Influence of elevated temperature on glued-in steel rods for CLT elements

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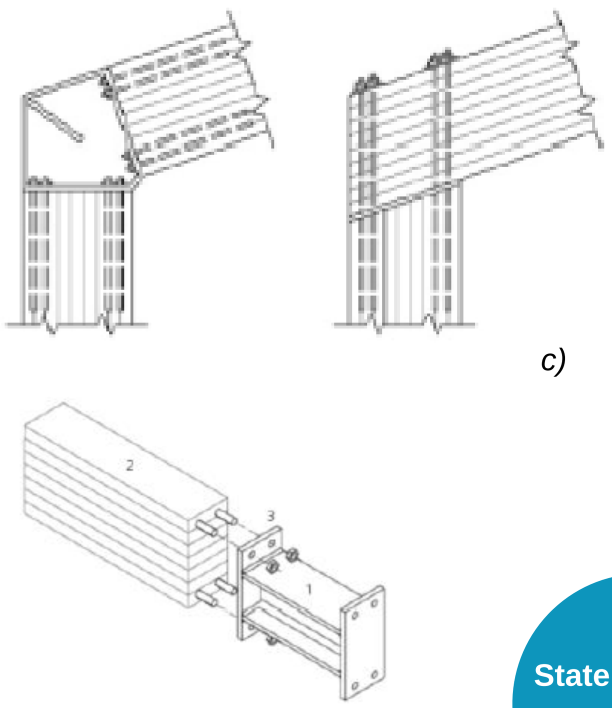
Abstract

Structural bonding technology has proven to be an economically and attractive connection process in timber engineering. Connections and reinforcements with glued-in rods have been used for many years. Glued-in rods (GiR) are an effective way to connect timber elements from both load-bearing capacity/stiffness and aesthetic points of view. The load-bearing capacity of GiR is significantly influenced by the temperature of the adhesive. Although GiR are widely used in timber structures, there are still no unified European test standards, product standards, or design equations for such connections. This work presents an experimental program for obtaining pull-out strength for GiR inserted to Cross Laminated Timber (CLT) when subjected to both ambient and elevated temperatures. Within the experimental investigation, the total number of 36 specimens were tested at ambient temperature and 10 specimens at elevated temperature. Results obtained from both tests are shown, discussed, and compared in this work.

Introduction

Glued-in rods (GiR) are an effective way of producing stiff, high-capacity connections in timber structures. GiR are used for column foundations, moment-resisting connections in beams and frame corners, as shear connectors, and for strengthening structural elements when extensively loaded perpendicular to the grain and in shear. The main advantages of glued-in rods are high load transition, good application in combination with prefabrication for fast installation. In addition, the aesthetic appearance of the finished joint also plays an important role. GiR are often used as a connection method in structures that are landmarks and testimonials to the achievements of structural engineering like exhibition halls, long-span buildings, and timber bridges. Examples of such structures with GiR connections are shown below - Figure 1.

a)



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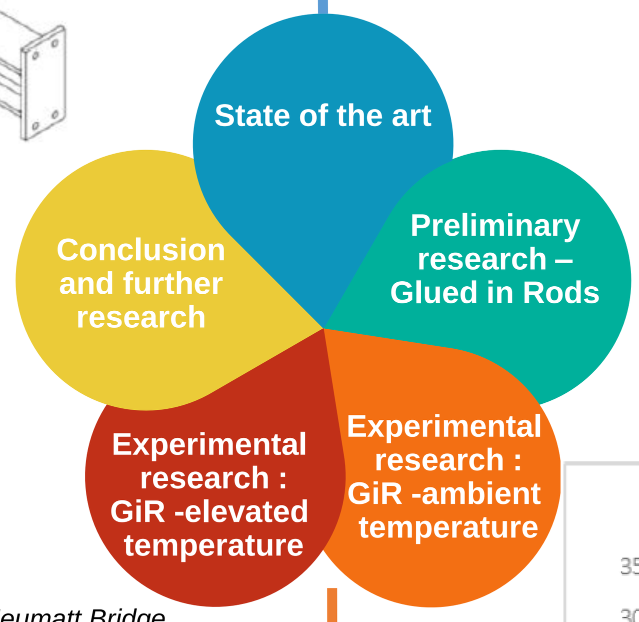


Figure 1: a) Glued-in rods as a connection method in long – span timber structure – Metropol Parasol in Seville, Spain; b) Neumatt Bridge, Switzerland – joints in the timber truss were made using GSA® technology developed by neue Holzbau AG; c) Application of GiR in moment-resistant joints

Great experience has been gathered in the repair and strengthening of beams made of solid timber, both softwood and hardwood, and in connecting concrete slabs to floor beams. Examples are notched beams or beams with holes, curved or tapered beams, and contact zones/supports with high compression stress perpendicular to the grain as shown in Figure 2.

