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EFFICIENT SOLUTIONS FOR COMPOSITE BRIDGES

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Abstract: 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.

Key words: Composite bridges, sustainability, VTF girder, integral bridges

1. INTRODUCTION; SOME GENERAL CONSIDERATIONS

Bridges are of essential importance to the European infrastructure; in the last decades composite bridges already became a well-liked solution in many countries as a cost-effective and aesthetic alternative to concrete bridges. Their competitiveness depends on several circumstances such as site conditions, local costs of material and staff and the contractor’s experience.

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.
- Because the low dead weight of the composite bridges deck is, 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, leading to a minimum of traffic disturbance and restrictions.
- Reduced environmental impact in comparison with other bridge types.

Composite bridges are sustainable structures [6], taking into account the general characteristics of these structures. In Fig. 1 some aspects in this direction are presented. If some usual conditions are fulfilled, composite bridges have an adequate durability (Fig. 2).

Another 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. A robust system must keep its integrity even in the case of accidents like powerful impact with vehicles, earthquakes, landslides, storms, explosions, etc. 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. 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.

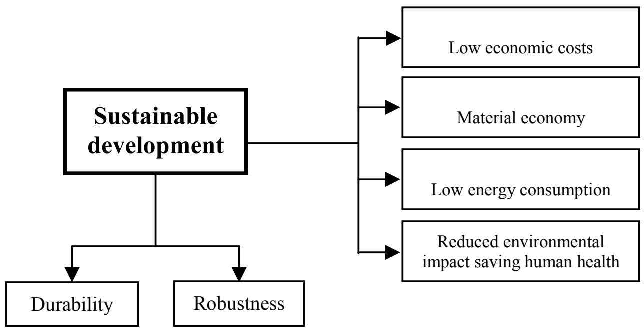


Fig.1 Sustainability of composite bridges

Composite bridges – because of their slenderness - are sensitive to truck impacts, in comparison to concrete structures, especially for bridges over motorways; a special attention must be paid to the clearance. It is also important to mention that modern composite bridges designed according to the seismic codes (EC 8), are highly resistant to earthquakes.

