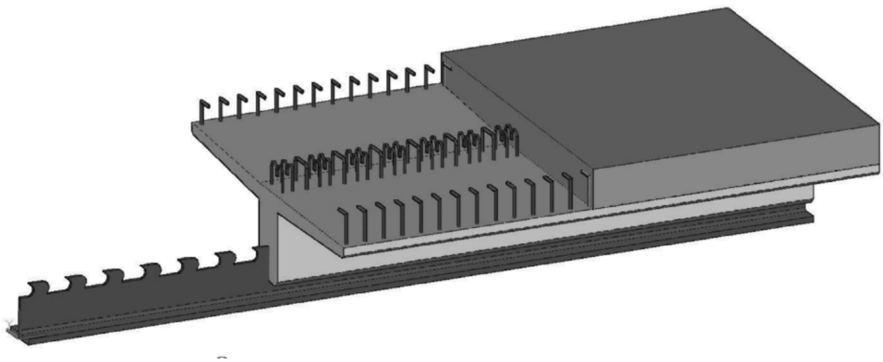

Figure 4: VFT-WIB® girder and concrete deck

The composite dowel strips were studied in the past years and design details can be found in [3], [5]. For this bridge the fin or SA shape was chosen (“Fig. 5a”), which is designed to transfer the shear forces in only one direction. Since the dowel shape is not symmetric, the dowel orientation changes at the middle of each steel girder (“Fig. 5b”).

The composite dowel strip is located quite far from the neutral axis and the steel dowel not only gets local shear loads but also centric tension as a result of global bending moment and gets consequently higher fatigue loads due to global bending moments [4].

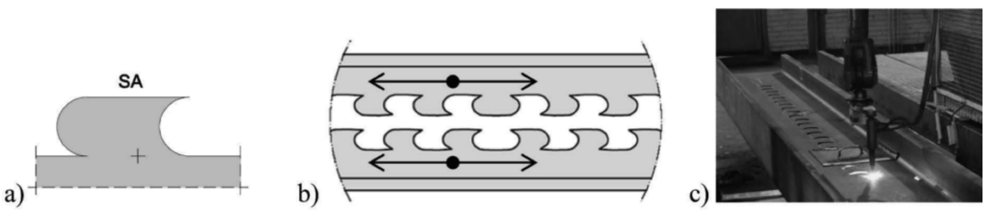

Figure 5: SA or fin shaped steel dowels [5]: The SA shape (a), Direction change of the composite dowels in the middle of the girder (b), Cut along the separation line in the plant (c)

This construction method was chosen due to advantages such as the robust bearing behavior in the case of impact loads assured by the concrete web, facile prefabrication possibilities, materials savings – especially regarding the steel use. High slenderness can be obtained if used for frame type systems.

2. Design aspects

The cross section of the bridge (“Fig. 6a”) aligns two mono-WIB girders bound together by a 20 cm thick concrete deck. The design of the prefabricated girders is shown in Fig. 6b and are made each of one ½ HEM 600 steel rolled profile of quality S460 ML, and of an upper concrete flange and a concrete web of C50/60 class. The concrete flange is 10…13 cm thick and ~2,60 m wide; the concrete web is 30,5 cm wide with a height of 70 cm. For the entire three-spanned bridge with a total of six prefabricated mono-WIB girders only three rolled girders HEM 600 were used.

The ½ HEM 600 and the steel dowels are obtained by cutting a regular HEM 600 rolled profile according to a pre-established geometry (“Fig. 7”, “Fig. 8”, “Fig. 9”) with the adequate technology in the factory. Only a low amount of outcuts result. Afterwards the girders are brought to the factory, where the dowel reinforcement, the binding reinforcement and the required carrying reinforcement are disposed (“Fig. 10”). High class concrete is poured in the formwork and after hardening, the prefabricated girders are carried to the site. The prefabricated girders can also be produced on site, near the infrastructure.

