Shear Capacity of Bridge Deck Cantilever Slabs without Shear Reinforcement

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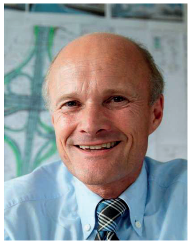

Summary

Rising traffic loads have increased the requirements for the load-carrying capacity of bridges significantly. Furthermore, German design code rules have changed during the last decades reducing the calculated shear capacities of reinforced concrete members without shear reinforcement. Therefore, the calculated shear capacity of many existing bridge deck slabs without shear reinforcement is not sufficient according to the present design rules. These deficits are demonstrated by means of a design example. Since shear failure and excessive crack formation have not been observed in existing bridges to date, the bridges are evidently able to carry the increased traffic loads. The shear capacity of reinforced concrete slabs without shear reinforcement has therefore been investigated at the Institute of Structural Concrete at RWTH Aachen University and a modified approach for the effective width for shear of cantilever slabs is proposed.

Keywords: shear, bridge deck cantilever slab, reinforced concrete, effective width, haunched slab.

1. Introduction

Most bridges in the old West German states were built between 1965 and 1985, making assessment, maintenance and refurbishment of the existing network increasingly important. Most existing bridge deck slabs were designed without shear reinforcement according to former design codes. In contrast, current design codes require shear reinforcement in many cases. Hence, a large number of existing concrete bridge deck slabs in Germany is deficient according to current design codes. In the full paper, the development of design rules in bridge engineering concerning the load models and the shear capacity of slabs without shear reinforcement is presented. Particular attention is payed to the effective width for shear and the influence of flexure on the shear capacity.

2. Comparison of design methods and evaluation of shear tests

In practical dimensioning of bridge deck slabs, the effective width for shear is determined according to book 240 of the German Committee for Structural Concrete (b_{b240}), calculated under consideration of a load spreading under 45° ($b_{45°}$) or approximated by linear-elastic finite element calculations (b_{le}). In members with variable height, the vertical components of the tension and compression forces may be taken into account in shear design. For bridge deck cantilever slabs with an inclined compression zone, the shear forces are reduced by the vertical component V_{ccd} of the compression force. The application of V_{ccd} for members without shear reinforcement could not yet be verified by experimental investigations. Experimental investigations showed that the application of flexural loads resulted always – regardless of whether the cantilever slab was haunched or not - in a higher shear resistance. Hence, the reduction by V_{ccd} exclusively for haunched members does not accurately capture the influence of flexural loads on the shear resistance. Based on tests results, an approach to determine the effective width for shear b_{le}, which was derived by linear-elastic finite element calculations, was revised to account the influence of flexural loads. In Fig. 1 experimental and calculated mean shear capacities are compared for various combinations of design locations and effective widths.

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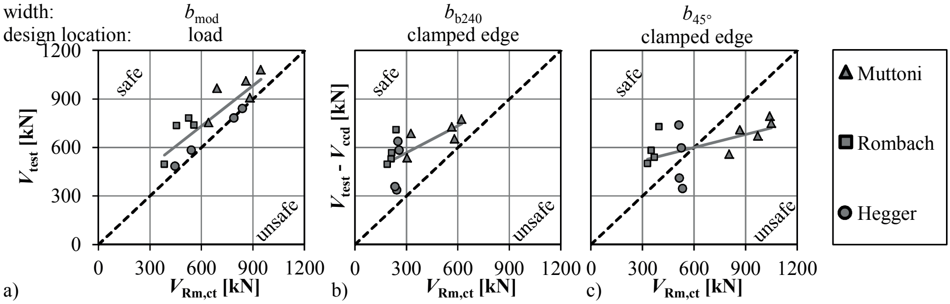

Fig. 1: Comparison between experimental and calculated shear capacities for various effective widths and design locations

The application of the proposed effective width b_{mod} with the critical design location at the load and without additional consideration of V_{ccd} (Fig. 1-a) gives a far better correlation with the test results than the effective widths b_{b240} and $b_{45°}$ with the design location at the clamped edge and including the reduction by V_{ccd}, as it is usual in design practice (Fig. 1-b and -c). In contrast to the safe design considering the effective widths b_{mod} and b_{b240} (Fig. 1-a and -b), the assumption of the critical design location at the clamped edge of the cantilever slab in combination with $b_{45°}$ may lead to an unsafe design, if the reduction by V_{ccd} is also included (Fig. 1-c).

3. Design example and conclusions

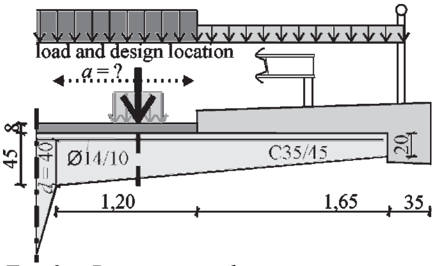

Fig. 2: Design example

For the shear design of haunched bridge deck cantilever slabs, the critical wheel load position and the critical design location have to be determined, considering:

- the influence of the shear span on the effective width,
- the reduction of concentrated loads close to supports with the factor β,
- the varying shear forces due to area loads,
- the reduction by the vertical component V_{ccd} of the compression force, and
- the dependence of the calculated shear capacity on the effective depth.

According to former design rules (DIN 1072 and DIN 1045 before 2001), no shear reinforcement was required for the shown design example in Fig. 2. Under consideration of β, the biggest distributed applied shear forces are obtained when the wheel load is positioned at the distance from the clamped edge, that describes the limitation for the use of β. At this critical design location, the applied shear forces reduced by v_{ccd} in accordance with the current design codes and using the effective width b_{b240} according to book 240 of the German Committee for Structural Concrete are greater than the allowable shear forces leading to the requirement of shear reinforcement. In contrast, using the proposed approach with b_{mod}, no shear reinforcement is required. As the bridge deck cantilever slab in the example features similar dimensions and support conditions as used for the derivation and verification of b_{mod}, the proposed approach seems to be appropriate and the requirement of shear reinforcement by the current code provisions using b_{b240} seems to be too conservative. Since the data bases to verify new approaches are limited, additional research is required to further validate the proposed approach.

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