

How Durable is Particleboard?

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This valuable and timely report presents the results of tests of the physical and mechanical properties of boards of various densities made with different types of binders and tested after 3 years of exterior exposure.

LITTLE IS KNOWN ABOUT THE long-time durability or resistance of particleboard to varying climatic conditions because of the relatively short time that this material has been manufactured. Studies of the relation of durability to variables in production processes and materials used in the manufacture of these boards are necessary to determine probable limitations on the use of the product. Besides indicating the relative importance of the different variables in the composition of particleboards, these studies also would be helpful in suggesting new work that may be needed to improve the product.

In 1958, therefore, the U.S. Forest Products Laboratory embarked upon a long-term study of particleboard durability. It was recognized that species, size and shape of particles, moisture content of particles, type and amount of binder, density of board, and various forming and bonding conditions, and many other production variables might influence the initial properties as well as the permanent characteristics of particleboard. Because there are so many possible combinations of variables, it was decided to confine the study to particleboards that were made from Douglas-fir flakes and to limit the other variables to density, and type and amount of binder. These variables, however, were so selected as to provide a broad range of board types that fell within the limits of typical commercial particleboard processes.

This study is intended to show the general effect of the variables on the durability of the board after exposure to outdoor weather condi-

Abstract

Protected and unprotected specimens of Douglas-fir flakeboard of various densities and containing different types and amounts of binders were tested after 1, 2, and 3 years of outdoor exposure. Similar specimens were given the ASTM accelerated aging test. Results indicate most deterioration in unprotected specimens occurs the first year, and longer exposure had relatively little effect on properties. Specimens that were painted or contained wax were more durable than similar unprotected specimens. Phenolic-resin binders were more durable than urea or urea-melamine binders. Longer outdoor exposures are needed to determine whether the ASTM test is comparable to exterior exposures.

tions and various laboratory-controlled conditions of temperature and humidity. Painted samples were included to evaluate the possible uses of particleboard for such exterior applications as house siding. This report contains the results after 3 years' exposure on a test fence at Madison, Wis., and the results after the ASTM Accelerated Aging Exposure, D1037-60T. A report on the results of laboratory exposures is planned for later publication.

Preparation of Specimens

Flakes: Douglas-fir flakes that were cut from resoaked, 1/2-inch-thick lumber on the Forest Products

Laboratory flaker² were used to make all boards in the study. The average density of the Douglas-fir lumber at about 12 percent moisture content was 25.5 pounds per cubic foot. The flakes were 1.0 inch long, about 0.015 inch thick, and up to 0.5 inch in width. After cutting, the flakes were dried to about 8 percent moisture content in an air-circulating oven, and then conditioned before fabrication to about 6 percent moisture content in conditions of 80° F. and 30 percent relative humidity.

Board Fabrication: Forty-eight panels, 0.5 by 24 by 28 inches in size, were fabricated – six each of eight different binder and density combinations – as shown in Table 1.

The resin was applied by spraying the desired amount of binder on the flakes while they were being tumbled in a rotating drum blender that was 4 feet in diameter. Spraying was done with a spray gun at pressure of 20 to 25 pounds per square inch. The time required to spray the desired amount of binder varied from 3 to 6 minutes, depending on the amount of binder. After application of the binder, the flakes were mixed for another 2 minutes in the rotating blender. The flakes were removed from the blender and immediately felted into a mat preparatory to pressing.

The flakes were felted by hand into a transparent forming box, which was placed on a 1/4-inch-thick aluminum caul. The uniformity and level of mat buildup during felting were checked by frequent sighting through the box and comparing with index lines scribed on the walls of the forming box at various levels. After felting, the

¹A contributed paper approved for publication August 1962.

²Heebink, B. G., and Hann, R. A. 1959. Stability and strength of oak particleboards. For. Prod. J. IX: 7 236. July.

