Discussion

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Studies on prestressed concrete hollow beams in combined torsion and bending*

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Professors Rangan and Hall should be congratulated for putting forward an approach to the calculation of the cracking and ultimate loads of prestressed concrete hollow beams under combined torsion and bending. There are, however, several matters that must be questioned.

The authors have assumed two different tensile stresses, namely $F'_t = 0.62 F'_c$ for flexure-shear type of cracking and $F'_t = 0.33 F'_c$ for the diagonal type of cracking. The former is nearly 88% higher than the latter. Though the authors have tried to justify the assumptions because of their use in the Australian code (reference 5 of the paper), they have failed to realize that, in the present case, the tensile stress is produced not only by flexural stress but also by torsional shear stress. As a result, the Test/Calc. ratios of cracking torques in Table 5 are observed to decrease with the increase of T/M ratio in FS (flexure-shear) type of cracking. The above assumptions will be highly questionable if the width of the beam is greater than its depth and the section is subjected to significant torsion under the combined load. Further, because a smaller value of F'_t has been assumed, the specimens showing diagonal-tension (DT) type of cracking show, in general, a higher value of Test/Calc. ratio of cracking torques, as in Table 5.

A close study of the expressions for the ultimate torques under three different modes of failure given by equations 12 to 14 reveals that (1) the ultimate torque is independent of the grade of concrete; (2) the level of prestress has nothing to do with the prediction of ultimate torque either under combined load or in the limiting case of pure torsion obtainable from equation 14. Both are against the observed behaviour of prestressed concrete beams under pure or combined torsion. Moreover, yielding of horizontal legs of stirrups in Mode 1 type of failure cannot be justified from test observations made by Hsu (reference 6 of the paper). An analysis based on neglect of torsional contribution of concrete may lead to a conservative estimate of the ultimate torque in most cases; as such, it cannot be treated as a general solution.

Reply by the authors

We thank Dr Chakraborty for his interest in our paper.

The cracking strength of a structural concrete beam depends largely upon the tensile strength of the concrete. In our tests, we have observed two types of

*Pages 28 to 36 of MCR 106.

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cracking behaviour, i.e. flexure-shear type cracking when bending is predominant and diagonal-tension type cracking when torsion is predominant.

In order to quantify these two different behaviours, we have adopted two different empirical values for the tensile strength of the concrete. It might be possible that one could vary these values with respect to T/M ratio and obtain a better fit with the test data. We did not make such an attempt, however, as it can hardly be justified in the light of the approximate nature of the entire process of calculating the cracking strength of concrete beams in any circumstances.

As stated in the paper, equations 12 to 14 apply to under-reinforced beams only. Dr Chakraborty is incorrect in stating that these equations are independent of the grade of concrete. The value of M_o in these expressions is affected by the compressive strength of concrete. However, for under-reinforced beams (similar to those used in Table 6) the effect of the grade of concrete upon the ultimate strength of beams is insignificant. This is an established fact. We

cannot see why the level of prestress should influence the ultimate strength of under-reinforced beams.

Our Figure 4b and similar data clearly show the yielding of the bottom horizontal (short) legs of stirrups. The test observations given in reference 6 of the paper are based on readings obtained from only a few strain gauges placed over a wide region and therefore cannot be considered reliable. Our beams were more thoroughly instrumented in order to obtain the data given in Figure 4.

We consider that apportioning the failure torque as 'contribution of concrete' and 'contribution of steel' is possible only in an empirical solution to the problem. The predictions of equations 12 to 14 are, on average, 17% conservative (Table 6), owing to the neglect of the moment of the forces in the vertical legs of hoops (horizontal legs in the case of Mode 2) in the basic equilibrium equation and to the use in the theory of an approximate value for the lever arm between the compressive and tensile forces acting on the skewed failure surface (reference 7 of the paper).