Structural assessment of the integrated steel fly-overs widening the historic multiple-arch concrete viaduct over the Pede valley

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Summary

The 523 m long historic viaduct crossing the Pede valley in Belgium consists of 16 three-hinged reinforced concrete arches with a span of 32 m each and a maximum height of 20 m. With respect to the heritage structure, two additional lateral fly-overs consisting of steel box girders with variable hollow section are integrated in the existing viaduct. This paper shows the results of the detailed monitoring program verifying the design and behaviour of the newly built superstructure. Extensive strain measurements were performed during a two-day load test, together with acceleration measurements in order to evaluate the dynamic response of the structure. In addition long term strain monitoring is carried out in order to study the effect of temperature gradients on the closed steel box girders of the fly-overs.

Keywords: steel box viaduct; extension; multiple-arch; historic; strain monitoring; acceleration measurements; long-term temperature effects.

1. Introduction

As part of a large-scale project in order to improve the accessibility of the Belgian capital by train, the existing railway line between Brussels and Ghent is expanded from 2 to 4 tracks over a length of 25 km. This line crosses the valley of the river Pede by a 523 m long historic viaduct, built in the 1930’s. The structure consists of 16 three-hinged reinforced concrete arches with a span of 32 m and a maximum height of 20 m. Extension of the railway facilities to 4 tracks needs to widen the existing structure by two additional lateral viaducts, with respect for the heritage structure.

2. Design of the integrated steel fly-overs

After consideration of various alternatives during the pre-design stage, the final design consists of a steel superstructure with variable hollow sections supported by integrated cantilever pier structures, as shown in Figure 1. The box section is characterised by waving patterns complying with the existing arches, both in horizontal plane as in the front view. To raise the torsion stiffness, internal diaphragms were installed. Additional stiffness is realised by providing a concrete deck plate of 0,25 m thickness.

The new superstructure is supported by steel cantilever structures, fixed to the existing piers. Each vertical pier has a rectangular box section in a conical shape and fades into the lower part of the concrete pier. Two cantilever piers are joined by a transverse internal steel framework located in the hollow parts of the existing piers to ensure horizontal stability in transverse direction. Due to the additional load, strengthening of the existing foundation was needed, which was realized by grouted piles drilled around the existing footings. The grouting piles are designed to replace the existing concrete piles and are founded at a deeper level to carry the additional load. After drilling of the grouting piles, the existing foundation slab was extended by a new concrete slab and post-tensioning cables were used to put together both the new and existing slab.

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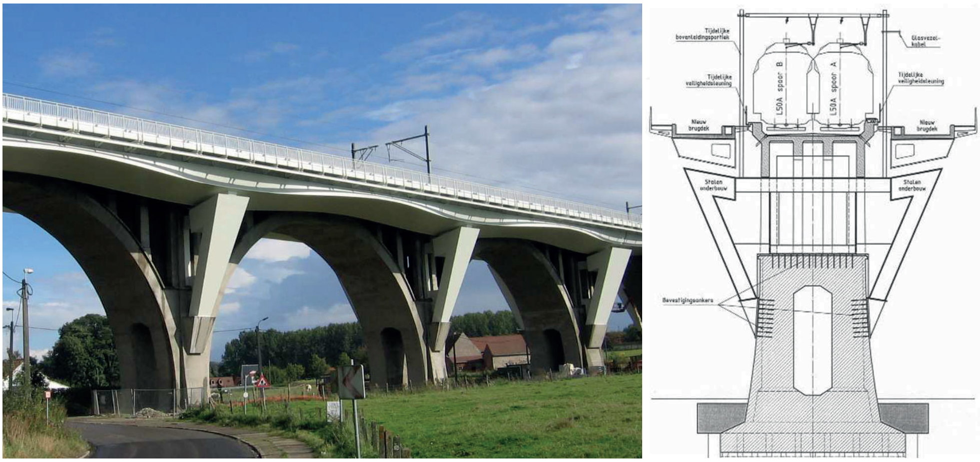

Fig. 1: Final design of the integrated steel fly-overs: front view (left) and cross-section (right)

3. Measurement program

In order to verify the design and behaviour of the newly built superstructure, a monitoring program was set up comprising several components. Extensive strain measurements were performed during a two-day load test on the steel fly-overs as well as their supports. The structure was equipped with 326 strain gauges and a total of 12 heavy lorries were applied as loads during the execution of various static and dynamic load cases. At the same time the dynamic response of the structure was evaluated by acceleration measurements. Structural vibrations were measured using uniaxial high-precision accelerometers, attached to the steel portal frame of the piers and fixed on top of the concrete deck plate at mid span. Furthermore long term strain monitoring is carried out on a selected number of strain gauges in order to study the effect of temperature gradients on the closed steel box girders of the fly-overs. For this reason a fully autonomous measurement system was installed, consisting of a data logging set-up powered by 4 lithium-ion D-cell batteries.

4. Results

A selection of the large amount of measurement results is presented to demonstrate the accuracy and reliability of the measurement set-up and to illustrate the usefulness in verifying design assumptions. In spite of the small absolute values of the measured strains, in general a good resemblance of the results can be observed. Dynamic load cases allow following the response of the structure to a passage of the trucks continuously, while results of the acceleration measurements allow determining the natural frequencies of the entire structure and its components. Long term measurements show temperature gradients between inner and outer web plates reaching almost 15°C at mid span.

5. Conclusion

During a two-day load test and following long term measurements, detailed strains, temperatures and frequencies were monitored which allow for evaluating the conceptual design. The performed measurements provide the designers the ability to assess the behaviour and stiffness of the structure under static, dynamic and thermal loading cases.

6. References

[1] DE PAUW B. and VAN BOGAERT PH., "Integrated Steel Viaducts for Railway in Extension of a Historic Multiple-Arch Concrete Viaduct", *Proceedings of 8th International Conference on Short and Medium Span Bridges, Niagara Falls, Canada,* 2010, pp. 198.1-198.10.