Table 1. - BINDER AND BONDING VARIABLES EMPLOYED IN FABRICATION, OF VARIOUS PARTICLEBOARDS

Variable No.	Type	Binder ¹ Amount	Spread <i>lb. per 1,000 sq. ft.</i>	Wax ² <i>per-cent</i>	Moisture content ³ <i>per-cent</i>	Closing time ⁴ <i>sec.</i>	Cure temperature <i>°F.</i>	Cure time ⁵ <i>min.</i>	Density ⁶ <i>lb. per cu. ft.</i>
1	Urea	4	0.5		10	45	310	15	34.3
2	do	4	.5		10	55	310	15	42.0
3	do	4	.5	1	10	60	310	15	42.8
4	Urea	2							
	melamine	2	.5		10	45	310	15	33.9
5	Urea	8	1.0		10	45	310	15	35.5
6	Phenolic	3	.38		13	45	350	15	34.1
7	do	3	.38		13	60	350	15	43.4
8	do	6	.76		13	45	350	15	34.8

¹ Percent of binder solids was based on the weight of dry wood. American Cyanamid Calco Yellow B fluorescent dye (0.1 percent), based on the weight of binder solids, was added to the binder solution of urea resin. No dye was added to the phenol-resin binder. Spread values are in pounds of dry binder per 1,000 square feet of flake surface area.

² Percent of wax solids was based on the weight of dry wood. The wax employed was an emulsion type, which was applied by spray after the application of binder.

³ Moisture content of the flakes at press time. This was obtained by adding the required amount of water to the binder solution.

⁴ Closing time is the time between insertion of the panel in the press to closing of the press to 0.5-inch-thick stops.

⁵ Total time in press after closing to stops.

⁶ Density based on the weight and volume at equilibrium at a temperature of 80° F. and 65 percent relative humidity.

forming box was removed, and the mat was covered with another 1/4-inch-thick aluminum caul and placed in the press. The press was closed to 0.5-inch-thick stops in a minute or less by the application of a pressure of 500 pounds per square inch. The rate of press closure was directly related to board density. The presence of wax in the binder increased the press closure time slightly.

The urea resin was applied as a water dispersion. The solids content of the dispersion, depending upon the binder and wax content desired in the board, was adjusted to provide a moisture content of 10 ± 1 percent in the flakes ready for pressing. The urea-bonded panels were pressed at 310° F for 15 minutes. A pressure of 500 pounds per square inch was applied for 4 minutes, followed by 200 pounds per square inch for the remaining 11 minutes. After the top caul once touched the stops, it was in contact with the stops during the entire cycle.

The melamine-fortified urea-resin binder was prepared by dispersing the powdered melamine resin in the liquid urea-resin sirup and adding the required amount of extra water to provide 10 ± 1 percent moisture content in the board at press time. The boards were pressed at 310°

F. for 15 minutes. After 4 minutes in the press, the pressure was reduced from 500 to 200 pounds per square inch. After reaching the stops, the top caul remained in contact with the stops during the entire cycle.

The phenol resin also was applied as a water dispersion, and extra water was added to the dispersion to give a flake moisture content of 13 percent. Twelve grams of water also were sprinkled on each face of the mat before pressing, as recommended by the adhesive supplier. The panels that were bonded with phenol resin were pressed at 350° F. for 15 minutes, removed from the press, wrapped in aluminum foil, and placed overnight in an oven at 160° F.

The 48 panels were conditioned at a temperature of 80° F. and 65 percent relative humidity and then trimmed to 22 by 26 inches. Each panel was then cut into pieces 7-3/16 by 13 inches. This made a total of 288 pieces, or 36 specimen pieces for each of the 8 different compositions of board. The specimens were not sanded.

Methods of Investigation

Exposure Conditions and Times: Sixty-four unpainted specimens, eight pieces for each different board composition, were placed on the

Laboratory's test fence at Madison, Wisc. for study after exposure periods of 1, 2, 3, 4, 6, 8, 10, and 12 years.

Twenty-four painted specimens, three for each different board composition, were placed on the test fence for study after exposure periods of 2, 4, and 8 years.

