THE INTERNATIONAL REASEARCH GROUP ON WOOD PRESERVATION

Section 4 Processes

Worldwide In-Ground Stake Test of Acetylated Composite Boards

R.M. Rowell[1], B.S. Dawson[2], Y.S. Hadi[3], D.D. Nicholas[4], T. Nilsson[5], D.V. Plackett[6], R. Simonson[7], and M. Westin[7]

[1] USDA, Forest Products Laboratory
One Gifford Pinchot Drive
Madison, WI 53705, USA

[2] Forest Research Institute
Private Bag 3020
Rotorua, New Zealand

[3] Faculty of Forestry
Bogor Agricultural Univ.
Bogor 16001, Indonesia

[4] Mississippi Forest Products Laboratory
Mississippi State University, Box 9820
Mississippi State, MS 39762-9820, USA

[5] Department of Forest Products
Swedish Univ. of Agricultural Sciences
Box 7008, S-750 07 Uppsala Sweden

[6] Forintek Canada Corporation
Western Laboratory, 2665 East Mall
Vancouver, B.C. V6T 1W5, Canada

[7] Dept. of Forest Products and Chemical Engineering
Chalmers University of Technology
S-412 96 Göteborg, Sweden

Paper prepared for the 28th Annual Meeting
Whistler, Canada
25-30 May, 1997

IRG Secretariat
KTH
Brinellvägen 34
S-100 44 STOCKHOLM
Sweden

Worldwide In-Ground Stake Test of Acetylated Composite Boards

R.M. Rowell[1], B.S. Dawson[2], Y.S. Hadi[3], D.D. Nicholas[4], T. Nilsson[5], D.V. Plackett[6], R. Simonson[7], and M. Westin[7]

[1] Forest Products Laboratory, Madison, WI, USA
[2] Forest Research Institute, Rotorua, New Zealand
[3] Bogor Agricultural University, Bogor, Indonesia
[4] Mississippi State University, Mississippi State, USA
[5] Swedish Univ. of Agricultural Sci., Uppsala, Sweden
[6] Forintek Canada Corporation, Vancouver, B. C., Canada
[7] Chalmers University of Technology, Göteborg, Sweden

Abstract

Acetylated wood composite stakes are being tested in ground contact (graveyard test) in seven fields around the world. Three types of acetylated wood composites were prepared: spruce fiberboard in Sweden, aspen fiberboard in Madison and rubber wood particle board in Indonesia. Two levels of acetylation were used, a high level of ≈20% acetyl content and a low level of 10% acetyl content. Control boards of unmodified wood fiber/particle were also included. Stakes for the in-ground testing were taken from the boards and the size of each stake was 5x30x1.25 cm. The stakes were put out in four continents: one test field in USA, one in New Zealand, two in Indonesia and three in Sweden. After three years of testing, results show that acetylation of wood provides excellent protection against fungal attack and minimizes swelling.

Keywords: Acetylation, wood, composite, fiberboard, particle board, decay, durability, fungus, termite.

Introduction

Increased environmental concerns and life cycle requirements of treated wood composites have brought the use of alternative methods of preservation to the fore. Acetylation is a method for chemical modification of wood, well-known for its efficacy against decaying organisms in laboratory tests [Nilsson et al. 1988, Rowell et al. 1989]. Acetylation also renders the wood dimensional stability [Rowell et al. 1989] and decreased rate of UV-deterioration [Feist et al. 1991]. However, the influence of different climates at different fields and the inluence of subterranean termites in some of the fields was not known prior to this project.

