EFFECT OF WEATHERING ON THE DIMENSIONAL PROPERTIES OF PARTICLEBOARD DECKING[1]

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ABSTRACT

The effect of outdoor weathering on the dimensional properties of phenolic-bonded particleboard manufactured as decking for factory-built housing was evaluated. Results were compared to those for urea-bonded particleboard made with a similar southern pine furnish. Results indicate that in terms of linear expansion, thickness swelling and swelling recovery, and resistance to buckling, weathering did not severely affect the performance of the phenolic-bonded decking material. Weathering significantly affected the performance of urea-bonded material.

Keywords: Dimensional change, durability, factory-built houses, linear expansion, thickness swelling, particleboard, southern pine.

INTRODUCTION

Several structural particleboard products have been developed recently that will probably begin to make an impact in the marketplace in the next few years. One structural application for particleboard is decking for factory-built housing. For this application, conventional particleboard bonded with a phenol-formaldehyde resin is used. Engineering developments have taken place for this material that have resulted in the establishment of standards by the National Particleboard Assocaition (NPA 1971). These standards specify that decking for factory-built housing meet the requirements for Type 2B2 mat-formed particleboard, including the optional hardness requirement plus a concentrated load requirement. Questions still remain as to how well this material will perform as a decking material, particularly when exposed to adverse environmental conditions. Under such conditions, dimensional properties are particularly important.

The dimensional behavior of particleboard has been documented in the literature. Since 1963, the U.S. Forest Products Laboratory has been investigating the effect of aging on various types of boards over several exposure periods (Gatchell et al. 1966; Lehmann 1968; Geimer et al. 1973; Lehman 1974; McNatt 1974).

This paper presents partial results of a comprehensive evaluation of Type 2B2 phenolic-bonded particleboard decking meeting the property requirements for factory-built housing. A similar urea-bonded particleboard meeting Type 1B2 property requirements was also evaluated. Dimensional properties evaluated were: linear expansion, thickness swelling, swelling recovery, water absorption, buckling, and layer density of particleboard decking as a function of resin type and weathering.

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FIG. 1. Vertical test fence used in the weathering of particleboard sheets.

MATERIALS

Fifty sanded commercial southern pine particleboard panels, 4 by 8 feet by ⅝-inch thick, bonded with urea formaldehyde or phenol formaldehyde resin were randomly selected. The phenolic-bonded board conformed to the requirements of commercial standard CS236-66 for Type 2B2 board and carried the NPA 2-72 grademark (National Particleboard Association 1972). The board contained no wax. The urea-bonded board conformed to the Type 1B2 board requirements in CS236-66 (U.S. Department of Commerce 1966) and carried the NPA grademark for such boards. This board contained wax.

TABLE 1. *Linear expansion (LE) and thickness swelling (TS) for weathered and unweathered urea- and phenolic-bonded particleboard decking.*

Board[a] type	Linear expansion (LE)[b,c] ASTM % LE, 50–90RH	ASTM % MC 50 RH	ASTM % MC 90RH	ASTM α_L %/%	VPS % LE	VPS % MC Initial	VPS % MC Soaked	VPS α_L %/%	Thickness swelling (TS) % TS	TS % MC Initial	TS % MC Soaked	α_T %/%
2B2	0.244A	7.45	12.71	0.0465	0.982	8.13	83.02	0.013	8.24A	8.11	40.71	0.253
1B2	0.281	7.76	12.94	0.0540	1.371A	9.24	91.57	0.017	2.90	9.40	16.77	0.393
2B2/W	0.220AB	8.61	12.30	0.0600	1.407A	10.12	97.54	0.016	8.93A	10.03	73.68	0.140
1B2/W	0.192B	8.38	11.20	0.0677	1.466	10.05	110.89	0.015	11.61B	9.48	62.12	0.221

[a] W designates weathered board.
[b] Means not followed by a common letter differ at the 0.05 level (for % LE and % TS only).
[c] α is the expansion coefficient defined as the % change in dimension per 1% change in moisture content. The subscripts L and T refer to movement in the plane of the board and through the board thickness, respectively.

