

## *Discussion* on paper published in

*Magazine of Concrete Research*

1995, 47, No. 173, Dec., 329–344

---

### **Strengthening of shear-damaged RC beams by external bonding of steel plates**

A. Sharif, G. J. Al-Sulaimani, I. A. Basunbul, M. H. Baluch and M. Husain

**Contribution** by D. M. F. Orr

*University College Cork*

The paper draws attention to the brittle nature of shear failure and of failure caused by the separation of externally bonded shear reinforcement. In the paper it is speculated that, in the case of external shear reinforcement, 'yielding failure could occur if the thickness of the plates used were small enough for yielding to overtake the interface failure, or if the top and bottom of the strips or wings were anchored'. Ref. 5 of the paper suggests that for externally bonded flexural reinforcement, peeling failure of the flexural plate will not occur if the width-to-thickness ratio is not less than 60. Such limitations on plate thickness may greatly reduce the strength enhancement that can be achieved with external reinforcement, especially in the case of T beams, which are a more common shape of cross-section in actual structures than the rectangular shape which has been used for most of the tests carried out on beams with external reinforcements, including the tests reported in the paper.

T beams are frequently substantially under-reinforced because of the large area of concrete in the compression flange, and hence they have a considerable potential for flexural strengthening with external reinforcement. Limiting either the thickness of the flexural plate, or else the stress in the plate, to avoid anchorage failure, reduces the flexural strength enhancement that

can be achieved. This is a severe limitation in the case of T beams, where flexural plates can be no wider than the width of the web of the beam.

Both anchorage failure of flexural plates and deficient shear strength in beams may be overcome by the addition of external shear reinforcement which is fully anchored as suggested in the paper. To be effective, shear reinforcement must pass through the flange of T beams, because of the high shear stresses that occur where the web joins the flange and thus it is appropriate for externally bonded shear reinforcement to be in the form of links passing through the flange and surrounding the web of the beam. A number of T beams reinforced in this way have been tested by the writer,<sup>1</sup> and these tests have shown that, in general, conventional design procedures, such as the procedures of BS 8110, may be used to determine the dimensions required for external flexural and shear reinforcements used to strengthen existing reinforced concrete T beams. However, additional external link reinforcement is required near to the ends of a flexural plate, to resist anchorage forces that would otherwise cause peeling failure. A rational method for designing this additional reinforcement and determining its optimum distance from the end of the flexural plate has not been found, and this is the main outstanding problem

## Discussion

to be solved for designing externally bonded reinforcements.

External links are preferable to internal bolts for anchoring the ends of flexural plates because the presence of the internal obstructions deflects the direction of shear cracks in the concrete and reduces the shear strength of the beam.<sup>2</sup> Inclined external links were found to be more effective than vertical links for preventing anchorage failure of the flexural plate. The tests showed that an enhancement of the flexural strength of T beams by at least 66%, together with a ductile failure mode, can be achieved by careful design and detailing. The tests also demonstrated that it is practical to install, in T beams, external links that are either vertical or inclined.

## Reply by the authors

The authors declined to reply.

## References

1. ORR D. M. F. and LYNCH C. Design of externally bonded flexural and shear reinforcement for strengthening reinforced concrete T-beams. *Proc. 13th Australasian Conf. Mech. Struct. Mater., University of Wollongong, Australia*, 1993, 651–656.
2. BALUCH M. H., ZIRABA Y. N., AZAD A. K., SHARIF A. M., AL-SULAIMANI G. J. and BASUNBUL I. A. Shear strength of plated RC beams. *Mag. Concr. Res.*, 1995, **47**, No. 173, Dec., 369–374.