

64 IN-SERVICE MOISTURE CONTENT OF HARDBOARD LAP SIDING IN SOUTHERN FLORIDA

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Abstract

To evaluate the effect of backpriming on in-service performance, hardboard lap siding from one manufacturing plant was exposed on two test buildings in southern Florida for 29 months. The two buildings were identical, except that one had 0.3 m (12-inch) roof overhangs without gutters and the other had gutters but no roof overhangs. Siding installation was the same on both buildings and was essentially as recommended by the manufacturer. Laboratory tests revealed that edge swell and other properties of this particular siding were much better than required by industry standards. With only one exception, noticeable caulk seal failures either did not occur or were promptly corrected. All siding remained dry and in excellent condition over the exposure period. Some water intrusion occurred between some of the window units and trim. The siding system dissipated this water intrusion without suffering damage. Roof overhangs reduced moisture levels in the exterior millwork and trim, but did not appear to reduce the moisture content of this siding. Backpriming did not improve the performance of this particular hardboard siding nor did it lower in-service moisture content.

Keywords: hardboard siding, moisture content, backpriming, effect of roof overhangs, effect of gutters.

1 Introduction

In response to incidence of moisture-induced deterioration of hardboard siding in south Florida, the U.S. Department of Housing and Urban Development (HUD) proposed a Local Acceptable Standard (LAS) for southern Florida, which prescribed factory prefinishing of the siding and priming all surfaces (including the back surface). The field study reported in this paper was intended to address the

uncertainty about the necessity and effectiveness of these proposed measures. The study's objective was to determine if backpriming or factory pre-finishing might improve the durability of hardboard lap siding when installed according to recommended practice.

To determine the effects of backpriming and factory pre-finishing on the potential for deterioration, we monitored moisture content, thickness swell and appearance of site-finished, factory finished, backprimed, and non-backprimed hardboard siding on two full-size buildings in Florida. Although we expected that two years of exposure would not induce siding failure, we envisioned that differences in moisture content, thickness swell, or appearance would indicate potential differences in performance or durability. This paper presents some study findings; it is limited to observations of moisture history and physical condition of siding and of exterior wood millwork and trim.

2 Methods

The two test buildings were in Palm Beach County near the Atlantic coast of southern Florida. Siding installation was the same on both buildings and was essentially as recommended by the manufacturer. The siding on two test buildings was finished with four different finish treatments. The siding was on the building for approximately 29 months, after which the buildings were demolished. Temperature and humidity inside the buildings were controlled. We continuously monitored the moisture content and periodically visually inspected the siding.

2.1 Test buildings

One building had 0.3-m (12-inch) overhangs, including the gable ends, and had no rain gutters; the other building had no roof overhangs, but had rain gutters on the eaves. The buildings were otherwise identical. Dimensions of the buildings were 9.75 by 9.75 m (32 by 32 ft). The gable ends faced northeast and southwest. Walls were wood frame nominal 2x4 construction and were insulated with glass fiber batt insulation. The interior of the walls and ceilings was finished with taped and painted gypsum wallboard. Each building was air-conditioned, and distribution ducts were within the conditioned interior (not in the attic), while ceiling fans provided additional air mixing.

Each side of the buildings consisted of four 2.4 m (8 ft) long wall sections of varying construction; most were sheathed with plywood, while some had no sheathing. All walls included a secondary weather barrier, either #15 asphalted felt or woven polyolefins sheet. To prevent air movement between them, adjacent wall sections were separated with pressure-treated nominal 2x6 lumber, sandwiched between the end studs of the wall sections, except at outside corners. The outside edge of the 2x6 separator protruded beyond the face of the siding. At outside corners, walls were joined in a standard manner, with vertical outside corner trim consisting of western redcedar (*Thuja plicata*) strips.

Two doors and 12 windows were installed in each building. The doors were steel-door units with pine jambs. The windows were aluminum single-hung units with side nailing flanges. Exterior trim for windows and doors was site-fabricated from western redcedar strips. Window trim was installed over the window flanges. The

piece of trim at the bottom of the window was sloped to the exterior. The trim was caulked to the window unit with urethane caulk, and joints between the pieces of trim were also caulked. Aluminum head flashing was installed over the top cedar trim piece above all window and door units.

