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MECHANICAL PROPERTIES OF A BALSA WOOD VENEER CORE MATERIAL AT ELEVATED TEMPERATURES

Chao Wu[1,a], Niloufar Vahedi[2,b], Anastasios P. Vassilopoulos[2,c] and Thomas Keller[2,d]
[1] School of Transportation Science and Engineering, Beihang University, China
[2] Composite Construction Laboratory (CCLab), École Polytechnique Fédérale de Lausanne (EPFL), Switzerland
[a] wuchao@buaa.edu.cn
[b] niloufar.vahedi@epfl.ch
[c] anastasios.vasilopoulos@epfl.ch
[d] Corresponding author E-mail: thomas.keller@epfl.ch

1. INTRODUCTION

High strength-to-weight and stiffness-to-weight ratios make Balsa wood a preferred material for cores of sandwich structures [1, 2]. The major disadvantage of this system is the heat damage and softening that occurs in the event of fire. The stiffness and strength properties of the Balsa core and laminate skins are reduced by thermal softening, heat damage and decomposition [3]. Goodrich et al. [2] performed an experimental study on mechanical properties, physical degradation, and decomposition of Balsa wood at high temperatures. It was found that the compression strength of Balsa decreased at a quasilinear rate with increasing temperature up to 250°C. The reduction was attributed to the softening of the hemicellulose and lignin above 120°C. The authors also claimed that the loss in strength up to the point of decomposition was reversible for short-term fire exposure and the strength could fully recover when samples cooled back to room temperature. Since the mechanical properties of Balsa wood vary considerably, new configurations composed of veneer layers of different fiber orientations, which are adhesively-bonded together, were developed. The behavior of such materials at elevated temperature has not yet been investigated.

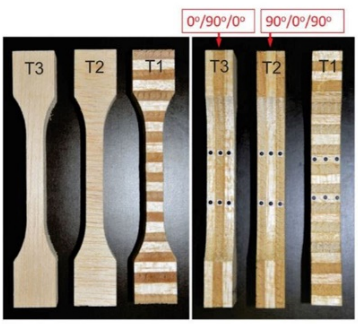
2. EXPERIMENTAL INVESTIGATION

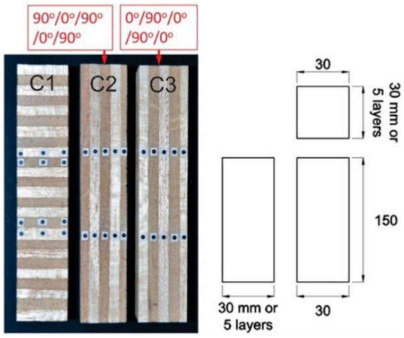
Materials

The Balsa wood used in the current study was BALTEK® VBC provided by 3A Composites Core Materials at Sins, Switzerland. This product consists of Balsa veneer layers, which were produced through a rotary peeling process of Balsa trunks using a roller pressing bar. Each veneer layer had a nominal thickness of 6 mm. They were alternatingly stacked in 0°/90° grain orientations and bonded together with a one component cold curing and foaming Polyurethane (PU) adhesive, Jowapur 687.22. The veneer layers were compressed and cured at room temperature for at least twenty four hours.

Tensile, Compression and Shear experiments under Elevated Temperature

Considering all possible load directions which could be developed in the core of the sandwich panel, three tensile configurations (Fig. 1 (a)), three compressive configurations (Fig. 1(b)) and four shear configurations (Fig. 1(c)) were selected. The dimensions were determined according to ASTM D3500-14 [4], ISO 22390:2010 [5], ASTM D3501-05 [6] and ASTM D5379-12 [7]. The selected temperatures were ambient/laboratory temperature (27~31°C), 100°C, 150°C, 200°C and 250°C. For each temperature, at least 5 specimens were examined. Before the mechanical experiments, all specimens were stored in a condition room with a constant temperature of 20°C and a relative humidity of 65%. The temperature in the chamber was first increased to the target temperature. The specimen was then installed and left under the constant target temperature for 20 mins to ensure that the temperature of the specimen is uniform and equal to the target temperature. The load was then applied at a rate of 2 mm/min until failure of specimen.





