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Orientation of bars glued on glued laminated products: Parallel vs. perpendicular

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ABSTRACT

This paper presents the results of a comprehensive experimental study of joints made with threaded steel bars glued with epoxy in both parallel and perpendicular directions to the timber fibres. Two types of wooden products, namely, glulam and laminated veneer lumber (LVL), were used due to their widespread use in notable timber engineering designs. Experimental results showed that the behaviour of glued joints with bars parallel and perpendicular to the timber fibres differed, depending on the slenderness of the joint. It was also observed that specimens made with LVL had lower strength than those made with glulam, regardless of whether the anchors were parallel or perpendicular to the fibres.

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1. Introduction

Joints made with glued bars offer numerous possibilities for the design of timber structures. The joints' high capacity for stress transmission and limited deformation make them a high-efficiency solution for the realisation of spatial structures and in the formation of rigid nodes in beam grids and porch structures. Such joints can also be useful in the rehabilitation of old structures.

As an example, Fig. 1 shows the hollow bars of laminated timber used in the cover of a sports arena in A Coruña [1]. Another well-known example is the grating designed with pieces of laminated veneer lumber (LVL) for the remarkable Metropol Parasol building in Seville [2]. Both designs are examples of complex, unusual structures in which glued bars were used as a linkage system.

The resolution of joints between different parts of a structure results in frequent coexistence on a joint of glued bars parallel to the fibre with glued bars tilted from the timber fibres, as is the case with beam–column joints or nodes in truss structures. The anisotropic nature of timber necessitates evaluating the impact of the gluing direction of bars on joint strength. Most of the strength properties of timber diminish significantly when bars are glued in directions that are inclined or perpendicular to the fibre [3]. Conversely, it is well-known that the withdrawal resistance of joints made with lag bolts is higher when they are screwed perpendicular to the fibre than when are screwed parallel to the fibre.

Previous studies have not shown any definitive conclusions on the tensile strength of joints made with glued bars when comparing their orientations to the fibre [4]. This lack of clarity may be due to the limited number of existing studies on bars glued in the perpendicular direction.

Among the pioneering studies available, Gerold [5] has concluded that the strength needed for the withdrawal of bars glued perpendicular to the fibre was slightly higher than for bars glued parallel to the fibre. However, these conclusions have not been corroborated by subsequent studies. Kangas [6] has conducted tests with welded v-shaped corrugated bars that were glued to 30°, 45°, 60° and 90° with respect to the fibre. This researcher has concluded that there are no noticeable differences in failure values obtained for the different directions. Harvey and Ansell [7] have conducted tests on LVL with glass fibre reinforced polymer (GFRP) bars. The results have indicated that the fibre does not influence resistance to the withdrawal resistance of the joint because the tensile strength value obtained when gluing the bars in the perpendicular direction is virtually the same as that obtained for the parallel direction. Within the GIROD project, Blaβ and Laskewitz [8] have performed tensile tests of bars glued perpendicular to the fibre in spruce laminated timber. These authors concluded that there are no significant differences between the shear stress obtained for these specimens and that of those glued parallel to the fibre. More recently, Yeboah et al. [9,10] conducted tests with threaded bars and corrugated bars. These researchers noted that the resistance to withdrawal is lower for joints glued perpendicular to the fibre. The average shear stress of the joint decreases with

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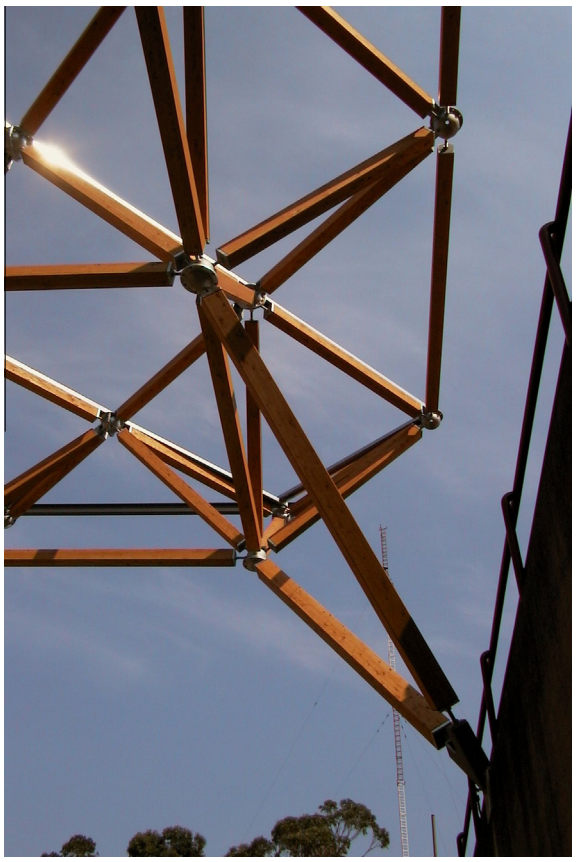

Fig. 1. Spatial mesh of hollow bars made with glued laminated timber and joints made of threaded bars glued with epoxy resin.

Fig. 2. Pull–pull type testing device. Failure by perpendicular shear stresses in glulam specimens.

the length of gluing for both parallel and perpendicular orientations.

Some studies have been carried out on the influence of environmental conditions on the strength of joints made with bars glued parallel to the fibre [11,12], since mechanic properties of timber and adhesive vary depending on the temperature and humidity in service. Further studies need to be done to evaluate the influence of the bar orientation on the strength of the joint in different environmental conditions.

Considering the results described above, an experimental analysis was performed with the goal of evaluating resistance to the extraction of bars glued in the parallel and perpendicular directions. The results obtained from this study are presented in the following sections.

2. Materials and methods

Two types of glued wooden products, glued laminated (glulam) spruce timber [13] and LVL, were used in the testing. The selection of these two types of glued wooden products was based on the fact that they are the most widely used products in the construction of wooden large structures. The specimens' transverse sections measured 160 × 160 mm^2.

Threaded steel bars of quality 12.9 (f_u = 1.20 kN/mm^2, f_y = 1.08 - kN/mm^2) [14] with 12 mm of nominal diameter (d) were used in the design, and the gluing of the threaded bars was performed with epoxy-based two-component HILTI HIT-RE 500 with a glueline thickness of one millimetre. Five gluing lengths (L_b) were tested: 60, 90, 120, 150, and 180 mm; and gluing was performed in the parallel and perpendicular directions with respect to the timber fibres. For this purpose, the length of the timber pieces was 1.5 times the gluing length. This length was parallel or perpendicular to the fibre depending on the direction tested. A total of 140 specimens were tested, with seven specimens representing each combination of gluing length and direction with each type of material.

Table 1 shows the properties of the materials used. The specimens were tested up to the rupture point in a universal machine with a maximum load capacity 1000 kN. The load was applied at a constant speed to obtain failure within a time of 5 ± 2 min. The relative displacement of the cross-head was registered in order to plot the curves load–displacement.

Table 1
Properties of the glued wooden products used in experiments.

	Glued laminated timber GL-28 h (UNE-EN 1194:1999)	Laminated veener lumber © Kerto-S Finnforest
Density (kg/m^3) characteristic values	410	480
Bending strength (N/mm^2) characteristic values	28.0	Edgewise = 44.0 Flatwise = 55.0
Shear strength (N/mm^2) characteristic values	3.2	Edgewise = 2.3 Flatwise = 4.1
Density of specimens tested (kg/m^3)	Mean = 443.5 Characteristic = 414.9	Mean = 536.8 Characteristic = 529.4

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