Materials and Methods

Wood materials

Three types of wood material were used:

A. Spruce (*Picea abies*) fiber from Caberboard MDF plant in Scotland

B. Aspen (*Populus tremula*) fiber from industrial production of Medium Density Fiberboard (MDF) in USA

C. Rubber wood (*Hevea brasiliensis Muell. Arg.)* particles from industrial production of particle boards in Indonesia.

Acetylation of wood fibers and wood particles

Acetylation was carried out according to the simplified procedure [Rowell et al. 1991], which involves reaction with a limited amount of acetic anhydride at 120°C for a few hours to reach a high level of acetylation or for a few minutes (plus drying step, where additional reaction takes place) to reach a low level. The low level was approximately 10% acetyl content in the wood material (corresponding to a weight percent gain, WPG, of 8 - 12). The acetyl content the wood material acetylated to high level was approx. 20% (corresponding to a WPG of 20-25 for spruce and 16-20 for aspen and rubber wood). Except for spruce fiber at the high level of acetylation, all wood material was acetylated in large laboratory reactors at Forest Products Lab in Madison, at Chalmers Univ. of Technology in Gothenburg and at Bogor Univ. in Bogor. Spruce fiber was acetylated to high acetyl content by BP Chemicals in Hull, U. K., in a 100 kg batch.

Production of composite boards

Spruce fiberboards were produced at Fiberboard Research Center at Sunds Defibrator AB in Sundsvall, Sweden. Resignation of fibers was carried out in a drum with 8% (m/m) commercial liquid phenolic resin (Casconol 1535, Akzo Nobel), based on resin solids content and oven dry fiber weight. Fiber mats were air-laid, and boards were pressed at 175°C for 8 min to a board density of 750 kg/m^3 and a thickness of 13.5 mm. All spruce fiberboards were sanded down to a thickness of 12.5 mm.

Aspen fiberboards were produced at FPL in Madison. Resignation of fibers was carried out with 8% (m/m) commercial liquid phenolic resin (GP 2341, Georgia-Pacific Resins Inc.), based on resin solids content and oven dry fiber weight. Fiber mats were air-laid, and boards were pressed at 180°C for 8 minutes to a board density of 800-900 kg/m^3 and a thickness of 12.5 mm.

Rubber wood particle boards were produced at Bogor University in Bogor. Resignation of particles was performed in a resignation drum with 9% (m/m) commercial liquid phenolic resin, based on resin solids content and oven dry particle weight. Particle stacks were air-laid, and boards were pressed at 180°C for 8 min to a board density of 750 kg/m^3 and approximately 12.5 mm thickness.

Control boards were produced from untreated wood material of all three types.

Testing procedure

Stakes for field test were prepared from boards of all types. They were conditioned and measured. A minimum of three stakes at each acetylation level and three controls of each composite type were put out in each of seven fields, providing a total of 215 stakes. Each stake was placed in such a way that half of the stake **was** below the ground line. Stakes were rated below the ground line and thickness of each stake measured at the ground line.

Location and desitiption of test fields

1. Gulfport, Mississippi, USA. A field with both fungal and termite activity.
2. Simlångsdalen, Sweden. A field with dominating brown rot. No termites.
3. Ultuna, Sweden. A field with dominating soft rot and tunneling bacteria. No termites.
4. Ingvallsbenning, Sweden. A field with dominating white rot. No termites.
5. Bandung, Indonesia. A field with preferably termite activity.
6. Bogor, Indonesia. A field with preferably termite activity.
7. Rotorua, New Zealand. A field with fungal activity and no termites.

Professor Nicholas was responsible for the rating of field no. 1, prof. Hadi for no. 5 and 6, Dr. Dawson for no. 7 and prof. Nilsson for the rating of fields no. 2,3 and 4.

Rating system

TABLE 1 *Rating system, both for microbial decay and termite attack.*

Rating figure	Decay (microbial)*— criteria	Termite attack — criteria
10	No decay	No attack or a few nibbles present.
9	Soft surface or edges, small decay pocket may be present. Decay does not exceed 3% of cross sectional area at any location.	Small tunnels on surface, less than 3% of cross sectional area affected at any location.
7	Decay affects 10-25% of cross sectional area at any location.	Termite attack affects 10-25% of cross sectional area at any location.
4	Decay affects more than 50% of cross sectional area at one location, but stake has not failed.	Termite attack affects more than 50% of cross sectional area at one location, but stake has not failed.
0	Failure	Failure

* Microbial decay includes decay by Basidiomycetes, soft rot and bacteria.