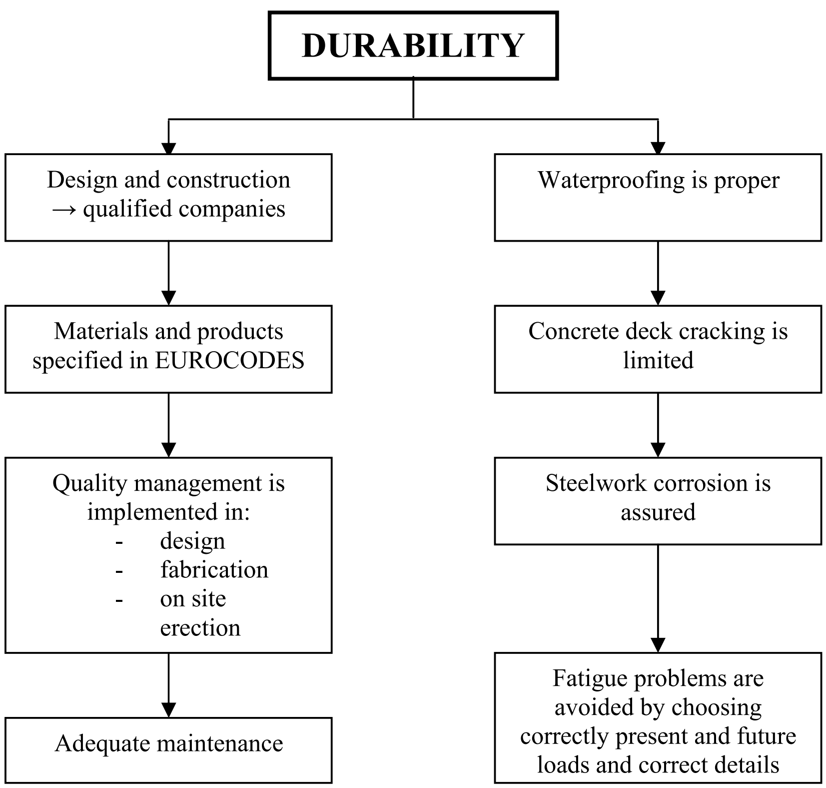
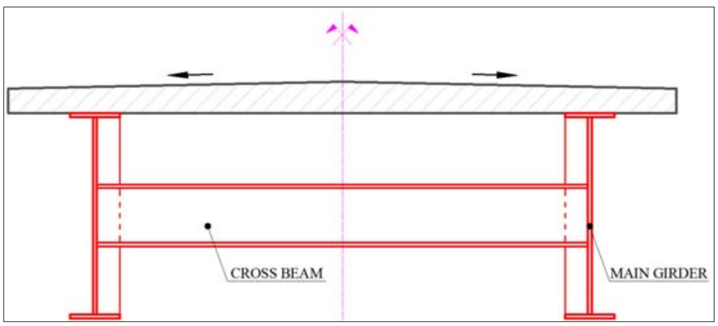
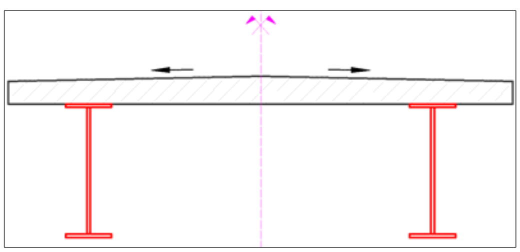
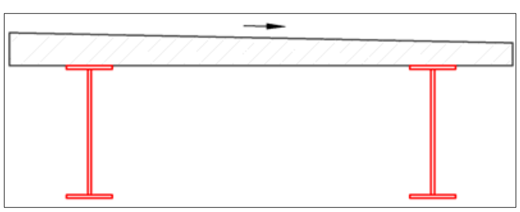
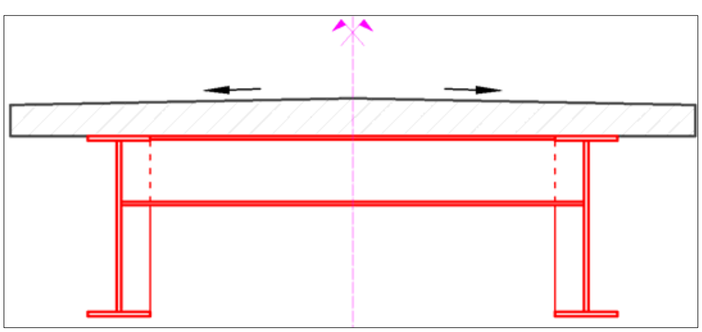


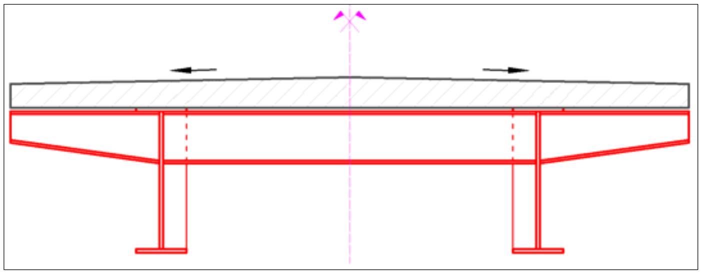
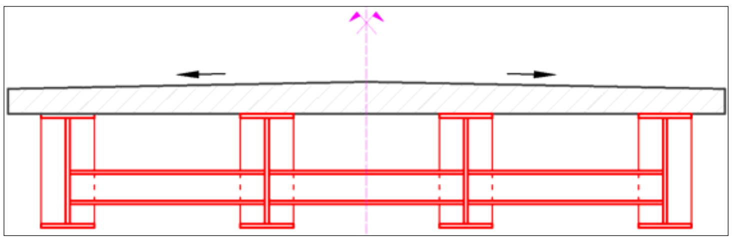
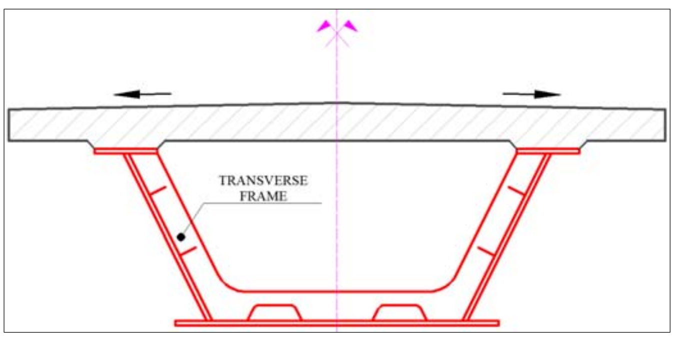
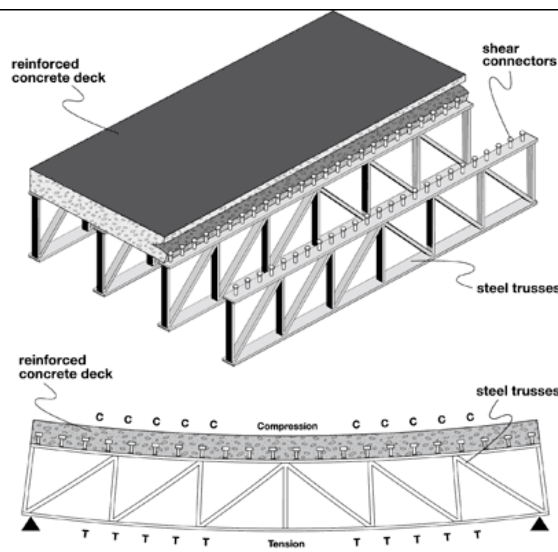
Fig.2 Durability of composite bridges

