EXPERIMENTAL RESEARCH ON THE MECHANICAL CHARACTERISTICS OF A HARDWOOD ELEMENT

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ABSTRACT

The paper presents the experimental results obtained for bending strength parallel to the fibers of a beam element made of hardwood (deciduous) glued laminated timber. At the same time, tests were carried out to determine the physico-mechanical characteristics of the wood specimens, in order verify the wood species.

Keywords: hardwood, glued laminated timber

REZUMAT

Lucrarea prezintă rezultatele experimentale obţinute pentru rezistenţa la încovoiere paralel cu fibrele a unui element de tip grindă realizat din lamele încleiate din lemn de esenţă tare (foioase). Totodată s-au realizat încercări experimentale pentru determinarea unor caracteristici fizico-mecanice ale lemnului utilizat.

Cuvinte cheie: foioase, lemn lamelat încleiat

1. INTRODUCTION

The ongoing climate change has a severe impact on our forests with impact on replacing to more adaptable, climate tolerant and species-rich mixed forests, so that the percentage of tree species, e.g. Douglas fir and beech, will distinctly growing. Therefore, the supply of raw material from the forest may change in the near future. To adapt to these changes, the woodworking industry needs to adjust the production processes. Alternatively, advantages can be taken by developing new and improved wooden products (Jiang et al., 2014). In this context, the bonding technology plays a key role. Bonding of various wood species with higher strength and/or durability, will lead to benefits for wood engineered products. However, experience shows that gluing of timber without sufficient technical knowledge and elaborateness can lead to serious damages. Investigations after the collapse of the Bad Reichenhall ice rink in 2006 showed that damages in structural elements made of glued laminated timber (GLT) are often caused by delaminated glue lines (Blaß and Frese, 2007, Dietsch and Winter, 2009). Today, in Central Europe GLT is almost exclusively made of spruce or pine (Ohnesorge et al., 2009). However, in the recent past, research and industry have shown increasing interest in using hardwoods such as beech. During the last years there are several buildings erected in Germany with GLT made of beech as structural elements. In Switzerland, where building regulations are less restrictive, some experience with GLT made of hardwoods such as ash and beech has been gained in the last decades.

In general the elements used in buildings in which normal atmospheric conditions prevail are not seriously deteriorated even after considerable periods of service. Casein-glued members used under more severe conditions, such as locomotive-repair shops, chemical plants, footbridges, and railway and platform structures, also were reported to have given good performance (Alan D. Freas, 1949).

The big challenges of wood structural design and execution are, the lack of constant material performance, even in the same structural element or specimen. The causes are natural flows of the material and natural growth patterns (natural wood rings) as well as its high sensitivity with respect to environmental conditions. The wood is still alive and reacts to temperature and humidity changes, which leads to important changes in terms of mechanical performance. The use of composite sections of laminated glued wood lamellas proved to improve the material constancy and, as consequence, the predictability of its behaviour under loading and the structural design, as well. In addition, higher bearing capacity and superior strength are achieved.

In the last decades there is an interest to use species of hardwood for GLT. A study was carried out (Bourreau et al., 2013) in French Guiana in which they used local wood species. The aim was to determine gluing parameters affording satisfactory behaviour to manufactured glulam in a tropical climate. Three wood species, with special properties, were selected for the study and resorcinol–phenol–formaldehyde resin was used for bonding. They considered three industrial parameters: adhesive spread rate, closed assembly time and gluing pressure. Delamination and shearing tests were carried out in accordance with European Standards. The tests revealed the influence of wood properties and manufacturing parameters on joint resistance. In fact, the results showed that specific gravity and the shrinkage coefficient greatly influenced the gluing step. Indeed, wood with a medium specific gravity needed more adhesive and more pressure than wood with a high specific gravity. In addition, planning and lamella thickness were found to affect glue joint resistance

2. EXPERIMENTAL WORK

2.1. The material

Test specimens were taken from a beam made of hardwood with variable longitudinal section as follows: C1...C24 test specimens 50×50×300 for the determination of compression strength and T1...T5 beams 50×150×2850 for bending strength parallel to fibers as well as for the modulus of elasticity. Immediately after sampling, the C16...C23 specimens were placed in the oven for moisture determination. Test specimens C1...C15 as well as T1...T5 beams were conditioned up to the test time as follows: 20°C and 58% humidity. The laboratory tests were carried out according to SR EN 408 and the strength classes – according to SR EN 338. The density of the material was 750 kg/m^3 which, according to SR EN 338, matches that of hardwood D50.

