CAPACITY PREDICTION OF BONDED BEECH JOINTS UNDER NORMAL AND ELEVATED TEMPERATURES

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ABSTRACT: Research on adhesively bonded timber connection has proven their superiority over mechanical fasteners in terms of strength and stiffness, but such research was often limited to consider softwood. Despite its abundant availability in Central Europe and its high mechanical resistance, which make it a promising material for structural applications, beech is only rarely considered as a structural material. Furthermore, research on bonded timber joints was almost exclusively carried out at room temperature. The research presented herein contributes to fill these two gaps by experimentally and numerically investigating adhesively bonded beech joints under elevated temperatures. A capacity prediction method is offered which sets the basis for subsequent dimensioning methods that at term enable practitioners to design their structures.

KEYWORDS: Hardwood, bonded, joints, capacity, temperature, failure, FEA, temperature.

1 INTRODUCTION

In recent years, research on adhesively bonded connections in relation with timber has increased, as demonstrated by the growing number of related publications, e.g. [1-4]. Traditional, mainly mechanical, timber joining techniques are not fully material adapted. The use of adhesive bonding is described as one of the most interesting fields of development: “just as adhesives have freed timber of its structural and size limitations, adhesives can free timber of the metal needed presently to make joints” [1].

2 PREMISSES

2.1 JOINTS UNDER TEMPERATURE

The performance of adhesively bonded timber joints must be reliably described, and ideally ensured, for temperatures up to values around 60 °C, which are considered to occur during the service life of structures. Regarding the behaviour of most adhesives, both strength and stiffness are affected by temperature.

2.2 CAPACITY PREDICTION OF JOINTS

Timber exhibits a large variability of its mechanical parameters, especially if considering strength data [2-4]. Practitioners usually consider a multi-axial failure criterion provided by Norris [5]. Since timber is highly brittle with regard to shear and transverse tensile stresses, its failure is conceptually considered to be triggered by a single defect, also labelled weak element. The probability that these randomly distributed defects are encountered increases with component size [6].

3 EXPERIMENTAL WORK

3.1 CHARACTERIZATION OF THE TIMBER

The beech was mechanically characterized with regard to strength, assuming, that the timber adherents fail. Failure is triggered by a combination of axial stresses, $\sigma_X$, transverse tensile stresses, $\sigma_Y$, and shear stresses, $t_{XY}$. Consequently, and in accordance with previous validated practice, 107 dog-bone shaped off-axis traction tests were performed.

3.2 CHARACTERIZATION OF THE ADHESIVE

An appropriate adhesive that achieves adherend failure, the preferred mode for structural applications, was selected on the basis of single-lap-shear tests. To quantify the influence of temperature on the selected adhesive, more specifically its stiffness, a Dynamic Mechanical Analysis (DMA) was performed.

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3.3 EXPERIMENTS ON BONDED JOINTS
Two series of symmetrical DLJ were considered:
- S1: Three different overlap lengths were considered: 80 mm, 120 mm, and 160 mm; at RT (22°C) and,
- S2: Constant overlap length of 80 mm, influence of temperature (60°C, 90°C, and 120°C)

Figure 1: Joint capacity in function of overlap, S1

Figure 2: Joint capacity in function of temperature, S2

4 RESULTS AND DISCUSSION

4.1 CAPACITIES AND CAPACITY PREDICTIONS
All joints tested below T_g failed inside timber; specimens tested beyond T_g, observations made after failure showed that the failure patterns shifts towards adhesive failure: while at 90 °C a small proportion of timber is still within the areas where failure initiated (i.e. end of the overlap), at 120 °C 100% adhesive failure occurred.

Experimentally determined joint capacities at RT and in dependency of the overlap length, series S1 graphically displayed in Figure 1. Capacities increase with the overlap length, the capacity plateau which delivers an upper bound, seems to have been reached between overlaps of 120 mm and 160 mm.

Quantitatively, predicted values are in good agreement with experimental values, which is well visualized by Figure 1; the deviation being between 1% and 7%.

Regarding the dependency of joint capacity on temperature, the experimental results of series S2 are shown in Figure 2. Predictions are very good for temperatures below T_g of the adhesive, covering the relevant temperature region for civil engineering practice. Predictions are non-conservative for temperatures higher than T_g (by 30% at 120°C). In this region, the probabilistic method that predicts failure of wood under multi-axial stresses is no longer valid.

5 CONCLUSIONS
Using specifically selected adhesives, it is possible to manufacture such joints, that their failure is governed by the material strength of timber under a combination of axial, transverse tensile, and shear stresses, and that the corresponding joint capacity can be predicted accurately using a probabilistic approach.

Considering elevated temperatures the results obtained on the characterization of the timber, the adhesive, and the joints indicated that the principles developed for the capacity prediction method at RT remain basically valid at elevated temperatures up to the adhesive’s glass transition temperature. The accuracy of the predictions declined with increasing temperatures clearly indicating the need for further research on this topic.

REFERENCES