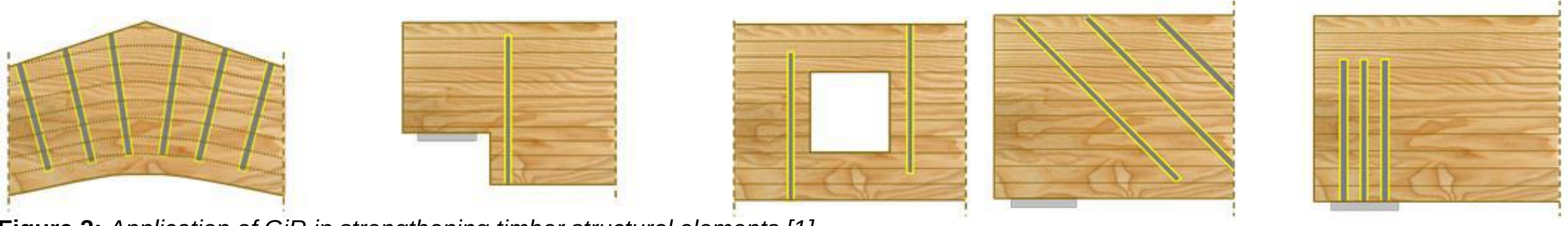
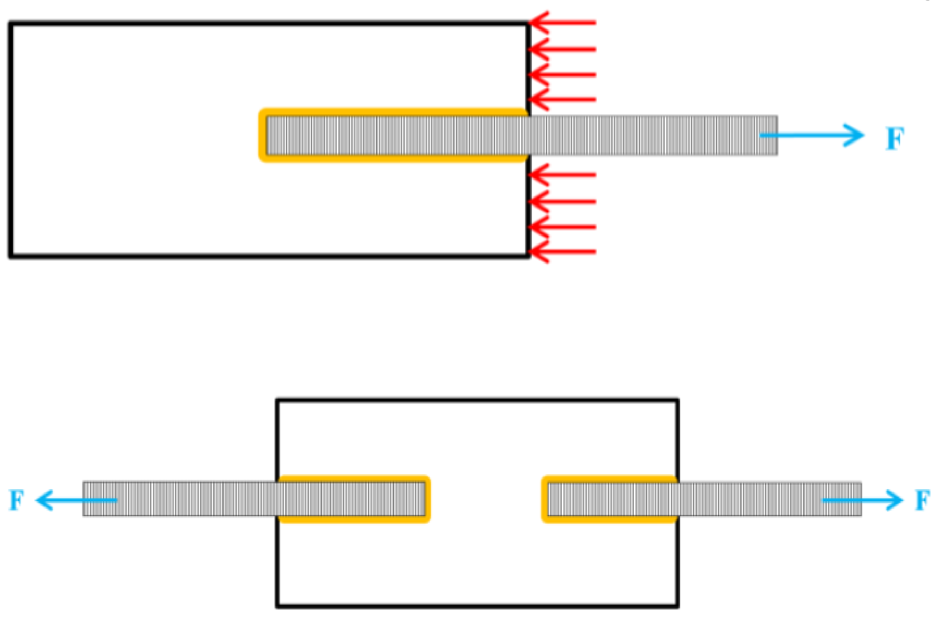


Figure 2: Application of GiR in strengthening timber structural elements [1]

Test methods

The tests in pull – compression (also known as the push-pull method) are widely accepted because of their simplicity, low cost, and comparability with other dowel-type fasteners. The tests are often performed as a push-pull test as it is characterized in EN 1382:1999. Failure modes like the tensile failure are excluded by this test setup and also the splitting of the specimen is detained by friction between the timber and the steel plate. Shear failure along the rod in the adhesive layer or the timber surrounding the rod can occur mostly combined as well as yielding of the rod. Figure 3 illustrates the test setup. The load is transferred from the rod in axial tension to the adhesive and the timber by mechanical interlock.