PROCEDURE

Twenty-one of the Type 2B2 and 16 of the Type 1B2 particleboard panels were placed on a vertical exterior test fence facing east located at Starkville, Mississippi. The test fence is shown in Fig. 1. The panels were allowed to weather in a virtually unrestrained condition for one year. This exposure is representative of the severe conditions found in the Gulf Coastal plain.

Randomly selected weathered panels (four for each board type) and unweathered panels (six Type 2B2 and four Type 1B2) were cut into test specimens. Tests included linear expansion (LE), using the vacuum-pressure-soak (VPS) method, thickness swelling (TS), and water absorption. The cutting diagram for factory-built housing decking shown in the NPA standards was used (NPA 1971). Testing was done in accordance with ASTM D-1037 (1969) or NPA (1971) standards. All samples were conditioned at 68 F and 50% relative humidity unless otherwise noted.

One panel each of weathered and unweathered Type 1B2 and Type 2B2 decking was randomly selected for the following additional tests: (1) linear expansion using the ASTM cycle of 50–90–50% relative humidity (weathered board only—20 replications for each board type); (2) ASTM-VPS correlation test (unweathered board only); (3) swelling recovery (unweathered board only); and (4) buckling.

For the correlation test, 20 sets of three edge-matched linear expansion samples (two for the VPS method and one for the ASTM method) were tested, and the relationship between the two methods was determined by regression analysis.

For the swelling recovery test, 6-inch-square samples were immersed as in the NPA standards for 2, 4, 8, 16, or 24 h. Five samples were tested for each soak time. After the appropriate immersion time, the samples were removed and measured as in the NPA standards. The samples were then reconditioned to equilibrium weight at 68 F and 50% relative humidity. The amounts of swelling and swelling recovery were calculated as a function of the original thickness.

The determination of buckling was done by a method described by McNatt (1973). Samples 2 inches wide by 12 inches long, conditioned at 50% relative humidity and 68 F, were placed in restraint frames. Angle stops were adjusted until the specimens were snugly in place. The frames were placed in a cabinet maintained at 68 F and 90% relative humidity. Deflections to the nearest 0.001

inch at the center span of the boards were measured periodically until equilibrium was attained (about one month). The specimens were reconditioned at 68 F and 50% relative humidity and remeasured. Ten samples were tested for each board type (five in each direction).

Layer density determinations were made on five samples of each particleboard type using the procedure described by Stevens (1978). The samples were randomly selected from board remnants.

RESULTS AND DISCUSSION

Linear expansion

The test results from the ASTM and VPS methods of determining linear expansion are given in Table 1. Variance analysis indicated no significant difference between means for weathered boards tested by the ASTM method. Weathering had no significant effect on the linear expansion of phenolic board, but weathered boards made with urea resin exhibited significantly less linear expansion than did unweathered urea-bonded boards.

Urea board exhibited a significantly greater linear expansion in the unweathered condition than the phenolic board. Presumably, this was due to the fact that phenol formaldehyde resins have good water resistance characteristics and provide a more stable board over a wide range of humidity conditions. A similar rationale leads to the conclusion that phenolic-bonded boards should be less affected by weathering in exterior exposure. Weathered and unweathered phenolic board had similar expansion characteristics.

The low expansion value for weathered urea board can perhaps be best explained on the basis of stress relaxation. During exterior exposure, the boards were exposed to repeated cycles of wetting and drying. This repeated cycling would have a greater effect on the urea board since it is less water-resistant. Cycling reduces the sorption hysteresis and, hence, would tend to relieve stresses inherent in the board. Both board types decreased in linear expansion as a result of weathering, with the greatest reduction occurring with the urea board.

