Bulletin of the *Transilvania* University of Braşov • Vol. 9 (58) - 2016
Series I: Railways, Roads and Bridges Section

EFFICIENT BRIDGES SOLUTIONS IN ROMANIA

C. DIRSCHL[1] S.B. KAISER[2] A. BARATKI[3] E. PETZEK[4]

Abstract: *An important factor within Europe's development process is the transportation system. "Design and build" projects allow the implementation of efficient, economical and also modern structures. The present paper presents a quick overview of new designed and executed structures in Romania. These bridge solutions combine many important aspects: reduced costs, fast and simple erection, modularity, durability and robustness, low maintenance costs and an appealing aesthetical aspect.*

Key words: *integral bridges, semi-integral bridges, modern bridge solutions, frame structures, composite dowels.*

1. Introduction

Many of the new investments in the land communication system are assigned by tender projects in form of „design & build" and in this way joint ventures between execution companies and structural engineering offices are given the possibility to build whole road sectors in an economic advantageous manner. This assignment method permits the newly developed, innovative and economical solutions to be used in Romania as well. The current paper presents a quick overview of a series of efficient solutions of integral bridges from Romania, that take into account several important aspects from the point of view of the builder and also from the administrator, these are reduced costs, simplicity of the construction details – modular systems, durability and robustness, low maintenance costs, aesthetic aspects.

The current trend aim is to develop concepts and technologies that simplify and streamline as much as possible the existing solutions on the market, thus various research programs were developed in the past years in which have been involved both the private business and the state. A step forward to increase the competitiveness of the bridges, the modular concept was development. By eliminating the bearings and the expansion joints leads as much to a simplification and acceleration of the construction phases, but also to a reducing of the maintenance costs for those structures.

In the design and construction of bridges, questions of sustainability, maintenance and durability become more and more important for European road

[1] Faculty for Civil Engineering, University Politehnica of Timisoara.
[2] Faculty of Architecture and Urbanism, University Politehnica of Timisoara.
[3] Faculty of Civil Engineering, University Politehnica of Timisoara.
[4] Faculty of Civil Engineering, University Politehnica of Timisoara & Structural office SSF-RO Ltd.

administrations in addition to safety and serviceability issues. From this perspective, integral abutment bridges turn out to become highly attractive to designers, constructors and especially road administrations. The main reason for this is that they tend to be less expensive to build, easier to maintain and more economical to own over their life time.

All these needs have been proven to be met by integral abutment bridges, as this bridge type not only lowers production and maintenance costs but reduces economic and socio-economic costs as well.

− The superstructure can be designed quite slender, which decreases the construction height and the earthworks respectively. This leads to a decrease of material, fabrication, transport and construction costs.

− Frame bridges allow for the elimination of the middle support. This simplifies the construction of the bridge without essential interference of the traffic under the bridge, as the road has not to be closed.

Due to the absence of bearings and joints, the maintenance costs can be decreased significantly.

2. Applied Solutions

An important step in the construction of efficient bridges was done in our country beginning with 2011 through reusing of integral structures. At these types of structures the abutments and the piers are monolithically connected to the superstructure and in this case a clear distinction between the superstructure and the infrastructure of the bridge is not possible. The integral bridges have a very long tradition; arch-like bridges have been erected for over 2000 years. Practically nowadays the frame structures are the so called "old arch bridges".

Fig. 1. *Integral structures on Euro-banknote*

The first lot of motorway Orăștie - Sibiu, which is part of the IVth pan-European corridor located near to the town Orăştie and the Mureş River and its confluents, with a total length of 24.110 km, where 27 bridges were included, represent the first example in this sense. On this section all structures are being designed and executed as bridges with integral abutments, except the viaduct from km 1+240, with a total length of 240 m, which is a semi-integral structure. As a consequence, only two pieces of expansion joint equipment and eight bearings were used for the whole motorway lot. This motorway lot can be considered a European premiere, having only integral or semi-integral bridge structures.

