BRIDGES WITH PROGRESSIVELY ERECTED DECKS

P. Novotny¹, P. Svoboda² and J. Strasky³

ABSTRACT

Two types of bridges with progressively erected decks are described in terms of the architectural and structural solution and technology of their erection. The first type is formed by a concrete spine box girder that is additionally widened by precast struts and cast-in-place overhangs. The decks are cast in formworks that were suspended on overhang movable scaffolding with so-called organic prestressing. The deck is post-tensioned both by internal and external tendons. The bridges have spans from 42 to 69 m; their width is from 25 to 31 m. The second type is formed by a steel trough that is composite with a concrete deck slab supported by steel struts. The deck slab is cast in a formwork formed by precast members. The steel sections are incrementally assembled beyond the abutments and consequently launched into their design position. After that the deck slab is progressively erected. The bridges have spans from 45 to 66 m; their width is from 25 m. The arrangement of the bridges was developed on the basis of detailed static and dynamic analyses. During the construction the strain gauges were placed in critical sections and the structures were carefully monitored both during the erection and service.

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Two types of bridges with progressively erected decks are described in terms of the architectural and structural solution and technology of their erection. The first type is formed by a concrete spine box girder that is additionally widened by precast struts and cast-in-place overhangs. The decks are cast in formworks that were suspended on overhang movable scaffolding with so-called organic prestressing. The deck is post-tensioned both by internal and external tendons. The bridges have spans from 42 to 69 m; their width is from 25 to 31 m. The second type is formed by a steel trough that is composite with a concrete deck slab supported by steel struts. The deck slab is cast in a formwork formed by precast members. The steel sections are incrementally assembled beyond the abutments and consequently launched into their design position. After that the deck slab is progressively erected. The bridges have spans from 45 to 66 m; their width is from 25 m. The arrangement of the bridges was developed on the basis of detailed static and dynamic analyses. During the construction the strain gauges were placed in critical sections and the structures were carefully monitored both during the erection and service.

Introduction

Bridge structures formed by concrete or steel box girders with large overhangs supported by struts represent an optimum solution for crossings of deep valleys. These bridges are esthetically pleasing and structurally very efficient. Their economy can be enhanced by a progressive erection of their decks. This is illustrated on construction of several viaducts built in the Slovak and Czech Republic.

Concrete Viaducts

Thirty year ago a cable stayed bridge across the River Elbe near a city of Podebrady was erected. Its 31.80 m wide deck is formed by a spine girder with large overhangs supported by not mutually connected precast slab struts. The one cell box girder assembled from precast segments was constructed first, then the struts were erected and the overhangs were cast in simple formwork that was supported by these struts. After that similar arrangement was used in a construction of the Vrsovice cable stayed bridge built in Prague and in several bridges designed by others.

Recently similar approach has been used in construction of several long viaducts that have been built in Slovakia - see Fig. 1. These bridges have span lengths up to 69 m – see Fig. 2, their widths are up to 28.70 m – see Figs. 3 and 4. The spine girder is cast span -

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Figure 1. Viaduct across the Hostovsky Creek: Completed bridge and its erection.

by-span in a formwork suspended on a special overhead gantry with ‘organic’ prestressing system (OPS) that eliminates deflection of the gantry. To reduce the self weight of the spine girder as much as possible, the girder is very narrow. Therefore the transverse projection of the overhangs is up to 11.00 m.

It is evident that this solution requires not only a careful analysis and detailing, but also an experience contractor. Also the construction and service of these bridges have to be carefully checked and monitored.

Figure 2. Concrete viaducts: elevations.
Recent Structures

The first structure of this kind is a 975 m long viaduct across the Hostovsky Creek built on the Expressway R1 near a city of Nitra – see Figs. 1 and 2 - R1 205. The bridge of the width of 25.66 m has 17 spans of lengths of 33.0 + 42.0 + 45.0 + 48.0 + 9×69.0 + 48.0 + 45.0 + 42.0 + 33.0 m. The depth of the girder varies from 4.00 to 2.60 m. The bridge was opened to traffic in September 2011.