The VPS results were different from those found by the ASTM test. Linear expansion of unweathered phenolic board was significantly lower than that observed for other boards. This difference may be explained in terms of differences in experimental procedure. In the ASTM test, boards were subjected to water vapor. Hence, any lateral movement would be due to diffusion of water into the cell walls of the component particles. In the VPS test hydrostatic pressure forced water into the walls and voids. The net result would be a lateral increase larger than that exhibited during the ASTM cycle. In weathered board, a higher moisture content would be expected after the pressure phase, because the wood particles are less tightly bonded within the board. The result would be greater expansion, as is shown. Since the VPS is a severe test, it may be well to take these values as limiting ones representing the maximum possible lateral movement.

In comparing differences in linear expansion of weathered and unweathered boards, it is perhaps more instructive to look at the expansion coefficient, α_L (percent linear expansion per 1% change in moisture content). These coefficients indicate a greater change (per moisture content change) in the weathered board than in the unweathered board, with phenolic board less affected in each category.

The relative high α_L value is consistent with a low expansion percentage in the weathered urea board based on the fact that the cyclic adsorption-desorption of water tends to reduce the hysteresis effect. The initial (50% RH) and final (90% RH) equilibrium moisture contents for the weathered and unweathered boards are shown in Table 1. It is clear that weathering increased the initial moisture content and decreased the final moisture content (i.e., reduced hysteresis) for both board types, with the greater reduction occurring with the weathered urea board. Suchsland (1972) has shown similar results with unweathered board. The α_L values from the VPS test are similar for all board types.

One other comment should be made at this point. The urea board had wax incorporated in it during manufacture, while the phenolic board had none. The inclusion of wax in the formulation of the board appeared to have little effect on its performance during weathering and did not seem to be as important as the resin type during long exposure cycles. According to the linear expansion values in Table 1, urea board would expand 0.27 inch per 8-foot panel when going from 50% to 90% relative humidity, assuming equilibrium. The corresponding change in phenolic board would be 0.23 inch.

The correlation between the VPS and ASTM tests was poor and was not as good as has been previously shown (Barnes and Wang 1976). The correlation coefficient between linear expansion coefficients using these two methods was 0.59.

Thickness swelling and related properties

During weathering, urea boards swelled 13.2% in thickness and phenolic boards swelled 8.1% in thickness. Results from the thickness swelling tests on weathered and unweathered specimens are given in Table 1. Weathering had no effect on the thickness swelling of phenolic board. The opposite is true for urea board. Unweathered urea board exhibited the lowest thickness swelling. Obviously, the wax incorporated into this board improved the performance of the urea board during brief exposure. This fact is consistent with the results from the linear expansion tests. In the short run, the wax should provide a protective effect, especially from liquid water. Given sufficient time, as in the longer ASTM expansion test, diffusion of water into the wood substance can occur, with the resulting increase in dimensional movement. The same would be true for the longer weathering cycle. Any initial lag in dimensional movement due to wax would diminish in such a long exposure. This can be seen by looking at the change in moisture contents of the particleboard during the soaking period. The urea board had a significantly lower moisture content change than did the phenolic board (7.3% vs. 32.6%). After weathering, there was no significant difference in the moisture content change.

Values for the dimension change per unit moisture content change in the plane of the board (α_L) and in thickness (α_T) are reported in Table 1. The α_T values are several times greater than the α_L values. This indicates a much greater effect of moisture on thickness swelling than on linear expansion and emphasizes the need for greater attention to factors affecting thickness swelling and a better understanding of these factors.

