

"EFFICIENT SOLUTIONS IN ROMANIAN HIGHWAY BRIDGES CONSTRUCTION"

Edward PETZEK¹
Radu BĂNCILĂ²

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Summary: *The paper presents an overview regarding to the classical highway composite bridges with some of their characteristics and the new efficient solutions for composite bridges like, VFT girders, Precobeam. Integral bridges are a further solution for low maintenance cost.*

Keywords: *Composite bridges, sustainability, VTF girder, integral bridges*

1. INTRODUCTION: SOME GENERAL CONSIDERATIONS

In the last years a large investment program on the Romanian motorway system was initiated, The whole Romanian highway network is in a renewal process. Many of the new investments are assigned by tender projects in form of „design & build”; in this way joint ventures between execution companies and structural engineering offices have the possibility to build whole road sectors in an economic and advantageous manner. This assignment method permits also to introduce some innovative and economical solutions. The present paper describes a series of efficient solutions of composite bridges implemented on the Romanian motorway system.

Composite bridges [1], [2], [3], [4], [5] dominate today the usual short and medium spans especially in the field of highway bridges. Some of the well known advantages can be underlined:

- 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.
- Low dead weight of the composite bridges deck - advantages with regard to the foundation and settlements of supports.
- Due to innovative methods the erection time is very short, leading to a minimum of traffic disturbance and restrictions.
- Reduced environmental impact in comparison with other bridge types.

¹ Assoc. Prof. Dr. Ing., Universitatea „Politehnica” from Timișoara, Civil Engineering Faculty, Department for Steel constructions epetzek@ssf.ro

² Prof. Dr. Ing., Universitatea „Politehnica” from Timișoara, Civil Engineering Faculty, Department for Steel constructions, radu.bancila@ct.upt.ro

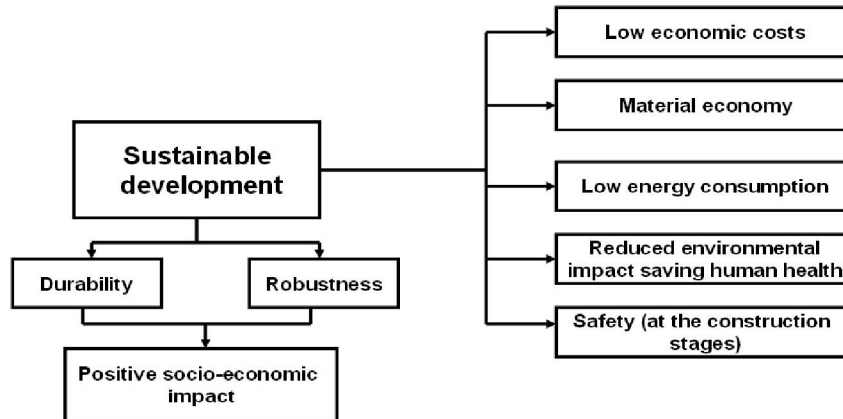


Fig.1 Sustainability of composite bridges

Composite bridges are sustainable structures [6], taking into account the general characteristics of these structures (Fig. 1). Another important aspect is robustness of composite bridges. The robustness of a structure has to be defined as being the capacity of the system to keep his structural integrity for any kind of action that may occur during its service life. Robustness must not be understood as an over dimensioning of elements but as the capacity of the system of adapting without damages to current actions and with minimum shortcomings to the extraordinary ones. In this context also the maintenance or repair costs are important. So, a robust system has to call for minimum maintenance costs during its life span and to call for reduced costs for putting into service in case of an accident.

