Application of Research into Deck Bridges with Encased Filler-Beams in Design Practice

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Abstract. Research into deck bridges has been conducted at the Faculty of Civil Engineering of the Technical University in Košice, Slovakia. Encased steel filler-beams in a wide variety of shapes and dimensions were designed for deck bridges, whereby reducing steel consumption by a significant 40 per cent, and maintaining the same resistance and stiffness of the bridges. Our theoretical assumptions were verified by experiments. Specimens were tested for static, dynamic, and long-term loads. Consequently, with the assumptions proved to be correct, a design protocol was elaborated to serve as a template or code of practice for designers and engineers.
Using this design protocol, a designer working for *Amberg Engineering Slovakia* designed a load-bearing structure for the reconstruction of a bridge in the village of Prituľany. The proposed technical solution took into account all local restrictions given by the horizontal and vertical alignment of the road structure on the bridge as well as its low building height. The plan of the load-bearing structure as viewed from above (i.e. the angle between the axis of the bridge and the axis of the obstacle being bridged) is oblique.

1. Introduction

Deck bridges with encased steel beams present a structural system that is commonly applied in small and middle-span constructions. Initially, in first designs, rails were employed as rigid reinforcement. Later, welded or rolled steel sections came into use. The currently valid and applied Eurocode 4 standard contains structural requirements and design procedures for such bridges; however, it also prescribes the application of I-sections only. At the same time, it allows for the plastic design, while the position of the plastic neutral axis is to be situated in the steel beam web. The upper flange of a beam thus appears to be near the neutral axis, and its contribution to the bending resistance of the beam is minimal. The fulfilment of this condition is required to ensure composite action as the structural system of this kind does not make use of any sheer connectors [12-19].

Research into deck bridges with encased steel filler-beams has been carried out at the Civil Engineering Faculty of the Technical University in Košice for several years. Our goal is to make the design of such bridges more efficient by lowering the consumption of steel while maintaining the same load-carrying capacity and stiffness of the structure. T-sections were suggested for deck bridges, and steel savings in the upper flange of the section were achieved as a result. The theoretically calculated resistance and stiffness did not change For the components to act together, several types of strip connectors were designed, and their design further refined and verified during the research at the Faculty in the past. The dimensions of the sections remained identical for all beams. We have been researching the deck bridges for over 10 years. In the following, we give only basic information [7-11].

2. Research results

2.1. Test specimens

Complying with the standard specifications, a single type of test specimens were designed for experimental research that served comparative purposes (Figure 1).

The width of the concrete section: 670 mm
The height of the concrete section: 270 mm
IPE200 rolled steel section
Theoretically calculated resistance moment using the measured material properties: 107.93 kNm
Theoretically calculated bending stiffness of the section: 11 959 kPa.m^4 [1-5]

Another type of test specimens contained a steel T-section, manufactured by the longitudinal flame-cutting of a rolled steel I-section in a comb-shaped manner (as can be seen from Figure 2), creating a profiled upper edge of the steel section.

The width of the concrete section: 670 mm
The height of the concrete section: 270 mm
IPE200/2 rolled steel section
Theoretically calculated resistance moment using the measured material properties: 99.91 kNm
Theoretically calculated bending stiffness of the section: 13 036 kPa.m^4 [1-5]

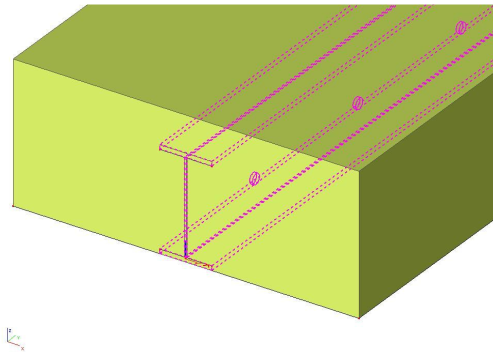

Figure 1: Specimens with an I-section

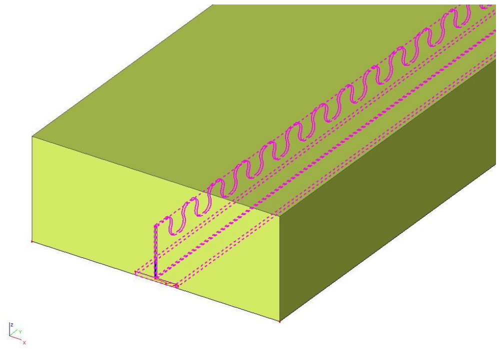

Figure 2: Specimens with a T-section

2.2. Test results

Deflections were monitored during experimental measurements. All changes depending on the amount of load applied are shown in Figure 3.