Results and Discussion

Spruce fiberboard stakes

Table 2 shows the performance of spruce fiberboard stakes during the first three years of testing. In all fields, except for two Swedish fields, all the controls have failed due to termite attack (Gulfport and Bogor) or fungal decay (Simlångsdalen, Bandung and Rotorua). The low-acetylated fiberboard stakes have not yet failed in all test fields, but may do so before next annual inspection. The high-acetylated fiberboards , on the other hand, are all without any trace of decay after about three years. The only exception was the stakes placed in the Indonesian fields of which all probably were completely destroyed by termites or fungi, since only fragments could be found at the 36-month inspection. However, after one year in the aggressive Indonesian fields the high-acetylated fiberboards were quite sound.

TABLE 2 *Rating and thickness swelling of spruce fiberboard stakes (for key to rating system, see tab. 1).*

Location of field/ Time in field	Control			Low-Acetylated (10% ac)			High-Acetylated (20% ac)		
	Percent swelling	Decay rating	Termite rating	Percent swelling	Decay rating	Termite rating	Percent swelling	Decay rating	Termite rating
I. Gulfport, Mississippi									
12 months	25.0	4	0	20.3	9	7	3.8	10	10
32 months	n.m.	—	—	n.m.	4	4	n.m.	10	10
II. Simlångsdalen, Sweden									
12 months	21.0	10	a	9.5	7	a	5.5	10	a
24 months	24.0	7	a	5.5	7	a	3.2	10	a
36 months	24.5	0	a	—	4	a	4.5	10	a
III. Ultuna, Sweden									
24 months	n.m.	9	a	n.m.	10	a	n.m.	10	a
36 months	15	7	a	6	10	a	3	10	a
IV. Ingvallsbenning, Swe									
17 months	23	9	a	9	10	a	3	10	a
26 months	26	7	a	10	10	a	5	10	a
V. Bandung, Indonesia									
1 month	n.m.	7 [b]	7 [b]	n.m.	9 [b]	9 [b]	n.m.	10 [b]	10 [b]
3 months	n.m.	4 [b]	4 [b]	n.m.	9 [b]	9 [b]	n.m.	10 [b]	10 [b]
12 months	n.m.	4 [b]	4 [b]	n.m.	7 [b]	7 [b]	n.m.	10 [b]	10 [b]
36 months	—	c	c	—	c	c	—	c	c
VI. Bogor, Indonesia									
1 month	n.m.	7 [b]	7 [b]	n.m.	9 [b]	9 [b]	n.m.	10 [b]	10 [b]
3 months	n.m.	0 [b]	0 [b]	n.m.	9 [b]	9 [b]	n.m.	10 [b]	10 [b]
12 months	—	—	—	n.m.	9 [b]	9 [b]	n.m.	9 [b]	9 [b]
36 months	—	—	—	—	c	c	—	c	c
VII. Rotorua, N.Z.									
9 months	20.3	7	a	5.1	9-10	a	1.6	10	a
18 months	24.2	7	a	5.3	10	a	5.4	10	a
29 months	23.4	0	a	5.3	7	a	2.3	10	a

n.m. Not measured.
a No termites in field.
b Lowest rating of fungal decay or termite attack.
c All stakes gone, probably due to termite and/or fungal activity.

Aspen fiberboard stakes

The performance of the aspen fiberboard stakes is shown in table 3. The ratings resembles the ratings for spruce fiberboard stakes, except concerning the low-acetylated aspen stakes — these stakes did not perform better than the aspen controls.
Again, the high-acetylated stakes are still rated 10 (sound) in most fields.

