Reinforcing concrete box girder bridges with external post-tensioning and steel

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Summary

The webs of the box girders of the Lower Rhine Bridge at Heteren (The Netherlands) have insufficient shear resistance. The bridge needed to be reinforced by introducing a vertical, upward force into the bridge a short distance from the bearing. An unique structure was designed for this purpose, using external post-tensioning applied to the bridge at an angle of approximately 32 degrees. A steel structure was attached under the bridge which bears the vertical and horizontal forces that are released. The reactive forces in the bridge are redirected to the abutments by means of a steel deviator. The reinforcement was successfully implemented as described and was completed in 2010.

Keywords: post-tensioning; box girder bridge, transverse reinforcement, post-tensioning, strand, bearing, concrete, steel.

1. Introduction

The bridge across the Lower Rhine at Heteren, built between 1968 and 1971, is part of the A50 motorway between the Grijsoord and Valburg junctions. This section of the motorway was planned to be widened from two to three lanes. The wider motorway would lead to an increase in traffic intensity, thus also increasing the traffic load on the bridge.

During inspections, significant cracks were noted in the outer and middle webs of the box girder bridge, at the location of the abutment bearings. Recalculations made it possible to trace how the cracks occurred. The transverse force test for the bearings significantly exceeded acceptable limits. These cracks were clearly visible to the naked eye and ran across the entire body at a 45-degree angle.

In the reinforcement measure that was selected, a vertical force was introduced into the concrete box girder bridge against the bridge on both sides of the bearing, at a distance of 5975 mm. This was achieved by applying external post-tensioning in the concrete box girder structure. The external post-tensioning would have to be directed into the box girder structure at an angle of approx. 32 degrees. Further details were requested on how the proposed solution would absorb the vertical, upward force and the horizontal forces and transfer them to the structure from the external post-tensioning. The vertical load should be absorbed in the webs of the box girder structure. The horizontal forces were not necessary for reinforcement purposes; rather, they were a consequence of the chosen solution. A more detailed design solution needed to be found for this aspect. A downward vertical force resulted at the cross-girder of the intermediate bearing as a result of the balanced forces.

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2. Design

The new design offered many more advantages than the reference design. The design used post-tensioning cables that entered the bridge at an average angle of 32,1 degrees. The horizontal force released was absorbed by a steel structure suspended under the floor. The vertical force released was transferred to the main structure via the steel structure and the bearings. These bearings were positioned under the side walls of the box girder bridge. Holes were drilled in the floor of the box girder bridge at an angle of 32,1 degree, large enough to accommodate the post-tensioning cables. The post-tensioning cables were bent at the cross-girder by a steel structure: the deviator. As a result, the deviator transferred its reactive force directly to the bearings of the bridge structure. The advantage is that no unintended forces could reach the floor and cross-girder of the bridge.

15-strand 0.6 post-tensioning cables were used (surface 15 x 250 = 2250 mm2) with flattened strands. This post-tensioning system does not use anchorages; the strand is in an HDPE sheath and coated in grease. The post-tensioning force needed per strand during tensioning is approx. 212 kN. These post-tensioning cables were chosen based on a life-sized test setup of the reinforcement structure. The post-tensioning cables should bend at the cross-girder, without damaging the HDPE sheath, since that protects the strand from corrosion. Post-tensioning cables without anchorages are used frequently in practice, but not with a bend of this type. The test setup primarily focused on the curve of the saddle at the bend. Variations were tried using different deviators, types and thicknesses of bearing materials and type of post-tensioning strand. The sheaths of the post-tensioning cables were then inspected for possible damage.

The conclusion was that the combination of a deflection radius of 600 mm, nylon felt and flattened strands does not damage the HDPE duct. Another type of strand, which is simply twisted, places more local pressure on the HPDE sheath due to the tight radius of the bend, causing damage to the sheath. The forces are distributed more evenly when flattened strands are used.

The transverse steel HE beam was a continuous beam overlaying three bearings; each field is 5175 mm long. The post-tensioning force was anchored at a distance of 1350 mm from the heart of the outer bearings. This directed approx. 38% of the vertical force for each field to the central wall of the box girder bridge and 62% to the side wall.

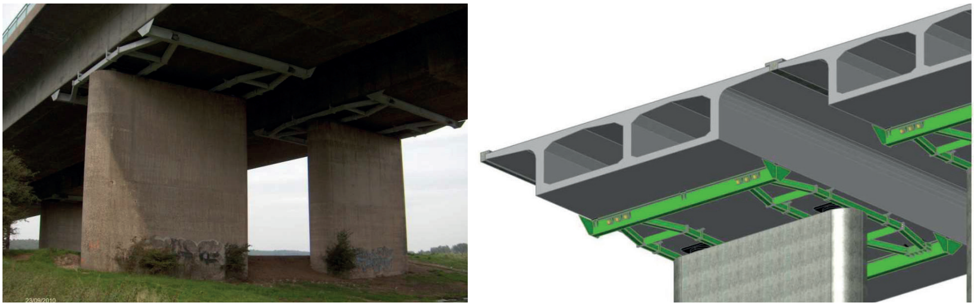

Fig: Reinforcement structure under bridge

3. Conclusion

The reinforcement of concrete box girder bridges with transverse force problems is feasible with external post-tensioning cables in combination with a steel structure. It can be stated that the solution is an innovative design that improved on various aspects of the reference design.

4. Acknowledgement

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