Thirty-two unpainted specimens, four for each board composition were placed in a room maintained at a temperature of 80° F. and 65 percent relative humidity. Eight of these specimens, one for each board composition, were subjected to the ASTM Accelerated Aging Exposure after 3 years of conditioning. The other 24 specimens will be used for other exposures or tests that may be developed during the course of the study.

The remainder of the specimens from each panel were cut into 2-by-13-inch strips and stored in various laboratory-controlled temperature and humidity conditions for future tests at different time intervals. The results of the laboratory exposures and tests will be presented in a later paper. The strength values used in this report as control values were obtained by testing three of these 2-by-13-inch strips selected at random for each board composition after 1 month conditioning at 80° F. and 65 percent relative humidity.

The 88 specimens for the test fence exposures, 64 unprotected and 24 painted, were selected by taking at least one specimen from each of the six panels for each board composition and from each of the six positions from which the pieces were cut from each panel. The 88 pieces were assigned randomly to the various test periods.

The specimens that were painted were first dipped into a water repellent preservative for 10 seconds after which they were air dried for 3 days. They were then sprayed with one coat of exterior undercoat and 2 days later with one coat of white-gloss house paint. The edges of the specimens then were heavily brush-coated with the same house paint.

The specimens were placed on the test fence racks in a vertical position facing south. They were held in position by bolts placed through holes drilled near the end of each specimen (Figure 1).

Determination of Mechanical Properties

After the specimens were removed from the fence, 3/8 inch was trimmed from their sides; none from the ends. These were then cut into three sections, 2 by 13 inches, for use as flexure test specimens. All specimens were conditioned to approximate constant weight at 80° F. and 65 percent relative humidity before the tests were made and final weight and dimension measurements were taken. ASTM aging specimens were similarly reconditioned and prepared.

The 13-inch length of the flexure specimen was loaded at the center of a 12-inch span, which provided a span-depth ratio of about 24 based on the original thickness of the board. Static-bend tests were conducted in accordance with methods described in ASTM D1037-60T. Load-deflection curves to maximum load were obtained for all bending tests. Modulus of rupture and apparent modulus of elasticity or stiffness were calculated for each specimen.

After flexure tests were completed, 0.5 inch was cut from the end of the three bend specimens and four 2- by 2-inch specimens were cut from the undamaged portions, making a total of 12 specimens from each test fence specimen. Four of these specimens were tested in tension perpendicular to the surface to study deterioration of the bond in the weakest plane. Four specimens were tested in shear parallel to the plane of the board midway between the two surfaces to study changes in the bond quality in the unexposed portion of the board. The remaining four 2- by 2-inch specimens were soaked 24 hours in water to determine the amount of water sorption and thickness swell. They were then reconditioned to 80° F. and 65 percent relative humidity and tested in tension perpendicular to the face. Moisture content determinations were made from the center portion of the static bend specimen. The finish was sanded from the face of the painted specimens before moisture content determinations were made and before internal bond (tension perpendicular) specimens were glued.

Shear specimens were prepared by bonding 1/4-inch plywood to both faces of the 2- by 2-inch blocks with polyvinyl emulsion adhesive and then cutting notches halfway through the specimen from opposite