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. In Table 1 is presented an overview of some usual solutions and their characteristics.

Table 1 Usual solutions for composite bridges

	SOLUTION	CHARACTERISTICS
TWIN GIRDERS	 Bi-directional slab  Mono-directional slab 	<u>Main girder:</u> ▪ L < small spans I rolled sections ▪ L > large spans ▪ I welded sections - flange width constant - flange thickness → variable - web depth → variable Slab thickness - constant longitudinal - variable transversal → from 25–40 cm Slab: - in situ cast - prefabricated segments ▪ For wide bridges (2x2 lanes) B = 8–15 m → transverse presstressing
		▪ Cross girders supporting the slab ▪ Slab connected to the cross girder ▪ Cross girders are closer spaced (about 4 m) in order to support a thin slab

		▪ Cross girders are executed under the cantilever part of the deck
MULTI GIRDER DECK		▪ Low constructive depth (h_c <) ▪ Deck with B > 25 m ▪ Site constraints ▪ Higher costs then twin girders
BOX GIRDER		▪ Usually when L > 90 m B > 20 m ▪ Inclined webs → good aesthetic appearance and smaller piers ▪ H ≥ 1.5 m → construction and inspection
TRUSS GIRDER		▪ Truss girder highway bridges for larger spans ▪ Small constructive depth ▪ Very efficient and economic (the concrete deck is reinforced.

The usual solution consists in main girders with constant height over the length of the structure (Fig. 3). 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.