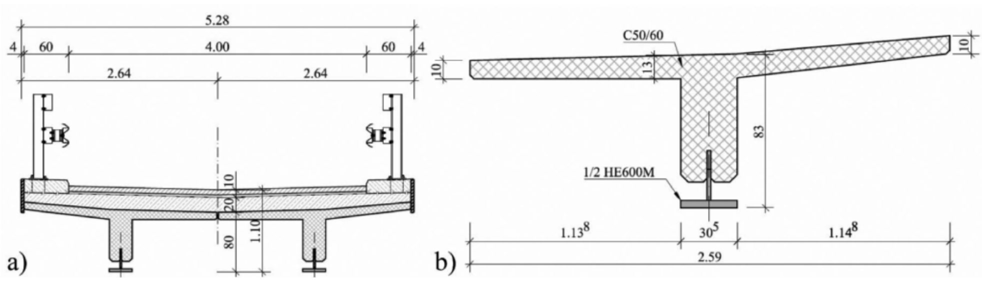

Figure 6: VFT-WIB – mono-WIB cross section (a), General superstructure cross section (b)

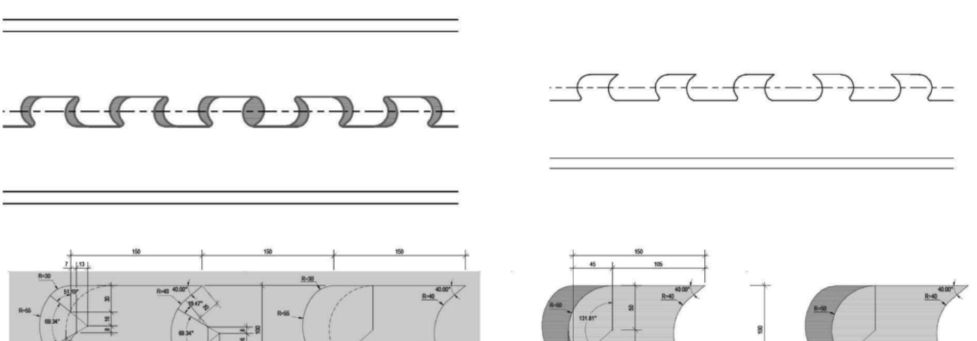

Figure 7: Execution details of the steel girders; Geometry of the steel dowel

Figure 8: External reinforcement

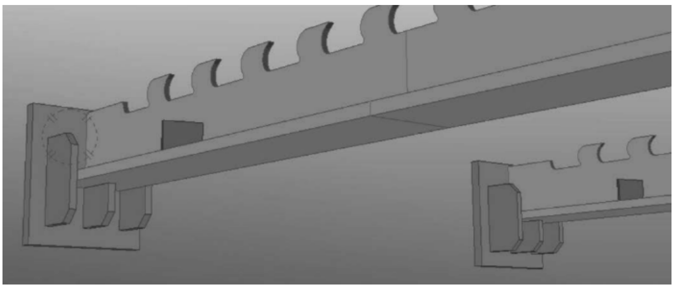

Figure 9: External reinforcement – end detail

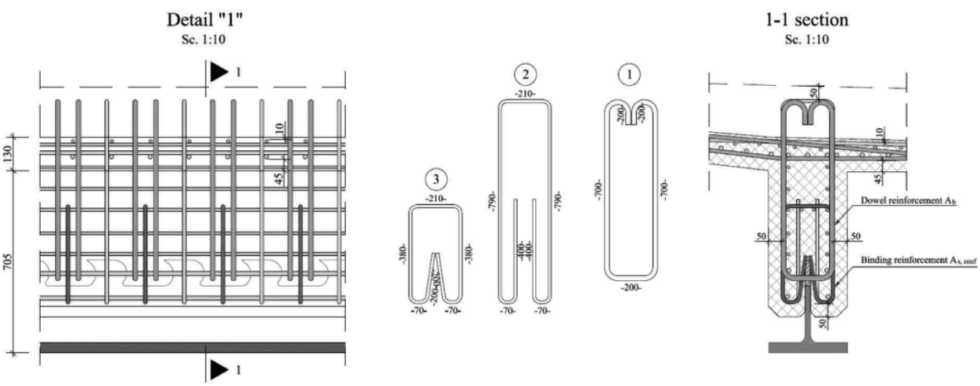

Figure 10: Composite dowels – reinforcement details

The infrastructure and superstructure of the bridge are monolithically bound together by in situ concrete and connection reinforcement from the piers/ abutments, the VFT-WIB girders, the deck and the frame nodes. The simple, rectangular shaped abutments are provided with relative small back walls and transition slab. The elevations rest indirect foundations with piles of 0,90 m in diameter. The bridge's static system ("Fig. 11") becomes a multi-span frame, resulting an integral bridge.

