STRENGTH TESTS ON ACETYLATED ASPEN FLAKEBOARDS EXPOSED TO A BROWN-ROT FUNGUS[1]

Roger M. Rowell
Research Chemist

John A. Youngquist
Supervisory Research General Engineer
U.S. Department of Agriculture, Forest Service
Forest Products Laboratory[2]
Madison, WI 53705-2398

and

Yuji Imamura
Wood Research Institute
Kyoto University
Uji, Kyoto, Japan

(Received May 1987)

ABSTRACT

Aspen flakeboards made from control flakes and acetylated flakes at 18% acetyl weight gain using phenol-formaldehyde or isocyanate adhesives were subjected to a bending creep test under progressive brown-rot fungal attack with *Tyromyces palustris*. Deflection of the boards was measured as a function of time until failure. Isocyanate-bonded control flakeboards failed in an average of 26 days, while isocyanate-bonded acetylated boards showed little deflection after 100 days in test. Average weight loss of isocyanate-bonded control boards at failure averaged 6.2%, while the acetylated boards showed about 1.0% weight loss at the end of 100 days. Phenol-formaldehyde-bonded control flakeboards failed in an average of 76 days, while acetylated boards showed little deflection after 100 days in test. Average weight loss of phenol-formaldehyde-bonded control boards at failure averaged 8.6%, while the acetylated boards showed no weight loss after 100 days.

Keywords: Chemical modification, acetylation, flakeboard, aspen, strength, fungi, mechanical properties.

INTRODUCTION

Much of the laboratory test data published on decay of wood uses methods based on weight loss after a certain period of time in the presence of single or mixed organisms. It is known, however, that, for brown-rot fungal attack on solid wood, large strength losses occur at very low wood weight loss (Cowling 1961).

A test method has been developed to determine strength losses in wood while under attack by a brown-rot fungi (Imamura and Nishimoto 1985). The test method determines deflection under load in a bending creep apparatus, coupled with fungal attack. The test is run until wood failure or a maximum of 100 days.

---

[1] This article was written and prepared by U.S. Government employees on official time, and it is therefore in the public domain and not subject to copyright.

[2] The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin.

Wood and Fiber Science, 20(2), 1988, pp. 266–271

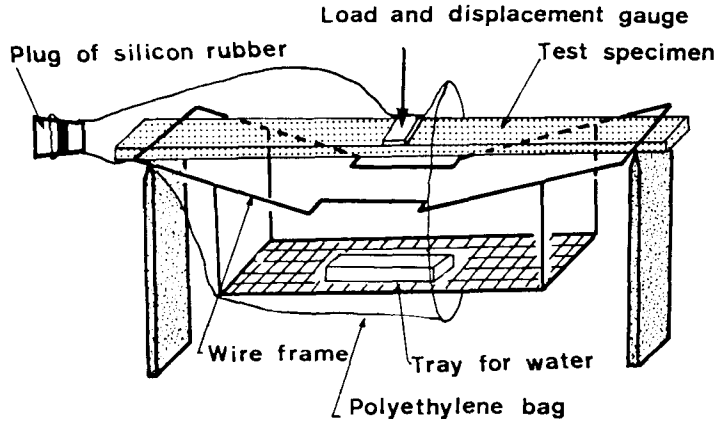

FIG. 1. A testing device for bending creep measurement coupled with fungal attack. (ML86 5398)

In a recent study, flakeboards made from acetylated southern pine and aspen flakes showed very little weight loss in both standard ASTM D 1413 soil block tests with the brown-rot fungus *Gloeophyllum trabeum* and in fungal cellar tests with brown-, white-, soft-rot fungi and tunneling bacteria (Rowell et al. 1987). Since strength losses can be high even at low weight losses, it was of interest to determine strength losses in acetylated flakeboards.

The purpose of this investigation was to apply the bending creep strength test to aspen flakeboards made using either phenol-formaldehyde or isocyanate adhesive with control and acetylated flakes.

EXPERIMENTAL

Reaction of flakes and board production

Oven-dry aspen flakes (all from one commercial batch) were acetylated using the dip procedure as described earlier (Rowell et al. 1986). Flakes with acetyl weight gains of 18% (based on the original oven-dry weight) were produced.