2.2. Determination of humidity

The test was performed according to SR EN 131383-1. Immediately after sampling, the C16...C23 specimens were measured, weighed and placed in the oven at 103 ± 2°C. Intermediate measurements were carried out immediately after the specimens were taken out of the oven. The mass difference between two successive weights, expressed as a percentage, was observed to be less than 0.1%. The moisture content, *w*, was calculated as:

$$w = \frac{m_1 - m_0}{m_0} \cdot 100 \quad [\%] \tag{1}$$

Table 1. Humidity

Specimen	Initial mass m_1	Dry mass m_0	w
	[g]	[g]	[%]
C16	567.8	508.7	11.6
C17	581.2	520.3	11.7
C18	569.4	516.7	10.2
C19	618.4	556.8	11.1
C20	535.6	481.9	11.1
C21	534.0	482.1	10.8
C22	578.8	516.4	12.1
C23	598.6	523.8	14.3

2.3. Determination of compressive strength parallel to the fibers

The test was carried out in accordance with SR EN 408:2010+A1:2012 and represents the evaluation of the compressive strength parallel to the fibers on the test pieces with the length six times the smallest dimension. The test time was within 300 ± 120s. The compressive strength parallel to the fibers was calculated as follows:

$$f_{c,o} = \frac{F_{\max}}{A} \quad [\text{N/mm}^2] \tag{2}$$

Table 2. *Compressive strength*

Spec.	Time	L	a mean	b mean	Aria	F_{max}	$f_{c,0}$	$f_{c,0,12\%}$
	[sec]	[cm]	[mm]	[mm]	[mm2]	[kN]	[N/mm2]	[N/mm2]
C2	330	300.12	50.895	50.705	2580.63	174	67.43	68.44
C4	185	300.57	50.665	50.86	2576.82	142	54.99	55.82
C6	250	300.37	50.28	50.455	2536.88	170	67.05	68.06
C7	192	299.45	49.29	50.515	2489.88	162	64.94	65.92
C8	210	303.58	50.86	49.845	2535.12	156	61.69	62.62
C9	225	302.79	50.98	49.77	2537.27	157	61.68	62.61
C10	178	300.85	50.685	50.885	2579.11	154	59.87	60.76
C11	197	300.35	49.49	50.455	2497.02	147	58.75	59.63
C12	249	300.36	51.065	49.785	2542.27	170	66.87	67.87
C13	234	299.28	50.35	50.38	2536.63	147	58.03	58.90
C14	258	300.77	50.615	50.345	2548.21	183	71.89	72.97

The test values were corrected, in accordance with SR EN 384: 2010, with 3% for each variation of 1% versus the 12% humidity resulting in the corrected value ($f_{c,0.12\%}$). The results for the C1, C3, C5 and C15 specimens were removed from the mean calculation because the specimens included a joint in the teeth and are distinct from the bulk mass of massive wood.