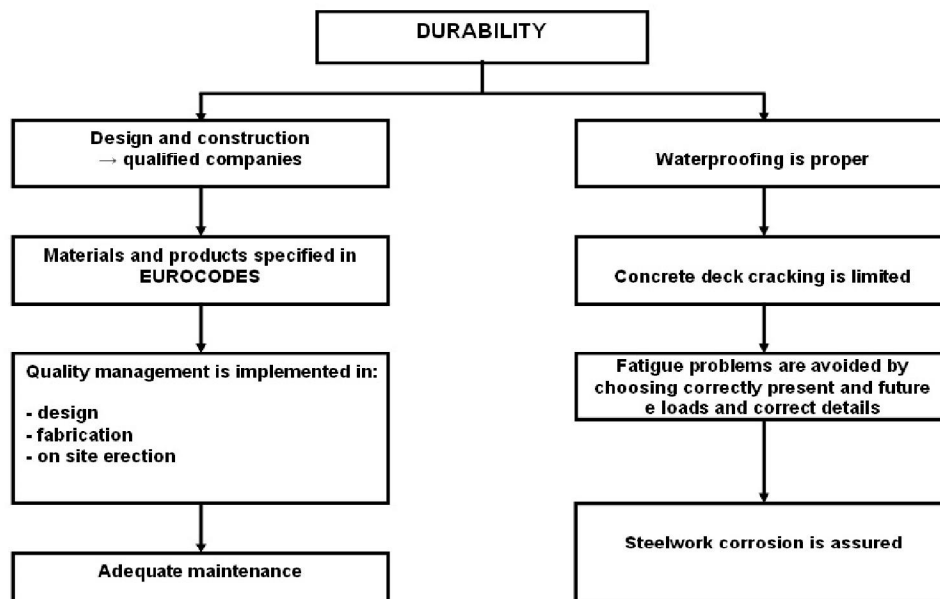


Fig.2 Durability of composite bridges

Composite bridges are usually difficult to demolish; however in comparison with concrete structures they have some advantages. The deck is not so thick, piers and abutments are smaller and consequently easier to demolish. Steel is recyclable. If some usual conditions are fulfilled, composite bridges have an adequate durability (Fig. 2). It is also important to mention that modern composite bridges designed according to the seismic codes (EC 8), are highly resistant to earthquakes.

2. CHARACTERISTICS FOR CLASSICAL COMPOSITE BRIDGES

The present tendency in composite bridges consists in simplifying as much as possible the structure. For usual spans, the result is a bridge with two I-beams (twin girders), reinforced concrete slab connected by studs and cross girders. In France [7] the usual range of composite bridges made by two girders are between 30 – 130 m and for box girder composite structures is from 50 – 150 m. Generally these solutions are cheaper than concrete bridges. The usual solution consists in main girders with constant height over the length of the structure. Obviously – from the point of fabrication and erection view, it is the most economic solution. Variable girder height (with haunches or continuous); it leads to steel economy, but also to some complications in fabrication (Fig.4). This solution is adopted mainly from aesthetic reasons. The most important aspect in steel quality for composite bridges is the toughness (capacity to avoid brittle fracture) [8]; with thick plates this risk increase. In the European Standard EN 10025 (part 1-6), it is specified that for plate thickness $t \leq 30$ mm, the minimum quality is a J2 – steel and for $t > 30$ mm, fine grained steels (N,M,Q) shall be used. The present tendency is to use high quality steels, like S 355 or S 460. In Annex 5 of EC 3, the maximum thickness for steel is given in function of the reference temperature and the level of stresses. If the plates are stressed in tension in thickness direction, the danger of lamellar tearing (delamination, separation in leaves) can appear; the Z – test must be done (EN 1993-1-10). Also ultrasound tests must be performed. Weathering steels with the well known advantages can also be used, with the observation that the patina (similar to rust) makes it difficult to detect fatigue cracks and produce an aesthetically discutable aspect. Assembly of different elements is recommended to be done by arc welding [9]. Bolted connection with HSFG bolts can be used, especially on site. Referring to the concrete quality, in the case of slabs casted in situ C 35/45 concrete is recommended. For precast slabs higher classes can be used.

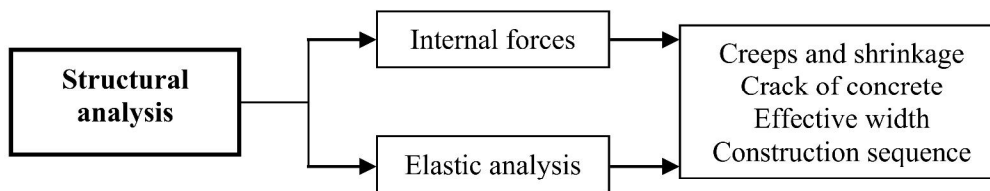


Fig. 3 Structural analysis of composite bridges

Internal forces are determined by elastic analysis (Fig. 3). The effects of creep and shrinkage are taken in consideration by a simplified method with different coefficients for different loadings.

