THE RIDDLE OF PREMATURE FAILURES IN PLATED RC BEAMS

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Background

The use of external steel and/or fibre-reinforced plastic (FRP) plates bonded to the tension face of reinforced concrete (RC) beams has, in recent years, become a common method for strengthening existing structures. However, despite extensive worldwide research on the various characteristics of externally plated RC beams, over the last two decades, a generally accepted method to predict the failure load of such 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 noteworthy that interface debonding 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.

Raoof and his associates have already reported details (as well as extensive experimental verification) of two distinctly different semi-empirical models for predicting both the peeling and the debonding failure loads of steel as well as FRP plated RC beams [1-3] , hereafter referred to as the Tooth and the Interface debonding models, respectively. Most importantly, in a recent publication[3] , Heathcote and Raoof argued that, in contrast to the previous widely held view in the literature, in their extensive tests on steel plated RC beams, even when the occurrence of premature plate peeling failure was successfully prevented by using effective plate end anchorages (in the form of sufficiently long prestressed bolts), the full flexural capacity of the steel plated beam was still not achieved and, instead, an interface debonding mode of premature failure was found to occur at the concrete/glue/plate interface with its consequent associated drastic reductions in the ultimate strength (cf. the full flexural capacity for the plated RC beam).

Bearing the above comments in mind, the purpose of the present paper is to propose a simple criteria for design against occurrence of premature (peeling or interface debonding) failures for both steel and /or FRP plated RC beams. To this end, extensive use will be made of previously reported test data (from both the literature- as cited in [4-6],and as obtained by Heathcote [5]) which includes results for 212 steel and 302 FRP plated simply supported RC beams with a very wide range of first order beam design parameters, including beams with widths $75 \leq b \leq 368$ mm, concrete cubic strengths $28 \leq f_{cu} \leq 104$ Mpa, FRP plate's young moduli $10.3 \leq E_p \leq 440$ GPa and shear spans $243 \leq a \leq 1983$mm, as well as certain other beam design parameters as given in Table 1.

Table 1 Range of certain primary beam design parameters in the test database.

Plate	Limits	effective depth,d (mm)	plate thickness, t_P (mm)	plate tensile strength, f_P(Mpa)	a/d
Steel	Max	305	15	337	11.56
	Min	150	1	175	1.67
FRP	max	467	9.525	3900	9.19
	min	100	0.0952	160.7	2.5

Results and Discussion

Fig.1a presents plots of M_{exp}/M_{debond} versus the specimen numbers, where M_{exp} =the experimentally obtained maximum moment capacity and M_{debond}=the maximum interface debonding moment, based on an extension of the original model proposed in [5] as fully reported in [6], with the very encouraging correlations between the theoretical predictions and wide ranging test data for 29 steel and 42 FRP plated RC beams as detailed in [6](all of which have failed in an interface debonding mode) presented in Fig.2. It is most interesting to note that in Fig.1a, in a significant number of cases : $M_{exp}/M_{debond}<1$. Similarly, Fig.1b presents $M_{exp}/M_{peel,1}$, for all the specimens, where $M_{peel,l}$=the lower bound peeling moment based on the simplified (non iterative) version of the Tooth model [7] which is based on an extension of the simple method originally proposed in [2]. The results based on the presently proposed design criteria are then presented in Fig.1c, in which, for each specimen, the minimum of M_{debond} and $M_{peel,l}$ is chosen to represent the critical premature failure load in practice, M_{crit} :it is most interesting that such plots of M_{exp}/M_{crit} in Fig.1c, for very nearly all the test data, are found to be higher than or equal to one- hence, demonstrating the suitability (i.e. safe nature) of the proposed criteria for everyday design purposes. Finally, the plots of M_{exp}/M_{RC} in Fig.1d clearly demonstrate that if the practising engineers do not guard against such potentially dangerous brittle premature plate failures, the ultimate moment capacity of steel or FRP plated beams can be significantly lower than even the ultimate (failure) moment capacities of the original corresponding unplated RC beams, M_{RC}, which have been designed according to the ultimate limit state code recommendations even when partial material safety factors are included in the design calculations of M_{RC} for the unplated beams: in Fig.1d, the predictions are all based on the British code BS8110 with the material partial safety factors included in the calculations-i.e. in the absence of effective design against the occurrence of premature failures, external plating can sometimes significantly weaken (rather than strengthen) the RC beams.

