Research on Assessment and reinforcement of bridge structures

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Summary

The experiment results given in the paper show that effective strengthening of bridge structural elements can be achieved by using advanced fibre composite systems. The theoretical study indicates that the current design methods are quite conservative. Based on finite element modelling new approaches are investigated experimentally and theoretically.

Keywords: bridge structure, retrofitting, post-tensioning; fibber reinforced polymers, testing.

1. Introduction

The bridges on road and railway networks were built at different periods. Thus, they are designed according to knowledge at the time of building, concerning moving loads, which reflected the state of transport technology. Moreover, load carrying capacity can be further reduced by member deficiencies including cracking, wearing or abrasion [1]. The recent technologies by means of fiber reinforced polymers materials (FRP) have become well-liked in the construction industry over the last few years. In comparison to the traditional methods, the FRP elements do not require much space because they are very thin. The results of the field as well as laboratory investigations of strengthening beams using this technology are presented in the paper.

2. Field investigation of bridge strengthening using FRP reinforcement

This strengthening procedure was applied to a 45° skew prestressed concrete bridge structure with two continuous spans of 26,0 m and 26,5 m. The T-beam structure consisted of a transversely reinforced slab deck, which spanned between the longitudinal support girders, having a construction depth of 2,05 m. The girder stem thickness was 0,5 m and lateral spacing 2,5 m. Reductions in dead load were obtained by removing the existing heavier concrete slab and replacing it with a lightweight cast in place concrete one acting compositely with girders. Further three 100 mm large and 3 mm thick carbon fibre-reinforced polymer (CFRP) sheets have been applied to strengthen the bridge concrete girders in the tension zones. Stress and deflection distributions indicated that the numerical model has provided results reasonably close to the measured values at certain location of spans and satisfying given criteria of the relevant code [2]. However, bridge testing has determined the live-load capacities considerably larger than derived from the analytical procedure, because it has made possible to take into account several contributions that could not be usually included analytically.

3. Theoretical study of strengthen reinforced structures

In our investigation, the beams of 1/3 scale of the existing reinforced concrete (RC) bridge have been considered. Initially, the non-strengthened beam model has been considered. After that, the effect of reinforcement with FRP has been studied.

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Firstly, the design moment $M_{Rd,0}$ of the ordinary beam has been determined considering the existing geometry, reinforcement and concrete quality by a straightforward design procedure. The required area of lamella and the resisting bending moment of the strengthen girder $M_{Rd,f}$ were derived from the conditions of equilibrium of normal forces and moments, considering the mechanical behaviour of each material. This simple design procedure was implemented in the software named S&P FRP. The value of the limit bending moment of the un-strengthened beam was $M_{Rd,0}$ = 5,06 kNm and corresponding concentrated load $F_{d,max}$ = 5,84 kN. Adding one FRP lamella, the value of the bending moment of the strengthened cross section could be increased to the value of $M_{Rd,f}$ = 8.56 kNm and $F_{d,max}$ = 9,84 kN.
The ATENA software Version 3.2.6 was used for the finite element design modelling, both plane (2D) and space (3D) beam design concepts. According to the Eurocode EN 1992 [3], the mid-span deflection was limited at 1/250 of the beam span, i.e. w_{lim} = 13.88 mm and the bending crack widths were restricted to ω_{lim} = 0.2 mm. These standard criteria were applied for determining of the maximum concentrated force F_{max}, acting on concrete beam specimens. Analysis using plane (2D) finite elements, respecting the above conditions have resulted in the transversal force F_{max}= 7.685kN. After reinforcement by added lamella, the beam bending load carrying capacity has become 1, 49 larger with F_{max}= 11.49 kN, hence indicating the positive effect of strengthening [4],[5]. The alternative, however very time consuming 3D calculations of the beam specimen have produced comparable, but slightly minor values of limit loads. Even, orientation and location of cracks as well as overall configuration are very similar for both plane and space numerical models. The specimens for laboratory investigation were designed as two series with obvious reinforcement as well as CFK sheets. Both specimens have a similar ultimate load of 50 kN. But load bearing capacity was referred to the crack widths less than 0,2 mm with corresponding forces F_{max}= 15 kN. In addition, the dynamic performance of two strengthened specimens was also investigated till 2.10^6 cycles. As the following static loading demonstrated, load bearing capacity was reduced merely, around 2,5%.

4. Conclusions

The behaviour of a reinforced concrete bridge structure strengthened with CFRP was investigated experimentally in-situ as well as in a laboratory. Beside obvious design procedures, most sophisticated finite elements modelling have been used. The comparative study revealed that such models are more capable of obtaining rather realistic prediction of the behaviour of retrofitted structural bridge elements.

5. References

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