The buildings were not shaded by trees, and there was no shrubbery within 6 m (20 ft) of either building. Gutters on the building without overhangs remained free of blockage over the course of the study.

2.2 Siding

The siding was 203-mm (8-inch) wide, 10-mm (0.2-inch) thick hardboard lap siding from one mill. We performed weatherability of substrate tests and linear expansion tests, as described in Standard AHA/ANSI A 135 (American Hardboard Association 1990), on samples of this siding. The weatherability of substrate test provides a measure of the board's permanent thickness swell when subjected to a series of wetting and drying cycles. The linear expansion test measures the board's change in length when brought to equilibrium at 90% relative humidity (RH) from equilibrium at 30% RH. The data (Table 1) indicate that this siding's properties substantially exceeded the minimum values required in the industry standard.

Table 1: Comparison of test results on boards used in this study and industry minimum standards

	Residual Swell ¹ , average and range (%)	Linear expansion ² , average and range (%)
Study material	4.3 (1.6-7.4)	0.23 (0.21-0.27)
ANSI/AHA requirement ³	20 maximum	0.40 maximum

¹ Weatherability of Substrate test as per section 4.2 of ANSI/AHA standard.

² 30% to 90% RH, in machine direction, as per Table 2 of ANSI/AHA standard.

³ ANSI/AHA A1356-1990, American National Standard for Hardboard Siding

Table 2: Equilibrium moisture content data

RH (%)	EMC of hardboard siding ¹ (%)	EMC of southern pine ² (%)	EMC of construction plywood ² (%)
30	3.9	5.3	4.8
43	4.7	7.0	6.3
65	6.8	10.8	9.7
79	8.9	14.8	13.4
90	10.4	20.0	18.5

¹ sorption only

² Source: Richards et al. (1992)

We measured equilibrium moisture content (EMC) of the hardboard siding (Table 2). The siding has lower EMC than solid wood or plywood at corresponding relative humidity conditions. Values for hardboard in Table 2 are in general agreement with previously published values (Bristow and Back, 1969) for heat-

treated hardboards.

2.3 Siding finishes

The exterior surface of all siding was either factory-primed or factory-primed and factory-finished. Factory-primed board was topcoated with a site-applied acrylic paint after installation on the buildings. About two months prior to installation, we primed the back surface of roughly half the boards with an alkyd (“oil-based”) primer. Backs of the rest of the boards were left un-primed, although all siding had a thin and incomplete cover of primer or finish coating on the back as it was received from the mill¹. This cover of primer or paint on the backs was generally continuous at the drip edges, although thin.

Finish treatments were: 1) backprimed, factory finished [BF]; 2) not backprimed, factory finished [NF]; 3) backprimed, one coat of site-applied finish [BS]; 4) not backprimed, one coat of site-applied finish [NS]. Site-applied finish was applied within ten days after siding installation. We used an acrylic-latex gloss exterior paint, applied by brush by a professional painter. The paint color was similar to that of the factory finished siding. Good coverage was obtained, and a mirror was used to inspect for full coverage of the drip edge.

2.4 Siding and trim installation

The siding was installed during the last week of November and first two weeks of December 1994. Siding moisture content at installation ranged from 5% to 7%, measured gravimetrically. The siding was manually face-nailed with galvanized nails. The minimum overlap between boards was 25 mm (1 inch). Siding crosscuts were left unpainted. Window, door, and outside corner trim were installed before the siding, as were the 2x6 wall section separators. All joints between siding and either trim or wall separators were caulked with urethane caulk. Gable end cuts of the siding on the building with overhangs were covered by aluminum soffit. On the building with overhangs they were covered with redcedar gable end trim, the top edge of which was in turn covered by metal roof edge. Gable end cuts were therefore protected from the weather, and did not rely on caulk seals for that protection.

The four different combinations of siding finish treatments were alternated vertically, according to the sequence (going upward): BS, NS, BF, NF. The finish treatment for the bottom siding course varied from wall section to wall section, such that all finish treatments were equally allocated to bottom-course locations.

2.5 Interior and exterior conditions

Between February 1995 and study termination, interior conditions in the buildings were maintained at approximately 75 °F and 50% relative humidity (RH).