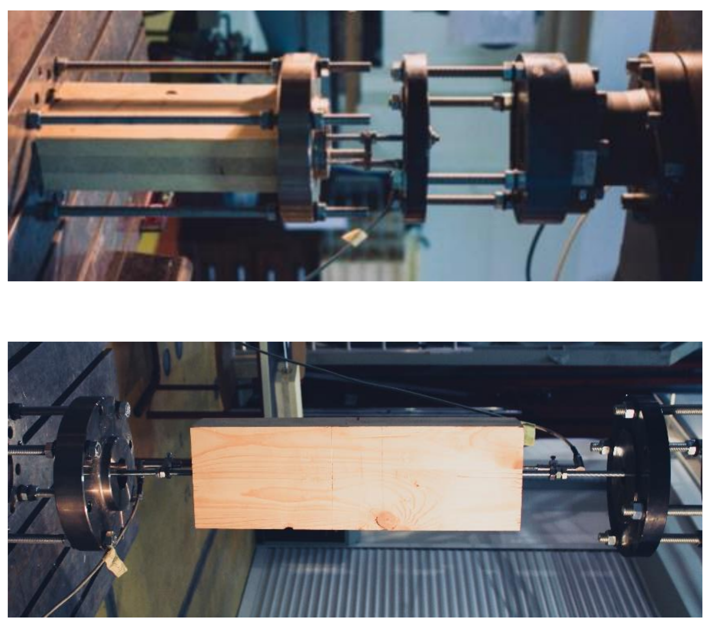


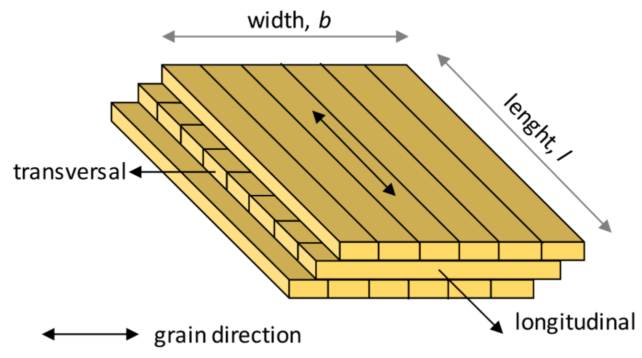
Figure 3: Pull – compression (above) and pull – pull setup

Materials and laboratory tests

The timber members, where the rods were glued-in, were made either of cross-laminated timber with lamellas of a grade CL24h. All timber specimens were equal in their dimensions with the length of 400 mm, the height of 160 mm, and the width of 90 mm.

Table 1: *CLT panel*

Nominal thickness [mm]	Designation	Layers	Grade
90	L3s	3	C24



The purpose of the research was to estimate the load-carrying capacity of GiR and to estimate the type of failure. Therefore, the rods had to be designed to remain in the elastic range at failure. Accordingly, steel bars with metric threads M10 with strength grade 8.8 (characteristic tensile strength fub of 800 N/mm2 and characteristic yield strength fyb of 640 N/mm2) were used. In the laboratory tests, two-component epoxy-based adhesive (EPOCON '88) by Croatian producer KGK was used. The modulus of elasticity of the adhesive in tension at 20 °C is 29,5 MPa.