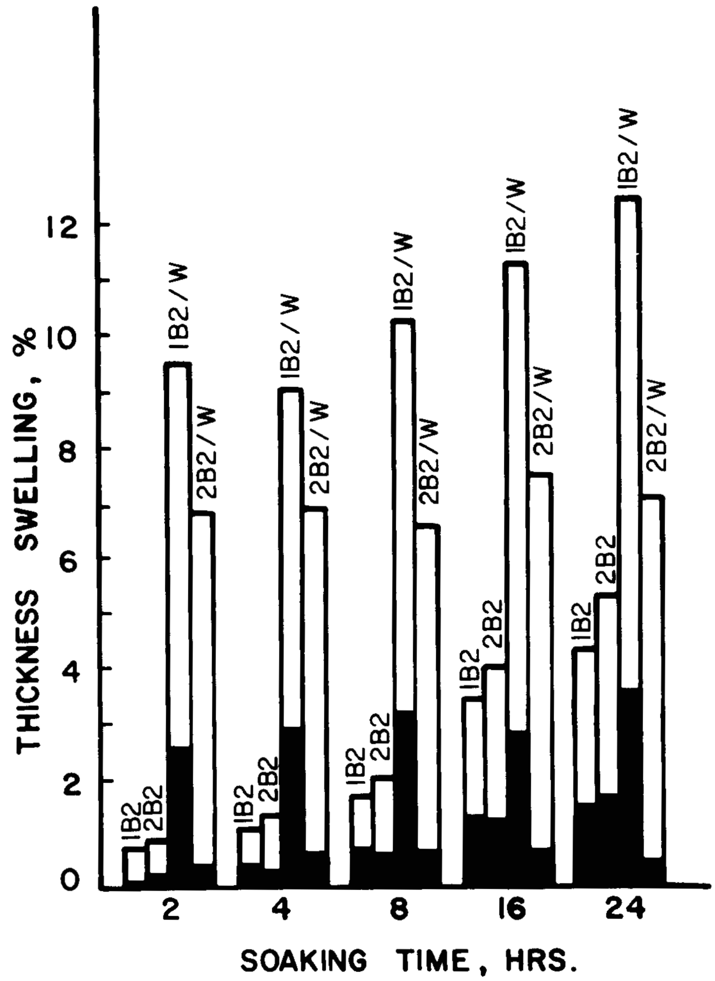

FIG. 2. Thickness swelling of weathered and unweathered particleboard decking at five soaking times. Shaded areas represent permanent thickness swelling.

Swelling recovery

Figure 2 shows thickness swelling at different soaking times. The shaded areas represent permanent thickness swelling components when soaked board was reconditioned at 50% relative humidity. Tabular results are provided in Table 2. Thickness swelling of both urea and phenolic board was linearly related to soaking time, as was residual thickness swelling. Thickness swelling of weathered phenolic board was not significantly affected by soaking time. In this instance it is thought that weathering resulted in springback. This would reduce the internal stresses formed during processing to a sufficiently low level so that additional springback would not occur during subsequent soaking. This was not observed with the weathered urea board, since, in addition to springback, additional swell-

TABLE 2. *Water absorption, thickness and volumetric swelling, and recovery for various soaking times for urea- and phenolic-bonded particleboard decking.*

Soaking time (h)	Parameters[a]	Type 2B2	Type 1B2	Type 2B2, weathered	Type 1B2, weathered
2	Initial–Final MC, %	7.7–12.6	8.7–11.4	11.7–74.5	11.4–86.3
	TS–VS, %	0.82–1.01	0.70–0.88	6.93–8.24	9.63–11.28
	α_T–α_V, %/%	0.18–0.22	0.23–0.30	0.12–0.14	0.13–0.16
	R_T–R_V, %	68.5–65.1	82.0–66.3	94.5–93.4	73.4–73.9
	Density, pcf	49.4	50.6	43.7	42.2
4	Initial–Final MC, %	7.9–15.1	8.5–12.9	12.0–71.4	11.3–80.7
	TS–VS, %	1.30–1.53	1.05–1.27	6.96–8.38	9.20–10.98
	α_T–α_V, %/%	0.19–0.22	0.23–0.28	0.12–0.14	0.14–0.16
	R_T–R_V, %	75.1–77.1	58.3–44.4	90.9–89.7	68.2–69.0
	Density, pcf	50.3	51.5	45.6	43.2
8	Initial–Final MC, %	7.8–17.1	8.5–15.4	11.4–66.0	11.4–84.6
	TS–VS, %	2.01–2.28	1.71–2.00	6.69–8.07	10.42–12.37
	α_T–α_V, %/%	0.22–0.25	0.24–0.29	0.13–0.15	0.15–0.17
	R_T–R_V, %	69.1–71.4	57.5–57.9	90.3–89.4	69.3–70.2
	Density, pcf	51.2	51.4	46.7	43.2
16	Initial–Final MC, %	7.8–24.4	8.4–19.4	11.9–78.9	12.0–99.9
	TS–VS, %	4.07–4.51	3.48–3.93	7.61–9.09	11.47–13.90
	α_T–α_V, %/%	0.25–0.27	0.30–0.35	0.10–0.12	0.13–0.16
	R_T–R_V, %	69.3–72.1	62.0–61.7	91.4–90.9	75.2–76.1
	Density, pcf	51.2	50.1	44.9	41.8
24	Initial–Final MC, %	7.7–26.2	8.6–21.1	12.0–89.7	11.5–88.9
	TS–VS, %	5.34–5.85	4.35–4.88	7.25–8.76	12.51–14.89
	α_T–α_V, %	0.29–0.32	0.32–0.37	0.09–0.11	0.17–0.20
	R_T–R_V, %	68.3–70.8	65.4–66.2	93.6–93.1	70.7–71.8
	Density, pcf	51.4	51.4	42.0	44.0