On-site rain gauge data were manually collected from April of 1995 until study termination, generally on weekly intervals. Data from the nearest National Weather Service (NWS) station at West Palm Beach, about 16 miles away, were in close agreement with site-collected data. Annual rainfall at the site was approximately 59 inches per year, close to the historical average (years 1961-1990) of 61 inches per

¹ Paint on siding backs was incidental to the factory priming and/or painting of front surfaces and drip edges.

year at the NWS site in West Palm Beach.

We used the NWS data for April 1995 through April 1997 to calculate the climatic decay hazard index (Scheffer, 1971). That index was developed as an indicator of the potential for decay of wood on building exteriors above ground. The calculated value for the exposure period was 154. Index values in excess of 65, based on historic average data, indicate climates of high decay hazard. Index values for the continental U. S., based on historic average data, exceed 110 only for the Florida peninsula (Scheffer, 1971).

2.6 Instrumentation and automated monitoring

On each building 46 siding boards were instrumented with thermocouples and moisture content pins. They were placed in a variety of exposures. Placement was essentially identical on both buildings. Of the 46 instrumented boards, 12 were in bottom-course positions, 28 abutted a window or door, and 6 were installed high on the walls (approximately at ceiling height). The four finish combinations were equally represented on each side of the building, and by type of exposure.

Moisture content was determined from direct current (DC) resistance between pins and adjusted for board temperature. We calibrated the pins for this hardboard siding at room temperature, and corrected for temperature as suggested by James (1975). The insulated MC pins were installed on the front faces of siding boards in pre-drilled holes and carefully caulked to prevent water entry into the holes. After attachment of the leads, the pins were covered with caulk for protection from rain. Leads were connected to signal conditioners with circuitry as shown in Carll and TenWolde (1996). Type T thermocouples were embedded in the boards, through holes drilled from the back of the board to a depth of about 5 mm (0.2 inch). Each building had its own data collection system, controlled by a personal computer. Readings on instrumented boards were taken hourly. Data collection commenced in April 1995 and ended on May 6, 1997.

2.7 Data reliability

The signal conditioner circuits for the moisture pins could not measure resistance exceeding the equivalent to between-pin resistance of the hardboard siding at room temperature and 7% MC. Therefore, with siding at room temperature, 7% MC was approximately the lowest measurable value. However, because the electrical resistance of wood at a given moisture content decreases with increases in temperature, we were able to measure down to approximately 6% MC when the siding boards were heated by the sun.

We used insulated pins so that wet board surfaces would not result in erroneous high moisture content readings. However, abrupt changes in MC readings sometimes occurred, and were most likely related to surface wetting, not to an actual increase in the MC of the siding. Average daily readings for any group of pin pairs that were above 9% MC appeared to be associated with abrupt jumps in individual pin pair readings, and were thus suspect.

Prior to February 10, 1996, there were errors in our MC measurements due to instrumentation and calibration problems. After correcting these, moisture pin readings made by the data collection system were compared with moisture pin readings from a DC resistance moisture meter, with siding temperature close to meter calibration temperature. The values agreed within 1% MC. At study completion,

samples of siding were removed from the buildings within 3 days of termination of automated data collection and their moisture contents determined gravimetrically. Average moisture pin readings for the final week of automated data collection, grouped by building and wall type, were within 1.5% MC of the corresponding final in-service MC's determined gravimetrically.

2.8 On-site inspections

2.8.1 Quarterly inspections

A total of ten quarterly inspections were performed. The first inspection was shortly after installation and painting of the siding in December 1994, and the final inspection was shortly prior to siding removal in May 1997. At each inspection, the appearance of each piece of siding was noted and thickness of the lower left and lower right edges of each siding board was measured in place using a specially designed tool incorporating a dial gauge.

2.8.2 Final observations and measurements

On May 5 and 6, 1997 we measured the moisture content of wood trim on each building (with the exception of the fascia behind the gutters of the building without overhangs), with a DC resistance moisture meter. On May 6-9, 1997 we removed siding from the buildings, except on gable ends above ceiling height, inspected siding back surfaces, and looked for evidence of rainwater leakage. On each building we cut a total of 128 siding specimens, representing all 32 wall sections, for gravimetric determination of moisture content. Five additional moisture content specimens were cut directly underneath windows on the building with gutters; these were windows which showed evidence of rainwater leakage.

