Integrated steel fly-overs for railway in extension of the historic multiple-arch concrete viaduct over the Pede Valley

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Summary

The existing railway line between Brussels and Ghent crosses the valley of the Pede by a 523 m long historic viaduct. This structure of the 1930's consists of 16 three-hinged reinforced concrete arches of 32 m span, reaching a maximum height of 40 m and supported by hollow concrete piers, having at least 3.5 m thickness. The railway company decided in increasing the number of tracks of the railway line from 2 to 4 tracks. Widening of the structure by two additional lateral fly-overs was only acceptable if these new structures are respectfully integrated in the historic work of art. The paper describes the final design of new steel fly-overs and its supports consisting of steel hollow ribs, which are fading gradually into the existing piers. In advance, the existing foundations were considerably reinforced by additional grouting piles. The design of the superstructure dealing with severe criteria for deformations and accelerations consists of a steel box with variable hollow section. The box section is rectangular at the piers and the upper flange is constant along each span. However, the lower flange rises as it reaches the span center, obtaining less section height, while the flange is twisted about a horizontal axis and becomes wider. This created a waving pattern of the steel structure, complying with the existing arches, both in a horizontal plane as in the view in front. As the conceptual design of the piers has to deal with both vertical and horizontal forces, the superstructure is made continuous over 4 spans. The paper describes the behavior of the slender pier structure as well as the influence to the bridge dynamics. After construction which is completed, continuing strain measurements as well as accelerations measurements were carried out in verifying the design and the stiffness.

Keywords: Integrated steel viaduct; slender pier structures; testing in situ; bridge dynamics.

1. Design of the integrated steel railway viaducts

Fig. 1: Pede viaduct in surrounding area

In figure 1 a view in front is given of the central part of the viaduct consisting of 16 concrete 3-hinged arches with 32 m span. Four arches are an independent group, since they are separated from the rest of the viaduct by double pier structures, allowing compensating the thrust force of each group. Extension of the railway facilities to 4 tracks will need to widen the structure by two additional lateral viaducts. The final design consists of a steel superstructure having variable hollow sections. The box section is continuous over 4 spans and it is characterised by waving patterns, both in the plan as in the cross-sections. The new superstructure is supported by a steel corbelling structure, which is fixed and fading gradually into the existing piers. The steel piers are joined by a steel transversal beam, located in the hollow parts of the existing piers. In figure 2, simulation of the final solution is given on the left as well as a cross section on the right.

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Fig. 2: View of the integrated steel railway fly-overs

2. Single and double pier structures

As for the horizontal stability in longitudinal direction, the horizontal traction and braking forces of the new structure on each cantilever pier is incompatible with the slender design. Therefore, the new superstructure is made continuous over 4 spans. This makes it possible to lead the high horizontal forces to the double piers with higher thickness having a thickness of 5.5 m. In designing the pier structure, the limitation of the transverse distortion of the pier is decisive. Due to the eccentric railway load on one track, the portal frame bends on the side where the charges are applied and rises at the unloaded side. Also a considerable transverse horizontal displacement appears.

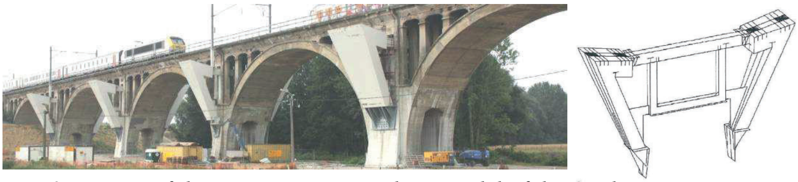

Fig. 3: Design of the pier structures and FE-model of the single piers

In the initial design, only an upper transverse beam connecting the two cantilever piers appears to be insufficient. Therefore a solution is found in using an internal framework to be placed in the internal hollow part of the existing pier as can be seen in figure 3.

3. In situ testing [1]

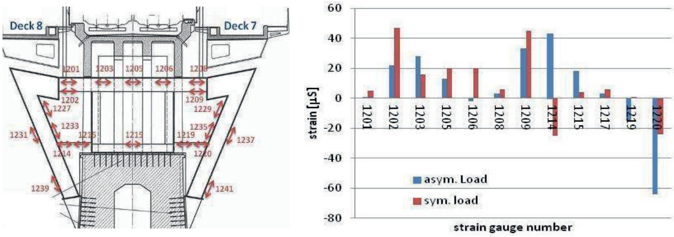

Fig. 4: Strains in the upper and lower horiz. parts of the pier n°12.

In order to verify the design and the real behaviour of the structure, an in situ testing by heavy lorries was set up comprising several components. A total of 12 heavy lorries were applied. In the figure 4, the strain values are given as for the horizontal parts of the framework in figure 3. Due to the eccentric asymmetrical loads on deck 8, severe tensile stresses and compression stresses occur in respectively the lower horizontal part of the framework in n° 1214 and n° 1220 in particular. When on the other side of the bridge also loads occur on deck 7, a uniform compression stress occurs with half the value of the maximum stress as for the asymmetric loading. Nevertheless, the mobile loads are doubled. The opposite can be found in the upper part of the framework. This confirms that the transverse stiffness is decisive in the design of the single pier structure. Besides static load tests, the dynamic response of the structure was evaluated by acceleration measurements as well as dynamic strain measurements. These included brake tests of five lorries stopping at the same time. In this paper, an interpretation is given of the static and dynamic behaviour of the single piers and superstructure under both symmetric and asymmetric loading.

4. References

[1] SCHOTTE K., STAEL D., NAGY W., DE BACKER H., "Structural assessment of the integrated steel fly-overs widening the historic multiple-arch concrete viaduct over the Pede valley", *Proc. Int. IABSE Conference*, Rotterdam, 2013