IOP Conf. Series: Materials Science and Engineering **419** (2018) 012016 doi:10.1088/1757-899X/419/1/012016

Advanced solutions with hot-rolled sections for more economical bridges

Wojciech Lorenc[1], Maciej Kożuch[1], Dennis Rademacher[2] and Wojciech Ochojski[3]

[1]Wrocław University of Technology, Faculty of Civil Engineering, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland
[2]ArcelorMittal Europe – Long Products, 66, rue de Luxembourg, 4221 Esch-sur-Alzette, Luxemburg
[3]ArcelorMittal Commercial Long Poland, Al. Piłsudskiego 92, 41-308 Dąbrowa Górnicza, Poland

E-mail: dennis.rademacher@arcelormittal.com

Abstract. The use of composite steel structures has gained significant market shares in road bridges across Europe over the last several decades. In particular, when high-strength steel is used, the total weight and the construction depth of the bridge deck can be significantly reduced. This also means lighter substructures and – if necessary – shorter approaching ramps to the bridge. Current developments of the market force designers, producers and fabricators to go new ways and to invent continuously new efficient solutions to save money and time. One big advantage can be achieved when using hot-rolled sections, which are available in higher strength S460 as standard and allow for simpler and more economical construction due to lower fabrication costs. Sophisticated designs with rolled sections allow not only small and medium span lengths, but also longer ones, e.g. in arch bridges with span lengths over 100m. This paper will show new trends in Europe using hot-rolled sections in steel and composite bridges.

1. Introduction

On the basis of hot-rolled steel sections there do exist several composite solutions, which are well known all over Europe. Multiple I-girder composite decks and filler beam decks are standard bridge designs since decades; the latter exists since more than 100 years. New and alternative methods of corrosion protection, such as self-weathering steel and hot-dip galvanizing, offer simple and economical solutions so that the steel part of the composite bridge can endure the designated lifetime without any need of maintenance or refurbishment. However, new market demands force designers and producers, as well as fabricators, to go new ways and to invent continuously new solutions, such as PreCoBeam bridges, where halved rolled sections are used in a more efficient way than full I-sections. About 35 PreCoBeam bridges have been built since 2003. Further optimization of this construction type allows to build bridges in medium span length range at lowest costs.

For longer bridges other advanced composite bridge type solutions were developed in Poland in the last years and successfully implemented in the market with first built examples. Here worth mentioning are the tandem solution and network arch bridges with extremely low steel consumption and manufacturing costs, due to the use of hot-rolled sections in high strength steel.

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

2. New PreCoBeam system using composite dowels for span length about 35m

A new system of PreCoBeam, dedicated to medium span lengths, was used for the first time for the "Elbląg" bridge (L=~38m). The system is quite aesthetic, see general view in Figure 1. The principles of the system (Figures 2-3), which are presented in detail in [2], were developed in 2015 in Poland [1].

Figure 1. General view of the "Elbląg" bridge in Poland finished 2016.