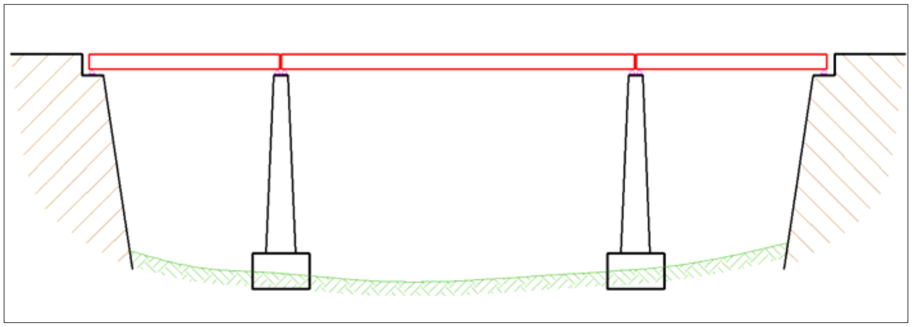


Fig. 3 Composite bridges with constant height

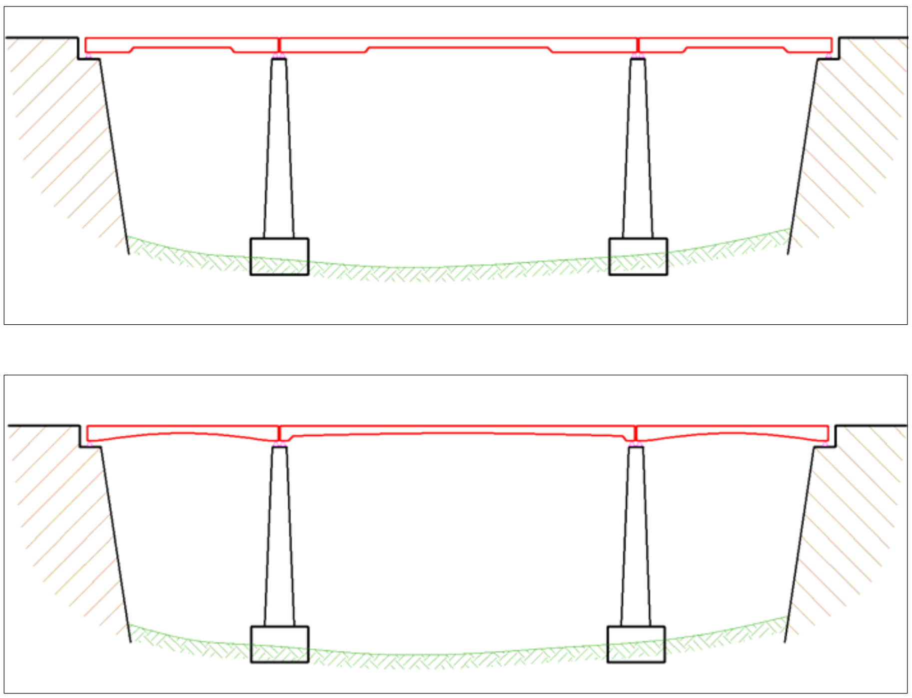


Fig. 4 Composite bridges with variable height

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. It is interesting to mention that, in France heavy thick steel plates are used, up to 150 mm, for the S 355 steel. In other countries this thickness is limited to 80 mm. 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.

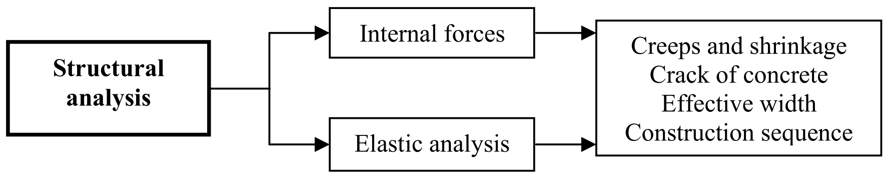


Fig. 5 Structural analysis of composite bridges

Internal forces are determined by elastic analysis (Fig. 5). 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. 6). 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.

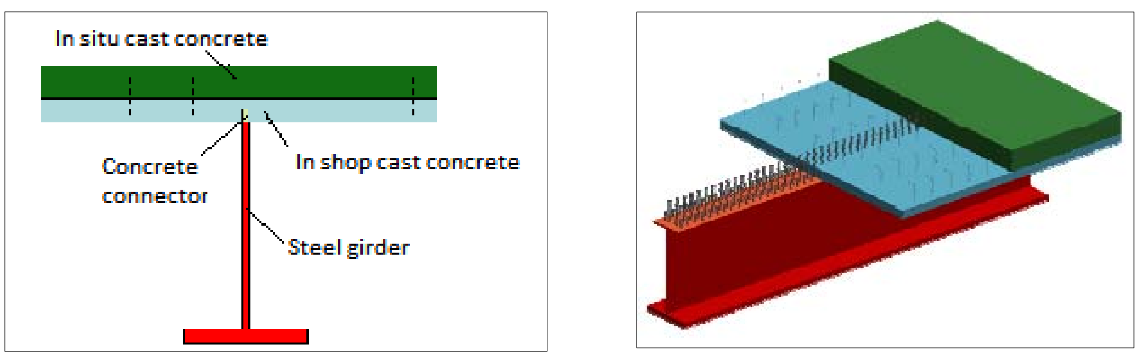


Fig.6 VFT – Method

The PRECOBEAM system – VFT girder with rolled girders in concrete – represents a further development of this method of construction. 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.