3. NEW EFFICIENT SOLUTIONS FOR COMPOSITE BRIDGES

Since 1998, bridges have been created in a composite pre-fabrication (VFT® = Verbund-Fertigteil-Träger = prefabricated composite beam) method of construction [10]. The system was used for over 300 erected structures principally in Germany as well in Poland and Austria. It is a cost-effective construction for composite bridges of small and medium spans with site-prepared traffic deck. The pre-fabricated composite beams consist of a steel beam with a concrete flange, which serves as a compressive chord and formwork element for the site-mixed concrete deck (Fig. 5). These not only absorb the compressive stresses while the bridge is under construction, but also stabilise the beam while it is being transported, and render unnecessary the installation of bracing for concreting of the site-prepared concrete deck.

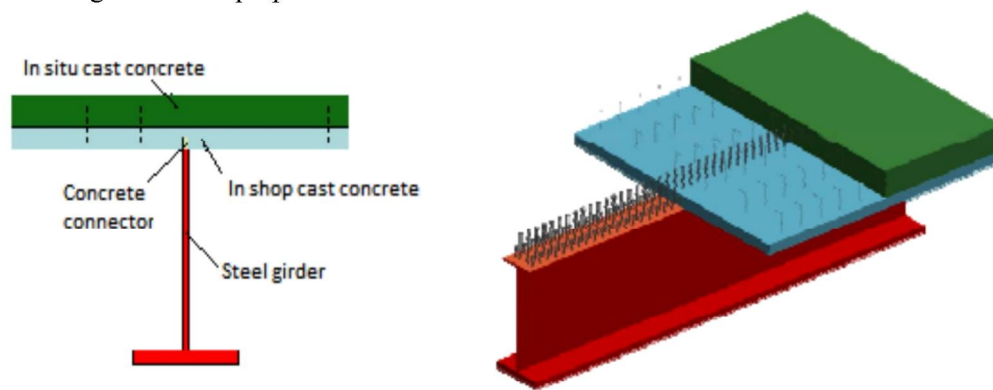


Fig.5 VFT – Method

The PRECOBEAM system – VFT girder with rolled girders in concrete – represents a further development of this method of construction (Fig. 6). The new system provides a rolled beam section that is cut in the web centre in such a way to result in 2 T-sections, whereas the cutting form provides the shear connector. This special cut of steel web allows a perfect connection to the upper concrete part. The cutting guide selected for the manufacture of the concrete dowels enables the manufacture of tall sections without waste (Fig. 7). With the separation technology used it is possible to achieve a high quality for the separating faces with minimum local notch effects.



Fig. 6 PRECOBEAM girder



Fig. 7 Cutting of the steel profiles

The PRECO principle [11] combines the advantages of the VFT girder with the robustness of the traditional “filler beam plate”. The steel components consist of profiles with no upper chord as shown in the schematic representations in Figure 8. The in-site concrete deck that is later completed is coupled by means of connecting reinforcement with the concrete chord of the pre-fabricated girder.

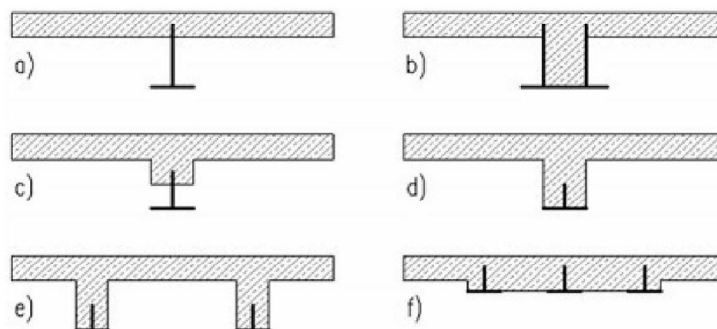


Fig. 8 Configuration variants of PRECO girders for bridge construction

In the last years, integral abutment bridges turn out to become highly attractive to designers, constructors and 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. This is principally due to the non-existence of bearings and joints that are main sources of maintenance costs during life time. In Fig. 9 the comparative maintenance costs for classical bridges and bridges with integral abutment is presented.

