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PII: S0263-8223(17)33203-8
DOI: https://doi.org/10.1016/j.compstruct.2017.10.010
Reference: COST 8985

To appear in: *Composite Structures*

Numerical Investigations and Capacity Prediction of G-FRP Rods glued into Timber

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Abstract

Glued-in-rods (GiR) represent a class of joints being used in timber engineering that are mostly used to transfer axial loads in structural members with Glass Fibre Reinforced Polymers (G-FRP) increasingly being considered as rod material in substitution for the usually considered metallic rods. The primary objective of the research presented herein was to apply a probabilistic capacity prediction method to timber joints with G-FRP GiR. Necessary secondary objectives were to mechanically characterise the involved components (adhesive, rods, and timber) and to numerically investigate the stress state inside the tested joints. The methodology shall be applied to a recently reported in literature [1] that was specific in two ways: firstly, G-FRP rods were bonded into both ends of the timber block with both ends being tested to failure—a deviation from common practice; and secondly, as opposed to most previous studies exhibiting stiff adhesives, a ductile Polyurethane with markedly non-linear behaviour was used. All material characterisation was performed with methods that can be reproduced by any standard laboratory equipment, to provide parameters for the subsequent numerical analyses. Based thereupon, a probabilistic method was used and provided reasonably accurate predictions of the joint capacities of 25 different geometrical GiR configurations. The probabilistic method was extended for realistic estimations of the experimental capacity scattering in form of upper and lower percentiles.

Keywords: G-FRP, Rods, Adhesive, Bonding, Timber, Hybrid, Joint

1. State-of-the-art

1.1. Background on Glued-in Rods

Glued-in-rods (GiR) represent a class of joints being used in timber engineering. As their name imply, GiR are joints in which linear rods are glued into timber members to join them to another structural component (either wood, steel or concrete) [1–7]. Glued-in rods conceal the connector inside the wood member which is both an architecturally pleasing feature, and provides the joint with better fire and corrosion protection if compared against conventional dowel-type timber connectors with steel plates [8].

Glued-in rods are mostly used to transfer axial loads in timber members. The load path is the following: axial stresses in the timber member are transmitted via the adhesive layer to the rod, which transmits them through shear stresses; at the other end of the rod, stresses are transferred either to another timber member, again via the adhesive layer, or to a steel backed or concrete foundation.

The important geometrical features of GiR, depicted in Fig. 1, are the rod diameter d_R, the embedment length ℓ, the sizing $a \times b$ of the timber element, the distance from the rod to the wood member edge e, the spacing between rods s (for multiple rod connections), and adhesive layer thickness t_a. Features derived thereof are, e.g., the slenderness ratio $\lambda = d_R/\ell$, and most notably average shear stress acting along the rod, $\tau_{avg.} = F_R/(\pi \cdot d_R \cdot \ell)$, with F_R representing joint load-carrying capacity.

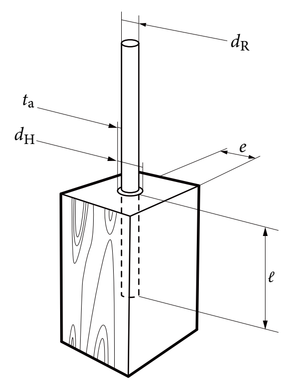

Figure 1: General layout of a GiR, and associated nomenclature

Because of the complex load path, GiR exhibit several potential failure modes. As illustrated by Fig. 2, GiR can fail by: exceeding tensile strength of the rod (1); adhesive (2a) or cohesive (2b) failure of the adhesive; local shear failure of the timber (3a); splitting of the timber (3b); or (the much less likely) tensile failure of the timber member (3c). Design approaches for GiR usually aim at avoiding adhesive failure [2].

To isolate the effect and influence of individual parameters on the mechanical performance of GiR, research focused primar-

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