Shear Assessment of Reinforced Concrete Slab Bridges

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Summary

The capacity of reinforced concrete solid slab bridges in shear is assessed by comparing the design beam shear resistance to the design value of the applied shear force due to the permanent actions and live loads. Results from experiments on half-scale continuous slab bridges are used to develop a set of recommendations for the assessment of slab bridges in shear. A method is proposed allowing to take the transverse force redistribution in slabs under concentrated loads into account, as well as a horizontal load spreading method for the concentrated loads. For selected cases of existing straight solid slab bridges, a comparison is made between the results based on the shear capacity according to the Dutch Code NEN 6720 and the combination of the Eurocode (EN 1992-1-1:2005) with the new recommendations, showing an improved agreement

Keywords: slab bridges; shear; assessment; live loads; effective width; case studies

1. Introduction

In the Netherlands, a large number of the existing reinforced concrete solid slab bridges have been built before 1975. Since then, the traffic loads and intensity have increased significantly, resulting in the heavier live load models defined in EN 1991-2:2003 [1]. Meanwhile, the shear capacity as prescribed by the codes is more conservative in the recently implemented EN 1992-1-1:2005 [2] than in the previously used NEN 6720 [3]. For that reasons several existing slab bridges do not satisfy the shear criteria anymore. The large number of shear-critical bridges represent a problem that requires a systematic approach. In a preliminary investigation the particular bridges requiring a more detailed analysis need to be identified. For this purpose, a fast, simple and conservative tool is required: the Quick Scan as developed by the Dutch Ministry of Infrastructure and the Environment. The output is a "unity check" value: the ratio between the design value of the applied shear force resulting from the loads (dead loads, superimposed loads and live loads) and the shear resistance. When a slab is loaded by a concentrated load, transverse load redistribution can result in a higher shear capacity. Recently [4] experiments have been carried out to study this mechanism.

2. Loads for assessment

The shear stress at the support results from the action of dead loads and live loads. The live loads are determined based on EN 1991-2:2003 [1] load model 1. Currently, the Eurocode only provides load factors for design and not for assessment. For assessment, the repair level from NEN 8700:2011 [4] is used.

3. Recommendations

Previously it was shown that, when using EN 1992-1-1:2005 [2], the effective width in shear can be determined from load spreading between the far side of the load and the face of the support. This conclusion results from series of experiments on slabs and slab strips, a statistical analysis of all

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slab shear experiments carried out at Delft University of Technology as well as relevant data from the literature and the results from a nonlinear finite element analysis. The minimum effective width to be used in the calculation is found to be $4d_l$. A comparison between the experimental results and the predicted shear capacity according to EN 1992-1-1:2005 [2] results in a 5% lower bound for the enhancement due to transverse load redistribution of at least 1,25. This enhancement factor can be combined with the reduction factor for direct load transfer into $\beta_{new} = a_v/2,5d_l$ for the case of concentrated loads on slabs with $0,5d_l \leq a_v \leq 2,5d_l$. A second series of experiments showed that superposition of the wheel loads distributed over their respective effective width can be combined with the shear stress due to the lane load and dead loads over the entire width. The minimum shear capacity from EN 1992-1-1:2005 [2] can be formulated as a function of f_{yk} in order to take into account the higher shear stress at which flexural failure will govern over shear failure for low strength steel.

4. Improved Quick Scan method

The original Quick Scan method is developed for statically determinate structures, but correction factors from case studies are used for continuous slab bridges. A minimum concrete cube compressive strength of 45MPa can be assumed. The most unfavourable position of the wheel loads is obtained by placing the first axle at $a_v = 2,5d_l$. In the second and third lane, the design truck is placed in such a location that the effective width associated with the first axle reaches up to the edge of the viaduct. Vertical stress redistribution of the wheel loads through the asphalt layer is taken at a 45^o angle, resulting in a fictitious tyre contact area on the concrete surface of 640mm × 640mm. The additional lane load $\Delta q_{load} = (\alpha_{q1} \times 9 \text{ kN/m}^2 - \alpha_{q2} \times 2,5 \text{ kN/m}^2)$ in the first, heavily-loaded lane is distributed to the mid-depth position of the cross-section ($d_l/2$).

5. Case studies

Case studies of 9 existing solid slab bridges having insignificant skew angles, with at least 3 spans and an (almost) constant cross-sectional depth are checked at minimum 3 different cross-sections with NEN 6720 [3] and EN 1992-1-1:2005 and the recommendations. The smallest resulting shear stress at the support is found when using the recommendations. The shear capacity from EN 1992-1-1:2005 [2] is found to be more conservative, especially for sections with a low percentage of longitudinal reinforcement and thick cross-sections. As a result of the smaller shear stress, however, the improved Quick Scan indicates less sections requiring a more detailed analysis, and has thus led to an improvement of the assessment practice.

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