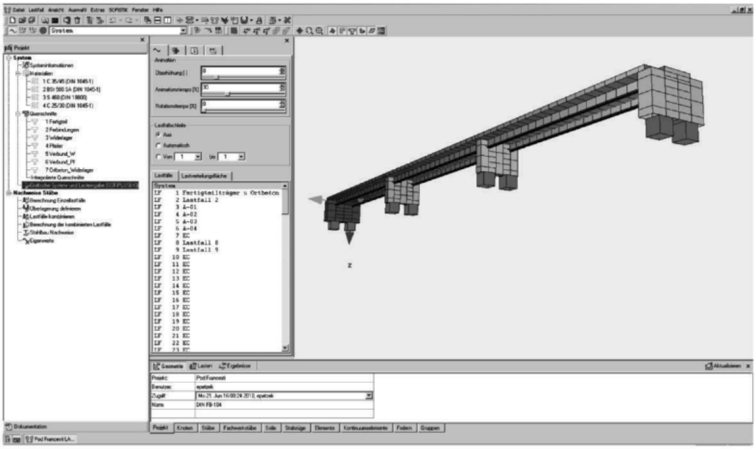

Figure 11: Static model

2.1 Construction stages

The infrastructure consisting of piles, foundation plates and elevations is classically erected, but due to the regular, simple and slender shapes of each part is economical, easy and fast to build. The VFT-WIB girders are made either in the prefabrication workshop or in situ on small concrete platforms. After the prefabricated mono-WIB girders are brought on site, they are lifted in their final position and fixed on top of the piers and/ or abutments ("Fig. 12a"). Reinforcement bars are added at the frame nodes and on the deck, and linked to the connection reinforcement from the elevations and the prefabricated girders. After the concreting of the frame nodes an intermediary static frame system is created ("Fig. 12b"), than the concrete deck can be poured ("Fig. 12c").

The integral building method implies the connection between all carrying elements. This is realized by outgoing reinforcement from every previously built/ added part. No props are needed during the concrete casting and only lateral formworks for the in situ deck are used due to the "T" -shaped VFT-WIB sections. The weight of the bridge's deck fresh concrete is taken over from the frame system: the two composite prefabricated girders, the frame nodes and the infrastructures. An optimal total superstructure height is obtained.

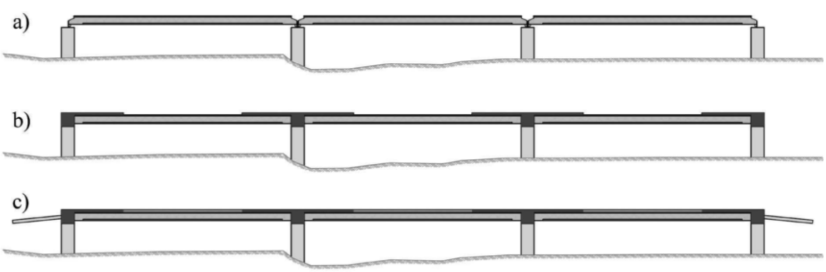

Figure 12: Superstructure construction phases: laying of the VFT-WIB composite girders in their final position (a), frame node and end sections of the deck concreting (b), deck concreting (c)

3. The site

Early 2012 the construction of the bridge infrastructure began. The piles, the foundation slabs and the elevations were built.

An indirect foundation made of bored piles, with the concrete class C25/30 was adopted, suitable for integral bridges. One pile beneath each foundation plate includes 3 tubes for the sonic tests ("Fig. 13"). The piles are 8 m, 10 m and 12 m long according to the geological necessities.

