INTERMEDIATE CRACK DEBONDING OF PLATED REINFORCED CONCRETE BEAMS

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ABSTRACT

With increasing number of structures reaching their designed life or capacities everyday, retrofitting has become an important area in civil engineering. A popular method of strengthening and stiffening reinforced concrete (RC) beams is by adhesively bonding steel or FRP plates to the external surfaces. This technique has been proven to be efficient, inexpensive, unobtrusive and can be applied while the structure is in use. However, it has been found that adhesively bonded plates are prone to premature debonding prior to reaching their designed capacities, which restricts the use of existing design rules and guidelines for retrofitting RC beams using this relatively new form of structure.

There are various forms of debonding including: plate end (PE) debonding; critical diagonal crack (CDC) debonding; and intermediate crack (IC) debonding. IC debonding is an especially important mechanism as it will occur at plated hinges of continuous members, and unlike other premature debonding mechanisms, IC debonding is very difficult to prevent. This debonding mechanism is associated with the formation of flexural or flexural-shear cracks in the vicinity of the plates, which causes slip to occur at the plate/concrete as well as the bar/concrete interfaces. Most research to date has been focusing on the bond-slip relationship at the plate/concrete interface, while little attention has been given to the IC debonding behaviour of flexural members. To allow safe and effective use of plated structures, it is necessary to model the debonding behaviours at the plate/concrete interface as premature debonding will affect both the strength and ductility of the members, and hence the ability of continuous structures to redistribute moment. Despite the importance of moment redistribution, very limited research has been carried out on the moment redistribution of continuous plated members. Since IC debonding is likely to occur at plated hinges of continuous members hence affecting the ductility of the hinges, the existing approaches for determining moment redistribution of reinforced concrete beams cannot be applied to plated members.

In this research a numerical model based on discrete cracking and partial interaction theory has been developed which models the IC debonding of plated beams, taking into account the slips at all interfaces. This model will allow a better understanding of the IC debonding behaviour of plated members, and also from the model, the rotation capacity of both plated and unplated hinges in continuous reinforced concrete beams can be determined. Mathematical models and design rules have been developed for analysing critical diagonal crack debonding, which is dependent on the IC debonding behaviour of the plated members. Moment redistribution of beams with externally bonded and near surface mounted plates is studied through a series of tests and a mathematical model based

on variation in flexural rigidity is proposed. Through the tests carried out on continuous plated beams, much moment redistribution is evident as oppose to that suggested by the existing design guidelines for plated members, where no moment redistribution is allowed for members plated with FRP.

From the models proposed for IC and CDC debonding in this research, together with the existing PE debonding models available, all debonding mechanisms can now be modelled. Furthermore from the research on continuous plated beams, moment redistribution of plated beams can be analysed, allowing safe, effective and economic use of this retrofitting technique.

This thesis is presented in the form of a collection of journal papers published or submitted for publication as a result of the research performed by the author. A selection of ten publications have been included in the following context, together with literature reviews performed on the related areas of studies, as well as further discussions on the papers, which consist of any additional information or work that was carried out in this research but not presented in the papers.

STATEMENT OF ORIGINALITY

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being available for load and photocopying.

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Irene Liu Date

LIST OF PUBLICATIONS

The following papers were written based on the work presented in this thesis.

JOURNAL PAPERS

1. Oehlers, D.J., Liu, I., and Seracino, R. (2004). "Passive prestress approach for CDC debonding of adhesively bonded steel and FRP plates." *Magazine of Concrete Research*, 56(8), 475-486
2. Oehlers, D.J., Liu, I., and Seracino, R. (2004). "Prestress code approach for shear deformation debonding of adhesively bonded plates." *Proceedings of the Institution of Civil Engineers*, Structures & Buildings 160, SB1, 1–7
3. Oehlers, D.J., Ju, G., Liu, I., and R. Seracino. (2004). "Moment redistribution in continuous plated RC flexural members. Part 1: neutral axis depth approach and tests." *Engineering structures*, 26, 2197-2207
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5. Liu, I.S.T., Oehlers, D.J., and Seracino, R. (2005). "Moment redistribution in FRP and steel plated reinforced concrete beams." *ASCE Journal of composites for constructions*, accepted for publication
6. Liu, I.S.T., Oehlers, D.J., and Seracino, R. (2005). "Tests on the ductility of reinforced concrete beams retrofitted with FRP and steel near surface mounted plates." *ASCE Journal of Composites for Constructions*, accepted for publications
7. Liu, I.S.T., Oehlers, D.J., Seracino, R., Ju, G. (2006). "Moment redistribution parametric study of CFRP, GFRP and steel surface plated RC beams and slabs." *International Journal of Construction and Building Materials*, 20, 59-70
8. Liu, I.S.T., Oehlers, D.J., and Seracino, R. (2005). "Partial interaction numerical simulation of hinges in FRP plated reinforced concrete beams." *Computers and Structures*, submitted
9. Oehlers, D.J., Liu, I.S.T., and Seracino, R. (2005). "The gradual formation of hinges throughout reinforced concrete beams." *Mechanics Based Design of Structures and Machines*, accepted for publication
10. Liu, I.S.T., Oehlers, D.J., Seracino, R., and Teng, J.G. (2005). "Study of intermediate crack (IC) debonding on adhesively plated beams." *ASCE Special Journal of Composites for Constructions*, under review (invited paper)

11. Oehlers, D.J., Liu, I.S.T., and Seracino, R. (2005). "A generic design approach for EB and NSM longitudinally plated RC beams." *International Journal of Construction and Building Materials*, accepted for publication

TECHNICAL REPORTS

12. Oehlers, D.J., Liu, I.S.T., and Seracino, R. (2005). *The gradual formation of hinges throughout reinforced concrete beams*. Research report no. R177, School of Civil and Environmental Engineering, University of Adelaide, Australia

CONFERENCE PAPERS

13. Liu, I.S.T., Oehlers, D.J., and Seracino, R. (2004). "Parametric study of intermediate crack (IC) debonding on adhesively plated beams." *Proc., the 2nd International Conference on FRP Composites in Civil Engineering*, CICE, Adelaide, Australia, 515-522
14. Oehlers, D.J., Liu, I.S.T., and Seracino, R. (2004). "Moment redistribution parametric study of CFRP, GFRP and steel surface plated RC beams and slabs." *Proc., ACIC 2004 Conference*
15. Liu, I.S.T., Oehlers, D.J., and Seracino, R. (2005). "FRP plated reinforced concrete hinges: Partial interaction numerical simulation." *Proc., 3rd International Conference on Composites in Construction*, CCC, Lyon, France
16. Oehlers, D.J., Seracino, R , and Liu, I.S.T. (2005). "Generic retrofitting approach for longitudinal plating reinforced concrete beams and slabs." *Proc., INCOS*, Portugal

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