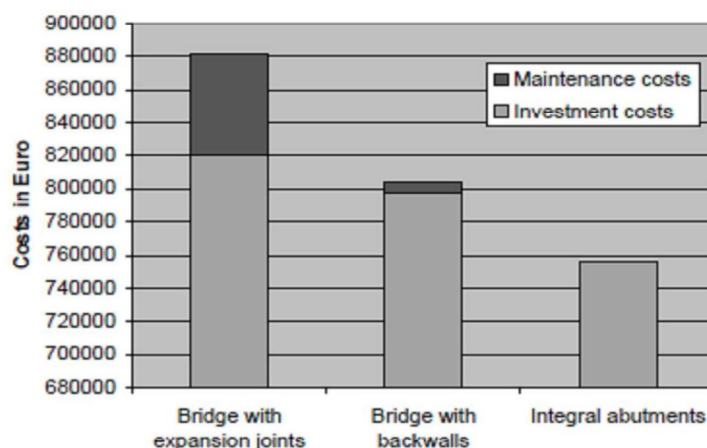


Fig. 9 Maintenance costs

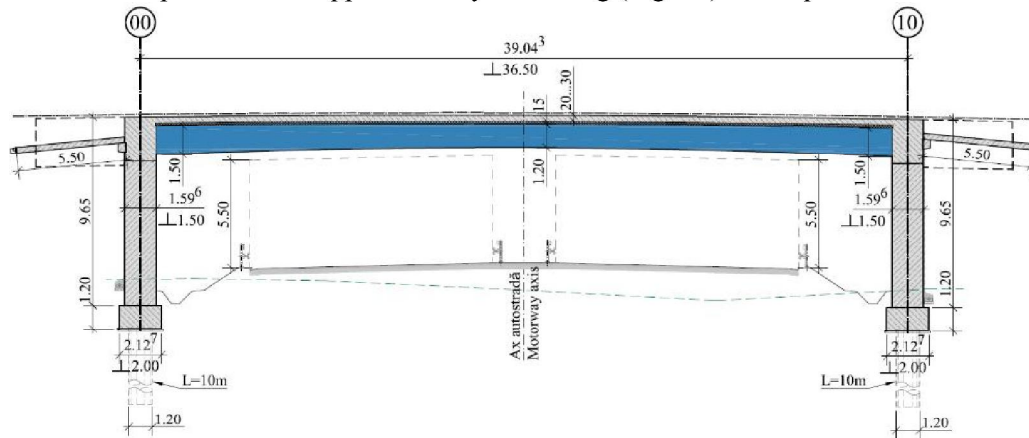
4. Case studies f

The Orăștie – Sibiu motorway section, with a length of approximate 82 km, crosses the counties Hunedoara, Alba and Sibiu. The first lot, near Orăștie and the Mureș River and its confluents, has a length of 24,110 km. It includes 27 bridges as follows:

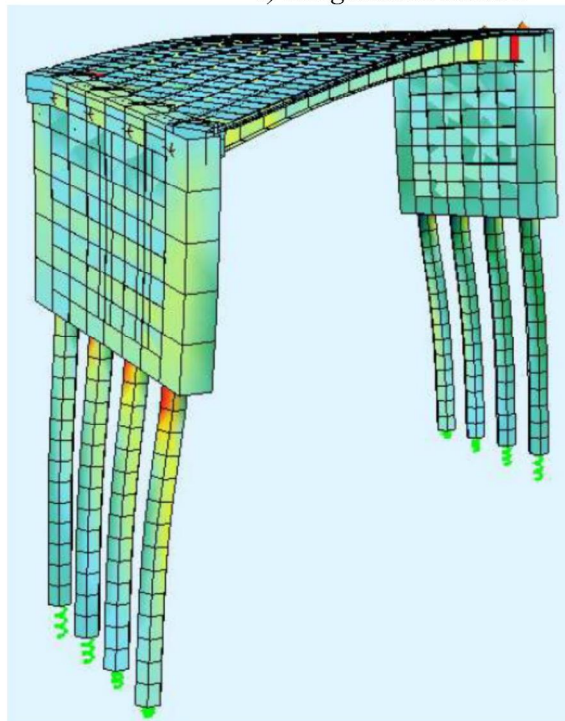
- 7 motorway bridges, of which 4 over water courses and 3 over other road transport systems (railways, national, county or agriculture roads),

