Effect of Resin Variables on the Creep Behavior of High Density Hardwood Composite Panels

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ABSTRACT

The flexural creep behavior of oriented strandboards (OSB) fabricated with mixed high, density hardwood flakes was investigated. Three types of adhesives, liquid phenolic-formaldehyde (LPF), melamine modified urea-formaldehyde (MUF),. and LPF (face)/MUF (core) were chosen in this investigation. The resin contents (RC) used were 3.5 percent and 5.0 percent. The flakes prepared from white oak, southern red oak and post oak with a mixed ratio of 1: 1: 1 were used for the panel fabrication. Results indicated that the panels fabricated with 5.0 percent RC of MUF had highest bending modulus of rupture (MOR), and the group fabricated with 3.5 percent RC of LPF (face)/MUF (core) was the lowest. Significant differences among the modulus of elasticity (MOE) of each resin type and resin content group were not found. Highest internal bond (IB) strength was observed in the specimens with 5.0 percent RC of LPF (face)/MUF (core) whereas lowest one was found in the group with identical resin combination but with a 3.5 percent RC. The flexural creep behavior of the fabricated OSB under a cyclic RH of 65 percent ⇔ 95 percent at a constant temperature of 75 °F (23.9 °C) was also investigated. The frequency of cyclic RN was 96-hour and the duration of load was 794 hours (approx. 1 month) while the duration of recovery (after unloaded) was 286 hours under constant 65 percent RH at 75 °F. Results indicated that the creep resistance of OSBs are very sensitive to the cyclic RH of 65

As expected the maximum loads for both species decreased as the hygroscopic cycles increased. Also, Kapur experienced an increased strength loss (25.5 percent for PVAc and 13.5 percent for UF) than Rubberwood (16.0 percent for PVAc and 11.4 percent for UF) at the end of the third cycle (18 days). The results also show that PVAc has poor gluability and is more sensitive to the moisture change than UF resin..

CONCLUSIONS

Dowel joints spread with UF resin resulted in significantly higher maximum bending strength and better glue bond durability than that of PVAc resin. Bending strength of dowel joints decreased with increasing hygroscopic cycle for all species and adhesives.

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percent ↔ 95 percent at 75 “F. MUF-boards performed best in creep resistance; LPF/MUF groups were the weakest. Significant effect of resin content level on the creep resistance in LPF- and MUF-OSBs was not found.

INTRODUCTION

In recent years, research and development on the technologies for manufacturing designs and engineering applications of wood composite panel products as structural components and/or systems have been focused on the low (specific gravity (S.G.) ≤ 0.4) and medium density (0.4 < S.G. ≥ 0.5) softwood and hardwood species. As a result, technical information on the wood composite panel products made of high-density hardwood species (S.G. > 0.5) is very limited.

In general, most high-density wood species are hardwood. The resources of these species are abundant in the southeastern region of the United States (4) as well as in many tropical and/or subtropical areas (2). However, utilization of these species as raw materials for panel products is still underdeveloped. Feasibility of utilizing tropical hardwoods from southeast Asia as raw material for UF-bonded particleboards was investigated by Iwashita (5). Twenty-eight out of 57 tropical species studied were of high density (i.e., S.G. > 0.5), and most species are high in extractives, and their pH values are generally lower than 7. Results indicated that UF-bonded particleboard from these high-density species showed low mechanical properties due to their non-compressibility.

Consumption of imported hardwoods in the Unite States has been increasing in recent years. Most of these hardwoods are of high-density species (approx. 70 percent) and imported from tropical/subtropical regions (9). These imported hardwoods are generally less utilized as raw materials for commercial wood composite panels, especially for the structural products. Perhaps this is due to the lack of technical information on the machinability of flaking, bondability, durability and dimensional stability of these high-density species. These properties are known to be important for the manufacturing design of structural composite panel products.

The quality and properties of wood composite panel products are known to be affected by many processing parameters (3). Two of these parameters, the resin type and resin content level, are of concern to the wood composite panel industry because they are the major factors to be used for the control of panel manufacturing cost. In this study, high-density and extractive-rich hardwood species, white oak, southern red oak and post oak, were used as raw material to fabricate the OSBs. The above-mentioned two processing parameters were considered, and their effects on the short-term and longterm properties were investigated. The results may provide some technical information for a better understanding of the effect of resin variables on the engineering performance of wood composite panel products made of high-density hardwood species.

