Influence of High Axial Tension on the Shear Strength of non-shear RC Beams

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Summary

This paper deals with the influence of high axial tension on the shear strength of beams without shear reinforcement. An experimental program with shear-tension tests was carried out. The experimental results have been used to evaluate the applicability of the Eurocode 2 (EC2) design formula in cases with large normal forces. In addition, the experiments have been used to evaluate an extension of the plasticity based Crack Sliding Model (CSM) to cover cases with large normal forces. The test results show, that even in the present of very high axial tensile stresses and strains, the member is still able to carry significant shear stresses. The analysis reveals that the EC2 formula is over conservative in this regard.

Keywords: Shear tests, Concrete beams, Axial tension, Eurocode 2, Crack Sliding Model.

1. Introduction

It is well-known that the shear capacity of reinforced concrete (RC) beams without stirrups can be enhanced by a compressive normal force. This enhancement effect is incorporated in most design codes, including the EC2. Even though the EC2-formula was developed to account for axial compression, it is also used for axial tension. This is apparent when reading the accompanying code text and the background document. The formula predicts a linear reduction of the shear strength for members with axial tension. Very little experimental work has been available for verification of this approach. Further, in the few existing tests, the applied axial tension was rather low.

Some studies have indicated that the shear strength is not dramatically reduced as predicted by the codes provided that the member is properly reinforced for the applied tension. The question is whether this also holds for high axial tension, measured both in term of stress and strain.

The issue of members subjected to shear in combination with high axial tension is relevant in many situations in practice. This could for instance be in a concrete slab which is a part of a continuous steel-concrete composite bridge deck. At the intermediate support, the negative moment from the global actions may result in large tension in the slab, which at the same time could be subjected to shear from the local action of traffic loads.

In this paper the influence of high axial tension on the shear strength is investigated. A test series has been conducted and the results are compared with the EC2-design formula. Further, the test results have also been used to evaluate, whether the plasticity based CSM could be applicable to model of the effect of axial tension.

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2. Experiments

The experimental program consisting of 23 beams without stirrups tested in combined shear-tension. The test specimen and the testing frame are illustrated in Fig. 1. The beams were tested for axial tension $\sigma_t = N/bh$ ranging from 0 to 50% of the concrete compressive strength. Maximum N corresponded to 83% of the yield force of the longitudinal reinforcement. This is equivalent to a maximum average tensile strain of ~ 0,40 %.

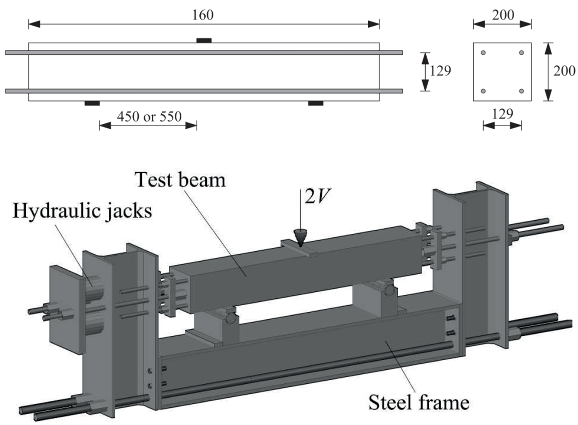

Fig. 1: (top) Specimen geometry, (bottom) frame for application of axial tension.

The specimens were longitudinally reinforced with four Ø15mm DYWIDAG thread bars with measured yield stress f_y = 1027 MPa and ultimate strength f_u = 1227 MPa. The c-c distance of the longitudinal reinforcement was in both directions 129mm. The high strength made it possible to conduct tests with high axial tensile strains.

Generally, it was observed that the shear strength was not significantly affected by tensile normal forces less than about 40% of the specimen tensile yield strength. This corresponds to an average normal strain of ~ 0,20 %. Beyond this level of tension, a decrease in the shear strength was generally observed for increasing axial tension.

Calculations using the EC2-formula have been conducted and compared with test results. This investigation is interesting from a practical point of view since this formula at the present moment forms the basis for shear strength verification in many European countries. Moreover, the tests are also compared with calculations by use of the plasticity based CSM. The CSM is interesting in this context because it allows a direct modelling of the influence of normal forces. In this paper, the model is extended to cover the case of large axial tension.

Fig. 2 depicts the tests with a/h = 2,25. In addition, $\tau_u/\sqrt{f_c} = V_u/bh\sqrt{f_c}$ versus N/A_sf_y as determined by CSM has been plotted. The shear strength calculated from the EC2-formula has also been plotted in the figure. It is clearly seen that this formula is not applicable for high axial tension.

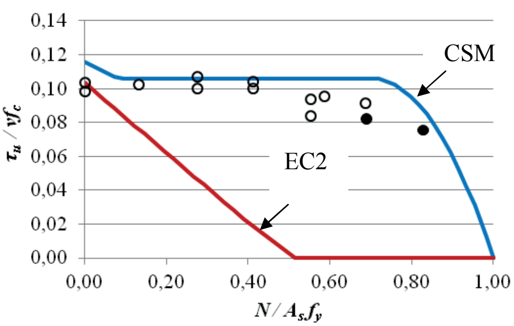

Fig. 2: Test results for a/h = 2,25 compared with CSM using average value of fc = 27,3 MPa.

3. Conclusion

The influence of high axial tension on the shear strength of beams without stirrups has been studied. Shear tests combined with a high axial tensile load have been carried out. The test results indicate that the shear capacity remains almost intact even when the axial tension corresponds to ~ 0,20 % strains. The EC2-formula was not developed for cases with high axial tension even though it is used for this purpose in practice also. Comparison with tests shows that the EC2-formula is conservative for high axial tension. Comparison with tests indicate that the CSM seems to work well, even for members subjected to axial tensile strains up to 0,30 – 0,40 %.