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. 7 PRECOBEAM girder

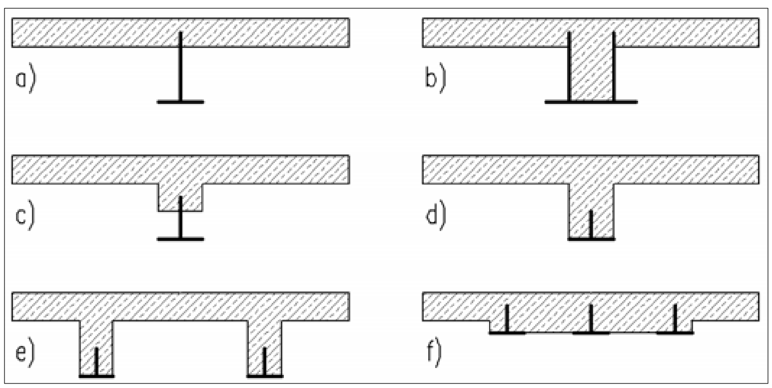


Fig. 8 Configuration variants of PRECO girders for bridge construction

In Figure 9 the evolution of the solution with embedded steel girders can be observed.

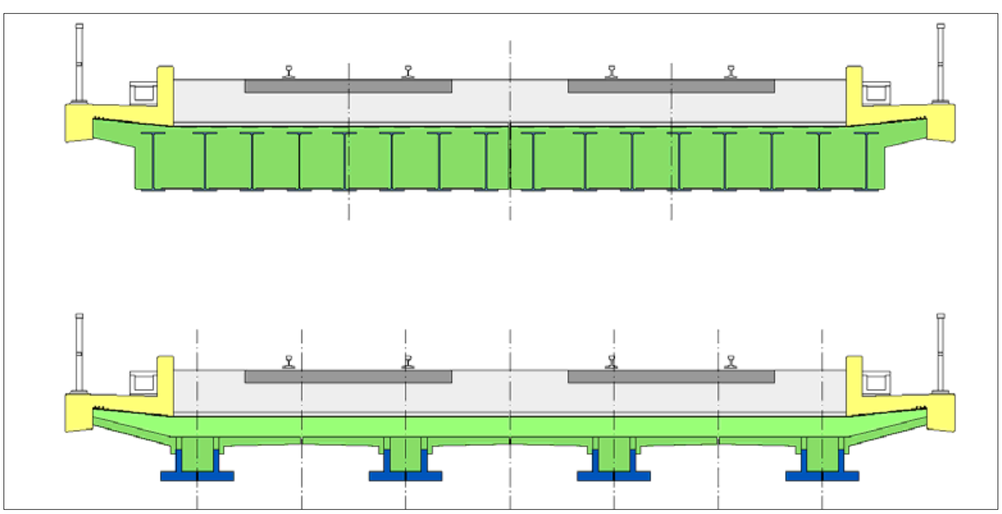


Fig. 9 Evolution of the solution with embedded girders

Case study: this solution was adopted for a bridge in the South of our country on a local highway deserving a rural community (Fig.10). The major advantages are reduced costs and simplicity in on site operations. The structure is an integral bridge, with three spans of 21,10 m. Three steel girder HEM 600 from steel S 460 ML where used and after cutting following a special geometry (Fig.11) six elements where obtained.

