Residual shear capacity of 50 years old RC solid slab bridge decks

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Summary

The paper presents a research program dealing with the shear capacity of existing solid slab bridge decks without shear reinforcement. The widely applied design formula in Eurocode regarding beam structures without shear reinforcement is evaluated as a reference. The research program is subdivided into several test series. The research topics include choice of the concrete strength for the evaluation of existing structures, the influence of structural boundary conditions, and the shear failure criterion to be considered. It is concluded that the shear capacity of existing structures can be based on the actual concrete strength derived from core sample tests; for continuous beams, the shear capacity is better defined by the shear slenderness given by the maximum *M/Vd* in the shear span than by the *a/d* ratio; the inclined cracking load V_{cr} is a more robust failure criteria than the ultimate shear load V_u.

Keywords: Shear capacity, no shear reinforcement, inclined cracking load, existing concrete structures

1. Introduction

A substantial amount of the bridges in the Netherlands is constructed in the 1960s and 1970s. Since then the traffic load has been increased enormously, on the other hand, the design methods have been improved significantly as well. Based on that consideration, the Dutch ministry of Infrastructure and the Environment started a survey to evaluate the residual bearing capacity of the bridges in the highway network. A large portion of those bridges are constructed before 1970, among that, 40% are solid slab bridges. As a part of the project, the residual shear capacity of reinforced concrete solid slab bridges is concerned. The decks of this type of structures usually have no shear reinforcement. Therefore, these structures are vulnerable to brittle shear failure when the load is close to the support. The survey showed that a large percentage of these bridges did not pass the Unity Check based on the current Eurocode 2 (ratio between design load and calculated capacity). This generates serious concerns on the public safety. On the other hand it is really costly to strengthen or replace these structures. However, it is believed that the actual shear capacity of those bridge decks is higher than what is predicted by the current design codes. In this paper the shear formula given in Eurocode [1] dealing with concrete beams or beam like structures without shear reinforcement is used as reference. The research aimed at improving the shear design with respect to the following aspects.

2. Concrete strength of existing structures

To evaluate the shear capacity of concrete structure without shear reinforcement accurately, proper concrete strength shall be adapted. Core samples drilled from existing structures show the actual compressive strength of the concrete is often much higher than the design strength when the bridge was built. This would also yield a higher shear capacity according to the current design codes such as Eurocode. However, the tensile strength from direct tension tests on the samples are reported to be 50% lower compared to what is normally expected for the actual compressive strength, although the splitting tensile strength showed the same relation to the compressive strength. Thus it is argued that whether the actual compressive strength of the old concrete can be used to check the shear capacity of the bridge deck, or is the direct tensile strength more suitable? Higher concrete strength

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will certainly yield higher structural capacity accordingly.

A test series of 6 shear tests on 50 years old concrete beams sawn from an existing slab bridge (Gestelsestraat Bridge, Eindhoven, the Netherlands) were executed. Thanks to the contractor Heymans, who give the opportunity to saw these beams from the slab bridge. The specimens were simply supported and loaded by single point load. The test results were compared with 6 reference test results of newly casted specimens with similar configurations and loading conditions. Besides, additional 9 tests on old concrete beams with more complex boundary conditions were executed. The results showed that the shear capacity of existing reinforced concrete beams without shear reinforcement can be safely evaluated with the concrete strength derived from compressive tests on drilled core samples.

3. Failure criterion

Often, large scatter is observed on the results of shear tests on specimens with small shear span *a* in literature. This may due to the mix of two different failure modes (flexural shear failure or shear compression failure). It is found in the experimental program that the transition of both failure modes can be easily influenced by facts such as the existence of flexural cracks caused by other load conditions. On the other hand, in both failure modes, inclined cracks always develop. The load level at which the inclined crack developed turns out to be more converge than the ultimate capacity at the same boundary condition. This load level is thus defined as inclined crack load. Although from the tests, higher ultimate capacity of the specimens may be expected, because of the uncertainty on how much the ultimate load can be increased after the inclined cracking load, the inclined cracking load should be used for design purpose.

4. Influence of boundary conditions

In general, a large percentage of experimental research related to the shear capacity of beams is carried out on simply supported structures. The design formulas based on the same batch of results do not take into account any other boundary conditions. However most of the bridges in reality are actually continuous supported and loaded by more complex loading conditions. The moment distribution will influence the development of flexural cracks. In case of shear failure the diagonal cracks are mostly developed from the already present flexural cracks. Therefore, the development of flexural cracks may influence the shear capacity of a structure significantly.

A series of 35 tests with different boundary conditions was executed. The test results are compared with the Eurocode prediction. The influence of the moment distribution is taken into account implicitly by the load reduction factor β in Eurocode. However, the comparison shows that with respect to continuous beams, by replacing $\beta = a_v/2d$ with $\beta^* = M/2Vd$, the Eurocode prediction is much closer to the test results. It is suggested that if the value of maximum *M/Vd* is smaller than 2,0 in the shear span, the shear force required to open an inclined crack can be increased by the factor $\beta^* = M/2Vd$. With the proposed adoption, the average difference between the individual results and the Eurocode prediction is about 11%.

5. Conclusions

This paper presents a research program dealing with the shear capacity of existing solid slab bridge decks without shear reinforcement. It is emphasized on the widely applied Eurocode formula when evaluating this type of structures. Several useful conclusions relating to design practice were derived from the test results.

Reference

[1] EUROCODE 2, *NEN-EN 1992-1-1 Design of Concrete Structures: General Rules and Rules for Buildings*. 2004. pp. 229.