Materials and Methods

Three U.S. grown high-density hardwood species, white oak (Quercus *alba*), southern red *oak (Quercus falcata),* and post *oak* (Quercus *stellata),* were chosen of these species for the raw materials of three-layer OSBs in this study. The specific gravities, based on ovendry weight and volume at 12 percent moisture content, are, respectively, 0.65, 0.59, and 0.67. Veneer-type flakes were prepared by using a laboratory model disk. The experimental designs for this study are as follows:

1. Flake dimension: approximately 3 inches long by 0.02 inches thick and 0.5 inches wide (7.62 cm x 0.0508cm x 1.27 cm).
2. Flake moisture: ~ 3 percent
3. Material-mix ratio: 1:1:1 (white oak: s. red oak: post oak)
4. Nominal density of OSB: 46 pcf (0.737 gr/cm^3)
5. Resin type:
   1. Liquid phenolic-formaldehyde (LPF)
   2. Melamine modified urea-formaldehyde (MUF)
   3. LPF (face)/MUF (core)
6. Resin content: 3.5 percent and 5.0 percent
7. Press type: conventional hot press
8. Press temperature: 425 °F (218 °C)
9. Panel dimension 42 in. square and 0.75 in. thick
10. Pressure and press time:
    350 tons: 3 min;
    250 tons: 3 min;
    150 tons: 4 min;
    50 tons: 2 min;
    0 tons: release
11. Panel replication: three in each resin type and resin content group

A total of 18 sheets of three-layer OSBs was fabricated for this study. Static bending, internal bond, and creep specimens needed for this study were cut from each panel. The following experimental procedures were designed for these three tests:

A. Static bending
1. Size of specimens: 3 inches wide and 18 inches long;
2. Number of replications: six for each resin type and resin content level and randomly selected;
3. Pretesting treatment: Equilibrated under constant 65 percent RH and 75 °F;
4. Test: flatwise bending according to ASTM standard D-1037 (1).

B. Internal bond:
1. Size of specimens: 2 inches square;
2. Number of replications: 12 for each resin type and resin content level;

3. Pretesting treatment: Equilibrated under constant 65 percent RH at 75 °F
4. Test: Tension ⊥ to the face of OSB according to ASTM standard D-1037

C. Creep:

1. Size of specimens: 3 inches wide and 18 inches long;
2. Number of replications: six for each resin type and resin content level;
3. Testing type: bending under conventional load with a span of 16 inches;
4. Pretesting treatment: Equilibrated under constant 65 percent RH at 75 °F;
5. Specimen direction: face flakes oriented ∥ to the span;
6. Load level: 660 psi;
7. Duration of load: approximately 1 month (794 hours) under a 96-hour cyclic RH of 65 percent ⇔ 95 percent at 75 °F;
8. Duration of recovery: 286 hours under constant 65 percent RH at 75 °F;
9. Deflection measurement: Computer-controlled data-acquisition system and a RDP-DCT 1000 electrical transducer with accuracy of 0.001 inch (0.0254 mm).

The creep test was conducted in a computer-controlled walk-in environmental room that accurately maintained the designated temperature and RH conditions. The setup of the test is pictured in Figure 1.