Two bridges of similar arrangement are being built on a motorway D1 section Fricovce – Svinia near a city of Presov - see Fig. 2 - D1 202 and 203. These bridges built across the Lazny and Stefanovsky Creek have total lengths of 269 m and 182 m; typical span...
length is 45 m. Both motorway directions are carried by one bridge of the total width of 29.5 m. The depth of the girder is 2.60 m. Since the bridge decks are frame connected with H shaped piers, the bridges form semi-integral structural systems.

Another two bridges of similar arrangement are also being built on a motorway D1 section Janovce – Jablonov near a city of Levoca - see Fig. 2 - D1 216 and 217. The bridges across the Lodina and Doliansky Creek Valley have total lengths of 367 m and 414 m; typical span length is 65 m. Both motorway directions are carried by one bridge of the total width of 28.70 m. The depth of the girder is from 4.00 to 2.60 m. Since the bridge decks are hinge connected with twin piers, the bridges form semi-integral structural systems.

The spine girder of all bridges is progressively cast span–by-span in a formwork suspended on the overhead gantries. The girders are cast with short overhanging cantilevers. The decks of all bridges are longitudinally prestressed by internal bonded tendons situated within the basic cross section and by external non-bonded tendons situated inside the central box. The bonded tendons are coupled in each construction joint. External cables are anchored at pier diaphragms and are deviated at pier and span deviators.

In the transverse direction the deck slab is prestressed by tendon formed by 4 strands lead at flat ducts situated at distance of 1.50 m. During erection the struts are suspended on two prestressing bars anchored at outer cantilevers of the basic cross section. The struts of a nominal width of 3.00 or 2.50 m are supported by short bottom corbels of the box girder - see Fig. 5 and 7. The cast-in-place deck slab was cast in the formwork supported by already erected precast struts - see Fig. 6. After the transverse prestressing of the deck slab is applied, the longitudinal external cables are post-tensioned.
Static analysis

The structural solution was developed on a basis of very detailed static and dynamic analyses. The structures were analyzed by a MIDAS program system. The bridges were modeled as 3D structures formed by beam elements and a 3D structure assembled of shell and solid elements. A detailed time dependent analysis of the progressively erected structure (see Fig. 8) was also performed. Also a strut and tie models were used for checking of important details. The design of the first structure – the Viaduct across the Hostovsky Creek Valley - had been performed according to the Slovakia’s standards (STN) valid at the time of the design. After that all other viaducts have been designed according to Eurocode. All aspects of the analysis are presented in [1].

The detailed analysis has confirmed that although the outer struts are not mutually connected (see Fig. 9), they contribute to resistance of the structure both in the bending and torsion. Since the function of the bridge depends on perfect connection of the struts with the box girders’ corbels that depends on perfect workmanship, following conservative approach was accepted. The spine girder was designed without contribution of the struts both for bending and torsion. On the other hand the precast struts were designed for the stresses that originate on condition of the perfect connection of the struts with box girders’ corbels. This approach guarantees that the struts will not be damaged during service of the bridge.
Bridge monitoring during construction and service

The first structure, the Viaduct across the Hostovsky Creek Valley (R1 205), has been carefully monitored during construction, in depth loading tests and during service. For monitoring of concrete stresses strain gauges were placed in four sections. Two sections were in span 6 and two sections were in span 7. Span 6 represents typical span supported by movable bearings on pier 6 and by concrete hinge on pier 7; span 7 is a special span hinge connected with pier 7 and frame connected with pier 8. In both spans one section is situated at midspan and one section situated at distance 0.5 from the pier table.

