Testing of continuous shear connector

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Abstract. Composite steel-concrete bridges are one of the most recent additions to the bridge science. By joining the two of the most commonly used materials it is possible to use their strengths combined. This was firstly presented for composite ceilings. It was assembled by encasing the whole I-beams into the concrete deck. Nowadays, it can also be used for short span railway bridges. Ongoing research at Technical University of Košice (TUKE), Faculty of Civil Engineering, is currently trying to prove the unnecessity of usage of the entire I-beam as well as the entire block of concrete by encasing only part of the beam, the so called perforated steel strip, into the concrete.

1. Introduction

There have been several researches investigating this topic. Oguejiofor and Hosain were one of the first researchers to publish studies of ‘perfobond rib shear connectors’ [1]. They performed several tests and compared the results with common headed shear stud connectors, proving the capabilities of the strip connectors. Kim and Jeong considered perfobond ribs welded onto decks, experimentally verifying their effectiveness [2]. In Slovakia, Rovňák et al have done extensive research comparing several geometric possibilities of connectors and adjusting their resistance formulas via regression analysis [3].

2. Geometry

The composite bridges consist of two key elements – steel and concrete. In this paper, the steel part in form of a strip fulfils a function of rigid longitudinal reinforcement.

2.1. Steel Connector

The shear connection is usually secured by friction between the surfaces of steel strip and concrete, as well as by concrete shear studs, which are formed in the holes of the strip. In the new design, developed at Faculty of Civil Engineering (TUKE), there was present an extra connection – via curved reinforcement welded onto the strips wall from both sides.

The continuous shear connector was made out of IPE220 cutted in the middle longitudinally, with 20 mm holes, 300 mm apart from each other. The reinforcement used was of 12 mm diameter and it was welded at the edge of the holes. Every 100mm by length it was kinked in 90° angle, with height of kinked parts equal 50 mm, as visible in figure 1 and 2.

2.2. Concrete beam

Steel-concrete composite bridges containing continuous shear connector are usually entirely or partially prefabricated. For this reason any changes in basic rectangle cross-section do not complicate the bridge construction, which makes it easy to remove the unnecessary parts of the concrete – the ones, where tension is present. The new, lightweight, cross-section is portrayed in figure 3. The beam prepared for experiments (figure 2) was 6 m long.
3. Material

Yield point of the steel was found out to be 315.3 MPa, via tensile tests performed by Faculty of Metallurgy, TUKE. Concrete was tested for Young’s Modulus, tensile and compressive strength at Laboratory of Excellent Research, TUKE. The results were 33 GPa, 3.7 MPa and 39.7 MPa, respectively. The reinforcement used was label as B500 B of which normative yield strength is 500 MPa [4].

4. Experiments

In order to determine the resistance of the composite bridge containing this type of shear connector, several experiments had to be performed. Each test was executed onto three specimens, to exclude the statistical error.

4.1. Push-out test

To find out the shear resistance of the shear connector, push-out tests (POT) had to be carried out. For the POT, the strip had to be turned into vertical position and poured into concrete block with 10mm layer of polystyrene between the two materials, as depicted in figure 4. This way the extrusion of steel
into concrete was prevented and only shear force was taken into account. The searched values were measured by hydraulic press software (as input data) and inductive displacement sensors.

4.2. Four-point flexural test
One of the most important internal forces in bridges is bending force. To prove the suitability of the connector for bridge usage, the four-point flexural test had to be executed. Its basic layout are two supporting points at the both ends of the beam and two points of loading, distance of which is \( \frac{1}{2} \) of beam length. This way, the beam had to face to maximum bending stress. To measure the searched values the same instruments were used as for POT, plus strain gauges attached to the steel strip, as visible in figure 2.

5. Results

5.1. Push-out test
Four specimens were made for the testing. First tests were manually stopped after reaching the searched value even though the specimens were not broken due to the first intention of the research being only the resistance value (see figure 6).

The estimated shear resistance was established as 889.67 kN [5]. The real shear resistance – determined at the end of the first, linear, section of the diagram (see figure 7), after which the increase of the slip was higher than the increase of the load and diagram passed to its horizontal part – was 1125 kN. The ratio between the estimated and real resistance was 1.26, which proved the safe usage of the formula.

The failure of the specimens occurred in concrete parts, where visible cracks were observed. They demarcated the concrete failure area, which is highlighted in the figure 9.

![Figure 6. Push-out tests results.](image)

![Figure 7. Diagram dependence of load onto the slip.](image)

5.2. Four-point flexural test
The four-point flexural test resulted with bending resistance equal 370 kN. At the course of the first part of the loading, two cycles were executed in which the specimens were unloaded from 210 to 50 kN and 350 to 150 kN and back (see figure 8). The cracks developed during loading at the sides of the beam closed almost entirely and the displacement of the specimen lowered nearly to its original value, which demonstrated the elastic behaviour of the specimen.

The test was stopped at 440 kN, after which the specimen was unloaded in three loading conditions. The deformation of the beam dropped about approximately 50 mm which suggests that the specimen was still in its plastic-elastic part and the plasticization did not occur. Although after the testing the specimen was not completely damaged and it had some elastic behaviour, there were still several cracks remaining, with the maximum width of 0.45 mm (see figure 10).
Figure 8. Four-point flexural tests results.

Figure 9. Concrete failure area after push-out test.

Figure 10. Cracks originated from four-point flexural test.

6. Conclusion
The resistance of the continuous shear connector with welded curved reinforcement was determined. For application in practice, the fatigue tests as well as long-term tests have to be provided.
7. References
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