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New Life by Post-Tensioning: Rehabilitation of Two Box Girder Bridges

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Summary

In this paper, a rehabilitation project of two box girder bridges is described. The aim of the project was to increase the load capacity of the bridges and, simultaneously, to ensure their durability by filling the cracks and repairing defects. The load capacity was increased by strengthening the bridges by external tendons, the criteria for choosing the tendon forces being to prevent further cracking and growth of the midspan deflection. The construction is shortly described, and the costs of the rehabilitation is compared to the costs of replacing the old bridges by new ones. The chosen solution is found more economical than building new bridges.

Keywords: post-tensioning; external tendons; strengthening; rehabilitation; concrete; bridges

1. Introduction

On the Finnish highway road net, there are about 150 reinforced concrete box girder bridges, which have similar features. These bridges were constructed between 1950 and 1970, at the time when prestressing technology was not widely used in Finland. Murhasaari and Puodinkoski Bridges, which are both of this type, are now chosen for rehabilitation. They are located on the highways 11 and 4, respectively, on parts which belong to the route net for heavy transport in Finland. The both bridges did not meet the requirements set on highway bridges [2,3]. The rehabilitation and improvement of the bridges was accomplished by strengthening them by external post-tensioning and repairing other defects. Post-tensioning was chosen as the strengthening method because of its positive influence to the cracking and deflection behaviour of the bridge superstructure.

2. The bridges before rehabilitation and improvement

The both bridges are three-span continuous reinforced concrete box girder bridges, the height of the girder varying along the span. Originally, a 140 kN axle together with a 30 m long distributed load of 4 kN/m^2 was applied as the design load. On this rehabilitation project, as design load was applied the actual bridge design load [4], which consists of an three-axle vehicle of 630 kN on max. two lanes and a distributed load $q = 3$ kN/m^2. Applying these design load results to a bearing capacity, which covers also the over-heavy loadings. The condition of both bridges was rather similar. Both had visually disturbing deflections and numerous cracks. The conrete surfaces were in relatively good condition. The carbonation depth was found to be only some millimeters in both cases.

3. Rehabilitation and improvement

By choosing the amount of prestress, two different criteria were applied. For Murhasaari Bridge, the amount of prestress and the tendon layout were chosen such way that the bending moment M_P due to prestress force P_∞ equals as accurately as possible the bending moment M_g due to permanent loads. For Puodinkoski Bridge, a criterion for concrete tensile stresses σ_c, which may not exceed the cracking stress σ_r, is applied. Under a quasi-permanent load combination $M_g+M_P+0{,}3M_q$, the whole cross-section is in both cases under compression. At ultimate, the following assumptions were made: 1) the rebars yield; 2) no additional strain of tendon is considered; 3) the compressive stress P_∞/A_c is considered. The permanent midspan deflection of the both bridges was not possible to be eliminated by the chosen prestressing.

Tendons consisting of 12 strands with 0,6" diameter (140 mm^2) was used in both cases. The strands are placed in a plastic duct, which will be injected by cement grout after tensioning. The anchors located at both ends, are of the types normally used for internal, bonded tendons. The works are planned so that at least one lane is on traffic all the time. The works were relatively simple and they were possibly to realise under ongoing traffic.

4. Discussion

The carbonation will probably not reach the level of the reinforcement during the following 70 years. The tendon protection is designed according the same criteria as in new constructions. According to the authors′ knowledge, the 70 years service life should be possible.

The estimated costs of the rehabilitation of the bridges were 500 USD/m^2, which also could be realised at Puodinkoski Bridge. With the assumed service life of 70 years, the annual costs are 19,3 USD/m^2. Replacing the old bridges by new ones would cause costs of 1100 USD/m^2, including demolishing works of the old constructions but excluding the costs of a temporary road connection. Using a service life of 100 years for the new construction, the annual costs will be 37,4 USD/m^2.

5. References

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