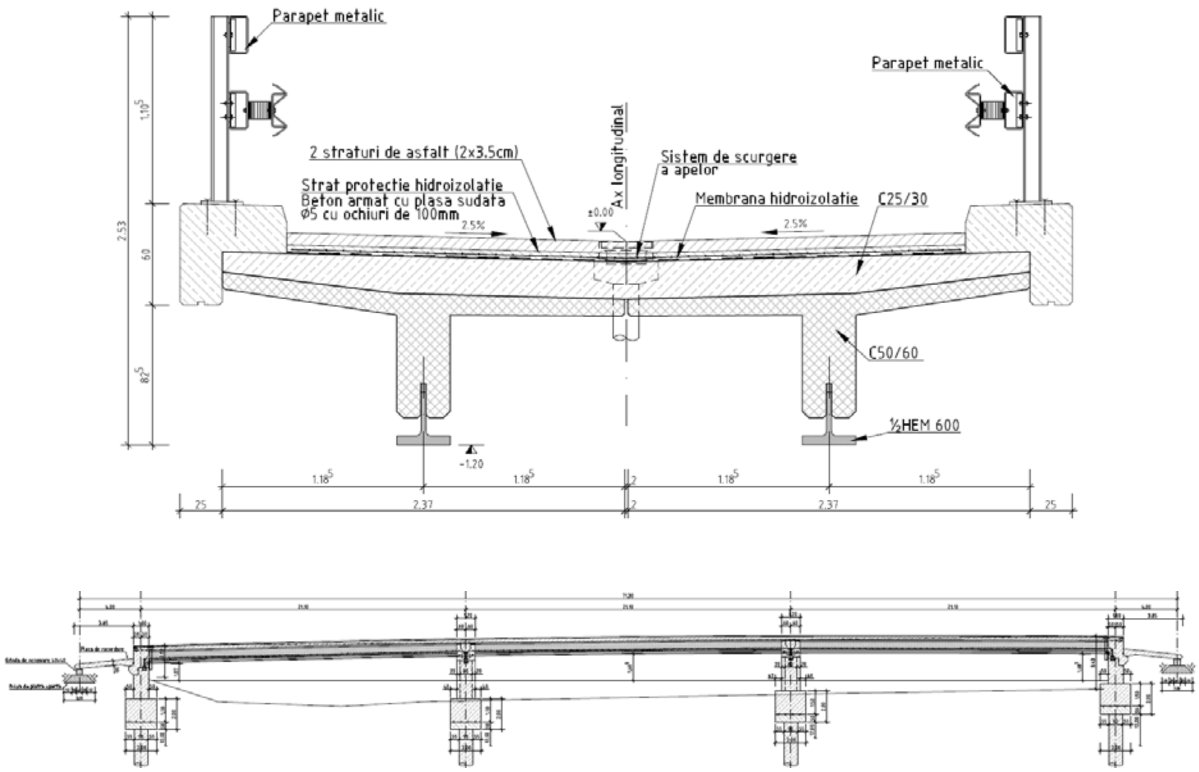


Fig. 10 –VFT-WIB bridge

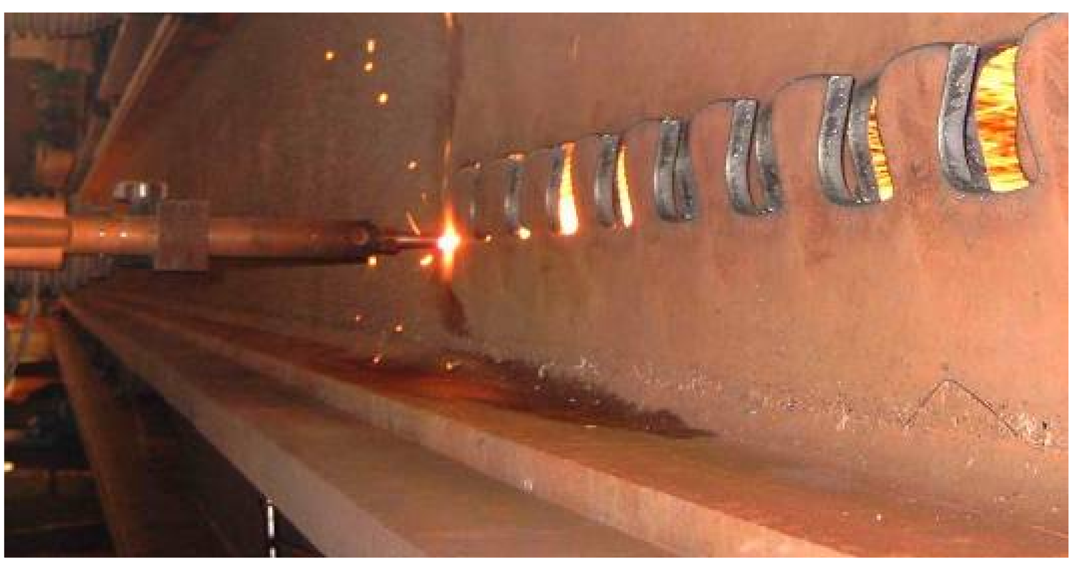


Fig. 11 Cutting of the steel profiles

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. Thus in some countries the solution with integral abutments is already a popular alternative to conventional bridges with bearings and joints. In Fig. 12 the comparative maintenance costs for classical bridges and bridges with integral abutment can be seen.