3 Results

3.1 Quarterly site inspections

Throughout the exposure period, the siding remained in excellent condition. No edge puckering was observed on any board on either building, nor was siding buckling or finish failure. Furthermore, we never observed any cracking of paint on drip edges. This indicates that the siding remained dry over the exposure period. In some shaded locations however, mildew growth occurred on board surfaces. Noticeable caulk failures between siding and trim either did not occur, or occurred early in the exposure period and were repaired. The exception was one caulk failure between a window and its trim unit that was noticed after 9 months of exposure and was left uncorrected for the remaining 20 months. Siding backs below this window were stained when we removed the siding in May 1997, indicating that water intrusion did occur.

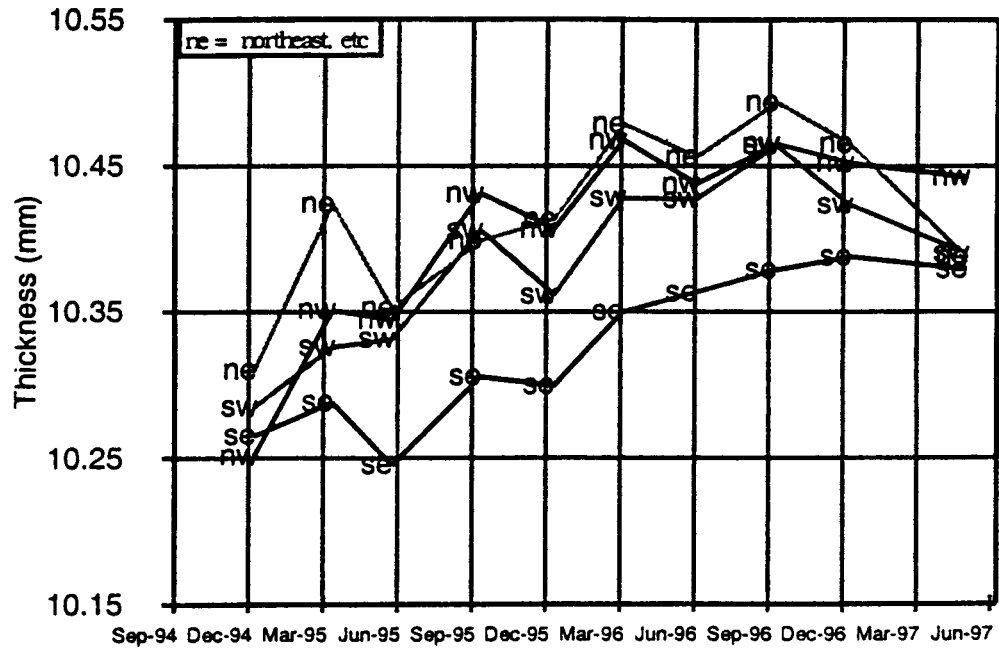


Fig.1(a): Results of thickness measurements on building with gutters, by wall orientation

