Analytical evaluation of bond models for glued-in rods in timber

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The experimental investigation of glued-in rod connections has been the subject of many studies. However, to date the modelling of these connections and the understanding of their mechanics has been limited in literature [1]. The aim of this study is to evaluate known bond models against experimental data of glued-in CFRP and GFRP rods in block laminated timber as reported in [2]. The CFRP and GFRP rods were tested in a pull-compression method with a 50 mm bonded length corresponding to 5D, where D is the core diameter of the rod. Despite pull-pull test method being commonly applied for studying glued-in rods in timber, the pull-compression test method allows experimental recording of the slip values at both the loaded end (end where the load is directly applied) and free end of the specimens. Therefore, bond stress slip models can be analytically studied following an energy based method according to Equation (1) [3]

$$W_{int} = {}^{1}/_{2}\, {}^{A_r}/_{E_r}\, \sigma^2 = \iint_{s_f}^{s_l} \tau(s)\,\mathrm{d}s\,\mathrm{d}\Omega = W_{ext} \qquad (1)$$

where W_{int} and W_{ext} are the internal energy and external work done respectively, A_r, E_r are the rod's cross sectional area and elastic Young's modulus accordingly, σ is the axial normal stress, $\tau(s)$ is the bond stress slip model, s_l and s_f are the loaded end and free end slip values and Ω is the surface area of the rod.

Moreover, specimens with 4 strain gauges attached on the rods and equally distributed along the bonded length (Figure 1a) and an additional specimen cut in half and analysed with Image Processing technique (GeoPIV) [4] (Figure 1b and c) were prepared to understand the bond stress transfer mechanism during the pulling out of the rods and any induced stress concentrations due to the adopted test method.

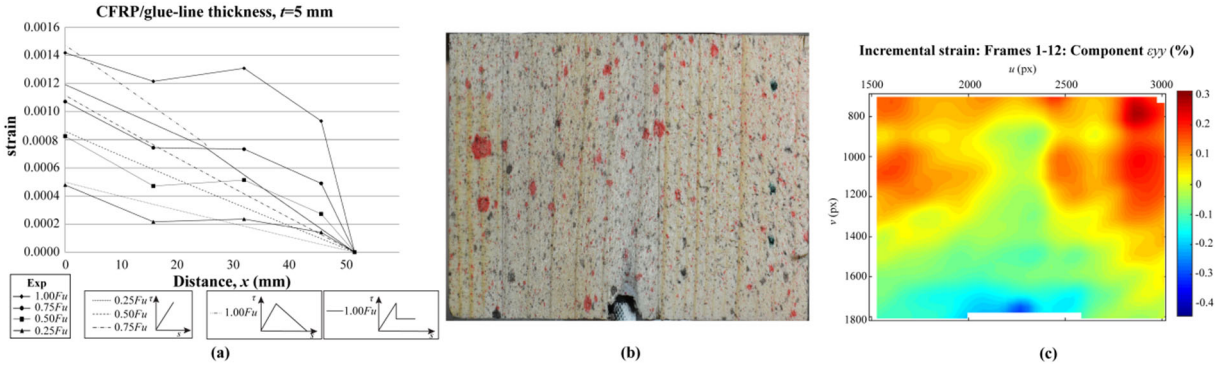

Figure 1: (a) strain distribution of a CFRP rod glued-in block laminated timber, (b) GeoPIV specimen and (c) strain analysis εyy.

A linear and the m.B.E.P ascending bond stress-slip models have been chosen and their constant values are derived following the Nedler optimization algorithm using a Matlab script such that the error function is minimized. To assess a non-uniform bond stress distribution scenario along the bonded length, bilinear models are also adopted. The aforementioned models neglect the mechanical properties of the adhesive layer and might be suitable for very thin glue-line thicknesses. For ease of comparison, the Volkersen model and a new model adapted from [5] that account for the mechanical properties of the adhesive layer are also studied.

The indentification of a suitable bond model relies on the bond failure mode of the glued-in rod connections and can enable their accurate modelling in a detailed analysis stage. The analytical prediction of the slip values allows the calculation of the bond stiffness at each loading stage and consequently the overall stiffness performance of glued-in rods in timber under tension.

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