[a] TS = thickness swelling; VS = volumetric swelling; R = % recovery. (Subscripts T and V refer to recovery for thickness swelling and volumetric swelling, respectively.)

ing occurred because of the deterioration of the adhesive bond. A relatively constant unrecoverable thickness swelling component for weathered board of both types is shown in Fig. 2.

Referring to Table 2, one may calculate the density loss due to weathering. The average losses for 2B2 and 1B2 boards were 12% and 16%, respectively. This compares with an 8% and 13% increase in thickness due to weathering for 2B2 and 1B2 board, respectively. Hence, the major component of the density change can be accounted for by changes in thickness, with only 3–4% of the total change due to area and mass changes. This serves to emphasize the need to control springback and thickness swelling, especially for board to be used in high hazard areas, a point made by the authors in a recent paper (Barnes and Lyon 1979).

The change in density through the board thickness due to weathering is shown in Fig. 3. For 2B2 board, the percent loss in density was fairly uniform throughout the thickness. The 1B2 board underwent a loss in density in the center half of the panels that was comparable to the 2B2 boards. The surface layers, however, underwent a severe loss in density as a result of the weathering process and

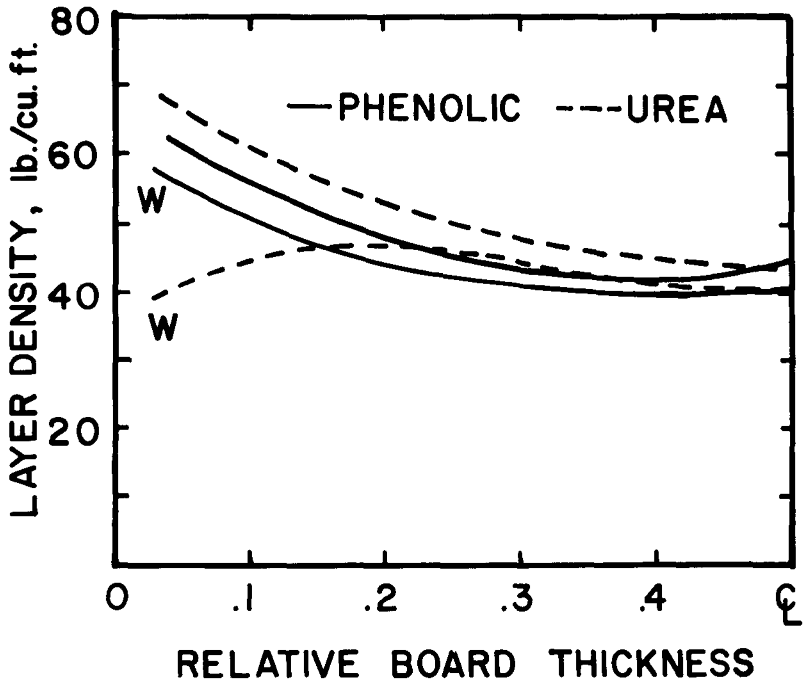

FIG. 3. Layer density for weathered (W) and unweathered 2B2 (phenolic) and 1B2 (urea) particleboard decking.

degradation of the urea resin. For example, at a depth of 0.0625 inch, the reduction in density due to weathering was 27% in the 1B2 board. This further emphasizes the need to protect urea particleboard from severe environments.

