Behaviour of Prestressed Concrete End Blocks

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Abstract

This paper briefly reports on a series of experiments carried out on strip-loaded prestressed concrete end blocks. The results show that corresponding design methods presently used in Europe are conservative. In all cases, failure of the end blocks was by initial cracking, followed by wedging punch-through of the plate.

Introduction

When a large prestressing force is applied to the end of a beam over a small anchorage area, tensile bursting stresses are developed behind the anchor plate. The problem of analysing the bursting stresses in concrete blocks under concentrated loading has been investigated in the past by several researchers [Clarke, 1976; Guyon,1974; Leonhardt,1964; Mörsch,1924; VSL,1975; Zielinski and Rowe,1960]. Such work has led to commonly accepted empirical design methods for the detailing of steel reinforcement in end blocks.

The present experimental series was carried out in order to study the effect of steel quantity and positioning on the load-carrying capacity of strip-loaded end blocks. The results from this test series are presently being used to verify upper- and lower-bound theories for the analysis of end blocks.

Experimental Procedure

Sixty specimens of overall rectangular dimensions 750mm × 250mm × 125mm were strip-tested to failure through rigid steel

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plates of varying length. The plates were placed centrally, and the ratio of loaded length, $2a_1$, to unloaded length, 2a (250mm), was varied between 0.1 and 0.7.

The concrete used was of average cube strength $f_{cu} = 60$ N/mm^2, and of average split-tensile strength $f_t = 4.0$ N/mm^2. Steel stirrups were included, of varying number and bar size, spread over 2a, 3a and 4a (250, 375 and 500mm) lengths from the strip-loaded end of the specimens. The yield strength of the steel bars varied between 424 and 446 N/mm^2. Electrical resistance strain gauges were fastened onto the stirrups in many reinforced specimens, in order to measure the variation of bursting strains in the end blocks, both before and after initial cracking.

Experimental Results

Elastic tensile bursting strain variations along the central axis of the specimens (measured at low load levels) are shown in figure 1 for the different a_1/a ratios adopted. Linear elastic finite element strain predictions are in reasonable agreement with these measured quantities[Ibell and Burgoyne, 1991].

It was found from the tests that the provision of steel reinforcing increased the cracking load of the specimens substantially. Cracking was initiated along the central axis when the average strain in the steel was about 600$\mu\varepsilon$ in most tests.

After this central cracking had started, downward propagation of the crack occurred. The accompanying loss in stiffness of the block created a redistributed stress condition under the loading plate, which led to ultimate wedging punch-through of the plate (figure 2).

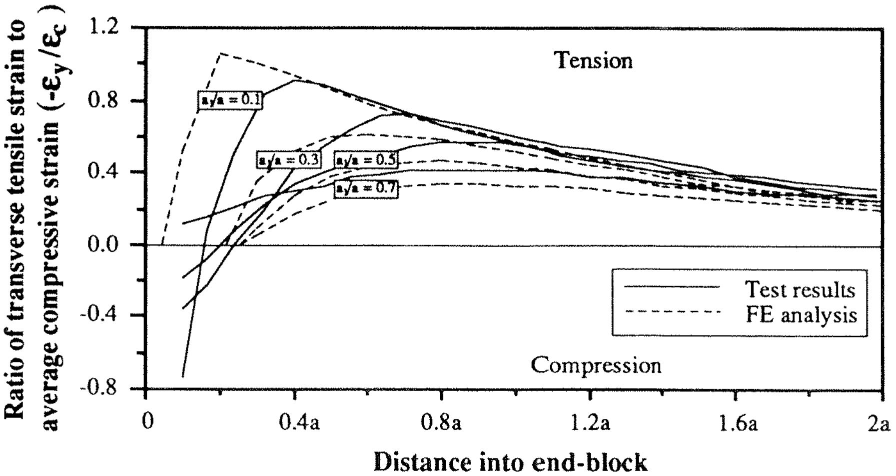

Figure 1 Variation of tensile strains along the end-block from the test results and finite element analysis.