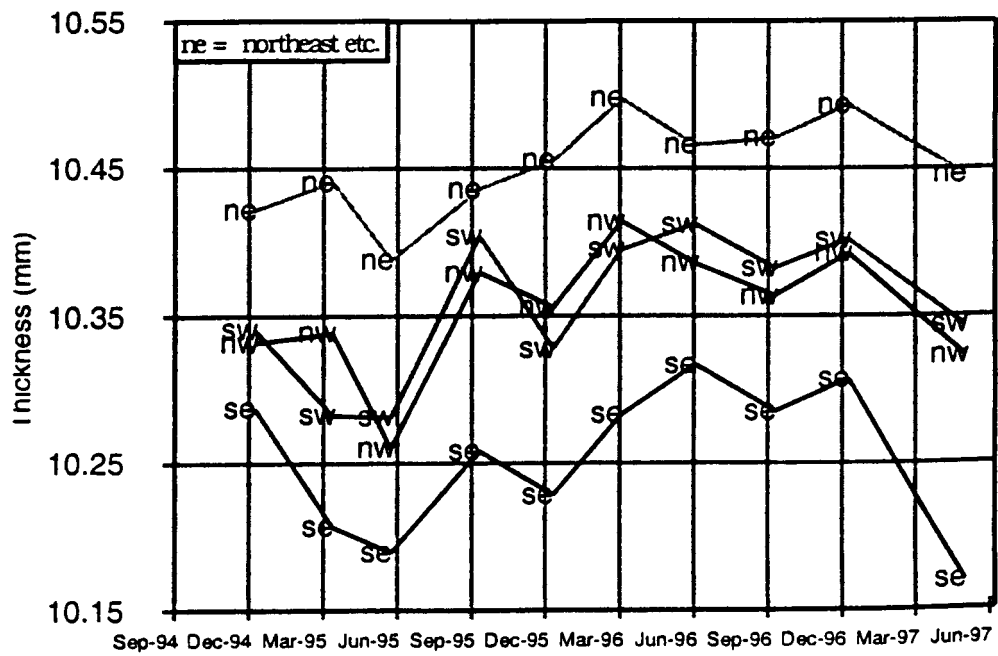


Fig. 1(b): Results of thickness measurements on building with overhangs, by wall orientation

Figures 1A and 1B show the results of the in-place thickness measurements. Thickness increased very little after March 1995 (3 months of exposure) and after March 1996 (15 months of exposure) no long-term increase is apparent. Based on an estimated initial thickness of 10 mm (0.4 inch), thickness swell stayed below 3% over the entire exposure period, while the average thickness swell was about 2%. Figures 1A and 1B also show a seasonal fluctuation in thickness, with some shrinkage during summer and swell during winter. Generally, siding on the shady sides of the buildings was thicker than boards on the sunny sides. Neither finish system, nor building (building with gutters versus building with overhangs) showed any consistent significant effect on in-place thickness.

32 Siding moisture contents

3.2.1 Moisture contents during exposure

Moisture pin data indicated that the siding remained below 9% MC over the monitoring period. Figure 2 shows daily average MC for all moisture pin readings on each building from February 10, 1996 until termination of data collection on May 6, 1997. Data collected prior to February 10, 1996 are not presented because of the calibration and instrumentation problems mentioned previously. Figure 2 shows a few short periods with a daily average MC above 9%. These corresponded with rain events, and, as indicated previously, are probably erroneous. The seasonal fluctuation in MC level shows a similar trend as fluctuation in in-place thickness data, i.e. lower MC in summer, higher MC during winter.

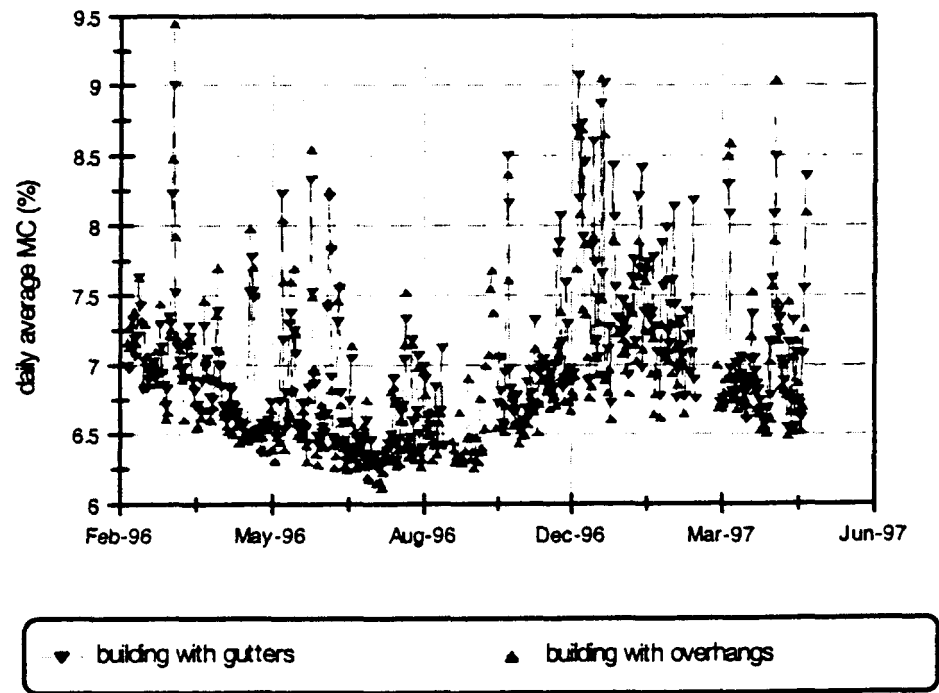


Fig. 2: Daily average moisture content readings from moisture pins, from February 10, 1996 through study completion

