New continuous 3-span concrete railway decks with extradosed post-tensioning cables in widening an existing multiple arch bridge

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Summary

In improving the accessibility of the capital of Belgium by train, the railway company wants to increase the number of tracks from 2 to 4 tracks for the main railway lines in the direction of Brussels. In the urbanized and densely populated area near the capital, the design of the new infrastructure in extending the tracks, one on each side of the double track line, must be done with respect to existing historic bridges dating from the early 30's. The paper describes the extension of a 3-span concrete historic multiple arch bridge over the canal Brussels-Charleroi by two new continuous 3-span concrete bridges with external post-tensioning and a total length of 102 m. Four extradosed post-tensioning cables make the construction a modern concrete structure contracting the existing arches. The paper describes the design of the railway bridge and the extradosed post-tensioning, as well as the design considerations using a 3D detailed finite element model. In taking into account the fact that the extradosed cables are totally free from the deck with exception of the vertical connection, the influence on the forces in the cables and the friction is described. Also fatigue considerations are given. Finally, the construction method is described .The decks were constructed integrally at one side of the bridge and were put over the canal during one week-end.

Keywords: continuous railway bridge; extradosed post-tensioning; extension of existing bridge.

1. Extension with 2 new continuous 3-span concrete railway bridges

Fig. 1: Existing 3-span concrete multiple arch bridge

In figure 1 a front view of the existing historic concrete multiple arch bridge with a central arch of 45 m span and two arches of 15 the side roads along the canal is shown.

The bridge was built during the construction of the canal in an area with poor soil conditions. In view of the rather exceptional qualities of the bridges, the extension will need to take care of the existing structure and integrate any new element respectfully into the historic work of art. The extension from two to 4 tracks consists of a new 3-span continuous bridge of which the pier structures are fully integrated in the old abutment structures and of which the superstructure is totally independent. A front view of the new structure is illustrated in figure 2 on the left. Besides new abutments, the structure is supported on two concrete piers of which the foundations are strengthened with a combination of bored piles and grouted piles and of which the piers are structurally integrated into the existing foundations using transverse post-tensioning in the slab plate. With this new foundation, a portal frame can be formed deriving all additional weight of the new structure to the new foundations. The horizontal beam of this portal frame consists of a new concrete slab in extension with the existing foundation.

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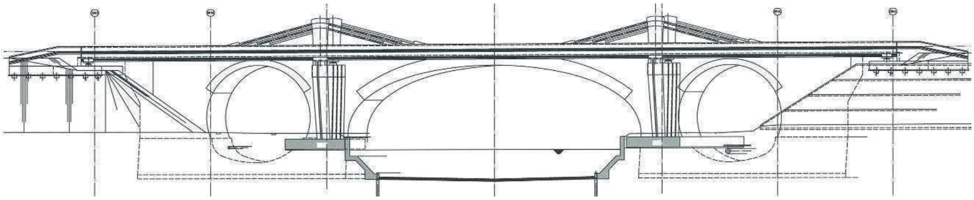

Fig. 2: Front view of the new railway bridge

As for the new superstructures, the one track superstructure is a fully concrete deck in U-shape having a width of 6.1 m and is continuous over 3 spans of respectively 30, 42 and 30 meter. The concrete strength is C40/50 and the structure is fully post-tensioned. Since the maximum possible parabolic curvature of post-tensioning cables within this optimal concrete section was not sufficient enough, four post-tensioning cables left the concrete section and became extradosed. A cross section of the deck as well as a front view during construction is given in figure 3. The combination of classic post-tensioning cables and extradosed cables can be noticed. In the paper, characteristics of the cables are described.

Fig. 3: Cross section of the superstructure in U-shape

2. Design considerations of the extradosed post-tensioning cables

Since the extradosed cables are free of moving in the cable ducts, it could be thought that this has an influence on the force distribution in the cables. Therefore, a detailed 3D finite element model was made. The model consists of plate elements for the deck and the pier column on top of the deck and cable elements for the extradosed post-tensioning cables. The modeling of these cables takes into account the same vertical deformations of the concrete deck. However, as for the horizontal deformations, the cables are relatively independent of the deck. Only friction occurs in the parts when the cables are into the concrete deck as well as in the parts of the cable saddles near the piers. The influence of this way of detailed modeling close to the real behaviour of the cables has been studied in varying different parameters. In this paper only two effects will be pointed out. In the first case, the influence on the total cable forces is given due to the behaviour of the free cable in the deck and on the saddle without friction. In the second case, attention is given to the effects of friction. Finally, attention is given to the fatigue strength of the external post tensioning cables in this particular railway bridge. It can be concluded that a test stress variation of 80 N/mm² at $0{,}65.f_{pk}$ will be sufficient.

3. Construction of the bridge

Fig. 4: Lifting of the bridge

The concrete decks were constructed integrally at one side of the bridge and put over the canal during one week-end. This operation was more delicate since a hyperstatic design consideration was replaced by an isostatic situation with a global bending moment in applying two mobile unites under the two side spans as can be seen in figure 4. This temporary situation is an opposite of the final design situation. Continuing strain gauge measurements and topographic measurements were carried out on both the deck and the cables during the whole operation.