DEBONDING CHARACTERISTICS OF MASONRY STRUCTURES RETROFITTED WITH FRP

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Introduction

In Australia the majority of unreinforced masonry (URM) buildings have been constructed with little or no seismic requirement. This has resulted in a large inventory of buildings that possess an inability to dissipate energy through inelastic deformation in an earthquake event. In recent years, several seismic retrofitting techniques for masonry structures have been developed and practiced and fibre reinforced polymer (FRP) material has been increasingly used due to their high strength/stiffness to mass ratio and easy application.

The literature review revealed however, the major research in this area has focused on the effectiveness of the retrofitting technique rather than developing a design model. Research work on the development of a design model for FRP strengthened URM structures is very limited [1]. In order to develop a design model and accurately predict the overall capabilities of FRP-strengthened masonry structure, the basic characteristic of shear debonding must be first studied and understood. Hence in this study, the existing models for estimating FRP strengthened masonry bond capacity due to pure shear is investigated. All existing models including models developed based on FRP strengthened concrete structures will be assessed using the testing data collected from the literatures.

Testing Results and Existing Shear Debonding Models

The test data from concrete specimen show that most FRP joints failed in concrete a few millimetres beneath the concrete/adhesive interface [2]. The same results were found from low-medium strength concrete/masonry testing [3] with failure of a thin layer underneath the adhesive is most common for medium strength concrete while crushing of thick stone layer occurred for low strength masonry.

Interfacial failure, between either the adhesive and the concrete or the adhesive and the plate, is not found in all available test data. This is a consequence of the availability of strong adhesives that bond well to FRP, and concrete. For the same reason, adhesive failure is rare, while considerable large number of specimen failed by FRP rupture in the testing conducted by [3] with different types of FRP-anchorage.

An extensive search of the existing literature has found six debonding models. However, none of them was developed for masonry, they are all for concrete. These models can be categorised in three categories: empirical, fracture mechanics and non-linear engineering models. Empirical model is solely based on the regression of the experiment data while the fracture mechanics and non-linear engineering model are based on some practical assumptions. The accuracy of each of these models will be assessed by comparing with the testing database collected by the authors.

Results

Table 1 presents the statistical results of the test-to-predicted debonding strength ratio for the five models. A separate statistical analysis was not undertaken for either the plate end interfacial debonding or mixed mode debonding result due to insufficient information for some test data.

Table 1 Test-to-predicted debonding strength

Category	Name	Average	Standard Deviation
Empirical	Tanaka [4]	1.03	0.67
	Maeda et al.[2]	0.56	0.24
Fracture mechanic	Blaschko et al [5]	0.74	0.33
Non-linear engineering	Chen & Teng[6]	0.83	0.35
	Sharma et al.[7]	0.71	0.38

Although the average test-to-predicted ratio is 1.03, the model developed by [4] was overall not conservative plus the high variation between results has shown that the model is unreliable. The result from [2] was extremely un-conservative. Previous research also indicted that this model has predicted the wrong trend on the effect of $E_p t_p$ on the effective bond length.

A more detailed analysis was conducted for the three remaining models and it was found that the discrepancies are due to the testings from [3] where the testing was conducted either by applying approximately 10 mm plaster or fan anchor and embedded anchors. The thin low strength plaster lead to adverse effect on the ultimate strength and this was not considered in all of the models and result in the “increasing trend” of the test-to-predicted ratio graph. Therefore, there is a need to develop a new model for more accurately predicting of the failure load.

New Proposed Effective Length Model

The literature review indicated that the width of FRP sheet is never considered as a parameter for predicting the effective bond length. Figure 1 below shows that the effective bond length has linear relationship with the ratio of $\frac{E_P t_P}{f_c^{'} b_P}$. Therefore, the absence of considering the width of FRP sheet in the previous effective bond length models necessitate the development of a new effective length model for predicting the ultimate strength of FRP bonded structure.

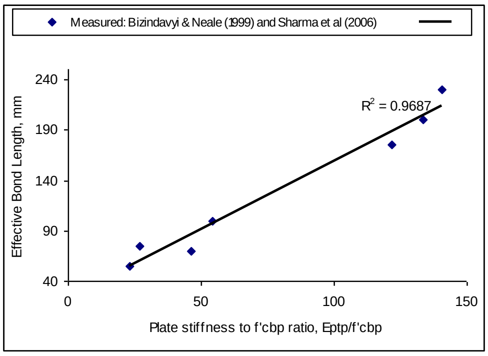

Fig 1 Linear relationship between effective bond length and plate stiffness ($E_p t_p$) on $f'_c b_p$

Initially we assume $L_{e1} = \sqrt{\frac{E_p t_p}{f'_c b_p}}$ and L_e proposed by [7] through regression analysis was replaced by L_{e1}. The results from this turn out to be a factor (Z) lower than the measured failure load obtained from the database. This factor (Z) is further analysed by comparing with the testing data and Z=10 produced the best result. Hence, based on the relationship of measured effective length (L_e) and $E_p t_p / f'_c b_p$, a new effective length equation is proposed below:

$$L_e = Z \times \sqrt{\frac{E_p t_p}{f'_c b_p}}, \quad \text{Where} \quad Z = 10$$

Table 2 shows the statistical results where the new effective length equation was used. When comparing with Table 1, it can be seen that the models were improved except for [5].

Table 2 Test-to-predicted debonding strength of masonry using new effective length model

Model	Average	Standard Deviation
Blaschko et al [5]	0.65	0.17
Chen and Teng [6]	1.10	0.29
Sharma et al. [7]	1.03	0.23

Conclusion

The study is carried out to review available models for predicting the shear bond capacity of FRP on masonry. Although 5 debonding models were found, they are all for FRP on concrete and are much less conservative and consistent when used for predicting the debonding of FRP on masonry structures. Due to failure usually occurs below the masonry surface, the masonry strength has great influence to the ultimate load and this should be considered when developing a debonding model for masonry. A new effective length model has also been developed to consider the width of FRP.

References

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