In most cases (except where $a_1/a = 0.1$) the ultimate wedging load was higher than the initial cracking load. When a_1/a was equal to 0.1, failure of the blocks was purely by splitting. The blocks were able to withstand no additional load after initial central cracking occurred.

Figure 3 shows a comparison between the test results for $a_1/a = 0.3$ and some design methods used in Europe for the detailing of end block reinforcing.

For the particular specimens used, it is unlikely that the average applied stress would ever exceed $0.33f_{cu}$, in keeping with BS8110 Structural Use of Concrete. This stress translates to a maximum applied load of about 62 tons, if $f_{cu} = 60$ N/mm^2.

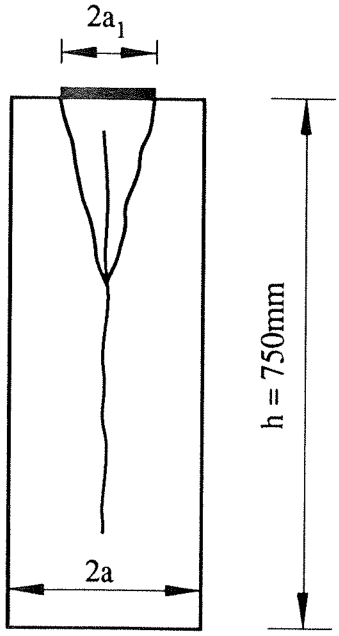

Figure 2 Central crack and wedge action under the plate.

Clearly, therefore, in the relevant load range, all the methods are exceedingly conservative. What is more interesting though, is that a commonly used method in Britain is that due to Zielinski and Rowe[1960], which in this particular case would suggest an excessively high quantity of steel.

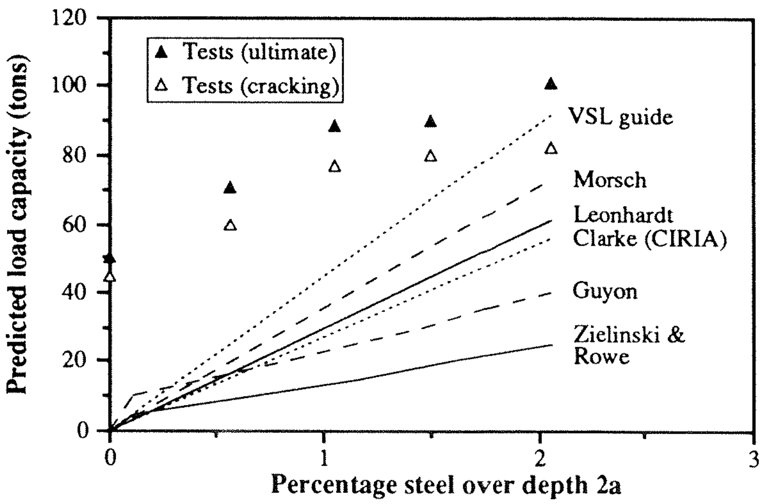

Figure 3 Comparison between European design method predictions and experimental results.

Figure 3 shows that as the quantity of steel increased in the specimens, the rate of increase in strength of the specimens dropped. This was due to third direction stresses causing out-of-plane wedging failure. This behaviour was partially prevented by providing steel cross-links between the stirrup legs to confine the concrete and maintain plane strain conditions.

The spreading of steel over depths of 3a and 4a was found to be beneficial, both in terms of cracking and ultimate load capacities of such blocks. Such dilution of steel content (compared with the case where steel is spread over 2a as suggested by European methods) could reduce congestion in end blocks, a notorious problem in the detailing of prestressed concrete structures [Collins and Mitchell, 1987].

Conclusions

Tests carried out on prestressed concrete end blocks have revealed that design methods used presently in Europe are somewhat conservative. Reduction in steel content might thus be possible in the future. In addition, it was found to be beneficial to spread steel over greater depths than that presently used, as strength capacities are almost unchanged, and the possibility of congestion is reduced.

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