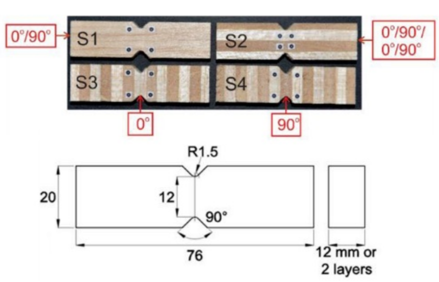
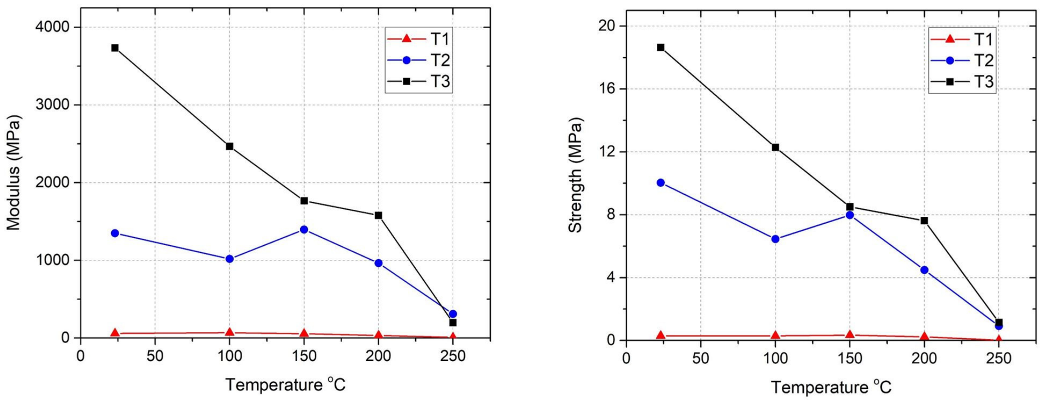


Fig. 1: (a) Tensile specimens, (b) Compressive specimens, (c) Shear specimens.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Tensile Properties under Elevated Temperatures

The temperature-dependent modulus and strength responses of the three tensile configurations are shown in Fig. 2. All properties basically decreased with increasing temperature; at 250°C modulus and strength approached zero. The decreases were not linear however: in T1 specimens even an increase occurred up to 100°C; in T2 specimens, after a first decrease, an increase between 100 and 150°C was exhibited too; while the T3 specimens showed a reduced slope of decrease between 150 and 200°C. This partially recovery or deceleration of decrease could be attributed to moisture evaporation [8], which occurred differently, depending on the specimen configuration. The rate of evaporation depended on the area of surfaces cut perpendicular to the fiber direction. Evaporation along the fibers was faster than perpendicular to the latter. T1 specimens exhibited, proportionally, the highest amount of areas perpendicular to the fibers, followed by T2 and T3. Accordingly, the associated recovery was seen already at the beginning in T1 and prevailed the degradation due to temperature. In T2, evaporation was delayed and recovery occurred later, while evaporation in T3 was slowest, resulting only in the change of slope. Depending on the amount of fibers in the loading direction, the properties of T3 were higher than those of T2; T1 exhibited the lowest values.

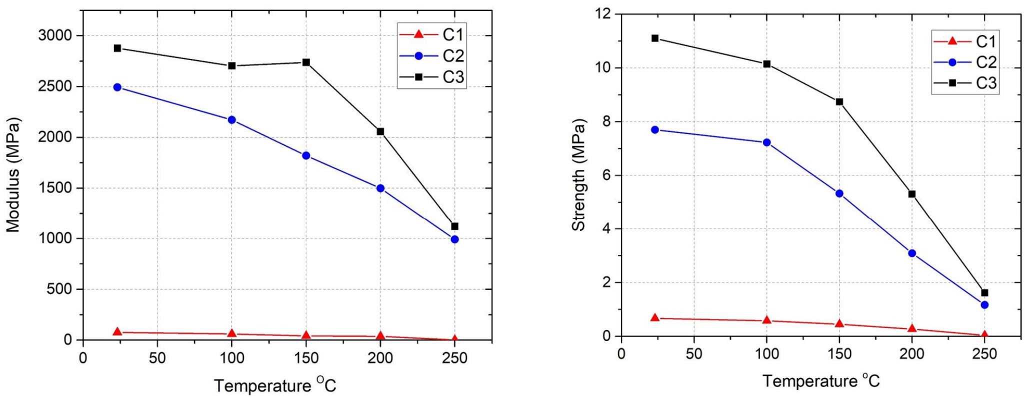


(a) (b)

Fig. 2: Degradation of (a) modulus and (b) strength of T1, T2 and T3 configuration against elevated temperatures.

