Upgrading mainland Europe's oldest suspension bridge

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Summary

In the beginning of the 19th century mainland Europe witnesses the construction of its first suspension bridges. The advent of two World Wars blew up or bombarded most of the strategic ones. Therefore the history of mainland Europe's suspension bridges can mainly be illustrated by decorative bridges in private parks. This preliminary structural study looks at restoration and strengthening methods to make the 20.5m span Wissekerke bridge, mainland Europe oldest suspension bridge, comply with current concepts of safety. Due to ill-maintenance and deterioration over decades as well as a function shift (from private to public use), the bridge does not fulfil current European norms for pedestrian bridge design. A strengthening strategy is discussed that targets maximum public use, optimal preservation, least visual impact, easy future maintenance and durability. This design preserves and restores all authentic elements (such as cast iron masts, wrought iron suspension chain, back stay and railing) and replaces the structurally inadequate non authentic deck structure with a shallow barely visible steel box girder. This girder carries its own and superimposed dead load as well as all the variable loads. It is designed to guarantee appropriate dynamic behavior. The authentic suspension structure is connected to the girder through a series of vertically and longitudinally sliding connections. These connections avoid load transfer from the new structure (girder) to the authentic structure (suspension system).

Keywords: suspension bridge, strengthening strategy, iron, preservation, renovation, dynamic, sliding connection

1. Introduction

The iron suspension bridge of the Wissekerke castle in Kruibeke-Bazel was designed and constructed in 1824 by the Belgian engineer J.B. Vifquain (1789-1854) (Fig. 1). A preliminary restoration and strengthening study was undertaken by the Vrije Universiteit Brussel, Belgium to upgrade this historical private bridge to current valid European public pedestrian bridges codes (EN 1991-2, NBN B03-101).

2. Authentic Structural System

The suspension bridge over the moot of Wissekerke's castle spans 20.5m between the abutments and has a deck width of 2m (Fig. 1). The suspension system is doubled up, entirely symmetrical about its longitudinal axis. The longitudinal stability of the system is guaranteed by a strut and tie configuration fixed to the abutment, the transverse stability by the mast portal frame.

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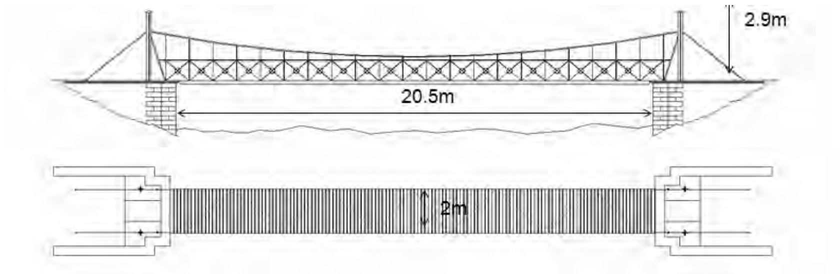

Fig. 1: Elevation and plan of the authentic suspension system and non authentic deck.

3. Strengthening strategy

3.1 Six initial strengthening strategies

Opening the bridge to the public unavoidably involves the creation of an additional structure to carry higher imposed variable loads (500kg/m² according to NBN B03-101 instead of the calculated 10 kg/m²) and exhibit appropriate dynamic behavior (according to NBN B 52-001). Six different strengthening strategies were envisaged: 1. addition of extra supports, 2. of a structure underneath the deck, 3. of a structure within the initial deck's height, 4. of a structure above the deck, 5. strengthening of the suspension chain and 6. strengthening with cable stays. The addition of shallow box girder in the bridge deck height turns out to be the most positive strengthening strategy.

3.2 Strengthening the bridge

In order to increase the bearing capacity, to limit deflection and to obtain appropriate dynamic behavior the inauthentic deck and substructure are replaced by one single symmetric steel box girder fixed to the abutments with a new timber deck. The girder is connected at its sides to the authentic suspension structure through sliding connections. Since this structure is warped due to settling abutments, it will not be taken apart but restored (i.e. sand-blasted and repainted in the initial colors) and renovated where needed.The girder's cross-section has a maximum central height of 500mm and tapers to its sides to 180mm (i.e. the authentic height of the timber side board).

3.3 Dynamic behavior and deflection of the shallow box girder

Since the box girder is extremely shallow (maximum height is 500mm over 20.5m) the main design criterion is its dynamic behavior. The own frequency of the bridge is found to be 5.7Hz (>5 Hz). This frequency is outside the danger zone. To limit deflection the girder is 10*mm* pre-cambered.

3.4 Connection between the authentic structure and the new girder and railing design

At the vertical sides of the girder the authentic suspension structure and the new girder are connected through sliding connections (in the vertical and longitudinal direction) allowing no load transfer between the two. Computational analysis showed that every other type of connection (e.g. hinged or fixed) between the authentic and new structure transfers a portion of the variable loads into the suspension structure, resulting in iron stresses exceeding allowable limit values ($670N/mm^2 > 200N/mm^2$ ULS). An additional hand rail is designed to satisfy the stability and safety requirements.

4. Conclusion

The preliminary design study for upgrading the Wissekerke suspension bridge to a public pedestrian bridge fulfilling current European has successfully achieved maximum public use (upgrade to public bridge), optimal preservation (restoration of all authentic elements), least visual impact (shallow grey box girder), easy future maintenance and durability (closed box girder).