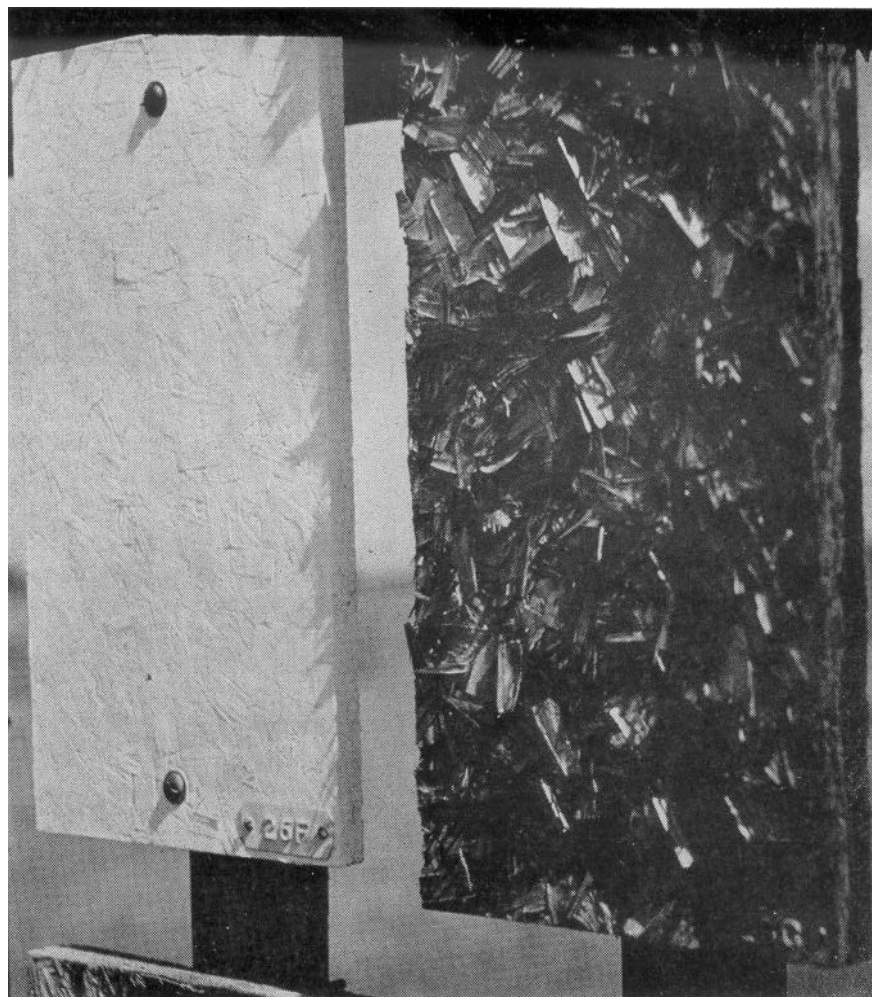


Fig. 1. - Painted and unprotected specimens of a 42-pound-per-cubic-foot density board bonded with 4 percent urea-resin binder and mounted on the Madison test fence. Photograph was taken after 34 months of exposure.

sides, 1/4 inch from each end. This left a shear area in the board of 3 square inches. The specimen preparation and testing procedures are described in ASTM D1037-60T.

The internal bond or tension-perpendicular specimens were prepared by bonding 2- by 2-inch steel blocks to opposite faces of the specimens with polyvinyl emulsion adhesive. The testing procedure is described in ASTM D1037-60T.

Results Obtained

Control Specimens: Table 2 shows the results of various mechanical and physical property determinations on control specimens, which were conditioned to apparent equilibrium at a temperature of 80° F. and 65 percent relative humidity. The conditioning period after specimens were cut was 1 month. The values obtained in these tests indicated the initial quality of the boards and were used as control values in determining the relative durability of the specimens after various exposures.

Fence Exposure Specimens: Unprotected specimens of the eight board variables included in this study were removed from the Madison test fence and tested after exposures of 1, 2, or 3 years. In addition, painted specimens were removed and tested after 2 years' exposure.

Tables 3 and 4 show the mechanical and physical properties of these specimens after exposure as well as the values for the control specimens.

Figures 2 and 3 are representative of the condition of the different board types, both painted and unprotected, when removed from the fence after 3 years' exposure. Figures 4 through 8 are graphs showing how some selected properties of unprotected specimens changed with continued exposure on the test fence.

