Design of Externally Plated R.C. Beams Against Premature Interface Debonding Failure

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Summary

As regards prediction of the premature interface debonding failure load of externally plated R.C. beams, over the last 10 years, a substantial literature of often very mathematical nature has appeared in the public domain, much of which is inconclusive and non of which appear to enjoy general reliability for everyday practical applications. Bearing this in mind, in the present paper, the salient features and the final simple formulations as well as extensive experimental verification of a very simple model (aimed at practising engineers) is presented with its final predictions backed by a substantial body of large-scale experimental data, covering a wide range of first order beam design parameters, with the experimental database including both steel and FRP plated beams. With the general reliability of the model verified, the paper will then report the outcome of a series of theoretical parametric studies aimed at optimising the design procedure against debonding failure. Finally, to facilitate the use of the proposed formulations, a worked example is also included.

Keywords: reinforced concrete, steel, FRP, plates, bond, shear, strengthening, buildings, bridges.

1. Introduction

The use of external steel and/or fibre-reinforced plastic (FRP) plates bonded to the tension face of reinforced concrete (R.C.) members has, in recent years, become a common method of repairing/strengthening existing structures. However, despite extensive worldwide research on the various characteristics of externally plated R.C. beams over the last two decades, a generally accepted method to predict the failure load of plated beams is not yet available. This is particularly true in the case of the widely observed undesirable premature (plate peeling and interface debonding) failures of such elements which are often of a largely brittle nature. It is, perhaps, worth mentioning that interface debonding (shear/bond) failure is associated with those instances when there is a bond failure occurring at the plate/glue/concrete interface whereas the peeling failure involves the plate and concrete cover separating as a unit from the underside of the main reinforcing bars.

Extensive tests by the present authors on 53 large scale, simply supported, R.C. beams strengthened in flexure by using externally bonded steel plates demonstrated that by using effective plate end-anchorages (in the form of sufficiently long prestressed bolts), the occurrence of undesirable premature plate peeling failure(s) could be avoided, with some associated (highly desirable) increases in ductility at failure. Most importantly, however, in contrast to the previous widely held view in the literature, it was found that even when the occurrence of premature plate peeling failure is prevented, the full flexural capacity of the steel plated R.C. beam may still not be achieved and, instead, another undesirable premature failure mode is likely to occur, with this being the bond (shear/bond) failure occurring at the concrete/glue/plate interface, commonly termed as intermediate debonding failure.

The purpose of the present paper is to present the salient features and the final simple formulations as well as extensive experimental verification of a very simple model (aimed at practising engineers) for predicting the interface debonding failure load of externally plated R.C. beams, with its final predictions backed by a substantial body of experimental data, covering a wide range of

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first order beam design parameters, with the experimental database including the results for both steel and FRP plated beams as tested by others, as well as the results based on the large-scale tests, conducted by the present authors, on steel plated RC beams. With the general reliability of the model verified, the paper will then report the outcome of a series of theoretical parametric studies aimed at optimising the design procedure against premature debonding failure.

2. Predictive Model for the Interface Debonding Failure Mode

The present authors have recently proposed a semi-empirical model for predicting not only the location where the critical shear/bond crack is initiated, but also the magnitude of its corresponding shear force as well as the ultimate shear strength(s) associated with shear/bond (interface debonding) modes of failure in steel and/or FRP plated beams in the presence or absence of effective plate end anchorages. In deriving this simple model, use has been made of certain previously available predictive models for unplated R.C. beams failing in a diagonal tension mode of failure.

Figure 1 shows the extremely encouraging correlations between the predictions of the present authors‟ model and the experimental results (as obtained from a total number of 14 references) for both steel (with 36 data points) and FRP (with 42 data points) plated R.C. beams, with the test results covering widely varying beam design parameters the range of which is given in the full version of the paper. Given the variable and somewhat unpredictable nature of shear failure and more importantly, crack spacings in concrete, the correlation factor $R^2 = 0.94$ for the line of best fit in Figure 1 is very encouraging.

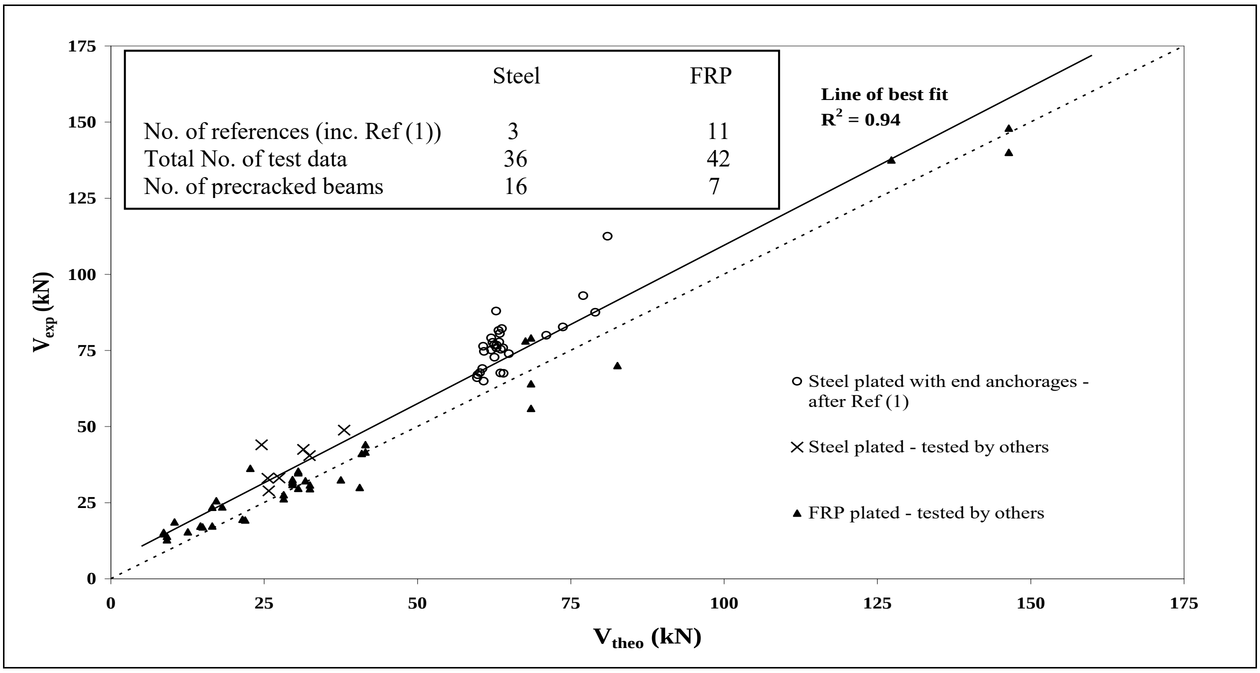

Figure 1: Comparison of the theoretical and experimental ultimate shear forces for steel and FRP plated R.C. beams with or without end-anchorages, experiencing shear/bond (intermediate plate-debonding) modes of failures.

3. Conclusions

The salient features and final formulations of a semi-empirical model for predicting the ultimate strength of steel or FRP plated R.C. beams experiencing a shear/bond (interface debonding) mode of failure, are presented. In view of the limited available space, rather than presenting the detailed derivations for the model, in the present paper, much attention is paid to experimental verification of the predictions based on the new model, with this, then, followed by the reporting of the results based on some extensive parametric studies using this model in order to identify the primary beam design parameters which control the interface debonding strengths of both steel and FRP plated beams. To facilitate the use of the simple formulations, a worked example is also included.