Comments on Technical Paper Published in Jurutera, July 2007

Dear Sir,

I wish to refer to the technical paper entitled Strengthening Of Reinforced Concrete Structures by Engr. Prof. Dr. Mohd. Zamin bin Mohd. Jumaat and Md. Ashraful bin Alam, which was published in Page 28 and Page 29 of July 2007 issue of Jurutera. This paper presented the test result for one steel plate strengthened r.c. beam as well as the test result for one FRP laminate strengthened r.c. beam and concluded that FRP laminate is more effective in increasing the flexural capacity of r.c. beam compared steel plate. In my opinion, the above conclusion appears to be premature and inconclusive as the following information regarding the 2 different methods for beam strengthening were not provided and compared with in the paper:

1. **The type, thickness and mechanical properties of epoxy resin adhesive used for bonding the steel plate and FRP onto the r.c. beam.**

   I believe that same type and thickness of epoxy resin adhesive shall be used in the experiment in order to make 'apple to apple comparison'. In addition, it may be necessary to use an epoxy resin adhesive that will not fail before the steel plate or FRP yield in flexure i.e. failure mode of strengthened r.c. beam should be flexural and not debonding.

2. **The width, thickness, yield strength and other mechanical properties of the steel plate and FRP used for strengthening the r.c. beam.**

   I believe that for fair comparison of the two different types of materials in beam strengthening, the cross-sectional area for each material times its yield strength shall be the same in the experiment.

The afore-said paper also reported that both the beams strengthened with steel plate and FRP failed by plate debonding with brittle manner. However, it should be noted that according to the technical paper entitled Structural Behaviour Of Externally Bonded, Steel Plated R.C. Beams After Long-Term Exposure by R.N Swamy, B. Hobbs and M. Roberts that was published in the Structural Engineer of August 1995 (Volume 73, No. 16, Page 255-261), most of the 21 plate-bonded r.c. beams tested failed in flexure, with externally bonded steel plate reaching its full yield stress and with no apparent reduction in bond between the plate and the concrete. Professor Swamy et al also reported that almost all the beams tested showed a good degree of ductility at failure.

I hope that my above comments and observations will be useful to Prof Dr Mohd Zamin in his study on r.c. beam strengthened with steel plate and FRP.

Thank you. ■

With kind regards,
Engr. On Seng Hooi MIEM, P.Eng

Response to Comments on Strengthening of Reinforced Concrete Structures

Dear Editor,

We refer to the comments made by Engr. On Seng Hooi on our papers entitled 'Strengthening of Reinforced Concrete Structures' which was published in the July issue of the JURUTERA monthly bulletin of The Institution of Engineers, Malaysia.

In this research work, the same type and thickness of adhesive, i.e. Sikadur, was used for both the steel and CFRP plates. The bonding process was carried out with the expert assistance from the Sika Kimia technical team. The adhesive was shown, from the experimental works, to be strong enough to resist debonding or peeling at the interface level (the interface between the strengthening material and concrete surface).

The strengthening plates reported in the paper were observed to have debonded at failure, due to the mechanism of end peeling, which is different from the mechanism of debonding at the interface level. A detailed description on this point can be found in reference (1).

All types of debonding failure in strengthened r.c. beams resulted in a brittle failure mode. Debonding at the interface level can be avoided by using proper adhesives (which was observed in this research work). End peeling can be minimised by using proper end anchors. In the case of the strengthened beams (with end anchors) which were also observed in this research work but not reported in the paper, ductile failure behaviours were observed. Investigations on the behaviour of end anchors strengthened beams were also reported in reference (1).

Ei-Mihilmin (2) and several other researchers reported that end peeling depends on plate stiffness, plate thickness, plate width and anchorage length among others. Since CFRP is less stiff and also due to the fact it has higher tensile strength compared to steel, normally thinner plates of CFRP is required. CFRP laminate, therefore, is more effective in increasing the flexural capacity of r.c. beam compared to steel plate.

The material properties of steel and CFRP plates, as mentioned, are different. Hence, comparative analysis between the two materials based on strength rather than based on material geometrical properties is more justified. In this study, both beams have been designed to take the same load. Since the report is meant to be a preliminary report, the detailed design approach and full data on the research work were not included. Detailed description on the research work can be found in (1). ■

REFERENCES

[1] Alam, M. A. (2006),"Behaviour of flexurally strengthened reinforced concrete beams using externally bonded plates and anchorages", Master of Engineering Thesis, University of Malaya.

[2] El-Mihilmy M. T. and Tedesco J. W.(2001), "Prediction of anchorage failure for reinforced concrete beams strengthened with fiber-reinforced polymer plates", ACI Structural Journal, vol. 98, no. 3, pp. 301-314.