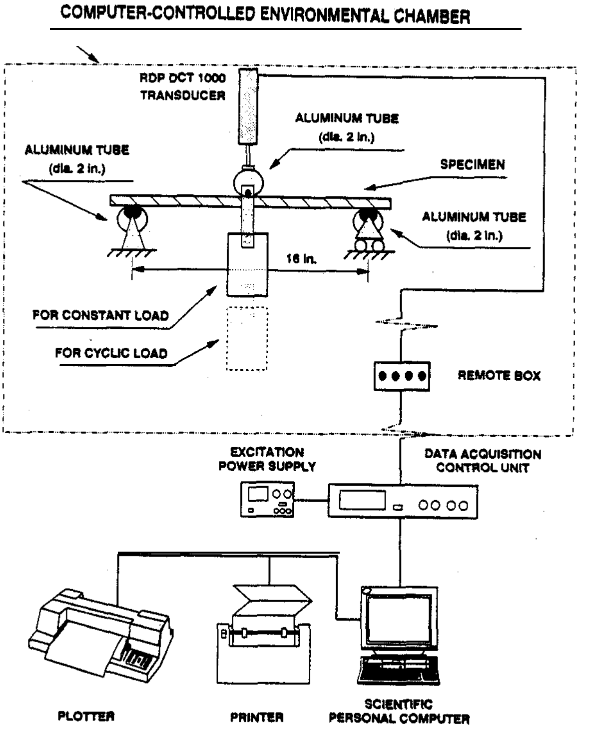

Figure 1. Loading protocal and data acquisition system

RESULTS AND DISCUSSIONS

Moisture Content and Thickness Swelling

The moisture content (MC) of OSBs prior to the creep test was approximately 10.5 percent, and values at the end of the testing period were measured. As expected, MC values for each resin type and resin content group were very similar (approximately 13.5 percent). The total thickness swelling (TS) of each group at the end of the testing period was recorded. The highest TS (based on the dimension under 65 percent RH and 75 "F), 8.94 percent, was observed in the group fabricated with 3.5 percent of LPF(f)/MUF(c).

Bending Properties and IB

The results of bending strength (MOR) and stiffness (MOE) and the internal bonding strength of the OSBs tested are tabulated in table 1. For comparative

Table 1. Properties of solid oaks and oak OSBs.

	Static bending		IB
Material	MOR psi	MOE x 10^6 psi	psi
	- - - Solid oak - - -		
W. oak	15,200	1.78	--
S. red oak	10,900	1.49	--
Post oak	13,200	1.51	--
	- - - Oak OSB - - -		
(Resin type/content percent)			
LPF/3.5	3949	0.626	43
LPF/5.0	3761	0.618	47
MUF/3.5	4022	0.619	47
MUF/5.0	4886	0.605	76
LPF(f)-MUF(c)/3.5	3342	0.559	39
LPF(f)-MUF(c)/5.0	4122	0.605	91
	- - - Commercial OSB - - -		
Aspen (37 pcf) (LPF(f)/ISO(c))	4309	0.822	41
S. pine (41 pcf) (LPF(f)/LPF(c))	4584	0.825	60

purpose, the properties of solid wood of the three high-density species studied (9) as well as two commercial OSBs (7, 8) are also given in table 1. The highest MOR (4,886 psi) was found in the group fabricated with 5.0 percent RC of MUF, whereas, the lowest one (3,342 psi) was observed in the group that used 3.5 percent RC of LPF (f)/MUF(c). Significant effect of RC level on the MOR was observed in the group fabricated with MUF and LPF(f)/MUF(c) but not found in the group of LPF boards. The values of MOE of the OSBs tested ranged from 0.605 to 0.626 x 10^6 psi, except the group of LPF(f) -MUF(c)/3.5 percent RC (0.559 x 10^6 psi). The highest IB (90.8 psi) was observed in the group of LPF(f)-MUF(c)/5.0 percent RC, whereas, the lowest one was the 3.5 percent RC group with the same resin combination.

Comparison of the lab-fabricated high-density OSBs with the commercial OSBs (Aspen and southern pine) indicated that the MOR and IB of OSBs made of high-density hardwood species are comparable to these of commercial OSB products used for decking and flooring.

Creep Deflections

The creep deflection-time and creep recovery-time curves of all resin type and resin content groups are plotted in figure 2. At the RC level of 3.5 percent, MUF boards had the best creep resistance, and LPF(f)/MUF(c)- boards were the poorest.

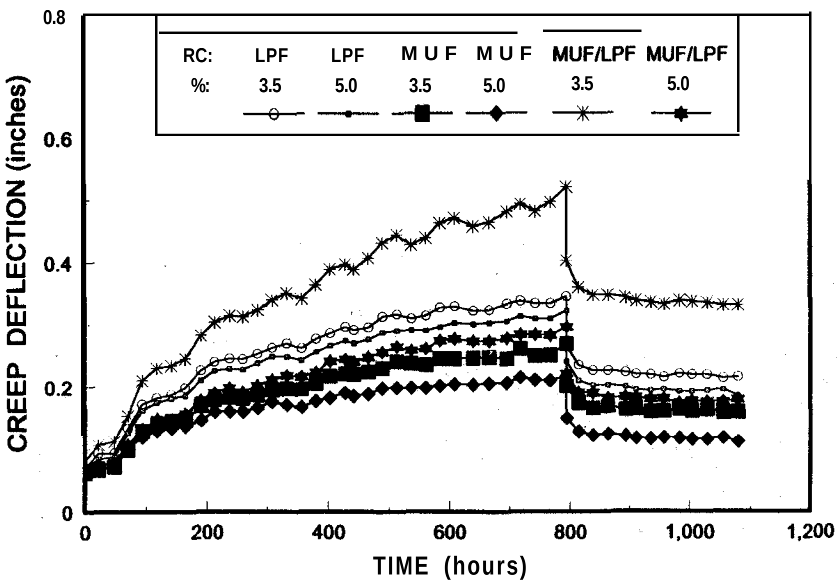

Figure 2. Creep deflection-time and creep recovery-time curves of high density hardwood composite panels under cyclical 65 percent-95 percent RH at 75 °F