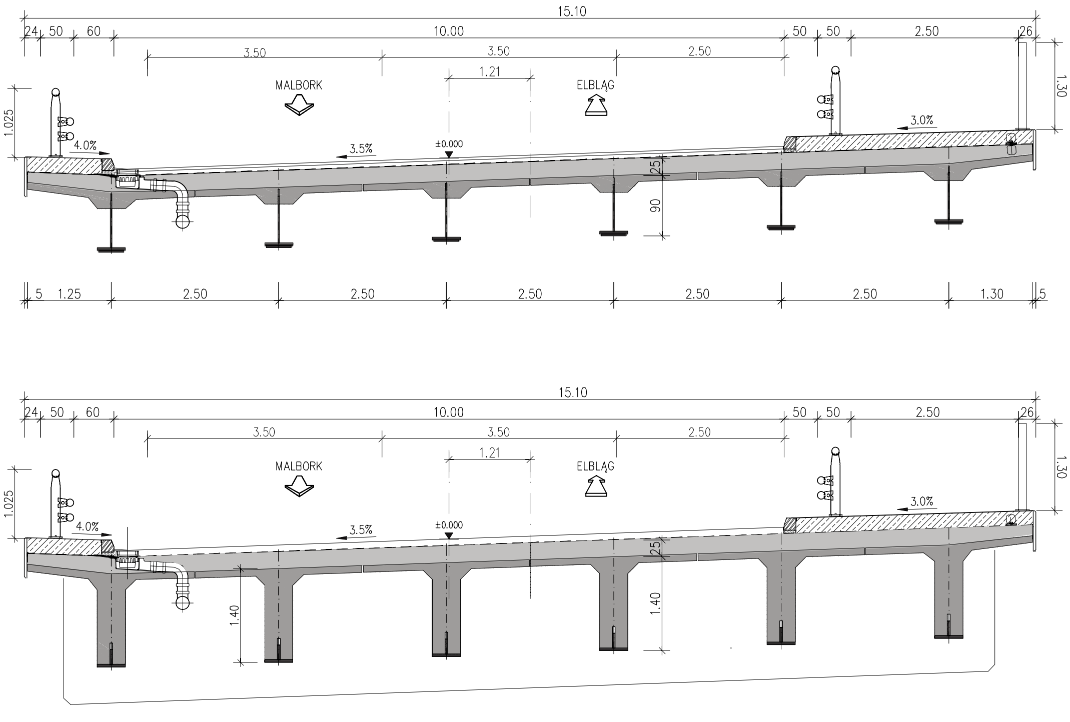

Figure 2. Cross-section of the bridge in the midspan and at the support [2].

The cross-section of this structure adapts significantly better to the distribution of forces in the bridge girder than a cross-section with a concrete girder of constant height. In this advanced design, the height of both the steel girder and the concrete web alters over the girder length. In support regions, where negative bending moments lead to compression in the lower part of the cross section, the concrete web goes down to the lower flange. The steel profile acts as external reinforcement. Towards midspan the compression moves to the upper part of the cross section. Thus, the concrete web is reduced and the steel web is enlarged and goes up to the concrete slab. The web of the steel profile is then in the tension zone. For large spans with corresponding beam depths there is the advantage that no tensile stresses arise in the concrete which lead to a crack pattern. At the same time, the weight of the beams is reduced considerably.

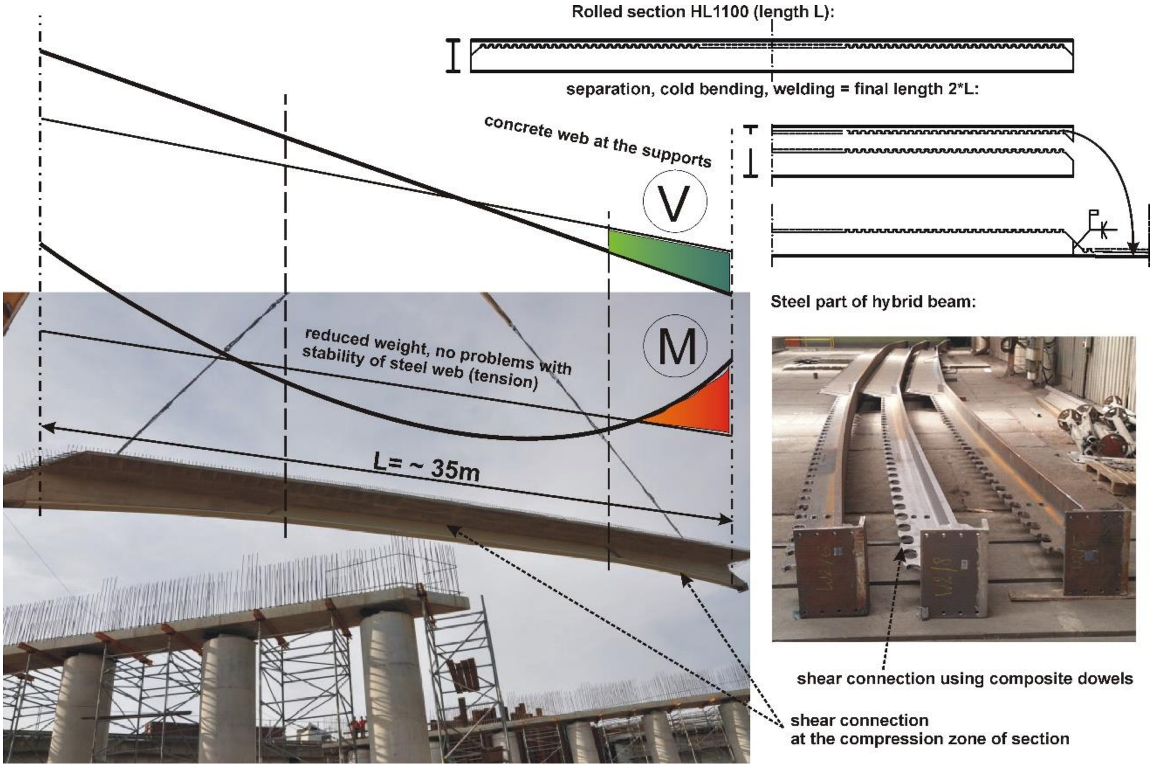

Figure 3. Principles of the new kind of PreCoBeam system (road viaduct WA-352, picture of prefabricated element from http://www.a1-rzasawa-blachownia.pl).

