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DOI: 10.2478/sspjce-2013-0012

State of the Art in the Utilization of Deck Bridges with Encased Filler-Beams in the Standard Construction Practice

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Abstract
Deck bridges with encased filler-beams have been used in construction for a long time. Nowadays they are employed mainly in the refurbishment of railways and in road construction. Regarding the method of construction, they can be divided into monolithic/cast-in-place (constructed fully in its final location) or prefabricated/precast structures (built at another location and then transported to their final location for placement in the full structure). Both methods of construction have certain advantages and disadvantages. Decision-making and selecting a better alternative depends on the building conditions and a means of transport (whether a road or railway) running on the bridge.

Key words: deck bridges, encased beams, construction

1 Introduction

One of the wide-spread types of composite structures is a deck bridge with encased filler-beams where the steel beam sections present rigid reinforcement in a longitudinal direction and the steel reinforcement bars reinforce the concrete deck in a transverse direction.

Deck bridges with encased filler-beams are primarily designed for short and middle span lengths in railway or road structures. These types of structures have been in use in our country for over 120 years with no major alterations. The then applied design methodology assumed static action of only steel beams made from rails, later from riveted, rolled or welded sections. The concrete in such a structure played a reinforcing role. Therefore, the load-bearing system still allows a margin of resistance.

This structural system was very popular and widely used at the beginning of the previous century and more than two thirds of the bridges from this period were built using this method. In the 1970s a new design concept was developed and came to be used in deck bridges.

According to the concept, deck bridges with encased filler-beams started to be considered reinforced concrete structures. Concrete was attributed an additional static function – action in compression. These structures were designed using the method of permissible stresses anchored in some technical standards, such as *ČSN 73 2089 Směrnice pro navrhování spřažených ocelobetónových nosníků - Directive for design of composite steel-concrete beams, ČSN 73 6205 Navrhování ocelových mostních konstrukcí - Design of steel bridges* and *ČSN 73 6206 Navrhování betonových a železobetonových mostních konstrukcí - Design of concrete bridges.*

The Railways of the Slovak Republic employed their own directives and model structural reanalyses. Their structures were designed in compliance with a regulation referred to as *"Směrnice pro návrh a provádění ocelobetonových nosních konstrukcí železničních mostů"*, ("Directives for Design and Construction of Load-Bearing Structures of Railway Bridges" in translation) issued by the National Institute for Transportation Engineering as early as in 1981. The calculation methodology used in this regulation was based on permissible stresses.

Today the ultimate limit state methodology is applied and the standard STN EN 1994-2 is in operation. The standard specifies some basic structural, design and verification requirements. It allows the use of rolled or welded beams of a constant section corresponding by its shape and dimensions to I– or H–sections. Thanks to their advantages they are utilized mainly in the refurbishment of railways.

Deck bridges with encased beams have a number of advantages, namely:

- little headroom and clear static action,
- simple structural design and little design effort demand,
- low labour intensity and short time of construction,
- construction with no falsework required,
- relatively greater resistance to car crash, and
- easy maintenance.

There are several disadvantages, however, for example, the economy of such structures. Thus, there is a need for more appropriate design methods and procedures and more purposeful and economical arrangement and employment of steel beams in such bridges.

2 Deck bridges with encased filler-beams recently constructed in Slovakia

2.1 Monolithic constructions

Reconstruction of a bridge on the Hodonín–Holíč railway

It is ideal to cast deck bridges in situ – monolithically. Steel beams are thus used as part of a self-bearing framework. This is exactly the method used in the refurbishment of a bridge on the Hodonín–Holíč railway (Fig. 1).

The original project assumed that the separate bridge members would be precast and hoisted on the existing supports using cranes. Therefore, the deck is longitudinally divided into three segments. Nonetheless, there was exceptional long-term closure of traffic on the railway, so the builders decided to cast the concrete in place and the bridge was eventually built monolithically.

The bridge runs over a river and warm-air heating pipes. (Fig. 2) [4].