The data show no discernable differences between buildings, nor between finish treatments (BS, BF, NS, or NF). No differences were apparent in MC of siding on different wall constructions, nor was there an apparent effect of wall orientation. Furthermore, siding boards on the bottom course were not wetter than siding boards in other locations. However, most of the moisture pin data were close to the lower measurement limit of the instrumentation, hampering our ability to discern actual differences in moisture content.

3.2.2 Final moisture contents

Gravimetric MC measurements indicated that final in-place siding MC was fairly low. Siding moisture content on the two buildings was essentially the same: Specimens from the guttered building had MC's in the range of 5% to 8%, with an average MC of 6.4%. Specimens from the building with overhangs also had MC's in this range, with an average of 6.3%. Final moisture contents of siding in bottom course positions were the same as the average moisture content of boards in other courses'. This is in agreement with moisture pin data.

Sorting the data by wall orientation and finish treatment generally reduced variability in the data, suggesting systematic influence of these variables on final in-place MC. We used group t-tests on the sorted data to identify if orientation (by building and finish treatment), or finish treatment (by building and wall orientation), had a statistically significant influence on final in-service MC. In most cases wall orientation had a statistically significant effect on final in-place siding MC (confidence coefficient of 0.95), with boards on the sides of the building that received more direct sunshine generally drier. This was in agreement with thickness measurements made at quarterly inspections. With the data sorted by wall orientation, t-test comparisons also revealed that, at the time of removal, boards not backprimed were drier than backprimed boards (confidence coefficient of 0.95) in roughly half of the comparisons, while there were no cases where backprimed boards were drier than boards not backprimed.

Average MC of siding specimens taken from below windows that showed evidence of leakage was 6.8%. One specimen which had water stains on its back surface, registered 9% MC. The rest of the specimens were 6 or 7% MC (including another specimen with water stains on its back).

We found that wall construction (i.e. presence or absence of plywood sheathing or type of secondary weather barrier) had no significant effect on final MC of the siding.

3.4 Rainwater leakage at windows

We found water stains on the back of siding below 6 of the 12 windows on the building with gutters (without overhangs). Four of these six windows were on gable-end walls. The leakage occurred between the window units and the trim, or between individual trim pieces. Although the water stains on siding backs indicated that some water had leaked into the siding system, there was no evidence of damage to the

²The buildings were surrounded by a roughly 18-inch wide margin bed of gravel and sand, which probably had substantial drainage potential.

siding. Water stains were limited to the three courses of siding directly below the window. Tracing of stains over the backs of successive siding courses indicated that in some cases the water drained to the front of the siding at the laps; in other cases the water apparently evaporated. On the building with overhangs we did not see staining of siding backs below windows.

Areas below windows were the only places with evidence of rainwater leakage into the siding system. The secondary weather barrier (#1 5 felt or polyolefin) did not show evidence (wrinkling, or staining) of exposure to water.

3.5 Moisture contents of wood trim

Most of the moisture meter measurements of wood trim, including pine door jambs and cedar trim, taken in May 1997, indicated moisture contents between 9 and 12 percent. One reading was over fiber saturation; this reading was in the trim of a window where subsequent siding removal indicated leakage had occurred. A few readings in trim on gable end walls were over 20 percent; they were taken at the lower end of door jambs (three readings), near the ends of window trim (three readings) or near the end of gable end trim (one reading). One lower end of a door jamb was decayed. Table 3 shows the distribution of all MC readings by building.