The solution called BFT® (Beton Fertigteil Träger – prefabricated concrete girder) was adopted for motorway bridges as well as for overpasses with one or two spans of 36.5 m. These are integral structures, having a frame as static system, and use prefabricated prestressed concrete girders. In addition, precast concrete slabs are used in the interspaces between the prestressed girders.

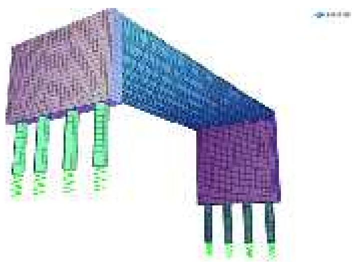

Fig. 2. *3D calculus model*

The concrete slab is casted in-situ and only a minimum of casings are needed. Also, due to the frame static system no consumables are used – no bearings and no expansion joint equipment. The foundation mode is elastic using drilled piles with large diameter.

Fig. 3. *Executed integral concrete motorway bridges and overpasses*

An important integral bridge is the three span (32.00m + 32.00m + 32.00m) motorway viaduct at km 9+405 over the Cugir River, at an angle of approximately 57º between the motorway axis and the flow direction of the river. Taking into consideration the long length for an entirely integral motorway bridge, the structure is a remarkable engineering achievement and as well a premiere. The superstructure aligns in cross section 7 prestressed girders for each deck. Between the girders, at the upper flange, prefabricated reinforced concrete slabs are added.

Fig. 4. *Motorway viaduct at km 9+405 over the Cugir River (2013)*

On the other hand, steel-concrete composite sections become more and more popular solutions in many countries and represent real alternatives to massive concrete bridges. The usage of prefabricated steel-concrete composite beams PreCoBeams and the modularity of the structures lead to large erection speeds. The high degree of prefabrication reduces the possibility of unexpected situations on site and offers execution simplicity. The steel performance and its optimum use of this material determine cost indices that rival the classical concrete solutions. The reduced weight of the prefabricated composite beams offers advantages both in the transportation as well as in the manipulation efforts and contributes to the success of modern composite bridges.

The introduction in the year 1998 of the prefabricated composite beams VFT® (Verbundfertigteil – Träger) was a success and proved a very good quality and efficiency of the constructive parts (the main girders) which are entirely made in the workshop. At present a few thousands of such examples exist in Europe. Through a sustained and systematic research activity a step forward was made regarding the development of efficient and innovative solutions for composite bridges by creating an efficient connection between the steel and concrete structure. The efficiency consists in the elimination of the classical Nelson type connectors and implicitly of the upper flange of the steel section, and creating the so called composite dowels by cutting the steel web according to a predetermined contour.

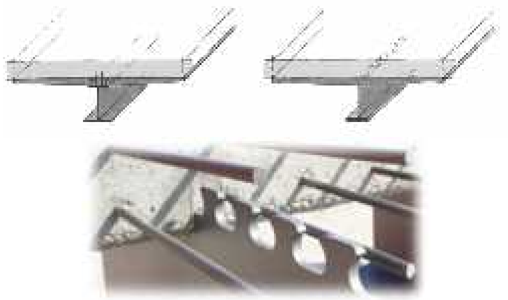

Fig. 5. *VFT® solution for composite bridges*

The solution was used in case of two of the Orăştie – Sibiu Motorway, lot 1, overpasses. This is the first time in Romania when the connection between steel and concrete is made through composite dowels and it is also a world premiere for a composite bridge not to have an upper steel flange and studs. Both passages have one opening and are oblique (approximately 70°), integral structures and they use four steel-concrete composite beams approximately 40 m long. The composite dowels require a cutting geometry on the upper part of the steel using a special form adapted to the requirements given by fatigue, reinforcement and concrete. Thus, a connector with superior behaviour to the studs results. If the elimination of the upper flanges of the steel girders and the studs are considered, namely material consumption and welding workmanship, the efficiency of the designed solution can be observed.

Fig. 6. *VFT® Orastie Overpass on A1 Motorway*

A very slender and aesthetic aspect was obtained for these overpasses and the solution allowed considerable material savings. Practically, for both bridges a very good steel consumption of 130 kg/m^2 was obtained.