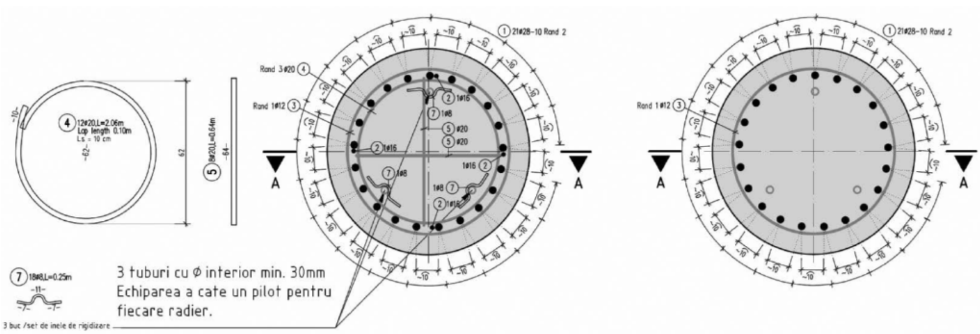

Figure 13: Pile sections – reinforcement and tubes for the sonic test

In spring 2012 the concrete foundations of class C30/37 were poured. The outgoing reinforcement ensures the connection to the infrastructure elevations ("Fig. 14").

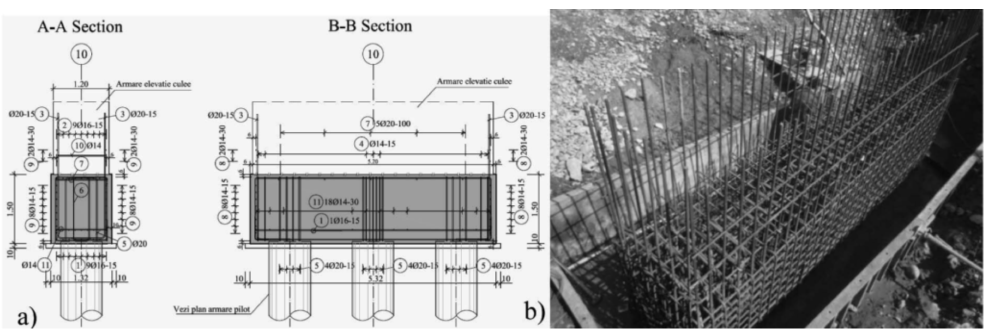

Figure 14: Foundation slab reinforcement plan (a), Site photo of the foundation slab reinforcement (b)

As a next step the elevations, abutments and piers were built ("Fig. 15", "Fig. 16", "Fig. 17"). To ensure the connection to the superstructure, thus underlining the integral character of the structure, reinforcement bars reach out from the concrete joints.