Table 3. Distribution of MC readings on wood trim taken in May 1997

MC readings Range	Building with Gutters Number of readings	Building with Overhangs Number of readings
MC ≥ 30%	1 (0.6%)	0
25% ≤ MC < 30%	1 (0.6%)	0
20% ≤ MC < 25%	3 (1.7%)	3 (1.6%)
15% ≤ MC < 20%	20 (11.6%)	12 (6.6%)
10% ≤ MC < 15%	122 (70.9%)	150 (82.4%)
MC < 10%	25 (14.5%)	17 (9.3%)
Total	172 (100%)	182 (100%)

Compared to the building with gutters, the wood trim on the building with overhangs had fewer high moisture content readings, with none over 22% MC. It appears that the overhang provided protection from rain and reduced the moisture content variations in the wood trim.

We sorted the moisture meter data for window and door trim, including pine door jambs, by gable-end wall versus cave wall. The data is shown in Table 4. With one exception, moisture meter readings on window and door trim were taken in identical locations on each building. We performed paired t-tests on the data (paired by individual location) to compare trim MC's between buildings. On gable-end walls, the difference in trim MC's between buildings was highly significant (confidence coefficient of 0.995). Thus roof overhangs appeared to help keep window and door trim dry on gable-end walls. On cave walls however, the difference between buildings was not significant. This suggests that rain gutters are as

beneficial as roof overhangs, provided the gutters are kept clear of obstructions.

Table 4 Average MC of window and door trim by building and wall type

Type of wall	Average MC (%) [Std. dev. (% MC)/number of specimens]	
	Building with gutters	Building with overhangs
Gable-end	12.8 [4.1/78]	11.6 [2.3/78]
Eave	12.0 [1.9/54]	11.7 [1.7/54]

4 Discussion

This particular hardboard siding remained dry and showed essentially no non-recoverable thickness swelling in service in a very warm and humid climate. In-service siding MC ranged from approximately 6% to 8% MC. This is roughly equivalent to the sorption EMC of this material for 55% to 75% RH. The lack of backside staining (except at windows) or of evidence of wetting of the secondary weather barrier suggests that wetting by wind driven rain at siding laps either did not occur or did not occur to any appreciable degree.

A limited amount of water leakage occurred in at least six of the 24 windows between the window units and the trim, and between individual pieces of trim. Prevention of water intrusion at these locations relied on the long-term performance of bedded and fillet caulk seals, which are not the most reliable type of sealant joints. Evidence of water leakage of this type was much more prevalent in the building without overhangs. The leakage occurred even though window installation, flashing, and caulking were done carefully. In some cases the lap siding permitted drainage of at least part of this leakage to the exterior. The leakage did not affect siding performance, but in some cases led to elevated MC of the cedar window trim and to fastener corrosion.

The relative prevalence of window leakage, and the final in-place MC of trim, suggest that roof overhangs reduced moisture stress on exterior millwork and trim but there is no indication that overhangs influenced the MC of the siding.

Finishing treatments used in this study had no visible influence on the condition of this siding. Final in-place MC of backprimed siding was not lower than that of siding without backpriming, but was sometimes higher. The full paint coverage over the entire backs of backprimed specimens apparently retarded drying of the siding through the back surfaces.

To obtain a better understanding of the effect of backpriming under cyclical conditions, we placed four 203 mm (8 in) square specimens (retrieved from the test buildings) in humidity rooms and monitored their MC. The rooms were at 27°C (80°F) and at 30% and 90% RH, respectively. Samples remained in one room for two weeks and were then moved to the other room. Figure 3 shows drying and wetting curves for the first full exposure cycle, along with MC's at the end of each two-week exposure period during the second cycle.

Figure 3 shows that backpriming significantly retarded both vapor sorption and desorption, i.e. backpriming retards both wetting and drying. Site-collected data suggest that heavy rains occurred in the months prior to siding removal, and dry weather the week prior to removal. At the time of removal backprimed siding consistently had a slightly higher MC possibly because it had not yet fully dried.