It is clear that the success of a new bridge consists in choosing the optimal solution for the given situation, while taking into account factors as structural robustness, slenderness, the economical aspect as well as a pleasant aesthetic aspect too.

Generally, at bridge conferences, extraordinary structures regarding the size, the difficulty degree or the aesthetic aspect are presented. A new construction solution for steel–concrete composite bridges was applied in Romania for two motorway bridges, structures which do not stand out because of their size or because of their complexity. But the VTR® solution is characterized by premises, which could be remarkable for beneficiaries as well as for contractors: a steel–concrete composite girder system can be realized economically and in short time; the use of open ditches which can be easily integrated in the superstructure, they simplify the construction process and are easy to maintain; the possibility to change individual slabs from the deck permits a long term exploration guarantee of the superstructure; and not least, the superstructure can be easily dismounted if necessary. We are convinced that the construction proceeding - VTR®, brought by us on the market, will impose itself.

Fig. 7. *VTR® composite bridge concept*

At very long composite bridges, the concrete carriageway is usually executed with the help of a formwork carriage. The short erection time enforces the usage of a girder system, on which the prefabricated concrete slabs can be placed. This is proposed by the VTR® concept. In order to simplify the work on site there has not been employed an exclusively steel cross beam, but a prefabricated concrete cross beam. The VTR® construction procedure permits wide concrete joints and large overlapping lengths of the reinforcement bars.

The usage of prefabricated elements leads to fast execution speeds. The high degree of prefabrication reduces the possibility of unwanted situations on site and offers simplicity in execution. VTR® by using the performance of the steel and optimal utilization of this material in the cross section achieves cost indices that rival with existing classical concrete solutions.

The first applied structure was the motorway viaduct over the Mureş River. This bridge is situated at km 19+857 on the motorway sector Deva – Orăştie. The structure is a curved composite bridge with a radius of 1800 m. The total length of the bridge is 720 m and has 12 spans of each 60 m. For the entire structure 4100 tons of steel were used, which lead to a consumption indices of 199 t/m^2.

Fig. 8. *VTR® Mureş Viaduct (2012)*

The static system of the bridge is semi-integral. On the 1st of August 2011 the first drilled pile was executed, thus the construction phase being started. Aim was to complete the bridge within 16 months, until December 2012. The high execution speed of the concrete carriageway slab practically contributed to keeping the deadline. It took only 4 months to finish the entire deck of the bridge which has a total surface of approx. 2 hectares.

The bridge is under traffic since December 2012, being inaugurated two and a half months earlier than the given deadline. The Mures Viaduct was at that date the longest motorway bridge in Romania.

The patented SSF – Rapid solution (VTR®), was adopted also for the motorway viaduct located on the Orăştie - Sibiu Motorway section at km 1+240 which crosses over in obliquity (approximately 33°) the Pan-European double railway corridor IV and the DN7 national road having a length of 240 m with 7 variable spans (28 + 32 + 3x36 + 40 + 32 m). The bridge is a semi-integral structure having bearings and expansion joints only at the abutments.

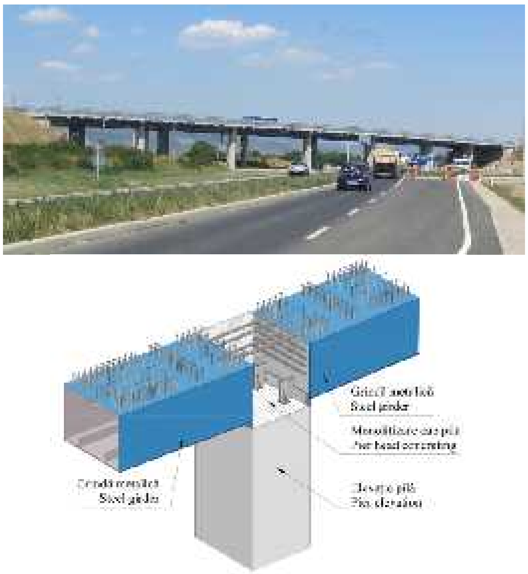

Fig. 9. *VTR® Orăştie Viaduct (2013)*

The combination of the two technical solutions: the VTR® system and semi-integral bridges is efficient. In case of the motorway viaduct at km 1+240 all piers are monolithically connected to the superstructure and the superstructure lays on bearings on the abutments.