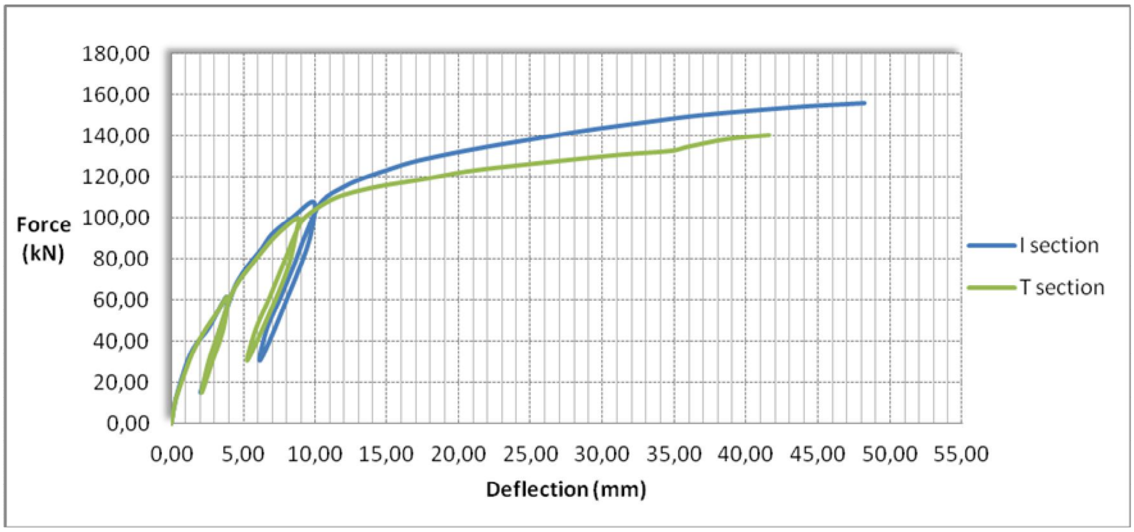

Figure 3: The load-deflection curves: Change in the development of deflections depending on the amount of force applied to the beams

Testing was completed when the deflections in the specimens increased excessively, signalling the plasticization of the sections. At this stage of the experiment, plastic resistance moments were detected as follows:

Specimens with an I-section: 124.8 kNm, meaning an increase of 15.6 per cent
Specimens with a T-section: 117.0 kNm, meaning an increase of 17.1 per cent

The specimens with T-sections were further verified by dynamic and long-therm load.

The results of the experiments proved that the designed solution is suitable for deck bridges. The assumption that resistance and stiffness are the same has been confirmed. However, limitation on the use of such a design is for bridges supported during their construction, not having a self-carrying function during the concreting process.

2.3. Application of the results

Based on the experimental results, a design protocol was elaborated to serve as a template or code of practice for designers and engineers. It contained calculation procedures for the verifications of bending resistance of deck bridges with encased T-section filler-beams, their serviceability, and the verification of composite action. Moreover, constructional requirements for this type of bridge were provided as well.

3. Reconstruction of 3822-002 Pritul'any Bridge

Parts of the village of Pritul'any are divided by the Pritulianka stream. Crossing the stream is possible over a composite bridge made of steel and concrete. Significant degradation of the concrete in the load-bearing structure of the bridge has taken place over the years, and increased permanent deformations and lateral buckling of the steel sections occurred. The bridge *per se* is in terrible condition. Neglecting the current status quo may lead to severe damage to the bridge structure.

Its reconstruction is to consist of the renewal of the original composite bridge structure, construction of a new bridge, alteration of some road sections before and after the bridge, and the remodelling of the stream bed under the bridge.

3.1. The technical solution for a new bridge

Because of serious space restrictions in the village area, a method of construction, a shallow building height of the bridge structure due to the maintenance of the stream flow rate, the best appropriate solution seemed to be a composite deck bridge with encased filler beams.

The load-bearing structure was designed as a reinforced concrete slab with an average width of 430 mm, made of C35/45 concrete, encased steel sections (structural steel grade S355) and soft secondary reinforcement (steel graded B500 B). In a transverse direction, the load-bearing structure consists of 10 welded T-shaped beams with a centre-to-centre spacing of 700 mm. The lower flange is 280 mm in width and 20 mm in thickness, while the web of the beam is the vertical flange, 260 mm high and 10 mm thick (Figure 4).

The width of the load-bearing structure is 7 100 mm, uniformly along the whole bridge. The length of the bridge is 11 000 mm (oblique), and the length of the load-bearing structure is 12 770 mm (oblique).

