TECHNICAL NOTE: A PRELIMINARY STUDY ON THE BENDING STIFFNESS OF CHEMICALLY TREATED WOOD MATERIAL FOR STRUCTURAL COMPOSITE LUMBER[1]

T. Eric McConnell†

Graduate Research Assistant

Sheldon Q. Shi†

Assistant Professor

Rubin Shmulsky†

Professor and Department Head
Department of Forest Products
Mississippi State University
Mississippi State, MS 39762

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Abstract. This research explored the effect of a chemical treatment on the stiffness of three southern hardwoods, yellow-poplar, sweetgum, and red oak, with the aim of broadening the potential feedstocks for structural composite lumber. Water-saturated 3 × 15 × 150 mm samples from each species were heated at 150°C for 30 min in three solutions: 1.0% H_2SO_4, water, and 1.0% NaOH. The specimens were nondestructively tested by static bending before and after treatment, and the reduction in modulus of elasticity (MOE) was determined. A significant interaction was present between the species and solutions. The trend in mean response for each species was generally a quadratic function of the solution. MOE was reduced the least for each species exposed to water. Sweetgum had a higher reduction in MOE in all three solutions, being significantly greater in the alkaline solution.

INTRODUCTION

The products classified as structural composite lumber (SCL) take advantage of wood material processed from small trees and branches that are inadequate for solid-sawn lumber production. The southern US current furnish for SCL is primarily southern pine (*Pinus* spp.), although yellow-poplar (*Liriodendron tulipifera*), sweetgum (*Liquidambar styraciflua*), and red oak (*Quercus* spp.) are readily available. Thus, efforts need to be made to use these species for large-scale SCL manufacturing.

Manufacturing constraints from density and adhesion, among others, limit the extensive use of hardwoods in wood-composite manufacturing (Hse 1975). It has been found during pressing that lower-density species are compressed more than higher density because of thinner cell walls (Halligan 1970). Swelling from springback, which weakens the wood–adhesive bond, is minimized at an appropriate compaction ratio (Caril 1996). Higher compaction ratios result in more efficient adhesive distribution and greater penetration (Larmore 1959). Modification of hardwoods by treating with heat, chemicals, or a combination can potentially overcome manufacturing and service limitations (Youngquist et al 1986; Paredes et al 2009).

The overall objective of this research is to improve the properties of three underused southern hardwoods for the manufacturing of SCL. This note reports on the initial step of determining the effect of a chemical treatment on reducing the

* Corresponding author: temcconnell@cfr.msstate.edu
† SWST member

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stiffness of the wood. Hydrolysis of miniature beams was done under pressurized, high-temperature conditions.

EXPERIMENTAL PROCEDURE

Yellow-poplar, sweetgum, and red oak specimens were treated in a 2 L reactor at 150°C for 30 min and tested by static bending. Three solutions, 1.0% sulfuric acid (H_2SO_4), water, and 1.0% sodium hydroxide (NaOH), were used. Specimens were tested before and after the treatments and the reduction in modulus of elasticity (MOE) determined. Six replications were performed.

Materials

Rough-cut boards of red oak, sweetgum, and yellow-poplar were obtained from a local sawmill. The red oak and sweetgum had been freshly sawn within the previous day, whereas the yellow-poplar had been air-drying for some time. Care was taken to select boards free of sawing and drying defects. The lumber was stored at 2°C.

For this initial study, one board was randomly selected from each species to create the experimental samples with minimal variation. The specimens were processed and tested following the principles described in AWPA Standard Method E23 (AWPA 2008). The board was ripped and then sawn into strips measuring 3 × 15 × 150 mm (T × R × L). The samples were stored at 2°C where they remained except when conditioned, measured, or tested.

Methods

The samples were immersed in deionized water at 85 kPa to achieve saturation. After a 1 h soak, length, width, thickness, and mass were recorded.

Static bending was performed using a 45 N load cell on a testing machine designed to be used for small three-point bending tests of preservative-treated samples. The specimens were placed at room temperature for 4 h before bending and tested to a deflection of 1.0 mm. The MOE was then determined. This was repeated three times for each sample with at least 24 h between each test. The value of the third test served as the initial MOE as per AWPA E-23.

Chemical treatment was conducted in a Parr 4843 2-L reactor. The vessel was filled with 1.7 L of solution, and a miniature beam was immersed for the designated treatment combination. Time measurement began at the point in which the reactor reached 150°C. After treatment, the specimen was washed and then placed in a bath of deionized water for 24 h. A blank run with only the next solution was conducted between treatments to thoroughly clean the vessel and prevent contamination by the previous species/solution combination.

The samples were stored for 1 wk and measured and tested to determine the postextraction MOE. Results were analyzed using analysis of variance with a 0.05 level of significance. Multiple comparisons were made using Fisher's protected least significant difference in SAS 9.1.3 (SAS 2003).

RESULTS AND DISCUSSION

Average pH values were 3.5, 6.5, and 10 for the acid, water, and alkaline solutions, respectively. After treatment, the acid solutions were emerald green, and the alkaline solutions were reddish brown from some lignin being removed (Hagglund 1951). The water solutions were amber in color. The species and treatment solutions interacted to significantly affect the mean reduction in MOE (p = 0.0212). The trend in mean response was generally a quadratic function of the solution for each species (p = 0.0036).

The results of the multiple comparisons in Table 1 indicated that some of the treatments were significantly different, notably the acid and alkaline solutions when compared with the water solutions. The acidic and basic solutions consistently reduced the mean MOE. Sweetgum had a greater reduction in MOE in all three solutions and significantly greater in the alkaline

Table 1. *Least significant difference results for treatment means based on six observations.*

Treatment	Reduction in MOE (%)	t Grouping
SG-NaOH	−65.21	A
SG-H_2SO_4	−60.25	AB
RO-H_2SO_4	−58.50	ABC
YP-NaOH	−56.98	BC
RO-NaOH	−51.33	CD
YP-H_2SO_4	−46.35	D
SG-H_2O	−2.21	E
RO-H_2O	0.08	E
YP-H_2O	11.71	F

RO, red oak; SG, sweetgum; YP, yellow-poplar. Means with the same capital letter (t Grouping) are not significantly different at $\alpha = 0.05$. Least significant difference = 8.07.

solution. Yellow-poplar had the least significant decrease in both the acid and water solutions.

Overall, treating with water produced the least significant loss in bending stiffness. In fact, results varied between species as mean stiffness decreased overall for sweetgum while increasing for yellow-poplar. Red oak showed virtually no change. When wood is first heated under moist conditions, initially the MOE increases slightly. A subsequent reduction follows with longer heating times and/or higher temperatures (Mitchell 1988). Differences in reactivity between species can also produce varying effects within the same treatment (Rowell et al 1986). Larsson and Simonson (1994) reported such results when Scots pine and Norway spruce underwent acetylation followed by a thermal treatment. They found that MOE decreased for pine and increased for spruce. Bongers and Beckers (2003) found that although mechanical properties varied between species after a chemical treatment, they were consistent within a species. In this research, water treatment provided inconsistent results for both sweetgum and red oak.

CONCLUSIONS

The effect of a chemical treatment on the bending stiffness of three southern hardwoods was studied. Water produced the least significant reduction in MOE for each species. Although water would be the most economical, higher temperatures, longer treatment times, or a combination should be further researched to attain comparative results with acidic or alkaline treatments.

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