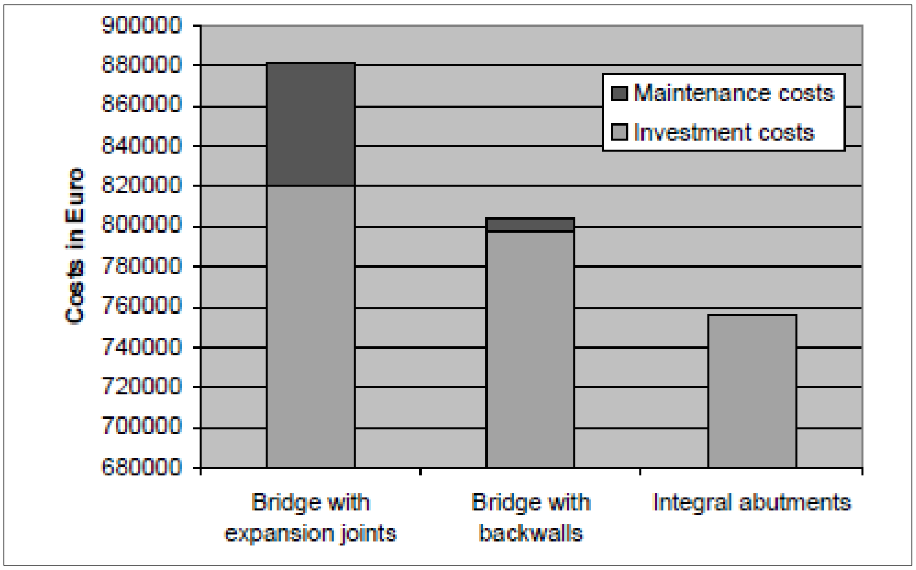


Fig. 12 Maintenance costs

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.

REFERENCES

1. *EN-1992-2, EUROCODE 2, Design of concrete structures, Part 2, Concrete bridges*, 2005
2. *EN-1993-2, EUROCODE 3, Design of steel structures, Part 2, Steel bridges*, 2005
3. *EN-1994-1 EUROCODE 4, Design of composite steel and concrete structures*, August 2005
4. *DIN – Fachbericht 101, Einwirkungen auf Brücken*, Mai, 2003
5. *DIN – Fachbericht 104, Verbundbrücken, Mai*, 2003
6. SETRA "*Steel concrete composite bridges; sustainable design guide*" Paris, May 2010.
7. RAOUL, J., DAVAINE, L. *Common composite bridges in France and main issues of the implementation of EN 1994-2*, Proceedings of the 6th Japanese – German Bridge Symposium, TU Munich, August 2005, pp. 21-23
8. PETZEK, E., BĂNCILĂ, R., *Bridges with embedded girders* (in Romania), Orizonturi Universitare, Timişoara, 2006

9. PETZEK, E., BĂNCILĂ, R., SCHMITT, V., „*Deconstruction of bridges*”, COST 25 Sustainability of Construction, Timisoara, 23-24 Oct.2009, Sustainability of Construction, Ed. Orizonturi Universitare, ISBN 978-973-638-428-8, pag. 199, 12 pagini.
10. SCHMITT, V., SEIDL, G., „*Verbundfertigteil-Bauweise im Brückenbau*, Stahlbau 70 (2001), **Heft 8**, pag. 546-553.
11. SEIDL, G., BRAUN, A., „*VFT-WIB Brücke bei Vigaun – Verbundbrücke mit externer Bewehrung*”, Stahlbau 78 (2009), **Heft 2**, pag. 86.

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