Performance of Finger Jointed Boards and Structural Glued Laminated Timber Beams Made of Thermally Modified Beech

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ABSTRACT

The paper describes tests with structural glued laminated timber (glulam) beams and finger-jointed boards made out of thermally treated hardwood (beech, *fagus sylvatica*) (TMTB). The finger jointed lamellas were tested in tension, flatwise- and edgewise bending. While automatically produced finger joints mostly showed unsatisfactory strengths it was possible with manually produced finger joints to achieve better strength values. Two series of 10 and 40 glulam TMTB beams were produced to evaluate their load carrying behaviour. They were tested in bending and the quality of the gluelines was tested with delamination tests and block-shear tests. Usually it is expected that combining lamellas of a certain quality to a glulam beam will enhance certain characteristic mechanical properties of the final product compared to the properties of the single boards. The results of the tests could not confirm this behaviour for the TMTB glulam beams even if the bond lines proved to be of a satisfactory quality.

INTRODUCTION

In the past 5 years products made out of thermally treated timber (TMT) are being increasingly used for a wide field of applications. For outdoor use its improved durability and dimensional stability upgrades TMT as a potential substitute for tropical hardwoods or impregnated softwoods. For indoor use as furniture of flooring TMT is becoming a competitor to dark coloured tropical hardwoods due to the wide range of possible colours resulting from the thermal treatment. Within the EC-funded FP6 project *Holiwood* it is intended to widen the field of uses for TMT made out of European hardwoods to structural applications. The heat treatment process limits the possible dimensions and cross sections of solid timber members. Therefore it is required to use glued products within the structures like it is the case in many common timber constructions. The heat treatment process at Mitteramskogler is limited to thicknesses of about 60 mm. However, square-cut timber members made of TMTB with these thicknesses showed considerable deformations like bow and twist which finally lead to reduced usable maximum thicknesses to about 45 mm to 50 mm. As a consequence glulam instead of solid timber has to be used already for relative small dimension (cross-section) timber members. For the development of glued structural products made out of TMTB the production and testing of finger-jointed boards is the first step. However, some preliminary series of finger-jointed TMTB boards produced according to standard procedures showed partly very low minimum bending strengths (6 N/mm^2), thus the assessment of suitable finger geometries, adhesive(s) and procedures for the production of improved finger-joints in TMTB was necessary. In the following the results of bending and tension tests on finger-jointed TMTB lamellas and untreated beech lamellas as well as bending, delamination and block-shear tests of glulam TMTB-beams are presented.

EXPERIMENTAL

Material

The raw material for the finger-jointed lamellas and the glulam beams consisted of high visual quality boards made of TMTB "Buche forte" (Mitteramskogler 2009 Thermoholz Kurzinformation. www.mirako.at) produced by Mitteramskogler GmbH in Austria (A). The thermal treatment – details are confidential - can be considered as being a strong treatment that enables the TMTB being assigned to durability class3. The finger joints were produced manually at Mitteramskogler as well as automatically at Obermayr GmbH (A). Obermayr also produced the glued laminated members using standard procedures and equipment.

Finger-jointing and gluing

For the production of the fingers two different cutter heads were selected, resulting in finger geometries of 20mm x 6.2mm (Series 1, "FJ1") and 15mm x 3.8mm (Series 2, "FJ2"). The lamellas were cut in two pieces, the fingers cut and the same pieces rejoined and glued. All joints were produced manually using an adhesive Dynea PRF Prefere 4099 and hardener Prefere 5827. The bonding pressure was applied by c-clamps. The lamellas for the glulam beams were finger-jointed automatically and had the geometry "FJ2". For gluing these finger–joints as well as the lamellas a Dynea MUF Prefere 4535 adhesive in combination with a Prefere 5035 hardener were used.

Specimens

On overview of the specimens used for the bending and tension tests of the finger-jointed boards (FJ) and the glulam beams (GL) is given in Table 1.

Table 1: Overview of tests specimens

		Flatwise bending		Edgewise bending		Tension		Glulam bending	
	Series	FJ1	FJ2	FJ1	FJ2	FJ1	FJ2	GL1	GL2
ℓ [mm]		540		1800		500		1845	4860
b [mm]		120		30		30		140	120
h [mm]		30		120		120		120	270
n []	TMT	18	18	16	16	10	12	10	40
	Be	16	18	15	16	12	14		
ρ [kg/m^3]	TMT	610-750	590-785	600-730	610-790	650-715	675-760	620-680	630-700
	Be	640-800	635-810	645-790	650-830	685-815	675-795		
u [%]	TMT	5.4-7.4	5.3-6.0	5.1-7.4	5.3-6.2	5.5-6.9	5.1-6.3	5.0-6.5	5.7-6.8
	Be	10-12	10-12	11-12	10-12	11-12	10-12		

The specimens for block-shear and delamination tests were taken from the glulam beams according to the relevant standards EN 391 and EN 392.

Procedures

The bending tests were executed as 4-point bending tests according to EN 408 and the tension tests were executed on a special testing device. Delamination and block shear tests were based on EN 391 (Method B) and EN 392 respectively but only the specimens of series GL1 underwent the two latter mentioned tests up to now.

