EVALUATION OF EXISTING MODELS FOR BOND CAPACITY OF NSM FRP

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It is now nearly two decades since Fiber Reinforced Polymer (FRP) was first used as structural engineering material. Ever since its main utilization has been in the strengthening of existing reinforced concrete structures. Flexural and shear strengthening of reinforced concrete elements using FRP are performed in two general methods: externally bonding FRP reinforcement (EBR) to element's surface or putting FRP in the form of rod, laminate and strip in a pre-cut groove and filling it up with epoxy paste. The latter called near-surface mounted FRP (NSM) is more effective method as compared to EBR because higher values of FRP strain can be attained. Thus higher values of FRP contribution to the loading capacity of strengthened members can be achieved.

In order to make an effective use of NSM FRP in strengthening of reinforced concrete structures, it is required to have an adequate understanding of the force transferring mechanism between junction of FRP and concrete. Thus many studies have been carried out aiming at developing a predictive bond strength model. In general, these studies are based on experimental programs, finite element method or analytical approaches.

In this paper, three models are studied. The first two models are based on fracture mechanics but the second model uses finite element method. Successful application of fracture mechanics to model EBR technique, has led it to use in NSM, too. The third model is a rather closed form model proposed by Bianco et al. (2009) based on constitutive law and equilibrium. Apart from differences inherent in development of each model, all three models need to assume a bond-slip relationship. Figure 1 shows the bond-slip relationship used in the first model proposed by Seracino et al. (2007).

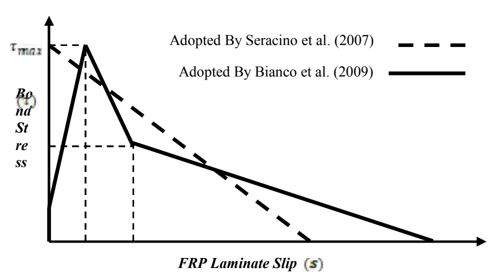


Figure 1. Typical local bond-slip relationships

As shown in Figure 1, the bond-slip curve adopted by Seracino et al. (2007) is very simple as compared to that by Bianco et al. (2009). Zhang et al. (2013) have recently developed a bond model which turns out excellent accurate results. This model uses a more complex relationship for bond-slip as a function of compressive strength of concrete and laminate's height to thickness ratio as follows:

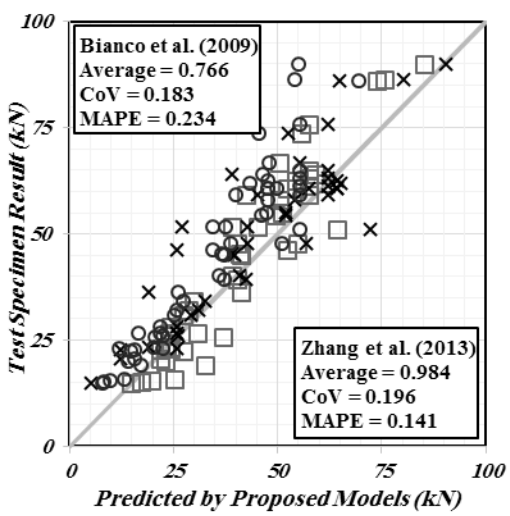
$$\tau(s) = A\left(\frac{2B-s}{B}\right)^2 sin\left(\frac{\pi}{2}\frac{2B-s}{B}\right) \quad s < 2B \tag{1}$$

$$A = 0.72\,\gamma^{0.138}\,f_c^{0.613} \tag{2}$$

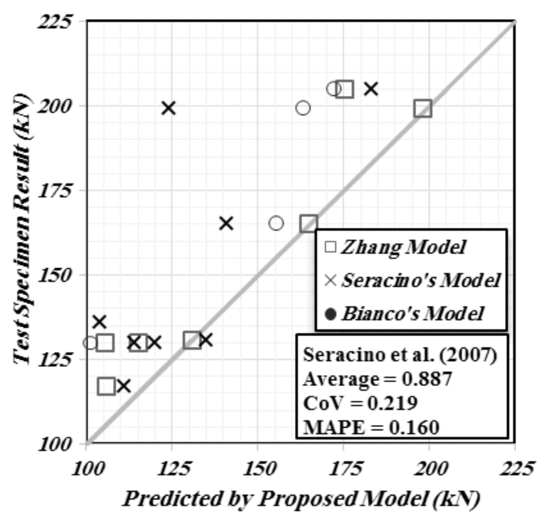
$$B = 0.37\,\gamma^{0.284}\,f_c^{0.006} \tag{3}$$

where $\tau(s)$ (MPa), s (mm), γ and f_c (MPa) are bond stress, relative slip of FRP, height to thickness of laminate and compressive strength of concrete, respectively.

The analytical model proposed by Bianco et al., (2009) is implemented by authors into a computer code using both bond-slip relationships stated in Equation 1 and shown in Figure 1. In order to compare the performance of the considered models, an experimental database containing 60 pull-out test results on NSM FRP which are extracted from eight experimental programs, is assembled from the open literature (Zhang et al., 2013, Bianco et al., 2009). Figures 2a and 2b show comparison of predicted values of three mentioned models against test results for bond strength values in range of 0-100 kN and 100-225 kN, respectively.



a) Bond strength values in range of 0-100 kN



b) Bond strength values in range of 100-225 kN

Figure 2. Comparison of proposed models against test results collection

Average and coefficient of variation (CoV), calculated for the ratio of the predicted bond strength to experimental result for each model, are also shown in Figure 2. Statistical parameters corresponding to the above mentioned models results give that these models have accurate predictions for NSM FRP bond strength. Also CoV of the analytical model is less than CoV of other two models but the model proposed by Zhang et al. (2013) has maximum value of average and minimum value of mean absolute percentage error.

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