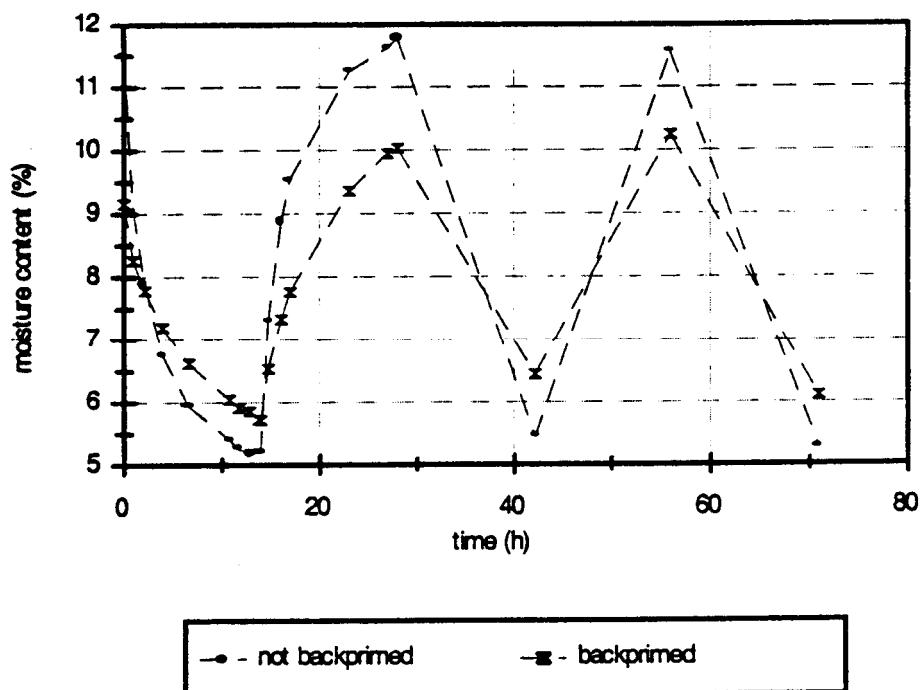


Fig. 3: Average MC of siding with, and without backpriming, when exposed cyclically to 30% and 90% RH

The residual edge swell and linear expansion properties of the siding used in this study was much better than minimum requirements in the product standard (ANSI/AHA, 1990). Biblis (1989, 1991) indicates that quality of commercial hardboard siding, as judged by performance in laboratory test procedures, can vary substantially, with some markedly inferior to that used in this study. Our observations therefore cannot be extended to all commercial hardboard siding.

5 Conclusions

Our observations apply to siding from one particular mill with properties substantially exceeding the minimum industry requirements, and installed according to manufacturer's recommendations.

- 1 All the siding used in this study remained in excellent condition after 29 months of exposure on test buildings in southern Florida, even though some water leakage at windows was not uncommon. Weather conditions during exposure

were close to historic norms for the location; annual rainfall was close to 60 inches per year, an extreme exposure for the continental United States.

- 2 The siding remained at 9% MC or less over the exposure period.
- 3 Water leakage at windows, apparently caused by less-than-perfect window-to-trim sealing details, was not uncommon, even though installation, flashing, and caulking were done carefully. This supports the contention that window leakage is common and that the cladding must therefore accommodate some degree of water leakage.
- 4 Roof overhangs had no apparent influence on MC of this siding, but did lower MC in exterior millwork and trim. Gutters, when kept unobstructed, had a similar effect.
- 5 Backpriming of the siding did not improve performance of this siding, nor did it result in lower in-service MC. Final in-place MC of backprimed siding was sometimes a little higher than that of siding not backprimed, but this could have been caused by slower drying of the backprimed boards after a period of rain. Because siding that was not backprimed had some paint coverage on the backs at the overlaps, our conclusion that backpriming was not beneficial may not apply when the comparison is made with siding that is completely bare on the back. The conclusion may also not be applicable to situations where backpriming is limited to a "border" strip at the siding overlap.

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Durability of Building Materials and Components 8

Service Life and Asset Management

Proceedings of the Eighth International Conference
on Durability of Building Materials and Components, 8dbmc

Vancouver, Canada
May 30- June 3, 1999

Volume One Service Life and Durability of Materials and Components

Edited by

Michael A. Lacasse and Dana J. Vanier
*Institute for Research in Construction,
National Research Council of Canada*

NRC-CNRC

NRC Research Press
Ottawa, 1999