Buckling

Dimensional changes can affect the performance of decking in use by resulting in buckling due to restrained hygroscopic expansion, particularly when exposed to high humidity conditions. This phase of the investigation was undertaken to determine whether buckling of thick (>0.5 inch) decking materials represented the same problem as has been shown for thinner panel products (McNatt 1973).

Results from the buckling experiment are given in Table 3 for phenolic and urea board. The following definitions were used for those parameters listed in Table 3:

(1) Buckling $|\beta|$—the absolute value of the difference between the initial (50% RH) and final (90% RH) mid-span deflection readings in the test frames;

(2) Elastic buckling recovery (EBR)—the absolute value of the difference in deflections at 90% RH in restrained and unrestrained conditions;

(3) Percent EBR—elastic buckling recovery as a percent of the buckling $|\beta|$;

(4) Set—the equilibrium deflection value measured when the unrestrained specimens were reconditioned to 50% RH less the initial unrestrained deflection;

TABLE 3. *Buckling of urea- and phenolic-bonded particleboard under restraint.*

	Board type	
	2B2	1B2
Initial MC, %	8.07	9.28
Final MC, %	9.97	10.81
Buckling—$\|\beta\|$, mils	9.5	18.0
Elastic buckling recovery, (EBR), mils	8.5	13.0
% EBR	89.5	72.2
Set, mils	6.5	5.0
Buckling/unit length, β_L, mils/mil	0.008	0.0014
Buckling/% MC change, β_M, mils/%	5.89	10.98
% LE, 50–90% RH	0.24	0.28

(5) β_L—buckling per unit length based on the original specimen length; and
(6) β_M—buckling per unit moisture content change from 50–90% RH.

The linear expansion test means from Table 1 are included for comparison.

Of the 20 specimens tested, ten deflected inward and ten deflected outward. No differences in the magnitude of buckling with respect to deflection direction were noted, thus indicating that the compression load was symmetrically applied to the specimens. Also, within each board type half of the samples were oriented with their long axes parallel to the machine direction, with the other half oriented perpendicular to the machine direction. No differences due to orientation were noticed; therefore, the averages in Table 3 represent both board directions. Deflection readings for the phenolic board ranged from 0.001 to 0.015 inches, and those for the urea board ranged from 0.008 to 0.025 inches. Residual deflections ranged from 0.0 to 0.009 inches for the phenolic board and from 0.001 to 0.014 inches for the urea board. The deflection measurements reported here are much less than those reported by McNatt (1973) for hardboard. This is attributed to the larger section modulus and length/depth ratio for the particleboard decking, which offers the advantage of increased resistance to buckling.

Elastic buckling recovery is a measure of the instantaneous recovery of the panels from restrained buckling. Phenolic panels recovered faster than urea panels, but both panels had nearly the same amount of set. This indicates that phenolic board is slightly better than urea board in terms of stress distribution.

The amount of buckling per unit length or per unit moisture content change for urea board was approximately twice that of phenolic board. This is thought to be due to the difference in the stability of these resins in the presence of water.

It appears that buckling in thick decking materials is related to the ability of the material to distribute the induced stresses without large deformations due to the increased section modulus. Buckling is related to linear expansion since an increased linear expansion would result in higher stresses and increase the probability of inelastic deformations. For thick materials, such as decking, buckling seems to be of little concern and should not represent a serious problem for the range of moisture content found in normal use.