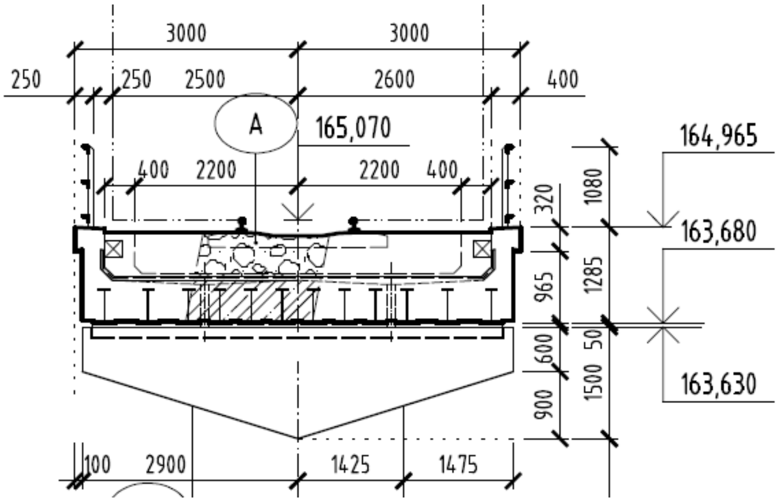

Figure 1: Cross-profile of the Hodonín–Holíč railway bridge

Figure 2: The Hodonín–Holíč railway bridge

Bridge reconstruction at the railway stop Báhoň

During the modernization of Railway Line 120 Bratislava–Žilina, the bridge at the railway stop Báhoň was reconstructed (Fig. 3).

The bridge structure is located on an open railway line. There is a double-track line on the bridge with an axial track distance 4.1 m. The road width under the bridge complies with the requirements stipulated for local roads and the road M 8/50 with double-sided pavements. The road under the bridge runs straight, then partly in a transition curve, vertically curving with a radius R=400 m. The bridge has two rail tracks; the clear distance between the abutments is 12.15 m, the overall length of the bridge 17.55 m and the span 13.5 m. The overall width of the bridge is 10.8 m. The underclearance over the spanned road is 4.685 m. The load-bearing structure consists of a deck with encased welded I–beams, 800 mm high and 14 m long. The decks at their highest point are 1030 mm thick and their falling gradient is 2.0 %. The decks are of concrete, Class C30/37. Bridge bearings are rails placed in concrete in the bearing blocks on the bridge supports. The load-bearing decks were concreted in place during the closures of traffic on the relevant railway line [7], [8].

Figure 3: The bridge at the railway stop Báhoň

2.2 Precast constructions

Construction of monolithic bridges is possible only for new railway lines or the lines where traffic can be rerouted. In the case of double-track lines one track is always closed and the other one is temporarily used in both directions. Many repairs of railway lines take place on single lines. Here, transport is provided by shuttle buses and the traffic closure time must be minimized. Therefore, most deck bridges are made as precast elements nowadays. They are longitudinally divided into two or three segments – depending on their weight – so that they are easy to transport and erect. Gaps between the segments are left open as movement joints for expansion and contraction or are filled with elastomeric jointing compound. A separate deck is constructed for each track.

Reconstruction of a bridge on the Michaľany–Palota railway line near the village of Veľaty

A railway bridge on the Michaľany–Palota line in the Michaľany–Úpor definition section near the village of Veľaty was constructed as a precast structure. Its load-bearing structure was originally formed as a stone arch. Reconstruction of the bridge was necessary as the passing clearance under the bridge was insufficient and the overall bridge condition was poor [5].

An obstacle to bridge is a third-class road. The proposed bridge is a single-span bridge with a main span of 9.7 m. The load-bearing structure includes three decks reinforced with steel beams. The live load caused by traffic is transmitted only through the 3280 mm-wide middle deck. The side decks with their respective widths of 1340 mm and 1140 mm are equipped with cornices. The deck thickness is 490 mm and the length 10.8 m (Fig. 4) [5].

