Lightweight reinforcement systems for orthotropic bridge decks

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Summary

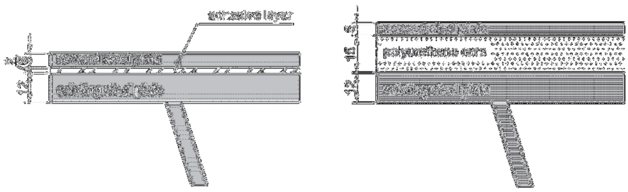
Two systems for reinforcing orthotropic bridge deck (OBD) have been researched: the bonded steel plates system and the sandwich steel plates system. The main idea of these type of reinforcement is to stiffen the existing deck plate, thereby reducing the stresses at the fatigue sensitive details, and thus extending the fatigue life of the OBD. Both reinforcement systems consist of adding a second steel plate to the existing steel deck. The behaviour and the effect of the reinforcement systems on full-scale OBD are investigated. Full-scale static tests and finite element analyses were performed on the reinforced deck panels, using realistic wheel loads. The results showed at least 40% of stress reduction close to the fatigue sensitive details after applying both reinforcements. The two suggested reinforcement systems showed a good performance and proved to be efficient lightweight solutions to refurbish orthotropic bridge decks and extend their life span.

Keywords: bridges, reinforcement, refurbishment, sandwich structures, adhesive bonding.

1. Introduction

Fatigue is a well-known phenomenon in orthotropic bridge decks (OBD). Several welded details turn out to be extremely sensitive to fatigue loading and shorten drastically the expected life span of OBDs. The main idea of the reinforcement approach is to stiffen the existing deck plate, thereby reducing the stresses at fatigue sensitive details, and extending the fatigue life of the OBD.

The research presented in this paper is focused on two lightweight solutions for strengthening OBD: the bonded steel plates system and the sandwich steel plate system (see Figure 1). In the former, a 6 mm thick second steel plate is bonded to the existing deck by vacuum infusing a 2 mm thick adhesive layer between the two steel plates (the existing deck plate and the second steel plate). In the sandwich steel plate system, the existing deck is reinforced by adding a sandwich overlay that is composed of a 15 mm thick polyurethane core and 5 mm thick second steel plate.



a) Bonded steel plates *b) Sandwich steel plates*

Fig. 1 – Lightweight reinforcement systems (dimensions in mm).

In this paper, the effect and the behaviour of the bonded and sandwich steel plates reinforcement systems applied on full-scale orthotropic bridge decks is investigated. The main goal is to determine the stress reduction at the fatigue sensitive welds when the reinforced OBD is loaded by realistic wheel prints.

2. Experiments and numerical simulations

Two orthotropic deck-panels were built in order to perform full-scale static tests. One was reinforced using the bonded steel plates system and the second one using the sandwich steel plates system. Figure 2 shows the geometry of the OBD specimens.

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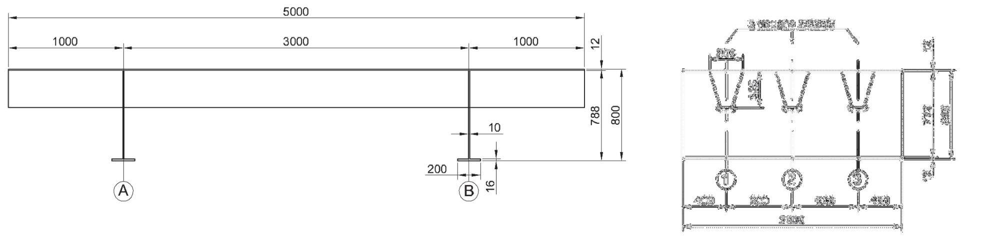


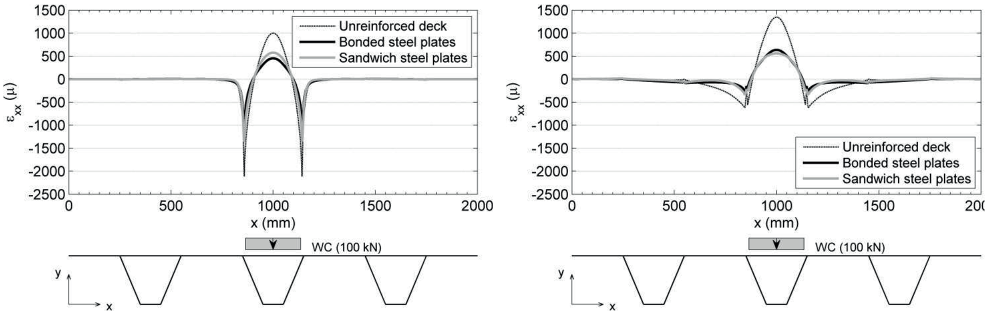
(a) Longitudinal view *(b) Transverse view*

Fig. 2- Geometry of the orthotropic steel deck specimens (dimensions in mm).

Static tests were performed at the crossbeam cross-sections and at midspan between crossbeams. The specimens were loaded with wheel prints type B (double-tyre) and type C (super single), in accordance with EN-standard fatigue load models. Strain gauges were applied to the existing steel decks to measure the strain values during testing and validated the numerical simulations. Finite element analysis (FEA) were performed in order to simulate the full-scale static tests and determine the stress distribution in the bridge decks and in the reinforcement systems during testing. The numerical simulations were validated with the experimental results.

3. Results

Figure 3 shows the transverse strain distribution at the bottom side of the deck plate given by the FEA of the unreinforced deck, bonded steel plates reinforced deck and sandwich steel plates reinforced deck. The wheel load is 100 kN and the wheel print is type C. Results show that the transverse strains decrease significantly after the reinforcement both close to the deck-plate-to-stiffener welds and at the deck plate between the stiffener webs, at the crossbeam as well as at midspan between crossbeams.



(a) Crossbeam cross-section. *(b) Midspan between crossbeams.*

Fig. 3 – Transverse strains ε_{xx} at the bottom side of the deck plate (FEA).

4. Conclusions

The transverse strains close to the fatigue sensitive welds decrease approximately 45% to 60% at the crossbeam and 60% to 80% at midspan between crossbeams, after applying the bonded steel plates reinforcement system. After applying the sandwich steel plates reinforcement system, the strains were reduced by at least 40% at the crossbeam location and by at least 50% at midspan between crossbeams. The suggested reinforcement systems showed a good performance and proved to be efficient lightweight solutions to refurbish orthotropic bridge decks and extend their life span.