SUMMARY AND CONCLUSIONS

The effect of one-year outdoor exposure on the dimensional properties of phenolic-bonded Type 2B2 particleboard decking and a Type 1B2 particleboard manufactured from a similar southern pine furnish was evaluated. Results indicate that, in terms of linear expansion, thickness swelling and swelling recovery, and resistance to buckling, weathering did not severely affect the performance of the decking material. Specific conclusions for each property evaluated are summarized in the following paragraphs.

Linear expansion

Weathering caused significant changes in the percent LE values from the ASTM tests for both particleboard types. The lower LE value for weathered urea board was attributed to stress relaxation. The percents LE from the VPS study were opposite to those found in the ASTM test. This effect was related to differences in the test methods. Correlation between the two tests was poor. The inclusion of wax in the urea board offered little protection during long exposure cycles.

Thickness swelling

Weathering significantly increased the percent TS of the urea board but had no significant effect on phenolic board. Thickness swelling was linearly related to soaking time and moisture content for both board types. The same was true for the residual thickness swelling of unweathered board. For weathered board, the residual thickness swelling was relatively constant. Swelling was less than would be expected on the basis of the volume of water absorbed, indicating the filling of voids and internal swelling in the boards.

Density changes through the board due to weathering were shown to be fairly uniform for the phenolic board. Urea board, on the other hand, showed large density reductions in the face layers, thus emphasizing the need to protect this type of board from weathering.

Buckling

Buckling in thick panel products, such as decking, was found not to be a serious problem. It is far more likely that thickness swelling and linear expansion will cause problems, especially when floor coverings are applied to the upper surface.

REFERENCES

American Society for Testing and Materials. 1969. Method D1037-64, Standard methods for evaluating the properties of wood-base fiber and particle materials. In Part 16—Structural sandwich construction; wood; adhesives.

Barnes, H. M., and D. E. Lyon. 1979. Effect of aging on the mechanical properties of particleboard decking. Wood and Fiber 10(3):164–174.

———, and S. Wang. 1976. Comparison of linear expansion test methods for particleboard. For. Prod. J. 26(8):27–28.

Gatchell, C. J., B. G. Heebink, and F. V. Hefty. 1966. Influence of component variables on properties of particleboard for exterior use. For. Prod. J. 16(4):46–59.

Geimer, R. L., B. G. Heebink, and F. V. Hefty. 1973. Weathering characteristics of particleboard. USDA For. Serv. Res. Paper FPL-212, U.S. Forest Products Laboratory, Madison, WI.

Lehmann, W. F.. 1968. Durability of exterior particleboard. Pages 275–306 *in* T. M. Maloney, ed. Proceedings of Second Washington State University Symposium on Particleboard, Washington State University, Pullman, WA.

———. 1974. Properties of structural particleboards. For. Prod. J. 24(1):19–26.

McNatt, J. D. 1973. Buckling due to linear expansion of hardboard siding. For. Prod. J. 23(1): 37–42.

———. 1974. Properties of particleboards at various humidity conditions. USDA For. Serv. Res. Paper FPL-225. U.S. Forest Products Laboratory, Madison, WI.

NATIONAL PARTICLEBOARD ASSOCIATION. 1971. Quality control manual. National Particleboard Association, Silver Spring, MD.

———. 1972. NPA2-72, Standard for particleboard decking for factory-built housing. National Particleboard Association. Silver Spring, MD.

STEVENS, R. R. 1978. Slicing apparatus aids in determination of layer density of particleboard. For. Prod. J. 28(9):51–52.

SUCHSLAND, O. 1972. Linear hygroscopic expansion of selected commercial particleboards. For. Prod. J. 22(1):28–32.

———. 1973. Hygroscopic thickness swelling and related properties of selected commercial particleboards. For. Prod. J. 23(7):26–30.

U.S. DEPARTMENT OF COMMERCE. 1966. Mat-formed wood particleboard, Commercial Standard CS236-66. U.S. Government Printing Office, Washington, D.C.