Experimental studies on the shear capacity of Prestressed Concrete Continuous Beams

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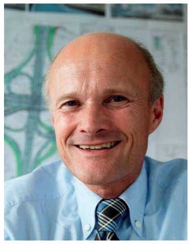

Summary

A large number of existing bridges of the German Federal Highways are built as prestressed concrete continuous beams. Because of rising traffic loads, the calculated shear capacity of some bridges is insufficient according to current codes. However, the calculated shear capacity might be underestimated by the design codes and the actual shear capacity may be increased, e.g. by using additional external tendons. This paper presents a research project that is carried out at the Institute of Structural Concrete at RWTH Aachen University. Six tests on three continuous beams with parabolic and additional external tendons were performed. The aim was to investigate whether the shear capacity is accurately predicted by the current bridge design code or if the shear capacity can be calculated more precisely by alternative approaches, especially regarding the influence of additional external tendons.

Keywords: shear capacity; prestressed concrete; continuous beams; parabolic tendon; external prestressing

1. Introduction

Many of the existing bridges of the German Federal Highways do not possess a sufficient calculated shear capacity to resist increasing traffic loads. As the new design rules are more conservative and the load model has also been adjusted in successive codes to reflect increasing traffic loads, more web shear reinforcement is now required. Since the traffic loads will keep rising in the future, post-strengthening measures will be necessary for many of these bridges. To reduce the obstruction of traffic during construction, external tendons might be suitable. Therefore, the effect of additional external tendons on the shear capacity of prestressed continuous beams was investigated within a research project. Within this project, six shear tests on three continuous beams (TB 1 – TB 3) with and without external prestressing were performed. Each of the three two-span beams had a total length of 11,3 m and a cross-section height of 0,6 m. All of the beams were prestressed seven days after concreting with an internal parabolic tendon and the same prestressing force of 430 kN. The first test beam (TB 1) served as a control specimen, whereas the two other beams were prestressed by two additional external centric tendons with a prestressing force of 270 kN (TB 2) and 450 kN (TB 3), respectively. The shear reinforcement of the test beams consisted of stirrups (Ø = 6 mm) spaced at 25 cm in one span (ρ_w = 0,154 %) and 50 cm in the other (ρ_w = 0,077 %). By this, shear failure first occured in the weaker span after which the specimen was strengthened with tie rods. A second test was performed in which the stronger span of the specimen failed. The tests were performed two weeks after concreting. The test programme is presented in detail within the full version of this paper.

In the following chapter the shear capacities calculated by different approaches are compared to the shear capacities of the test specimens.

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2. Test results

The calculated and experimental shear capacities for all three test beams (TB 1-TB 3) are listed in Table 1 and Table 2, respectively. All of the approaches predict an increase of the shear capacity with the additional external prestressing. For a shear reinforcement ratio of $\rho_w = 0{,}077\%$ (Table 1) the approach according to the bridge design code DIN FB 102 [1] predicts a 22 % increase of the shear capacity from TB 1 to TB 3, whereas the FE-Analysis and the approach by Hegger/ Goertz [2] predict an increase of 18 % and 13 %, respectively. However, the actual increase of the shear capacity, indicated by the test results, was only 8 %. For a shear reinforcement ratio of $\rho_w = 0{,}154\%$ (Table 2) the increase of the calculated shear capacity is approximately 8 % from TB 1 to TB 3 for all approaches, while the test results indicate an increase of only 4 %. On the one hand, the increase of shear force is lower than expected. On the other hand, the maximum shear capacity of the test is much higher than according to the approach of DIN FB 102 [1]. One reason might be that the shear capacity of the uncracked compression zone is underestimated, especially for prestressed beams. The approach by Hegger/Goertz [2] seems to be appropriate for a more precise prediction of the shear capacity of continuous beams.

Table 1: Shear capacity for $\rho_w = 0{,}077$ % [kN]

Approach	1st test: TB 1 $\sigma_{ext} = 0{,}0$ MPa	2nd test: TB 2 $\sigma_{ext} = 1{,}5$ MPa	3rd test: TB 3 $\sigma_{ext} = 2{,}5$ MPa
DIN FB 102	113 kN	128 kN	138 kN
FE-Analyis	262 kN	303 kN	308 kN
Hegger/Goertz	274 kN	307 kN	310 kN
Experiment	275 kN	288 kN	298 kN

Table 2: Shear capacity for $\rho_w = 0{,}154\%$ [kN]

Approach	1st test: TB 1 $\sigma_{ext} = 0{,}0$ MPa	2nd test: TB 2 $\sigma_{ext} = 1{,}5$ MPa	3rd test: TB 3 $\sigma_{ext} = 2{,}5$ MPa
DIN FB 102	140 kN	146 kN	150 kN
FE-Analyis	315 kN	321 kN	339 kN
Hegger/Goertz	317 kN	349 kN	341 kN
Experiment	358 kN	322 kN	374 kN

3. Conclusions and Future work

Six tests on three prestressed two-span beams have been performed within this project. The ultimate shear capacities of the tests were compared to the calculated shear capacities. According to the test results the shear capacity is underestimated by the current bridge design code by a factor of 2,1 to 2,5. In general the shear capacity was increased by external prestressing. To face the problem of shear capacity deficits a new approach is needed. According to the test results the approach by Hegger/Goertz might be suitable for predicting the shear capacity of prestressed continuous beams more exactly. This will be evaluated next using additional data gathered from new numerical parametric studies.

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4. References

[1] DIN German Institute for Standardisation , *DIN Fachbericht 102: Concrete bridges*, Beuth Verlag GmbH, Germany, 2001.

[2] HEGGER J., GOERTZ S., “Querkraftmodell für Bauteile aus Normalbeton und Hochleistungsbeton“, *Beton- und Stahlbetonbau* 101, Heft 9, pp. 695 – 705, 2006.