The load-bearing structure is placed on a reconstructed reinforced bearing block of concrete graded C35/45 and a flexible 20mm-thick strip. Bond at the interface between the new piece of the bearing block and the original part is made by a glued board.

The geometry of the new structure is determined by the horizontal and vertical alignment of the road SO 101-00. It is designed with a 0.66 per cent longitudinal and 2.5 per cent transversal roof-like inclines of the roadway [1-7].

Used materials

Concrete/Load-bearing structure: C35/45 – XC4, XD1, XF1 (SK) – Cl 0,4 – Dmax16 – S3
Structural steel: S355 X0
Reinforcing steel: B500B

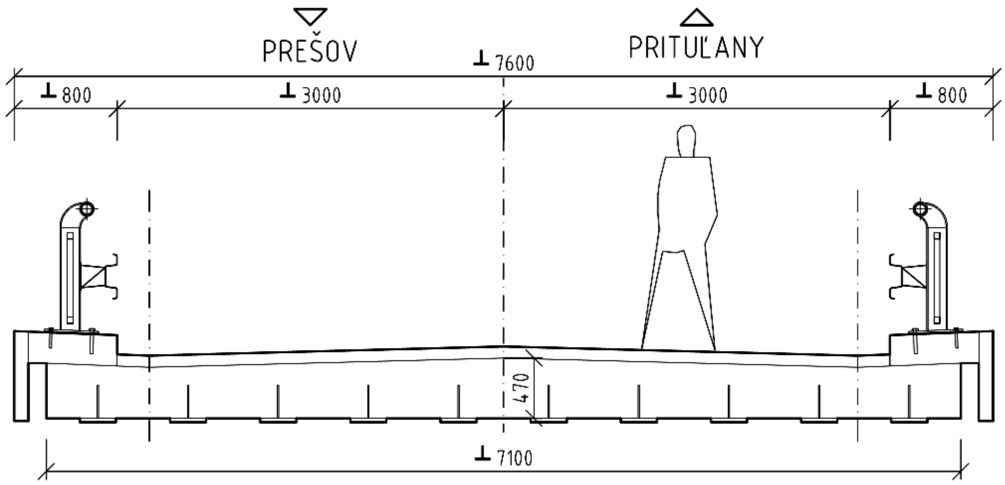

Figure 4: The cross-section of the bridge

The substructure of the bridge is supported by two existent supports – OP1, OP2. Both supports are massive, founded on flat bases. After the partial demolition of the original supports, a bearing block is built on each of them. The new load-bearing structure is supported using a transverse beam with elastic rubber base. All parts of the substructure below ground level, permanently in direct contact with earth, are protected by a damp-proof membrane.

New slab cornices in the form of prefabricated components were designed for the bridge. Both left and right cornices are 800 mm wide, protruding 250 mm from the edge of the load-bearing structure. The height of the end of the cornice/fascia is 750 mm, its lateral slope 4.0 per cent, leaning towards the roadway.

3.2. Model of a load-bearing structure

Midas Civil, a software programme, was used to design a grid-type model of the load-bearing structure of the bridge (Figure 5). Apart from the sequence of the bearing structure construction, the rheological properties of the concrete were considered in the model (Figure 6). Temporary point supports of steel T-sections were designed in the model during both the assembly of the steel construction and casting concrete. For the sequence of construction, both the loading states of placing fresh concrete in situ and loading by workers on the load-bearing structure acting compositely with still the green concrete were taken into account.