Control and acetylated flakes were made into flakeboards using the computer-controlled laboratory press as previously described (Youngquist et al. 1986). Each board was made with a density of approximately 640 kg/m^3, using either phenol-formaldehyde resin (5%) or isocyanate resin (3% based on oven-dry weight of control or acetylated flakes). The outer 3 cm were cut from each side of the flakeboards; then three specimens (5-cm × 35-cm × 1.25-cm) for each test were cut from the remaining board.

Bending creep test

The test boards were subjected to bending creep tests under progressive fungal attack in a newly designed decay chamber (Imamura and Nishimoto 1985) (Fig. 1). The chamber consisted of a metal-wire frame, covered with a polyethylene bag and a porous plug of silicon rubber. The brown-rot fungus *Tyromyces palustris* (Berk. et Curt) Murr, a standard strain for Japanese Industrial Standard (JIS) A- 9302-1976, was used for decay attack. Mycelial fragments prepared from shake

TABLE 1. *Load[a] which caused initial deflection of 1 mm in bending creep tests.*

Replicate	Isocyanate control	Isocyanate acetylated	Phenol-formaldehyde control	Phenol-formaldehyde acetylated
	kg/cm²			
I	44	25	22	44
II	30	31	30	32
III	36	26	30	39

[a] Bending stress calculated from specimen dimensions. The load recorded after inoculation but before incubation.

culture were spread on the bottom tension surfaces of the sterilized flakeboards. A tray filled with sterilized water was set at the bottom of the chamber to keep the specimen in a moist condition.

Load was applied at the center of each specimen outside of the decay chamber. The load applied to each test specimen was that amount to cause 1-mm initial deflection. Deflection of the board at the center of the span length (300-mm) was measured regularly with an electric dial-gauge as a criterion to determine performance. The bending creep test was carried out until the flakeboard broke under load or 100 days, whichever came first. The test apparatus was maintained in a conditioned room at 26 C, which was suitable for the incubation of the fungus.

After failure or 100 days, oven-dry weight loss was determined on each flakeboard.

RESULTS AND DISCUSSION

Loading stresses to cause an initial deflection of 1 mm (1/300 of the span length) in each test specimen ranged from 22 to 44 kg/cm² (Table 1).

Deflection-time curves for flakeboards made with isocyanate resin are shown in Fig. 2 and with phenol-formaldehyde in Fig. 3. These curves express time as a logarithm. There is an initial increase of deflection for both control and acetylated flakeboards, then a stable zone, and finally, for control boards a steep slope to failure.

The time to failure for the isocyanate-bonded control flakeboards ranged from 15 to 43 days (Table 2). Even though this range was large, the deflection-time curves (Fig. 2) for a given set of experimental conditions are similar. After failure,

TABLE 2. *Period of test duration until creep fracture and weight loss of specimens.*

Replicate	Control		Acetylated	
	Days	Percent weight loss	Days	Percent weight loss
	Isocyanate-bonded flakeboards			
I	43	8.3	—[a]	0.9[b]
II	15	4.8	—	1.0
III	20	5.5	—	1.2
	Phenol-formaldehyde-bonded flakeboards			
I	74	8.3	—	+[c]
II	82	9.6	—	+
III	71	7.8	—	+

[a] Not fractured for more than 100 days.
[b] Percent weight loss after test period of 100 days.
[c] Weight increased by less than 1%.