Figure 4. Steel part of PreCoBeam for WA-352, made from rolled sections HL1100.

Figure 5. WA-352 under construction, January 2018 (http://www.a1-rzasawa-blachownia.pl).

Although the solution is dedicated to rolled sections, the first bridge was constructed using plated elements because of specific contract conditions (the main contractor was a company with own steel production plants producing structures from welded plates). For the second bridge, a road viaduct in Poland with a larger skew than the first one (Figure 5), the initially intended hot-rolled sections of the HL1100 series (Figure 4) were used. The bridge WA-352 (Figure 6) transfers the highway A1, km 417+402,48 over the railway line no. 146 Częstochowa Wyczerpy – Chorzew Siemkowiced. The highway is still under construction.

Figure 6. Road viaduct WA-352, bottom view.

The solutions constructed in Poland and presented in this paragraph are a new kind of general composite forms. The basis for design are presented in [4]. They are possible to implement and develop due to the advanced shape of shear connection called "composite dowels". The implementation of composite dowels in a new CEN Technical Specification will make clear design rules widely available all over Europe. Appropriate works are ongoing in the frame of the CEN working groups for Eurocode 4. At the moment, only national guidelines and approvals are existing.

3. New system for spans at range 50-60 m.

The new system for spans at range 50-60 m was introduced in Poland for the first time. It is based on using rolled I-sections in midspan and T-sections with additional plates in between at support regions, see Figure 7. In addition, double composite action is applied (Figure 8). The system was developed as a result of R&D works of ArcelorMittal. The development and design of the system is described in detail in the free available report [5]. The 2017 finished bridge constructed in city of Opole in Poland (Niemodlińska street) is the first implementation [6], see Figures 9-12. The main span of the bridge is 54 m. First dynamic load tests proved good dynamic behavior of the bridge despite of its big slenderness.

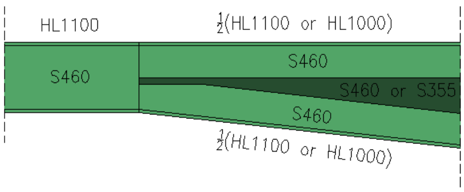

Figure 7. Assumption for steel beam of the new system [5].

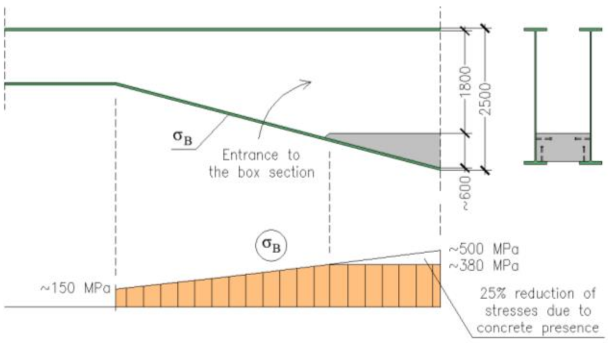

Figure 8. Assumption for double composite action of the new system [5].