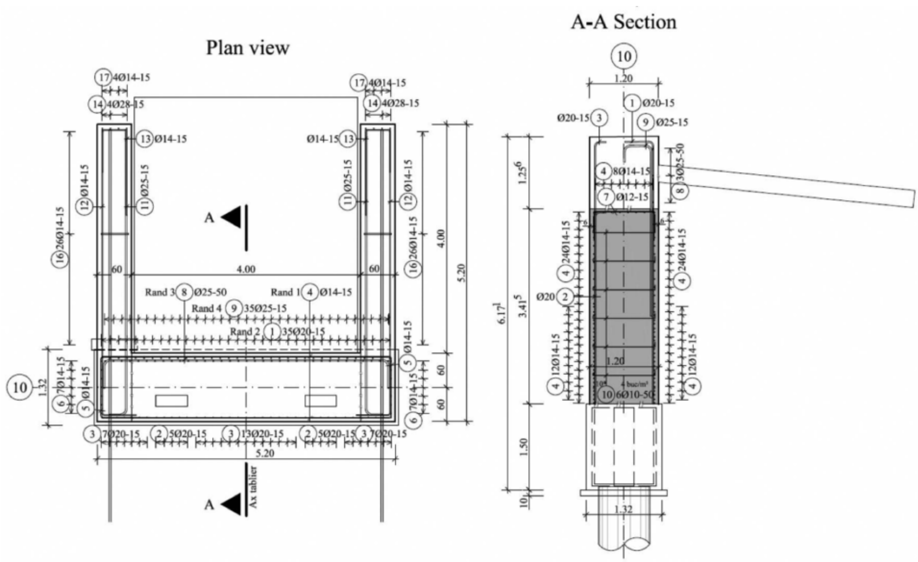

Figure 15: Abutment reinforcement plan

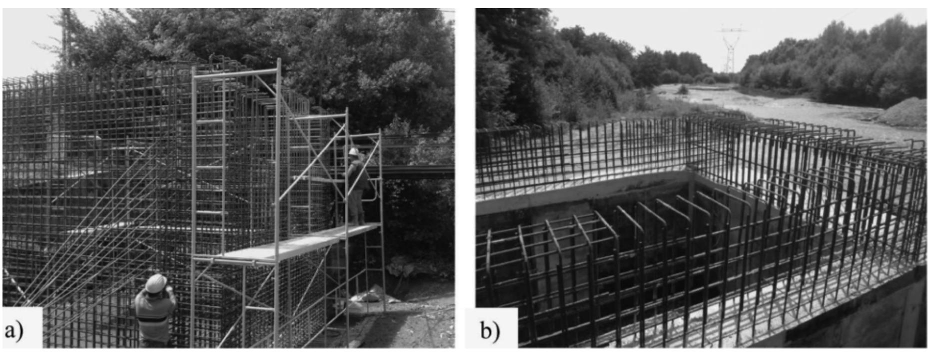

Figure 16: Site photo of the abutment reinforcement (a), Site photo of the abutment (b)

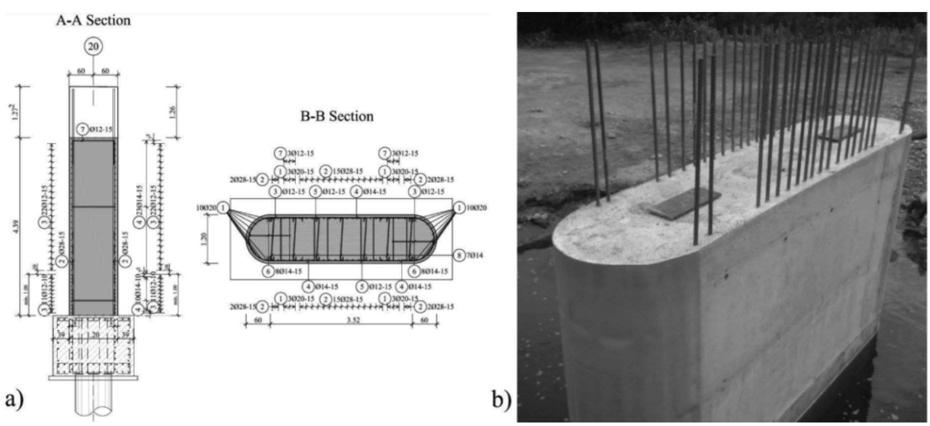

Figure 17: Pier reinforcement plan (a), Site photo of the pier (b)

The constructive details for the superstructure were designed. These include the formwork and reinforcement of the precast composite girders, the formwork and reinforcement from the cast-in-place concrete deck and the frame nodes reinforcement. The project also includes plans for auxiliary works. For example the river bank protection in area of the bridge was designed using gabions with terramesh modules. Also, the steel parapet was chosen according to the traffic type and volume.

4. Conclusions

The mono-WIB is an economical solution, as it requires low steel consumption and the prefabrication in the factory is facile. The steel profiles are obtained from regular rolled profiles without significant material loss, and their use is efficient acting as external reinforcement. No bearings and no expansion joints are provided, assuring simultaneously facile maintenance and driving comfort.

Using new technologies for the renewal process fallowing advantages are obtained:

- Robustness of the structure.
- Very slender and aesthetic bridges due to the optimal combination of high tensile strength of structural steel and the high compressive strength of concrete; costs are also minimized.
- High durability of normal reinforced concrete decks due to restrictive crack width limitation.
- Due to the low dead weight of the composite bridges' deck, composite bridges have advantages with regard to the foundation and settlements of supports.
- In comparison with steel bridges, composite highway bridges have a better behavior with regard to deck freezing in winter.
- Due to innovative methods the erection time is very short.
- Reduced environmental impact in comparison with other bridge types.
- Facile and cheap maintenance.

Important delays (even if at that time the bridge in Frânceşti was an absolute premiere in Romania), due to missing financial possibilities postponed the realization of the bridge in Frânceşti. Than the Romanian ECOBRIDGE team took the decision to analyze a new structure situated on the A1 motorway, part of the Orăştie – Sibiu motorway sector, lot 1 at km 8+755, which fulfills all conditions of the initial ECOBRIDGE project. The construction of the bridge at Frânceşti will hopefully soon be resumed, than the local community will safely travel.

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