Concrete Slabs under a Combination of Loads in Shear

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Summary

Previous experimental research at Delft University of Technology indicated an increased shear capacity of slabs under concentrated loads as a function of decreasing distance to the adjacent line support. Expressions have been derived for this increase, including the definition of an appropriate effective width. However, it is unknown if the uniformly distributed loads on solid slab bridges, e.g. due to dead loads, that act over the full width can be combined with the effects of concentrated loads acting only over the associated effective width at the support. To study this problem, additional experiments have been carried out at Delft University of Technology, in which a combination of loads consisting of a concentrated load close to the support and a line load over the full slab width are applied. The experimental results prove that the superposition principle applies to combinations of concentrated loads and distributed loads.

Keywords: slab bridges; shear; experimental research; effective width; tests; reinforced concrete; live loads; superposition

1. Introduction

As a result of the increased traffic loads and intensity over the past decades, the live loads prescribed by the current codes such as the recently implemented EN 1991-2:2003 [1] result in higher shear stresses at the support. These shear stresses can be higher than the shear stresses for which existing structures have been designed. At the same time, the requirements for shear in reinforced concrete as prescribed by EN 1992-1-1:2005 [2] are more conservative than the provisions from the former Dutch national code NEN 6720 [3]. These evolutions in the codes resulted in a number of existing bridges becoming shear-critical when assessed according to the governing codes. To better understand the behaviour of these structures in shear, an extensive research programme was carried out in the Netherlands. One of the aspects studied in this programme is the shear capacity of reinforced concrete slabs under concentrated loads, in which an increase of the shear capacity resulting from transverse load redistribution is expected. In the first series of experiments, a total of 18 slabs and 12 slab strips have been tested under a concentrated load near to the support. The first part of the research resulted in recommendations for slabs under concentrated loads near to the supports [4] and showed three-dimensional behaviour. A second series has been executed recently to verify if the principle of superposition of concentrated loads near to line supports and distributed loads is a correct assumption to be applied in shear design.

2. Hypothesis of superposition

If the hypothesis of superposition is valid, then the sum of the shear stress due to the concentrated load over the effective width τ_{conc} and the shear stress due to the distributed load at failure over the full width τ_{line} should be at least equal to the ultimate shear stress in an experiment with a concentrated load only, $\tau_{tot,cl}$, Fig. 1. For the practice of evaluating the bearing capacity of existing bridges, this principle can be applied to the occurring loads: the wheel load can be distributed per

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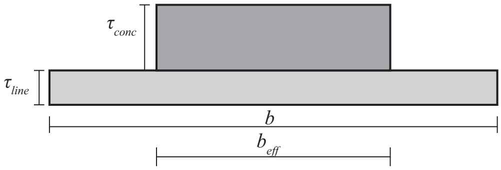

Fig. 1: Superposition of the shear stress due to a concentrated load over the effective width to the distributed load over the full slab width.

axle over the effective width associated with this axle and combined with the contribution of the composite dead load and lane load over the full width of the considered bridge.

The experiments on slabs in shear under a combination of loads are designed such that the shear stress at the support due to the line load corresponds with 50% of the shear stress at failure observed in the slab strips of 0,5m wide under a concentrated load. The resulting ratio of the contribution of the concentrated load and the distributed load to the shear stress at the support more closely resembles the ratio of contributions for the case of a slab bridge under composite dead load and live loads.

3. Experimental setup

A total of 8 slabs have been tested under a concentrated load at a variable distance from the support and under a line load at 1,2m from the support, resulting in 33 experiments. The dimensions of all slabs were 5m × 2,5m × 0,3m and the tests have been carried out at the simple and continuous support. Per support line, 7 bearings (steel or elastomeric) equipped with load cells were used.

4. Results and discussion

Superposition of the contribution of the concentrated load over the effective width and the distributed load over the full width results in conservative results when compared with the experimental results of the failure shear stress in a slab under a concentrated load only.

The shear capacity at the continuous support was measured to be 16% higher than at the simple support. The effective width from the distribution profile of the reaction forces is smaller at the continuous support than at the simple support. The additional capacity at the continuous support can be taken into account by adding the enhancement factor α for the moment distribution in the shear span to the shear capacity from EN 1992-1-1:2005, with:

$$\alpha = \sqrt{\frac{M_1 + M_2}{M_1}} \tag{1}$$

In slabs on flexible supports, a more ductile failure mechanism is observed and shear cracks are visible before the failure load is reached. The experiments do not support the provision from EN 1992-1-1:2005 that for slabs on flexible supports the reduction of the contribution of loads near to the support β to the resulting shear force at the support should be based on the distance between the face of the load and the centre of the support. It is recommended to use the face-to-face distance between load and support for flexible and rigid supports.

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