TABLE 3 *Rating and thickness swelling of aspen fiberboard stakes (for key to rating system, see tab. 1).*

Location of field/ Time in field	Control			Low-Acetylated (10% ac)			High-Acetylated (20% ac)		
	Percent swelling	Decay rating	Termite rating	Percent swelling	Decay rating	Termite rating	Percent swelling	Decay rating	Termite rating
I. Gulfport, Mississippi									
12 months	14.8	4	4	12.4	7	7	3.3	10	10
32 months	n.m.	0	0	n.m.	0	4	n.m.	9	10
II. Simlångsdalen, Sweden									
12 months	30.0	4	a	16.0	7	a	4.1	10	a
24 months	28.0	4	a	14.5	0	a	4.3	10	a
36 months	29.0	0	a	—	—	a	4.0	10	a
III. Ultuna, Sweden									
24 months	n.m.	7	a	n.m.	7	a	n.m.	10	a
36 months	24	4	a	12	4	a	6	10	a
IV. Ingvallsbenning, Swe									
17 months	25	7	a	15	9	a	3	10	a
26 months	30	7	a	20	7	a	4	10	a
V. Bandung, Indonesia									
1 month	n.m.	7 [b]	7 [b]	n.m.	7 [b]	7 [b]	n.m.	10 [b]	10 [b]
3 months	n.m.	4 [b]	4 [b]	n.m.	0 [b]	0 [b]	n.m.	9 [b]	9 [b]
12 months	n.m.	0 [b]	0 [b]	—	—	—	n.m.	4 [b]	4 [b]
36 months	—	—	—	—	—	—	—	c	c
VI. Bogor, Indonesia									
1 month	n.m.	4 [b]	4 [b]	n.m.	0 [b]	0 [b]	n.m.	7 [b]	7 [b]
3 months	n.m.	0 [b]	0 [b]	—	—	—	n.m.	7 [b]	7 [b]
12 months	—	—	—	—	—	—	n.m.	7 [b]	7 [b]
36 months	—	—	—	—	—	—	—	c	c
VII. Rotorua, N.Z.									
9 months	11.1	7	a	10.1	9	a	1.6	10	a
18 months	23.4	4	a	13.4	7	a	4.6	10	a
29 months	32.8	0	a	13.4	4	a	5.4	10	a

n.m. Not measured.
a No termites in field.
b Lowest rating of fungal decay or termite attack.
c All stakes gone, probably due to termite and/or fungal activity.

Rubber wood particle board stakes

In table 4, the performance of the rubber wood stakes are shown. Rubber wood particle boards are degraded faster than aspen and spruce fiberboards, as can be seen by the rating of controls. Even so, many high-acetylated rubber wood stakes are still sound after three years of exposure.

TABLE 4 *Rating and thickness swelling of Rubber wood particle board stakes (for key to rating system, see tab. 1).*

Location of field/ Time in field	Control			Low-Acetylated (10% ac)			High-Acetylated (20% ac)		
	Percent swelling	Decay rating	Termite rating	Percent swelling	Decay rating	Termite rating	Percent swelling	Decay rating	Termite rating
I. Gulfport, Mississippi									
12 months	43.8	0	0	21.6	7	7	9.9	9	10
32 months	—	—	—	n.m.	0	4	n.m.	7	10
II. Simlångsdalen, Sweden									
12 months	28.9	4	a	21.4	9	a	4.8	10	a
24 months	50.0	0	a	28.3	4	a	5.3	10	a
36 months	—	—	—	n.m.	0	a	7.2	10	a
III. Ultuna, Sweden									
24 months	n.m.	0	a	n.m.	9	a	n.m.	10	a
36 months	—	—	—	28	4	a	8	10	a
IV. Ingvallsbenning, Swe									
17 months	27	7	a	16	10	a	5	10	a
26 months	30	0	a	19	10	a	5	10	a
V. Bandung, Indonesia									
1 month	n.m.	7 [b]	7 [b]	n.m.	7 [b]	7 [b]	n.m.	10 [b]	10 [b]
3 months	n.m.	7 [b]	7 [b]	n.m.	7 [b]	7 [b]	n.m.	10 [b]	10 [b]
12 months	n.m.	0 [b]	0 [b]	n.m.	0 [b]	0 [b]	n.m.	10 [b]	10 [b]
36 months	—	—	—	—	—	—	—	c	c
VI. Bogor, Indonesia									
1 month	n.m.	0 [b]	0 [b]	n.m.	4 [b]	4 [b]	n.m.	9 [b]	10 [b]
3 months	—	—	—	n.m.	4 [b]	4 [b]	n.m.	9 [b]	10 [b]
12 months	—	—	—	n.m.	0 [b]	0 [b]	n.m.	9 [b]	9 [b]
36 months	—	—	—	—	—	—	—	c	c
VII. Rotorua, N.Z.									
9 months	46.9	0	a	5.2	9	a	6.8	9	a
18 months	—	—	—	23.7	0	a	7.5	7	a
29 months	—	—	—	—	—	—	7.5	7	a