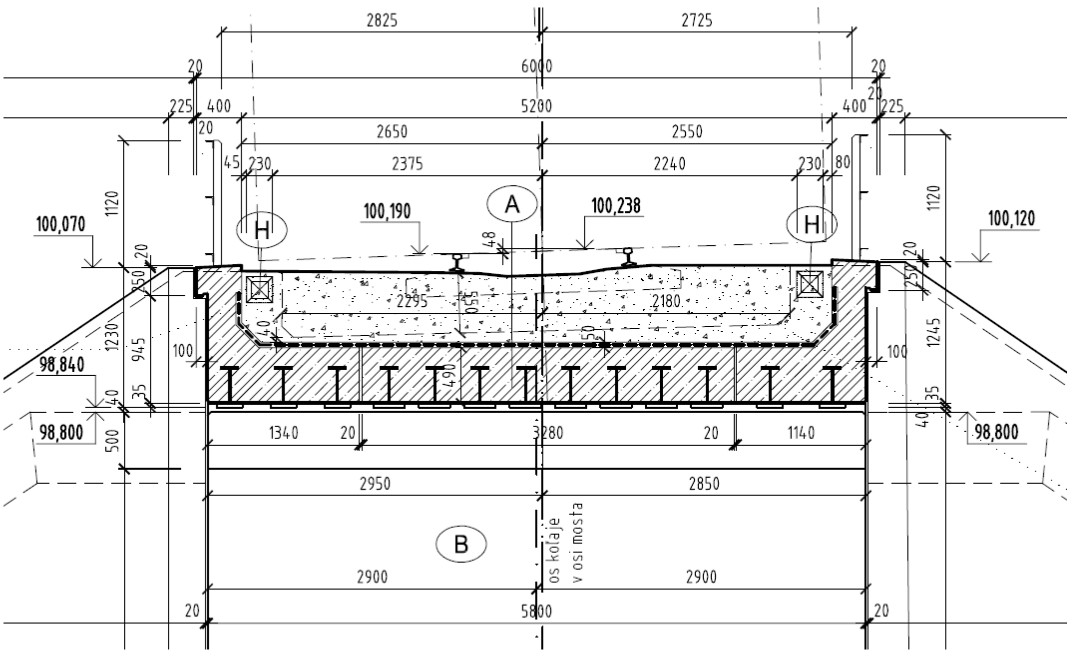

Figure 4: Cross-profile of the deck bridge near the village of Veľaty

The encased filler-beams are designed as welded asymmetric I–sections. The overall beam height is 355 mm. The arrangement and dimensions of the beams are shown in Figure 5. The beams are connected by means of round bars threaded at their ends to fix the position of the beams with nuts. The beams have web openings for the placement of the bars and transverse reinforcement. At the fixed bearing area of the beams there are end stops welded to the lower flanges. Concrete reinforcing bars include load-bearing bar chairs at the lower edge of the deck, secondary concrete links at the upper edge and longitudinal inserts at both sides. Stirrups are placed as far as to approximately one third of the span. Near the areas with erection openings the stirrups are closely concentrated. Concrete Class C35/45 and Steel 11 378 are used for the beams [5].

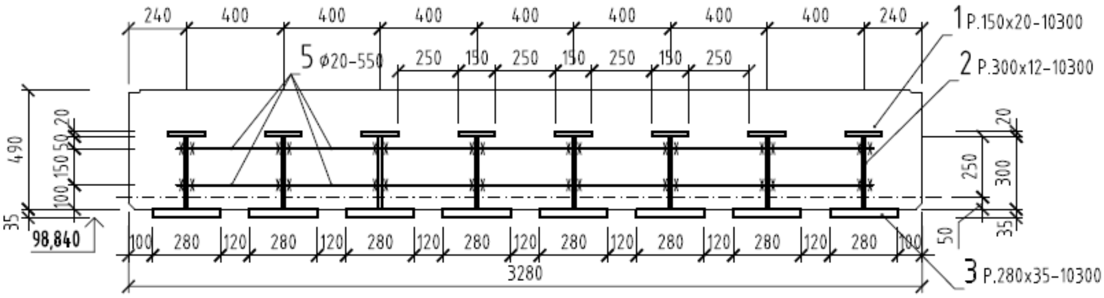

Figure 5: Arrangement of steel beams encased in the decks

The work was performed under the protection of a temporary bridge comprising two fields of two bridges SN15,0 embedded on two supporting stacks of sleepers at their ends and a propping temporary steel structure PIŽMO (Fig. 6) [5].