RESULTS AND DISCUSSION

Finger jointed boards

Within all test series the reference beech specimens failed in the adhesive layer or at the wood-adhesive interface of the fingers. As wood fibres could only be observed on less than 40% of the glued finger surface adhesive failure was determined as the dominant failure mode. In contrary the TMTB samples failed predominantly in the wood. Failure at the base of the fingers could be observed as well as wood failure that appeared to be independent of the presence of the joint. This was in particular the case for the tension specimens where only 20% of the specimens failed predominantly in the adhesive layer of the joint. An overview of the test results is shown in Figure 1. It can be seen that for every combination of wood and finger geometry the strength ranking (from high strength to low strength) flatwise bending – edgewise bending – tension is the same. TMTB tension specimens which didn't fail in the wood but in the joint showed (high) tension strengths in the range of the untreated beech specimens. About 50% of the tension specimens TMTB FJ2 failed inside the clamps of the tensile testing machine under low failure loads.

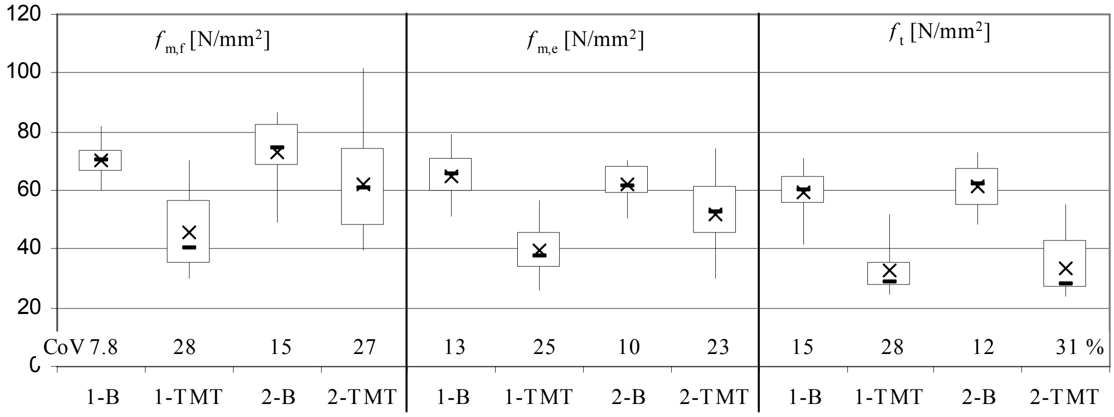

Figure 1: Boxplots of flatwise bending strength $f_{m,f}$, edgewise bending strength $f_{m,e}$ and tension strength f_t for two different finger-joint geometries (1,2) in boards made of heat-treated (TMT) and untreated (B) beech.

The relatively small number of specimens strongly influenced the determination of characteristic strength values and therefore these values can only be taken as an estimation of the potential of such a type of finger-joints. The strength of the reference samples was comparable to values found in literature (Blass *et al*. 2005) but the TMTB samples performed considerably weaker. However, the characteristic bending strength of the TMTB FJ2 sample permits to use these lamellas for the production of GL24 glulam according to EN 1194.

Glulam beams

The glulam beams showed typical bending failures. The initial failure occurred in the tension zone most often at or close to a finger-joint. Other lamellas in the tension zone failed due to excessive angle of grain or due to existing (micro) cracks resulting from the production process. The overall bending strength was found to be very poor (Figure 2). It has to be kept in mind that the reference depth for glulam beams is 600mm and the tested specimens had only depths of 120 and 270mm respectively. The bending strength of specimens that meet the reference depth can be expected as being even lower than these obtained in the bending tests.

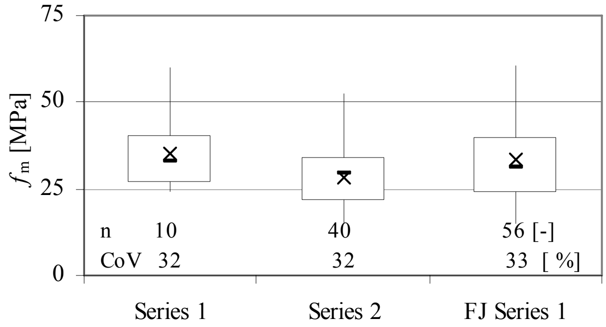

Figure 2: Bending strength of two series of TMTB glulam and one flatwise tested series of finger-jointed lamellas.

The bad bending performance can be mainly attributed to the brittle behaviour of the TMTB. Already in the production process cracks appeared in the course of automatically finger-jointing and or the gluing of the lamellas. This is partly confirmed by the low flatwise bending strength of the series 1 finger joints (see Figure 2). If compared to the results shown in Figure 1 it can be clearly seen that the performance of automatically produced finger-joints is considerably worse compared to the manually produced joints. The delamination tests of sections taken from glue-laminated beams of series 1 showed a high degree of delamination. Only 3 out of ten tested cross sections fulfilled the requirements of EN 386. However, the performance of the glue line in reference to block shear strength was sufficient, with mean shear strength of 13.8N/mm^2 and wood failure percentage exceeding 80%. Therefore the used PRF adhesive for series 1 can be considered as being suitable for gluing TMTB lamellas.

CONCLUSIONS

- Manually produced finger-joints in TMTB boards showed relatively high strengths compared to automatically produced finger-joints
- Glulam beams made of TMTB showed very low bending strengths (at least at the 5% level). In consequence an acceptance of such a product on the market for structural timber is more than questionable.
- The used MUF adhesive seems to be suitable for gluing lamellas and finger joints made of TMTB and the used PRF showed a good performance for gluing finger joints in TMTB.

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