n.m. Not measured.
a No termites in field.
b Lowest rating of fungal decay or termite attack.
c All stakes gone, probably due to termite and/or fungal activity.

General discussion

The most aggressive field in this test is the field in Bogor where all the controls had failed within 3 months. The field in Bandung is also quite aggressive, most of the control stakes had failed within a year. Still, most high-acetylated composite stakes were sound in these fields after one year, except for the aspen fiberboard stakes.

The next most agressive fields were: Gulfport, Simlångsdalen and Rotorua. All control stakes and most of the low-acetylated stakes have failed in these fields. The high-acetylated wood composites are, however, still intact except for rubber wood particle board stakes.

Two of the fields in Sweden, Ultuna and Ingvallsbenning, are slower in terms of decay rate of the controls. However, the stakes had not been in the Ingvallsbenning field much more than two years at last inspection, and the Ultuna field is known to be rather aggressive once decay gets started — CCA-treated pine stakes, at high retention levels, usually fail within 10 years in this field. The high-acetylated composite stakes are still completely intact in these fields.

The thickness swelling of the control fiberboards ranged between 20 and 30% at the first inspection compared to 5-20% for the low-acetylated fiberboards and 1.6-5.5% for the high-acetylated boards. The thickness swelling increased somewhat until failure for the control fiberboards, but the swelling of the high-acetylated fiberboard stakes has not changed much over the three year exposure period.

The thickness swelling of the control rubber wood particle boards were higher than the swelling of the fiberboards at the first inspection, and this appeared to be linked with heavy decay. The swelling of the high-acetylated particle boards was somewhat higher than that of the fiberboards at the first inspection, 5-10%, and then increased somewhat, probably a first sign of decay.

Finally it can be stated, considering these field results together with field results for acetylated solid wood that acetylation of wood material imparts excellent protection against microbial decay and termite attack in most locations, provided that a certain degree of acetylation is reached — preferably in the region of 20% acetyl content.

References

Feist, W.C.; Rowell, R.M.; Youngquist, J.A. 1991: Weathering and finish performance of acetylated aspen fiberboard. *Wood and Fiber Science*, 23(2): 260-272.

Nilsson, T.; Rowell, R.M.; Simonson, R.; Tillman, A.M. 1988: Fungal resistance of pine particleboards made from various types of acetylated chips. *Holzforschung*, 42(2): 123-126.

Rowell, R.M.; Imamura, Y.; Kawai, S.; Norimoto, M. 1989: Dimensional stability, decay resistance and mechanical properties of veneer-faced low-density particleboards made from acetylated wood. *Wood and Fiber Science*, 23(2): 67-79.

Rowell, R.M.; Simonson, R.; Tillman, A.M. 1991: A process for improving dimensional stability and biological resistance of lignocellulosic materials. *European Patent 0213252* .