The major advantages brought by the VTR® solution were associated with the particularly simple execution of a structure in pronounced obliquity above two important communication ways (national road and main / magisterial railway line) without traffic interruption.

As the VTR® solution presents indubitable economic advantages and regarding the execution time, as well as due to the fact that it is suitable for oblique intersections of two or more terrestrial communication ways, this solution increasingly finds more application fields. In the following two new projects are presented; they are to be executed in Romania starting with this year. The first project which is already designed and approved is a highway overpass, which has a total length of 184 m on 6 spans, crosses the Coslariu – Simeria railway route and ensures the continuity of National Road DN7. The main particularity of this semi-integral structure is represented by the sharp angle between the railway axis and the road axis which makes it very sensitive to torsion effects and seismic action. The angle between the two axes is of just 19o, fact which implies an offset between the infrastructures of 20 m. For this reason the VRT® solution was chosen to build the superstructure. The box-shaped steel girders could overcome very well high torsion effects and are also easy to be manufactured.

Fig. 10. *VTR® Simeria overpass*

The entire structure was modelled with FEM elements, and a global analysis was done.

Fig. 11. *The FEM model of the Simeria bridge*

The second example is a motorway bridge located on the A3 motorway section Sebes – Turda at km 26+350 under design and build contract. It is situated over three electrified main railway lines CF300 and CF201. The adopted technical solution is an integral bridge with compensation possibility of the dilatation and contractions by means of a reinforced concrete pendulum and expansion joint only at the abutments, whilst in the other cases rigid connection between superstructure and infrastructure was implemented. The bridge has 6 spans (28 + 36 + 48 + 40 + 28 + 28 m). The infrastructures are displaced in the railway zone due to the oblique angle between them and the highway axis.

3. Conclusions

Although the work is based on presenting the efficient, economical, but in the same time innovative and sustainable solutions, within the conferences they expect the presentation of esthetical and emblematic solutions, so in the final present article there can be seen two future bridges of Timisoara 2021.

Above all, the bridges are works of art, structures which make the link between the people, the nations and the various cultures. Within these ideas we would like to introduce another idea and would like to connect it to the new European Capital of Culture 2021, Light up your city!