Since longitudinal strains were measured, the gauges were placed longitudinally at the middle of the depth of top and bottom slab. The gauges were connected with Data Taker situated inside the bridge box. In selected periods the Data Taker saves frequencies of the individual strain gauges and their temperature. Also temperature and humidity inside the bridge box are monitored. After casting of the structural members in which strain gauges are placed, the measurement was performed. After that the measurement were done before and after post-tensioning of bonded tendons, stripping of the formwork, erection of the struts, casting the overhangs, post-tensioning of the external cables, applying of the additional dead load, loading test and bridge opening. During service of the bridge the measurement is performed twice a year. Fig. 10 presents calculated and measured values from which a good agreement of results is evident.

The strain measurement was also performed during the static loading tests for three loading stages. The spans 5 and 7 were loaded by 16 Trucks of average weight of 32.05 tons situated symmetrically to the bridge axis that created maximum positive bending moments. Span 6 was loaded by 8 trucks situated only on the left bridge side that created maximum torsion. The measured and calculated values were in a good agreement.
Composite Viaducts

After successful completion of the bridge across the Lochkov Valley Creek on the Prague Ring Road, Czech Republic, which deck is formed by a steel trough that is composite with a cast-in-place deck slab, two other long composite viaduct are being built on the highway I/11 in the North Moravia, Czech Republic - see Fig. 13. However, to simplify their construction, their deck slab is cast in a formwork formed by precast members – see Figs. 14 and 17.

The first viaduct, the Bridge across the Hrabynka Creek Valley (Bridge 206) of the total length of 330.0 m, is formed a continuous girder of 6 spans of lengths from 39.0 to 66.0 m, the second one, the Bridge across the Kremlice Creek Valley (Bridge 207) of the total length of 528.0 m, is formed by a continuous girder of 11 spans of lengths from 33.0 to
57.0 m - see Fig. 15. While the Bridge 206 has a straight axis, the Bridge 207 is in a plan curvature with radius of 900 m that transfers by a transition curve into the straight axis.

Both directions of the highway are carried by a bridge decks formed by a steel girder and a 25.5 m wide composite deck slab – see Fig. 16. The steel girders of the trough cross section assembled of top and bottom flanges and inclined webs are supplemented by central stringer and two edge stringers. While the central stringer has I cross section, the edge stringers have V shape with smooth surface that simplify the bridge maintenance. At distance of 3.0 m the stringers are supported by diagonal pipes attached to the girder’s bottom corners. The shape of the structure is secured by top transverse ties anchored at the top flanges and at the edge and central stringers – see Fig. 17.

The deck slab is composite of precast slab members and additionally cast deck slab.

![Figure 15. Composite viaducts: elevations.](image)

![Figure 16. Cross section of the Bridge across the Hrabyanka Creek Valley.](image)
The precast members of thickness of 100 mm are stiffened by steel trusses welded from reinforcing bars – see Fig. 18. Their function both, for erection and service load, was verified by loading tests done at Brno University of Technology [2].

Both bridges are incrementally assembled beyond the abutments and consequently launched into a design position. The steel structure of the Bridge 206 is assembled of 20 segments of lengths from 13.0 to 21.3 m. The steel structure was incrementally launched with precast members; only a part of the structure of the length of 66 m beyond the launching nose was formed by the steel section. When launching was completed, remaining precast members were erected and the deck slab was progressively cast.

The steel structure of the Bridge 207 is assembled of 25 segments of lengths from 13.0 to 29.0 m. Due to the complex bridge geometry the steel structure is assembled from two parts and it was launched from both abutments. The division is situated at the fifth span at the point of zero bending moment approximately in the place, where the straight bridge axis follows the transition curve. At first, the part of the steel structure close to the abutment 1 was incrementally assembled and launched, and then the part of the structure close to abutment 12 was assembled and launched. Due to the variable plan curvature the launched structure was
temporarily supported by pier transverse steel girders that allowed a transverse movement of the deck. To reduce the weight of the launched structure, the steel structure was launched without precast members. After connection of both parts the precast members were progressively erected and the deck slab was cast.

Conclusions

The described structures were erected without any significant problems. They proved to be elastically pleasing and cost effective.

Acknowledgments

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