Test protocols

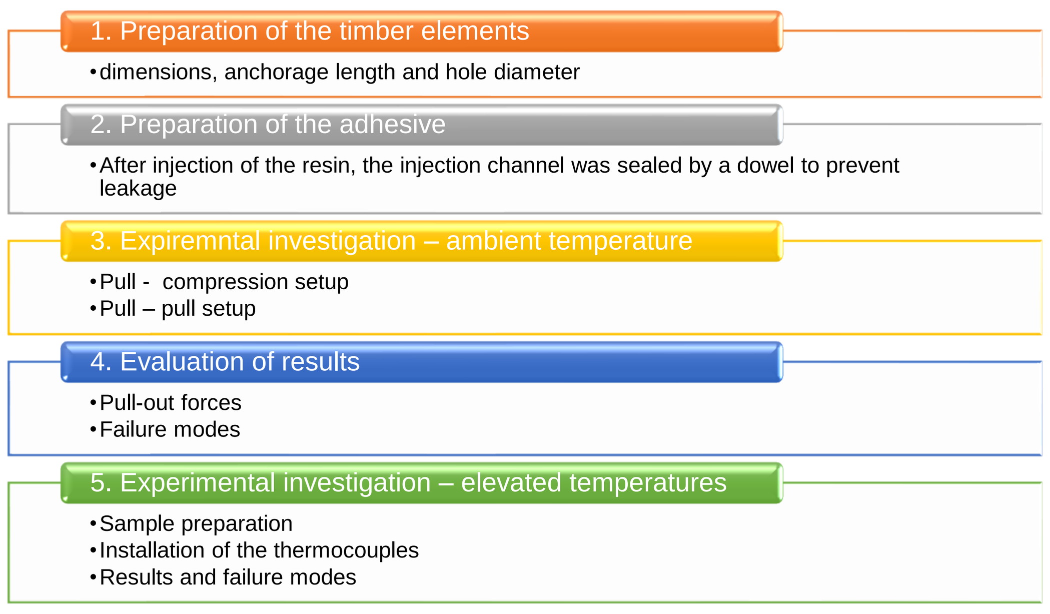


Figure 4 : *Thermal chamber and test setup*

Results – ambient temperature

The possible failure modes at ambient temperature that can occur are summarized in Figure 5.

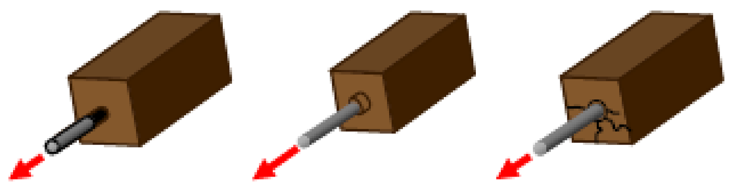
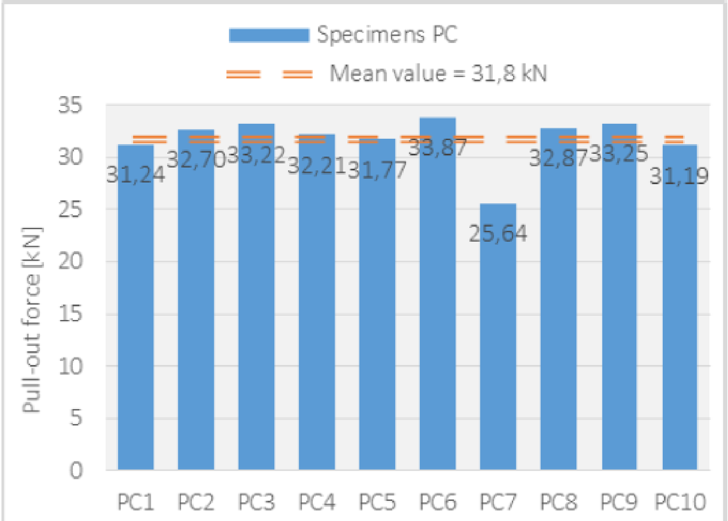


Figure 5 : *Possible failure modes: yielding of the rod, bond failure or cohesive failure in the wood near the bond line, splitting failure of the wood (only for pull-compression method)*

Results obtained from the experimental investigation of the CLT specimens are shown in Figure 6. It is visible from the figures that pull–out forces vary from 25,64 kN to 33,87 kN for the pull–compression test setup.