Figure 6: Bridge refurbishment work near the village of Veľaty

The running speed on the temporary bridge section was reduced to 10 km/h. Refurbishment work was performed in four steps. During the first step and the first closure of traffic on the line, the tracks were removed, the original bridge structure was knocked down and a temporary bridge assembled and erected. The traffic closure lasted approximately 48 hours. Earth excavation and demolition work was carried out as the second step – the old supports were demolished and new abutments and wings were made. During the third step the railway line was closed again. The temporary supporting bridge was erected and the precast decks constructed. Insulation was installed and protective external rendering completed. Finally, a ballast bed was laid and a new pre-assembled track section formed. This time the traffic was closed for approximately 48 hours (Fig. 7). The last step was finish work, such as the attachment of railings and the final disposal of building waste and construction site installations [5].

Figure 7: Bridge refurbishment work near the village of Veľaty

Reconstruction of a bridge on the Kraľovany–Trstená railway

The load-bearing structure consists of a pair of reinforced concrete decks (Fig. 8).

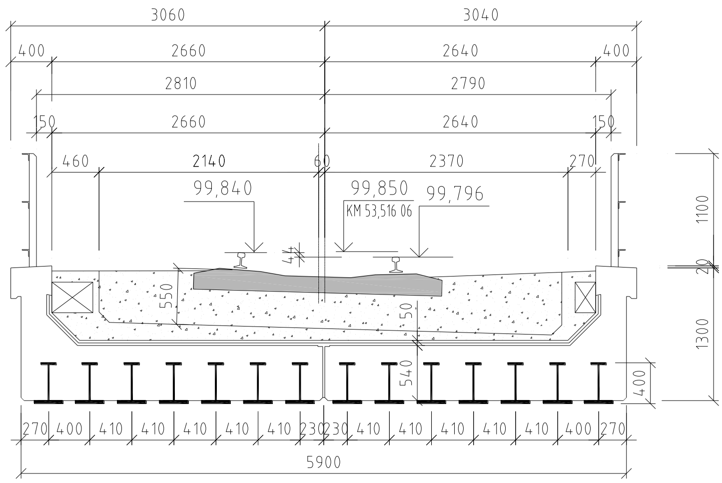

Figure 8: Cross-profile of the Kraľovany–Trstená railway deck bridge

The decks were designed and verified as simply supported beams. From the construction point of view, they were designed as precast segments continuously supported during the process of concreting. There is a movement joint between the decks. The deck length is 10 m and the span 9 m. Each deck comprises seven steel beams with asymmetric I–sections 400 mm high. The deck thickness is 540 mm [9].

3 Conclusion

The utilization of deck bridges with encased filler-beams in railway lines is a tried and tested process. Today more refurbishment work is carried out than new railway construction. One major advantage that makes this type of bridge so notable is the possibility of using beams as part of the self-supporting formwork during construction. Such advantage is lost in single railway lines since it is impossible to lock the line for the whole period of construction of a monolithic bridge. Therefore, segments of bridges are precast at another location and then transported to their final location for placement in the full structure. The utilization of I–sections is very uneconomical for such method of construction. The research currently done at the Institute of Structural Engineering at the Faculty of Civil Engineering of the Technical University in Košice is thus focused on design and experimental verification of deck bridges with encased beams using steel sections meeting all desired requirements and economising the process of their construction.

Acknowledgement

The paper was written with the support of the project ITMS: 26220220124 "Development of Bridges with Encased Filler-Beams of Modified Sections".

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