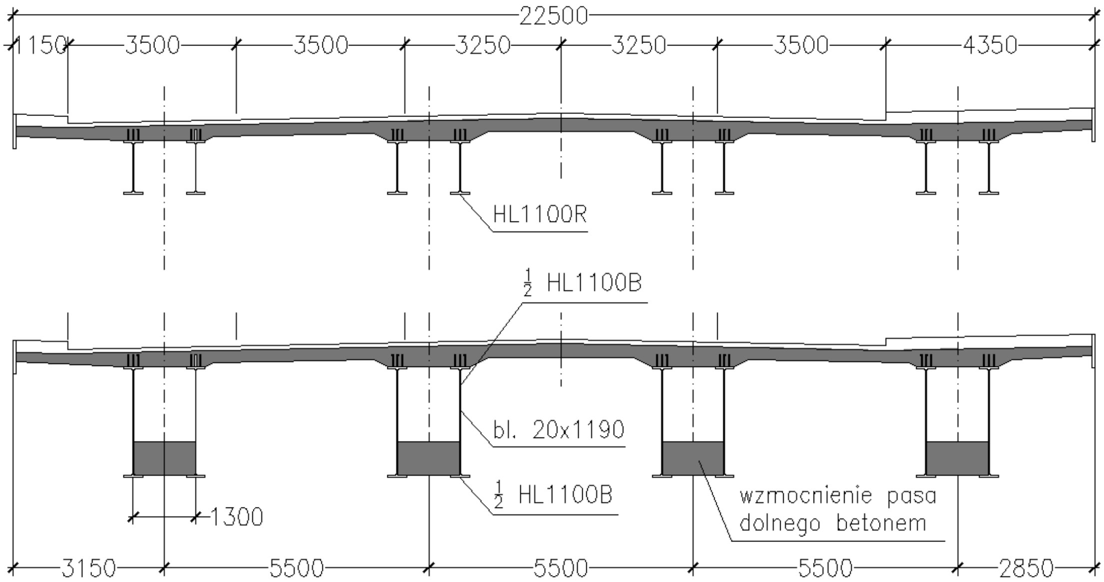

Figure 9. Cross sections of composite bridge at Niemodlińska street in Opole (top: midspan, bottom: supports).

Figure 10. The bridge in Niemodlińska street in Opole during load test.

Figure 11. Steel girder using two T-sections and welded-in plate of bridge in Niemodlińska street in Opole.

Figure 12. Bridge in Niemodlińska street in Opole: bottom view after construction of concrete slab.

The steel beams of the bridge were produced and delivered by ArcelorMittal. The steel structure was welded and the whole bridge was constructed by Banimex. More information and pictures from the construction can be found on their company website "www.banimex.pl". A detailed calculation report of a very similar structure (span 50 m) is included in the R&D report [5].

In the same year (2017) the construction of a second bridge with a similar solution started (Figures 13-14) next to Rzuchów in Poland. The span lengths are: 24.5 + 39.7 + 68.0 + 39.6 + 25.0 + 24.8 m. The new system is dedicated to bigger spans and it assumes the separation of HL sections at midspan as well. Thereby an asymmetric I-section is used at midspan and its web thickness differs along the web height. The main span is constructed using this new system with partly double composite action (4 girders connected by bottom concrete slab). For the other spans standard rolled sections are used.

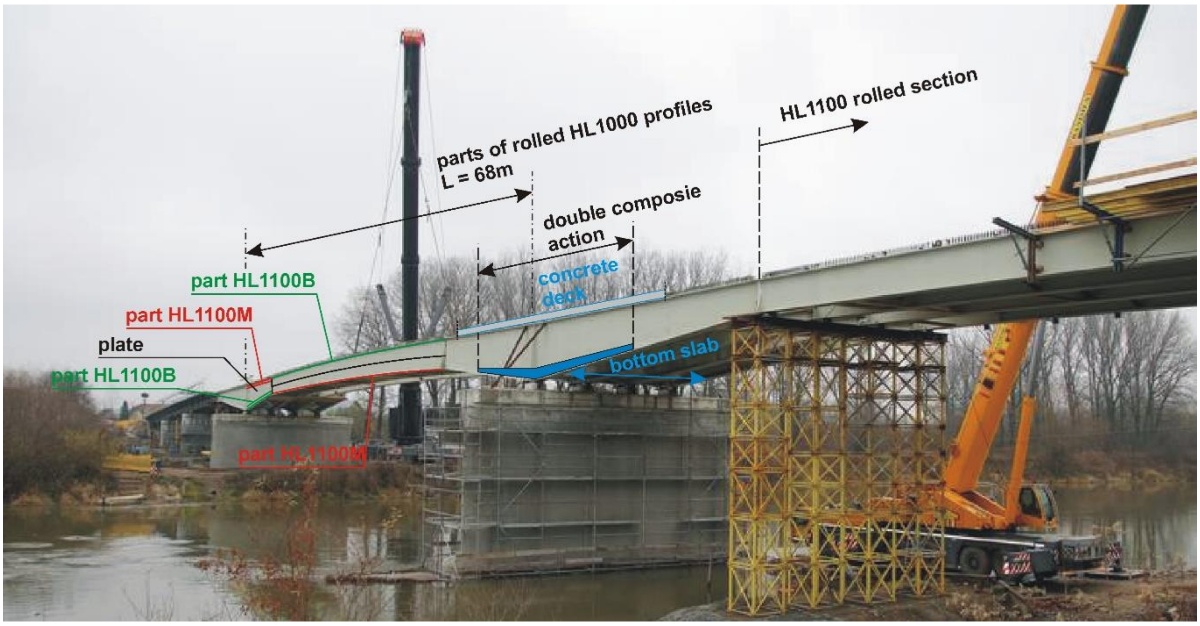

Figure 13. New system presented on the basis of the bridge in Rzuchów in Poland. Picture from http://www.nowiny24.pl/