Compressive Properties under Elevated Temperatures

Fig. 3 shows the reduction in mechanical properties of the C1, C2 and C3 configurations with increasing temperature. It is obvious that samples lost most of their strength and modulus at 250°C. Configuration C3 exhibited higher strength and modulus than the other configurations at each temperature. The reason was again related to the orientation of fibers. C3 had three layers loaded in the strong direction, whereas C2 had only two layers. C1 was loaded in the weakest direction (transverse direction), therefore, it exhibited noticeably lower strength and modulus compared to C2 and C3. The effect of moisture was not as pronounced as in the tensile configurations since the specimens were more compact.



(a) (b)

Fig. 3: Degradation of (a) modulus and (b) strength of C1, C2 and C3 configuration against elevated temperatures.

Shear Properties under Elevated Temperatures

Fig. 4 compares the degradation of modulus and strength of shear samples against elevated temperatures. A similar continuous degradation of the properties was exhibited as in tension and compression. Again moisture effects occurred with associated phases of recovery, depending on the specimen configuration. Therefore, the experiments at 100°C were repeated using dried specimens. The specimens were left in an oven at 105°C for 48 hours before the experiments. By drying specimens, modulus and strength increased approximately 11% and 25%, respectively (not shown in Fig. 4).

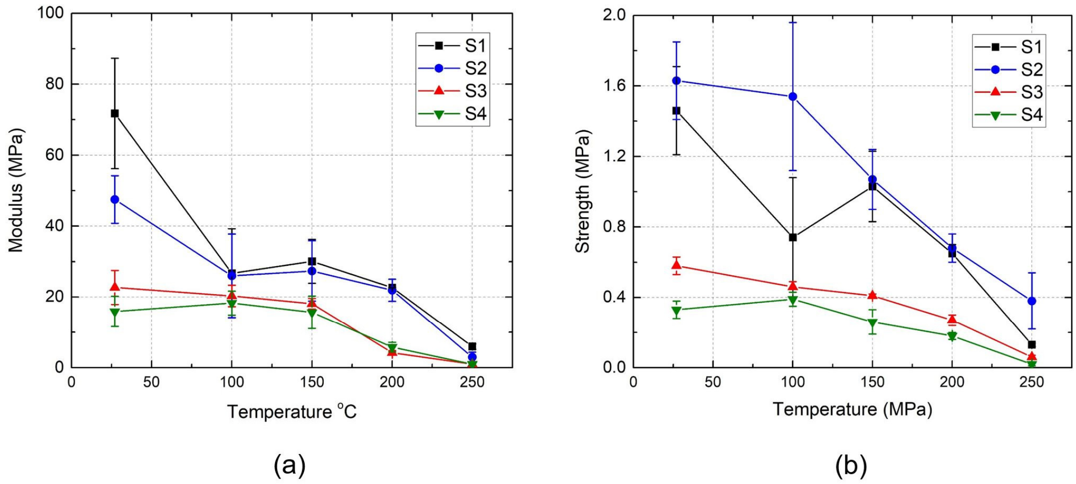


Fig. 4: Degradation of (a) modulus and (b) strength against elevated temperature of shear specimens.

4. CONCLUSIONS

This paper presents a comprehensive experimental study to characterize the tensile, compressive and shear properties of a veneered Balsa wood product, BALTEK® VBC, under elevated temperature. The following conclusions were drawn:

1. For tensile, compressive and shear specimens, the properties (modulus and strength) significantly decreased due to the effect of temperature. At 250°C, the material almost lost the load carrying capacity. Some specimens even started burning.
2. The effect of moisture content on the thermomechanical behavior was particularly noticed in the tension and shear experiments and was largely dependent on the specimen configuration, i.e. the portion of areas with cut fibers.
3. The results demonstrated that failure modes, stress-strain behaviors, modulus and strength values varied significantly and were closely associated with the fiber and loading directions.

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