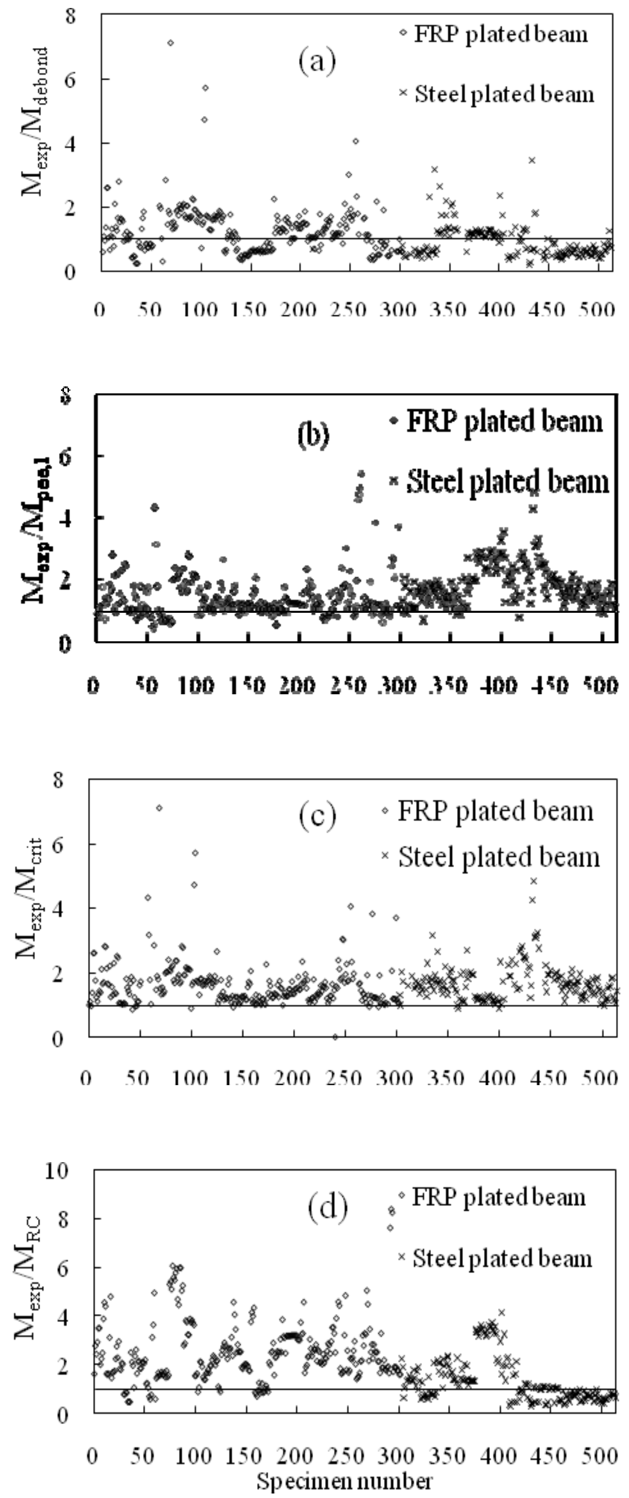

Fig. 1 Plots of :(a) M_{exp}/M_{debond},(b) $M_{exp}/M_{peel,l}$,(c) M_{exp}/M_{crit} and (d) M_{exp}/M_{RC},versus number of specimens for both steel and FRP plated beams.

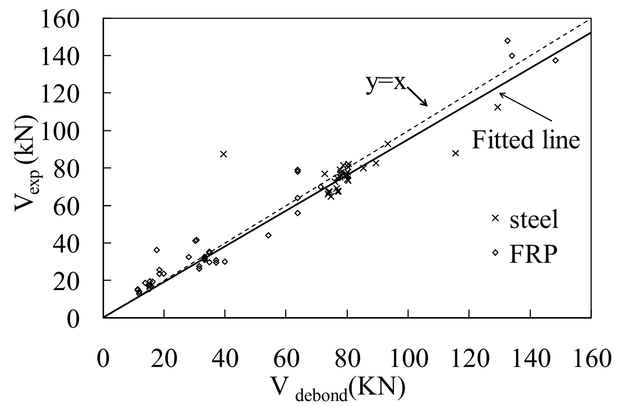

Fig. 2 Correlations between the predictions of the steel and/or FRP debonding model of [6] and test data.

Conclusions

Using an extensive set of test data relating to 212 steel and 302 FRP plated RC beams , covering a wide range of first order beam design parameters, ample support is provided for the general reliability of a simple design method against occurrence of premature flexural failures in externally plated simply supported RC beams with plates glued to their soffits. In particular, the proposed design method is amenable to simple hand calculations, using a pocket calculator, aimed at practicing engineers for their use in everyday designs.

References

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