Figure 14. Bridge in Rzuchów in Poland: erection of steel structure, Source: http://www.nowiny24.pl/

4. Net-arch bridges using HD-sections

Network arch bridges with the use of rolled I-beams in their arch structure (Figure 15) have been constructed for some time in Poland [7]. The main reason to use rolled sections instead of traditional welded box sections are cost savings and shortening of the construction time. Due to the availability of S460 as standard and a wide range of heavy rolled sections (HD profiles up to 140 mm flange thickness and with maximum weight of 1299 kg/m), less steel is needed to resist the high compression forces in the arches. Additionally, rolled sections are less costly in terms of fabrication and the connection of the hangers is much easier. Gusset plates can easily be welded into the chamber of the HD sections (Figure 16).

Figure 15. Net-arch bridge with span length 75m using rolled I-sections in western Poland (WD-57 bridge, S5 express road Poznań – Wrocław, part Kaczkowo-Korzeńsko) [8].

Figure 16. Detail: Gusset plate to connect hanger with arch of HD section.

Figure 17. Weld preparation of bended beams at ArcelorMittal Beam Finishing Center.

Figure 18. Prepared beam with weld access holes.

The positive experiences gained with this construction method and the cost-effectiveness have allowed this solution to spread and its significance is increasing now. Currently a network arch road bridge with 120 m span length is under construction (Figure 19). For this bridge HD400x744 and HD400x1086 profiles in HISTAR460 steel grade were used (Figure 17). Since the arches could not be delivered in one piece to the job-site, the construction had to be designed considering welded site joints. Therefore, a certain weld preparation (Figure 18) was applied to the beam segment ends to allow for a residual stress reduced joint.

Figure 19. Construction of MS-15 bridge with 120 m span length in northern Poland, road S51 Olsztyn-Olsztynek, part Olsztyn East – Olsztyn South [8].

5. Conclusions

The here shown projects can be considered as good examples of modern design of medium span bridges, and even longer ones. Thanks to the use of high strength steel sections and due to the latest developments of composite technologies such as PreCoBeams the efficiency of bridge constructions can be optimized. This makes bridge construction fast, efficient, sustainable and cost saving.

References

[1] Stacewicz M., Hukowicz A., Windorpski H., Kołakowski T., Kosecki W., Lorenc W., Nowatorska konstrukcja zespolona przęseł nowego wiaduktu ciągu DK nr 22 nad linią PKP koło Elbląga, Mosty 2017-1, pp. 57-62.

[2] Lorenc W., Kołakowski T., Hukowicz A., Seidl G. *Verbundbrücke bei Elbląg: Weiter-Entwicklung der VFT-WIB Bauweise.* Stahlbau. 2017, Jg. 86, H. 2, pp. 167-174.

[3] Lorenc W., Seidl G., *Anwendung von Verbunddübelleisten im Brückenbau.* Münchener Stahlbautage 2017

[4] Lorenc W., *Model for a general composite section with dowels*. Steel Construction, 2017 vol. 10, nr 2, pp. 154-167.

[5] Lorenc W. Kożuch M. Innovative design of composite bridges for medium spans based on rolled sections Project PFR338-14, 2016. (http://sections.arcelormittal.com/library/steel-research-reports/bridges.html)

[6] Kożuch M., Lorenc W., Rabiega J., Ochojski W., *Technologia budowy mostu drogowego o rozpiętości przęsła powyżej 50 m z dźwigarów walcowanych.* Seminarium Naukowo-Techniczne Wrocławskie Dni Mostowe, Wrocław, 28-29 listopada 2017

[7] Kaczmarek T., Radziecki A., Sygit M. *Network arch bridges over motorways in Poland – selected design and construction problems.* ARCH 2013

[8] Kaczmarek T., Galewski T., Topolewicz K., Sęk R., Ochojski W., Lorenc W., Kożuch M., *Mosty network arch z zastosowaniem dwuteowników HD giętych na zimno* (*Network arch bridges using cold bended HD sections)* MOSTY 3/18, 2018.