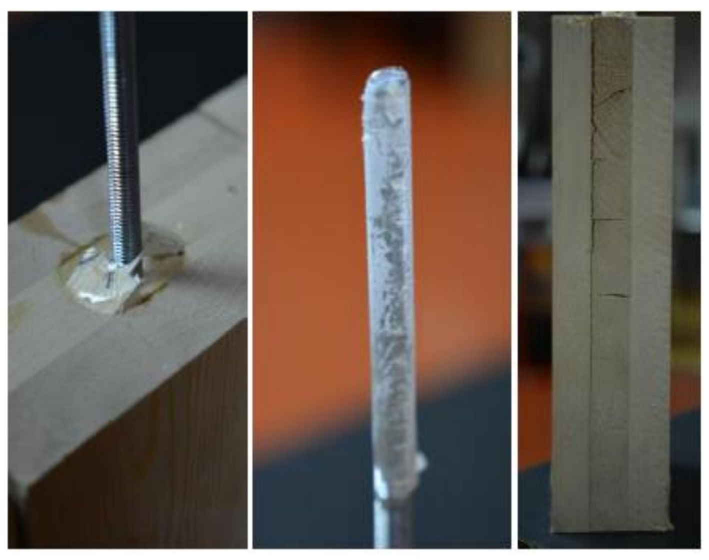
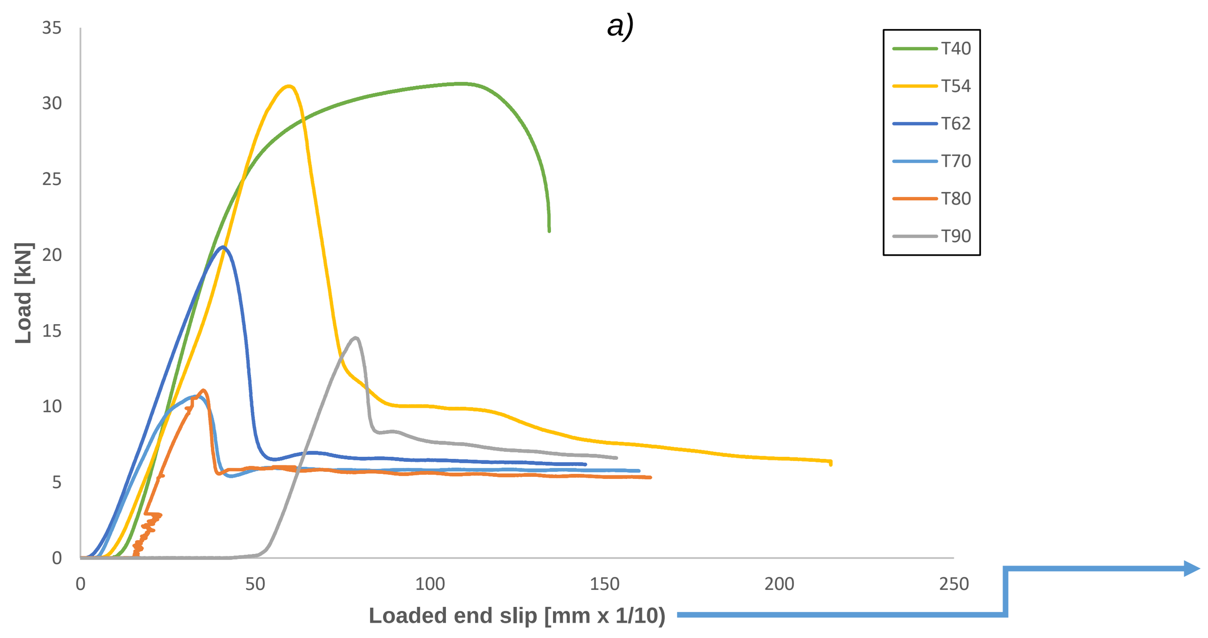


Figure 6: *Pull-out forces obtained from the pull-compression test method for GiR set in CLT (left); Shear failures (right) – ambient temperature (Rajčić et al. 2016)*

Results – elevated temperature



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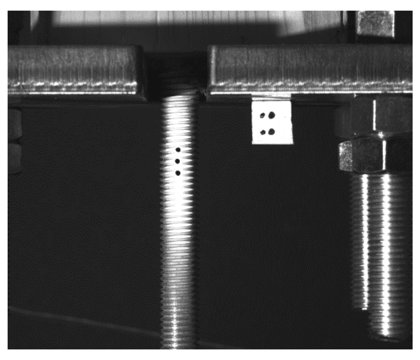

c)

Figure 7: *a) Load vs. slip curves; b) general view of the specimen in the thermal chamber; c) video extensometer; d) failure mode*

Conclusion

The experimental study exhibit a failure of the connection in the wood in the vicinity of the wood–adhesive interface. The experimental results revealed a significant decrease in the stiffness of the connection for temperatures above 60 C° (Figure 7). The diameter of the bar does not affect the resistance of such joints. the diameter of the bar does not affect the resistance of such joints.

d)

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