Bridge rehabilitation with a specific composite deck construction

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Richard GREINER
Professor
Technical University Graz
Graz, Austria

Robert OFNER
Dr techn.
Technical University Graz
Graz, Austria

Karl KERNBICHLER
Professor
Technical University Graz
Graz, Austria

Harald UNTERWEGER
Assistant
Technical University Graz
Graz, Austria

Summary

This paper reports on experimental and numerical investigations on the local-carrying behaviour of a composite deck consisting of a reinforced concrete slab and an orthotropic steel deck. This deck construction was used for the rehabilitation of a major motorway bridge of a transit route in Austria.

Abstract

The motorway bridge near Salzburg in Austria on the North-South transit route is one of the most heavily loaded road-bridges of this area. Up to the average of 7000 trucks daily and about 200 special vehicles of 150 to 240 tons a year the load impact on the traffic deck has been continuously increasing. The steel bridge in form of a 'middle arch structure' was built as the first example of this type of structural system in 1970. It is a structure with a bow string arch in the centerline with a span of 133 m and the traffic deck projecting to both sides over 15 m each (Fig. 1).

The deck construction is an orthotropic steel deck with an asphalt layer on it and covered by a concrete surface. As result of the highly increased impact of the traffic load compared to the construction time the deck surface has been damaged in form of cracks in the concrete slab, which allowed penetration of water, seriously impairing the consistency of the asphalt layer.

The rehabilitation of the traffic deck was based on the idea of rearranging the two layers on top of the orthotropic deck, the first now being the reinforced concrete slab (t=140 mm) and the second the asphalt surface (t=80 mm). The concrete slab could now be connected with the orthotropic steel deck by stud bolts resulting in a composite action.

In this composite construction the two plates of very different stiffness have to work together; the concrete plate should distribute the local traffic loads and the orthotropic steel plate should transfer them to the main girders.

For a realistic basis of design experimental and numerical investigations were performed. The tests were performed by models which represent a cut out of the traffic deck in the scale 1:1. The boundary conditions were adapted to the global plate behaviour of the deck construction by specific support girders. Fig. 2 illustrates the test model and the constructional details of the composite deck. The test loading was defined by local wheel-loads, which were derived from the load models given by EC1-2. The dominating local load resulted in the wheel-load of 200 kN acting on the base area of 40·40 cm. The test loading was carried out statically as well as dynamically up to $3 \cdot 10^6$ load cycles for ΔP=140 kN. Vertical deformations of the deck surface, differential deformations between the horizontal planes of steel plate and concrete slab as well as strains of the steel ribs were measured.

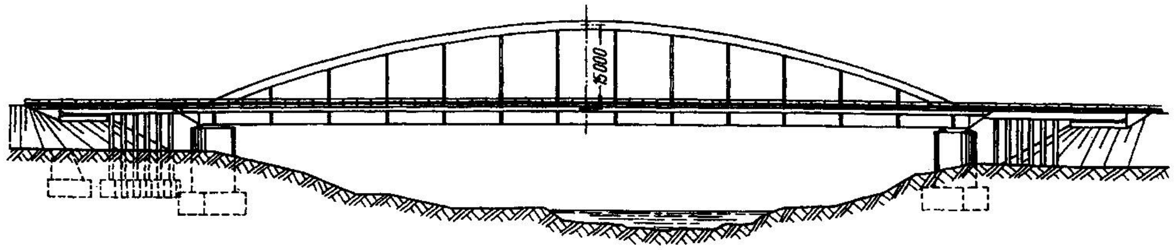

Fig. 1 Structural system of the motorway bridge near Salzburg

For reason of comparison the test-loadcases were also numerically calculated. The structural steel components were modelled by means of shell- and beam finite elements. The concrete slab was represented by shell elements and a material model, which accounts for the specific behaviour of concrete and reinforcement. The composite action between the concrete slab and the steel deck was investigated by various assumptions, i.e. discrete shear studs of different stiffness, continuous rigid composite action or pure contact without any composite action.

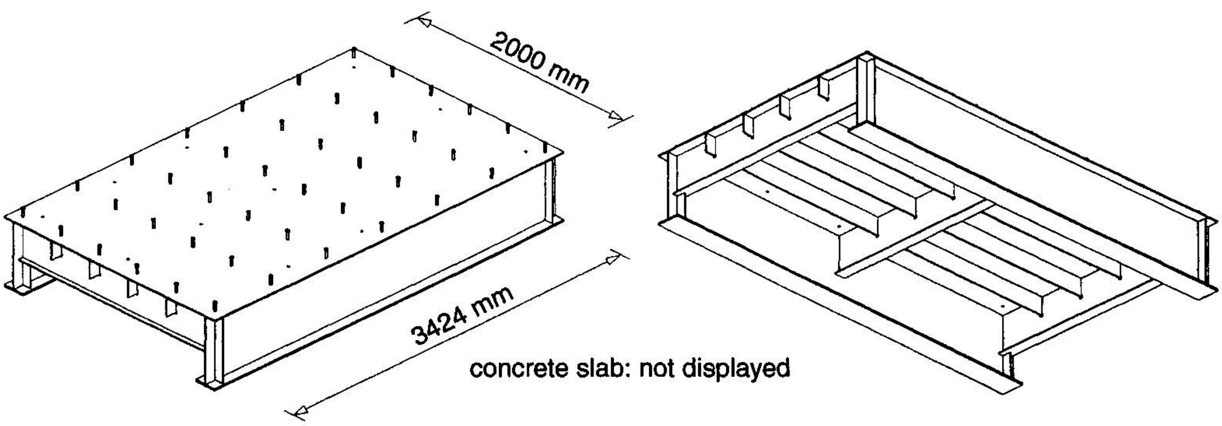

Fig. 2 Local test model

Four test models were investigated. Test model (1) and (2) differ in its strength class of the concrete. The results show that the effect of the two concrete classes is practically insignificant. The tests further verified that the fatigue effect in the composite action due to about $3 \cdot 10^6$ load cycles was very low, resulting in an increase of deformation up to about 10% only. Among the numerically investigated alternatives the closest accordance with the test results was obtained for the assumption of rigid composite action. Further to the tests with the EC-load model 2 increased load steps were investigated up to 980 kN. At the load step 740 kN the test indicated acoustically as well as by a jump of the differential deformation between concrete plate and steel deck that the adhesive strength in the contact plane had been exceeded.

Test model (3) was carried out without a regular composite action, i.e. without the action of shear studs and adhesive strength. The beneficial effect of the composite action on the load carrying behaviour could be evaluated by comparison with test model (2). The maximum deformations and stresses for 200 kN differ by a factor of approximately 2.

Test model (4) was carried out for the pure steel deck without a concrete slab; it indicated that the steel deck without concrete slab would significantly be overstressed.

The investigations resulted in fairly good accordance between test and numerical analysis and indicated that the composite construction presents a robust load carrying behaviour for the high local traffic load of EC1. The rehabilitation of the motorway-bridge accordingly was carried out in this way.