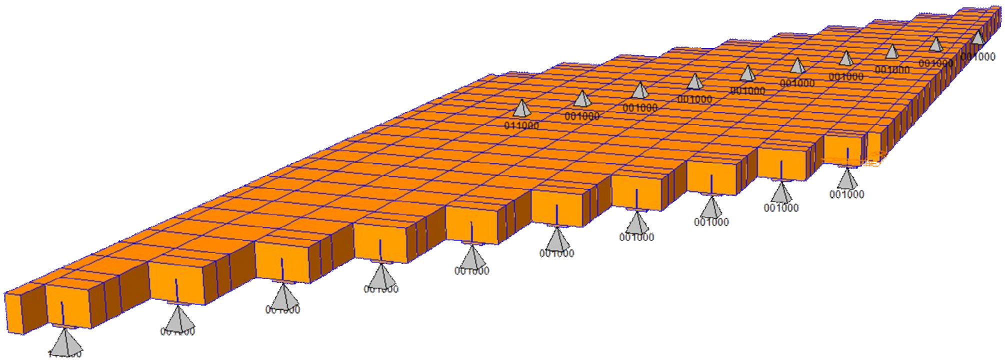

Figure 5: A new bridge model using the Midas software

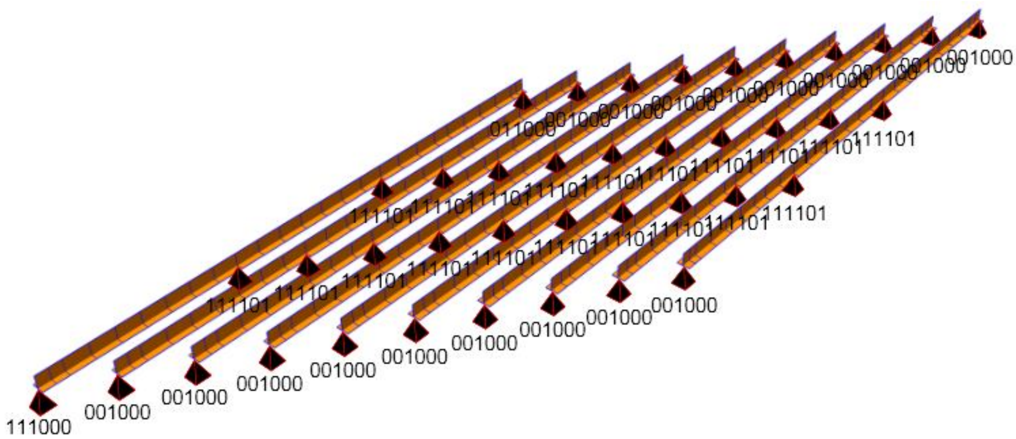

Figure 6: Point supports as considered during the sequence of construction according to Midas

The temporary supports were removed in the programme after the green concrete had set, hardened and reached the required strength. The load of the superstructure (such as the cornices, insulation, etc.) and transport is borne by the composite structure.

Stresses in the T-section were observed at each stage of construction, whereas those in the concrete started to be monitored at the time when it was possible to consider loading the green concrete by construction workers. The section in the Midas Civil programme was designed as a composite-general section. The bridge was verified for seismic effects as well.

The grid-type model used for modelling this load-bearing structure describes the actual behaviour pattern of this type of structure correctly enough. In its layout, it is an oblique bridge, and the grid-type model was constructed according to the recommendations provided by the designers of the Midas Civil programme for grid-type oblique bridge models. Long-term observation of bridge deformations will take place in the future. The results are display in the axes of steel beams (Fig. 7).

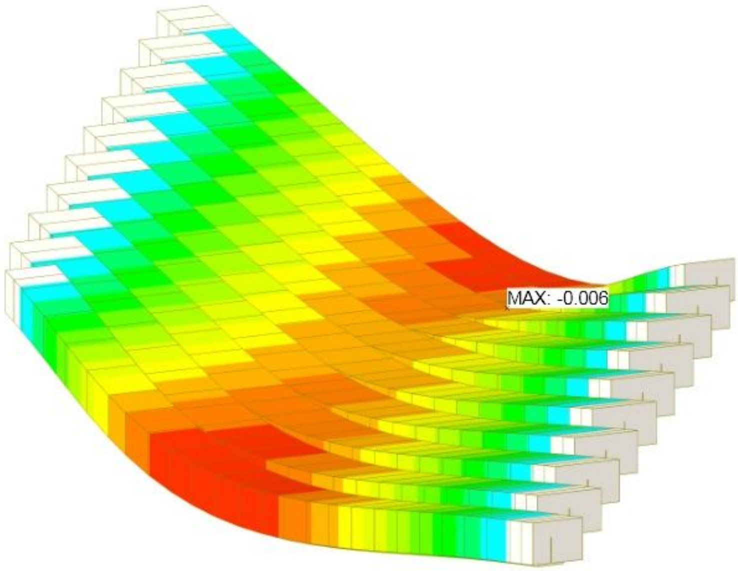

Figure 7: Deflection in model of bridge

4. Conclusion

The load-bearing structure of the bridge was verified under the stringent Eurocode standards currently in force. Verification of the stress condition of the bridge structure at each stage of its construction was based on an analytical model. The bridge, as well as all its structural details, was designed according to *Deck Bridges with Encased Filler-Beams of Modified Sections [5],* a publication written at the Civil Engineering faculty of the Technical University in Košice during the research in progress.

These days, the bridge is under construction. Measurements are being carried out during the construction stage, and a loading test on the bridge is being prepared to follow successful completion of the construction work.

Acknowledgements

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