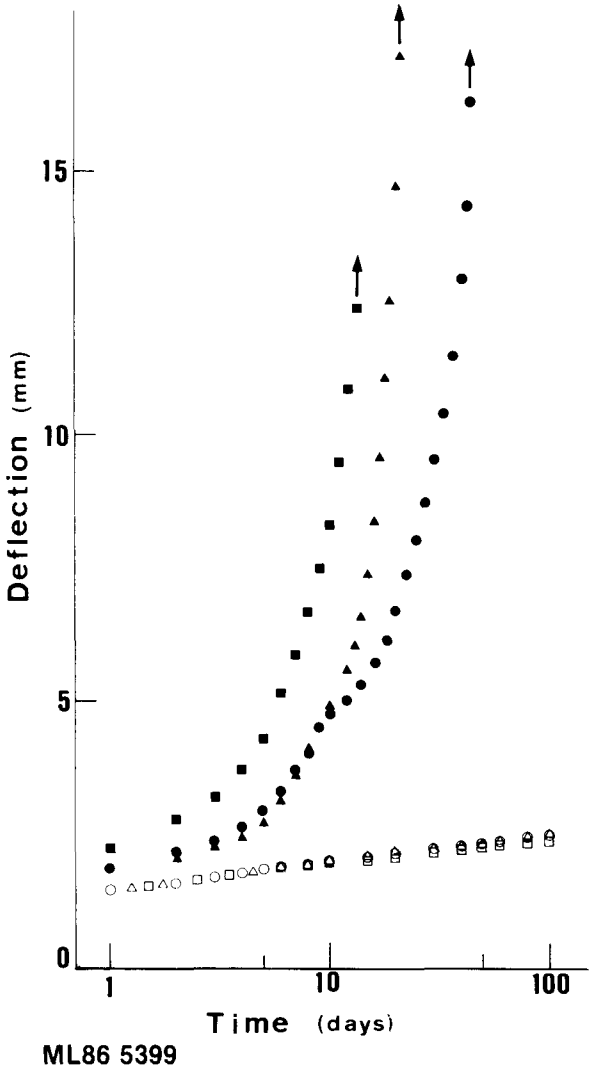

FIG. 2. Deflection-time curves of isocyanate-bonded flakeboards in bending creep tests under progressive fungal attack by *T. palustris*. ■ ● ▲, controls; □ ○ △, acetylated. Fracture of test board is shown by arrow. (ML86 5399)

weight loss averaged 6.2%. It can be seen in Fig. 2 that isocyanate flakeboards made from acetylated flakes showed only a very small deflection after 100 days, and Table 2 shows only about 1% weight loss at the end of this time.

Phenol-formaldehyde-bonded control flakeboards failed in an average of 76 days with a range of 71 to 82 days (Table 2). There was much less variation in the control test specimens as compared to isocyanate-bonded control specimens. After failure, weight loss averaged 8.6%. Phenol-formaldehyde-bonded boards maintained their strength longer than isocyanate-bonded boards, and all specimens failed within a short timespan of each other. Phenol-formaldehyde flakeboards made from acetylated flakes showed only a very small deflection (almost