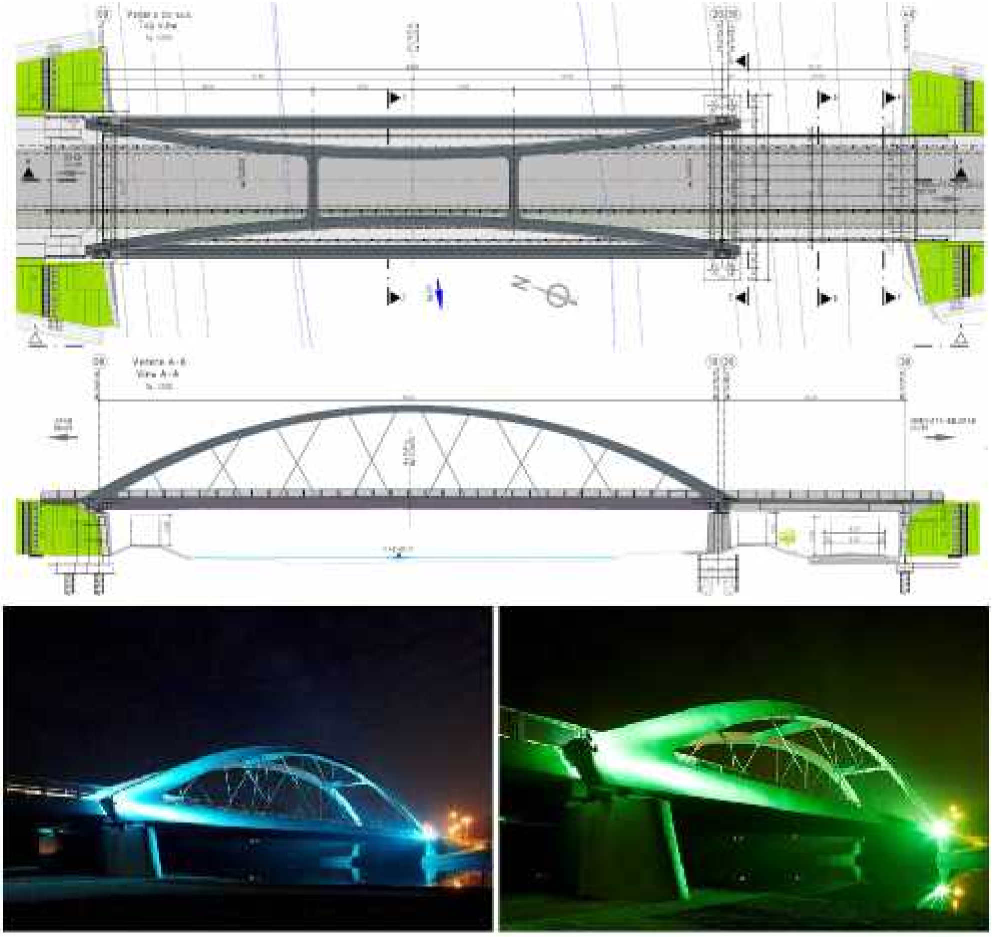

Fig. 12. *Bridge over Bega on the future bypass of Timisoara*

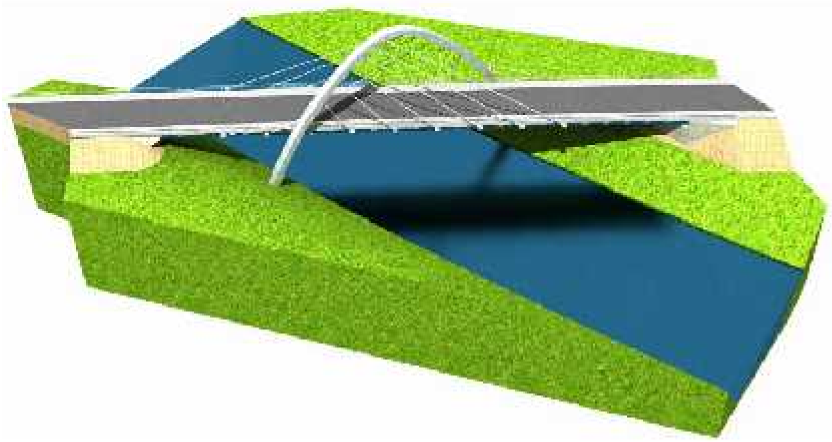

Fig. 13. *Bridge Bridge over Bega for the closure of the second central ring*

References

1. Petzek, E., et alt., *VTR® a modern composite bridge concept*, Springer Vieweg, ISBN 978-3-658-03713-0.
2. Petzek, E., Băncilă., R., Schmitt, V.: *Romanian experience in new efficient solutions for composite bridges*, Eurosteel 2011 Budapest, 978-954-724-014-5, 2011.
3. Petzek, E.,, et alt., *New Integral Bridges for the Romanian Motorway*, ISBN 978-3-658-03713-0, Springer Verlag, 2013, pp. 339-352.
4. RFCS research project 2010. ECOBRIDGE: *Demonstration of economical bridge solutions based on innovative composite dowels and integrated abutment*, Grant no. RFSP-CT-2010-00024.
5. Europäische Patentschrift, Patentblatt 2013/47: *Steel-concrete-composite girder for a bridge construction*, Patentinhaber SSF Ingenieure AG, European Patent Office, 2013.
6. Petzek, E., Toma, L., Meteş, E., Băncilă, R., *Innovative composite overpasses on the Romanian A1 motorway, economical bridge solutions based on innovative composite dowels and integrated abutments*, ISBN 978-3-658-06416-7, Springer, Wiesbaden, 2015.