Fig. 1. Failure mode of a specimen

2.4. Determination of bending resistance parallel to the fibers

The test was carried out in accordance with SR EN 408:201 and represents the evaluation of bending strength parallel to the fibers on 50×150×2850 mm. The elements were extracted from the composite beams. The elements were symmetrically loaded in two points over 18 h span, according to Fig. 2. The elements were simply hinged at the ends in a device that allows turning in the longitudinal direction and prevents the lateral buckling. The bending resistance parallel to the fibers was calculated as follows:

$$f_m = \frac{3 \cdot F \cdot a}{b \cdot h^2} \quad [\text{N/mm}^2] \tag{3}$$

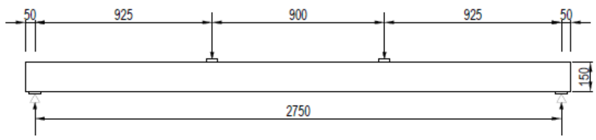

Fig. 2. Static scheme

Fig. 3 shows the force – displacement variation curve.

Fig. 1. Force – displacement variation

2.5. Determination of the modulus of elasticity parallel to the fibers

The test was carried out in accordance with SR EN 408:2010+A1:2012 and represents the evaluation of the overall bending modulus parallel to the fiber on beam elements with the dimensions of 50×150×2850 mm. As stipulated in norm, the maximum load applied shall not exceed 0.4 F_{max} or lead to degradation unless the test is performed at the same time as the bending strength determination. Record the applied force and deformation w in the middle of the opening at the underside of the stretched fiber. The modulus of elasticity was calculated with:

$$E_{m,g} = \frac{3 \cdot a \cdot l^2 - 4 \cdot a^3}{2 \cdot b \cdot h^3 \left(2 \frac{w_2 - w_1}{F_2 - F_1} - \frac{6 \cdot a}{5 \cdot G \cdot b \cdot h} \right)} \tag{4}$$

Table 3. *Modulus of elasticity*

Spec.	b	h	l	F_1	F_2	w_1	w_2	$E_{m,g}$
	[mm]	[mm]	[mm]	[kN]	[kN]	[mm]	[mm]	[kN/mm^2]
T 1	50	150	2750	2.41	9.72	3.09	14.37	17.1
T 2	50	150	2750	2.33	9.36	2.98	12.82	18.9
T 3	50	150	2750	2.3	8.52	2.72	11.93	17.8
T 4	50	150	2750	2.66	10.34	3.43	16.07	16.0
T 5	50	150	2750	2.16	8.64	2.83	12.79	17.2

3. CONCLUSIONS

Based on the experimental tests carried out, the following conclusions were drawn:

- the values for bending, modulus of elasticity and compression tests showed that the wood is falling in strength class D60;
- in what concerns density, the wood with a mean value of 750 kg/m^3 is of strength class D50;
- failure occurred mainly in the lamellas starting from the teeth joint;
- only one beam failed due to the separation of lamellas;
- a partial separation of the lamellae was observed due to the drying process.

REFERENCES

Jiang Y., Schaffrath J., Knorz M., Winter S. (2014), *Bonding of Various Wood Species – Studies about Their Applicability in Glued Laminated Timber.* in: Aicher S., Reinhardt HW., Garrecht H. (eds) *Materials and Joints in Timber Structures*, RILEM Bookseries, vol 9. Springer, Dordrecht, pp 365-374.

Blaß H.J., Frese M. (2007), *Damage analysis, causes of damage and assessment of the stability of existing wooden structures* [in German], Research Report of the University of Karlsruhe, Chair of Timber Engineering and Structural Design, Karlsruhe, Germany.

Dietsch P., Winter S. (2009) *Assessment of the Structural Reliability of all wide span Timber Structures under the Responsibility of the City of Munich.* in: *33rd IABSE Symposium Proceedings, 9-11 September 2009, Bangkok, Thailand,* pp. 322 - 323

Ohnesorge D., Henning M., Becker G. (2009), *Importance of hardwood in glulam production* [in German], Holztechnologie 50: 47–49.

Alan D. Freas (1949), *Studies of th strength of glued laminated wood construction*, Report R1749, United States of Agriculture, Forest Products Laboratory, , Wisconsin, USA.

Bourreau D., Aimene Y., Beauchêne J., (2013), *Feasibility of glued laminated timber beams with tropical hardwoods*, European Journal of Wood and Wood Products, **71(5)**: 653–662.