- 7 motorway overpasses for national, county or agriculture roads,
- 13 box bridges, with spans greater than 5,0 m.

All structures were designed as bridges with integral abutments, except for a viaduct with a total length of 240 m, which is a semi-integral structure. As a consequence, only four expansion joint equipment pieces and eight bearings were used for the whole motorway lot. One of the solutions used in case of two overpasses of the Orăștie – Sibiu Motorway, is described below. Both passages have one span (without intermediate support) and are skew (approximately 70°), then are integral structures. Four steel-concrete composite beams approximately 39 m long (Fig. 10) are disposed.



a) Longitudinal section



b) Design model

Fig. 10

The composite dowels require a cutting geometry on the upper part of the steel, having a special form adapted to the requirements given by fatigue, than reinforcement and concrete. Thus, a connector with superior behavior to the studs results. Considering the elimination of the upper flanges of the steel girders, the absence of the classical studs, the efficiency of the designed solution can be observed.



Fig. 11 The cutting line geometry of the composite dowels and steel girders in the workshop

The novelty of the system used for these two bridges represents the welded steel girders made of S355 J2+N and the prefabricated composite beams. The middle section of the steel girders is made of a bottom flange and a web with steel dowel cuttings on top. Only at the end zones, of each 6 meters, a slender U-shaped upper flange having a thickness of 12 mm was introduced.

4. CONCLUSIONS

Composite structures are highly competitive solutions – over a wide range of spans in comparison with other solutions. Beside the classical solution, the new ones with efficient design and construction improve and consolidate the market position of the steel construction and steel producing industry. Additionally this advanced form of construction is contributing to savings in material and energy consumption for the structure during production and maintenance.

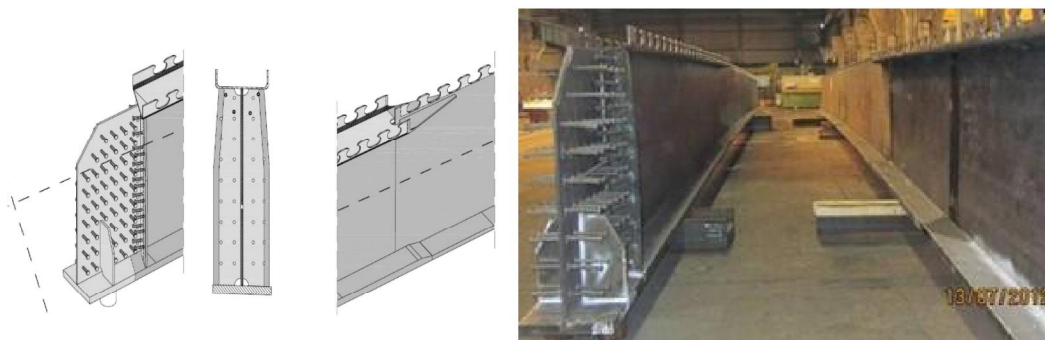


Fig. 12 The Steel girders

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"ЕФИКАСНА РЕШЕЊА КОНСТРУКЦИЈА МОСТОВА НА АУТОПУТЕВИМА У РУМУНИЈИ"

Резиме: У раду је дат преглед веза класичних спрегнутих мостова са неким од њихових карактеристика и нових ефикасних решења за спрегнуте мостове попут, VFT носача, Пресобеат, на аутопутевима. Интегрални мостови су и даље решења са ниском ценом одржавања.

Кључне речи: Спрегнути мостови, одрживост, VTF носач, интегрални мостови