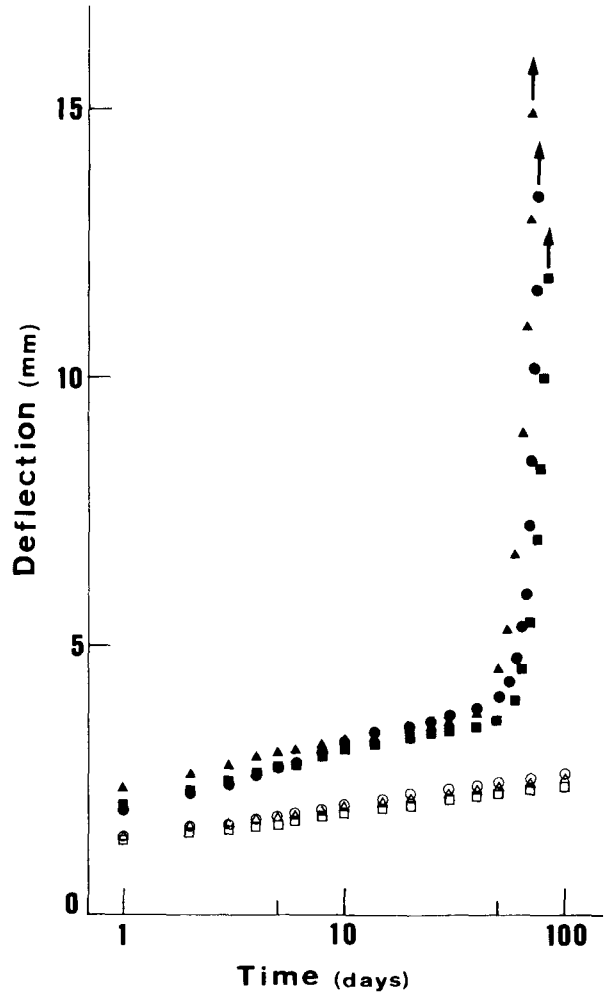

FIG. 3. Deflection-time curves of phenol-formaldehyde-bonded flakeboards in bending creep tests under progressive fungal attack by *T. palustris*. ■ ● ▲, controls; □ ○ △, acetylated. Fracture of test board is shown by arrow. (ML86 5400)

the same as acetylated isocyanate boards) after 100 days. At the end of 100 days, the oven-dry weight of all acetylated boards was slightly heavier (less than 1%) than before test. This was probably due to fungal mycelia, which were not removed after test.

Mycelium fully covered the surfaces of isocyanate control flakeboards within 1 week, but mycelial development was significantly slower in phenol-formaldehyde control flakeboards. It has been shown that unleached phenol-formaldehyde flakeboards show some toxicity to a brown-rot fungus in soil block tests (Rowell et al. 1987). The presence of some soluble toxic materials in the phenol-formaldehyde-bonded flakeboards may inhibit or slow the attack by *Tyromyces palustris*. This may account for the longer time to failure for phenol-formaldehyde control flakeboards as compared to isocyanate control flakeboards.

Both isocyanate and phenol-formaldehyde-bonded acetylated flakeboards showed surface mycelium colonization during the test time, but the fungus could not attack the acetylated flakes so little strength was lost.

Since creep in wood is dependent on moisture content, it is important to determine the creep due to the moisture present in the wood separately from the creep due to strength losses associated with decay. In developing the standard test procedure, two sets of control specimens were used. One set had aqueous inoculum applied to bottom tension surface of the test specimens, while a second set had an equal amount of sterile water applied to the bottom side. The wet sterile controls showed less than a 5-mm deflection during the 100-day test, while the controls with decay fungus failed within the 100-day test. This showed that only a small part of the deflection observed was associated with creep due to moisture.

SUMMARY

Phenol-formaldehyde and isocyanate-bonded aspen flakeboards made from acetylated flakes showed no strength or weight losses after 100 days in a decay chamber.

Aspen control flakeboards made with phenol-formaldehyde resin are more resistant to brown-rot fungus attack than are boards made with isocyanate resin. This may be due in part to a toxic phenolic component in the phenol-formaldehyde boards which inhibits fungal growth. Even at low weight losses (less than 10%) both control phenol-formaldehyde and isocyanate-bonded flakeboards failed, due to strength losses in the creep bending test, within 100 days.

These results show the importance of determining strength losses in brown-rot fungal tests rather than weight losses. Significant strength loss occurs even at very low weight loss. Future research will be aimed at determining the mechanism of biological resistance due to acetylation.

REFERENCES

COWLING, E. B. 1961. Comparative biochemistry of the decay of sweetgum sapwood by white-rot and brown-rot fungi. USDA Forest Serv. Tech. Bull. No. 1258, p. 50.

IMAMURA, Y., AND K. NISHIMOTO. 1985. Bending creep test of wood-based materials under fungal attack. J. Soc. Materials Sci. 34(383):985–989, Japan.

ROWELL, R. M., G. R. ESENTHER, D. D. NICHOLAS, AND T. NILSSON. 1987. Biological resistance of southern pine and aspen flakeboards made from acetylated flakes. J. Wood Chem. Technol. 7(3): 427–440.

———, A.-M. TILLMAN, AND R. SIMONSON. 1986. A simplified procedure for the acetylation of hardwood and softwood flakes for flakeboard production. J. Wood Chem. Technol. 6(3):427–448.

YOUNGQUIST, J. A., A. KRZYSKIK, AND R. M. ROWELL. 1986. Mechanical properties and dimensional stability of acetylated aspen flakeboard. Holz Roh Werkst. 44(12):453–457.