However, at the RC level of 5.0 percent, significant differences were not observed. A significant difference between groups with RC of 3.5 percent and 5.0 percent was not observed in the LPF and MUF specimens, but a marked difference showed in the LPF(f)/MUF(c) group, whereas lowest value was observed in MUF boards. Similar pattern showed in the 5.0 percent RC groups. Regardless of the type of resin used, increase of RC from 3.5 percent to 5 .O percent will reduce the permanent deflection.

Relative Creep

To compare the realistic creep behavior between OSBs with different MOE values, the relative creep concept was usually employed. The relative creep, R&t), is defined as:

$$R_c(t) = \frac{C(t) - C_o}{C_o}$$

where, c(t) = deflection at time t;
c_0 = instantaneous deflection.

The values of relative creep of the tested OSBs were calculated for the entire loading period, and they are plotted in figure 3. At the end of loading (794 hours),

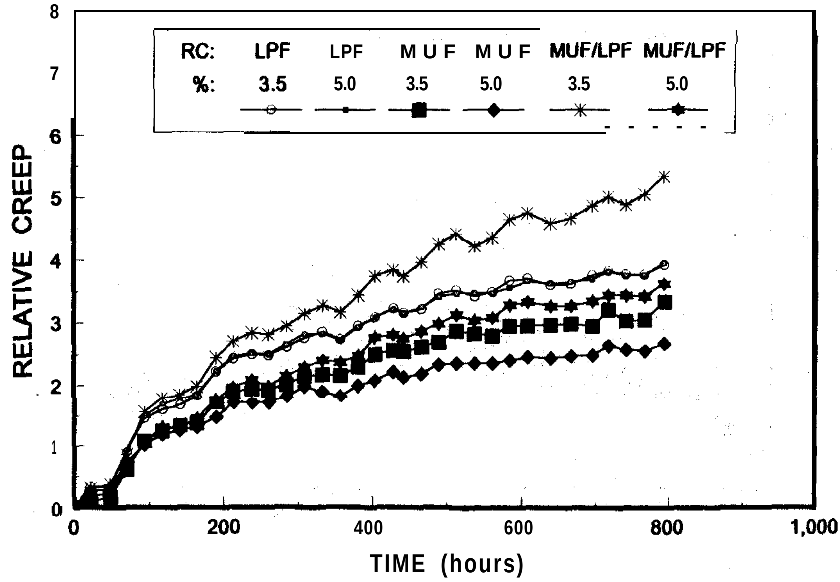

Figure 3. Relative creep-time curves of the high density hardwood composite panels under cyclical 65-95 percent RH at 75 °F highest relative creep was observed in the LPF(f)/MUF(c) - boards, whereas MUF specimens had the lowest value among the 3.5 percent RC groups. No significant differences were observed among the three resin-type specimens fabricated with 5.0 percent RC. Significant effect of RC on the relative creep was observed in the LPF(f)/MUF(c) group, but such effect showed inconspicuously in the groups of LPF and MUF specimens.

CONCLUSIONS AND REMARKS

The strength and internal bond properties of OSBs fabricated with mixed flakes of high-density hardwoods are comparable to those of commercial OSB products made of aspen or southern pine. The cyclic RH of 65 percent ⇔ 95 percent at 75 °F had a significant weakening effect on the creep resistance of high density OSBs made of high density hardwood. MUF - OSBs had best performance in creep resistance followed by LPF and LPF(f)/MUF(c) groups. Longterm engineering performance of OSBs fabricated with combined resins of LPF(f) and MUF(c) can be substantially improved when RC is increased from 3.5 percent to 5 .O percent, but such an increase has less effect in the groups of LPF and MUF boards. To develop better utilization of high-density wood species as raw material for structural panel products, additional research is needed on short-term and longterm properties of OSBs fabricated with other types of press, such as the steam-injection press, using mixed flakes of various high-density woods and/or mixed with low-medium density softwood/hardwood.

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