ASTM Accelerated Aging Exposure Specimens: Table 5 summarizes the results of the ASTM Accelerated Aging Exposure. Figure 9 shows the condition of selected specimens after 3 years on the Madison test

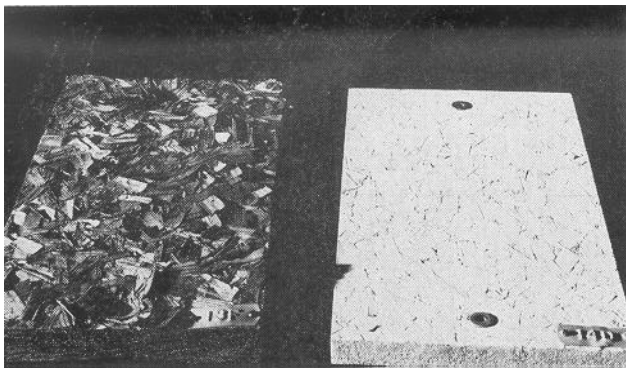


Fig. 2. - Unprotected and pointed specimens of variable number 1 (4 percent urea-resin binder, 34 pounds per cubic foot density) after 3 years of exposure on the test fence.

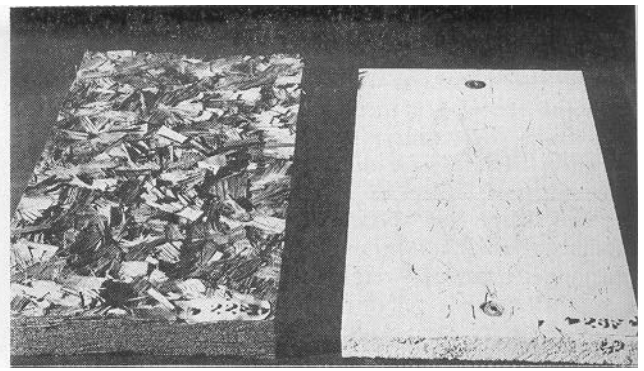


Fig. 2-A - Unprotected and pointed specimens of variable number 2 (4 percent urea-resin binder, 42 pounds per cubic foot density) after 3 years of exposure on the test fence.

fence and after completing one and four cycles of the ASTM Accelerated Aging Exposure.

Discussion

Because this study was designed to explore a broad range of variables and exposures, no replicate specimens were prepared. All specimens for a single exposure time were selected from a single board position. The total variation in board properties may be due to both the effect of time and original position in the board. Only trends, and not specific amounts of deterioration, are considered in this discussion.

Control Specimens: There was no consistent difference in the effects of binders in the control tests, al-

though a direct comparison is not possible because the amount of resin and board density differs among binders. The most notable comparison is between variables 2 and 3, where the addition of 1 percent wax to a 4 percent urea-resin-bonded board decreased the amount of water absorption after a 24-hour soak, as expected (Table 2), and also improved very markedly the internal bond strength of the board. This effect of the addition of 1 percent wax has been reported previously by Talbot and Maloney³ for Douglas-fir bonded with 3 percent of a powdered phenolic resin, but work by Heebink and Hann² on red oak bonded with 8 percent urea res-

in did not show this effect. It may be that a species effect exists or that wax is noticeably beneficial only with low amounts of resin.

Increasing the density from 34 to 43 pounds per cubic foot with the 4 percent urea-resin binder increased the bending strength, shear strength, and internal bond strength but also increased the amount of swelling in water. Bending strength and shear strength would be expected to increase as density increased but, since internal bond strength also increased, it is likely that the greater compaction of the high-density boards either increased the number or improved the quality of the bonds between flakes, or both.

Table 2. - PHYSICAL AND MECHANICAL PROPERTIES OF VARIOUS UNEXPOSED PARTICLEBOARD SPECIMENS CONDITIONED TO EQUILIBRIUM AT A TEMPERATURE OF 80° F. AND 65 PERCENT RELATIVE HUMIDITY

Board variable No.	Variables in board composition				Bending properties ¹		Strength in tension perpendicular to face ²		Water absorption after 24-hour soak	Increase in thickness ²		tension perpendicular to face ²		
	Binder Type	Amount	Spread	Density	Thickness	Modulus of elasticity X 10 ⁻³	Modulus of rupture	perpendicular to face ²		Shear parallel to face ²	After 24-hour soak	After 24-hour and re-conditioning	After 24-hour soak	Loss in strength after 24-hour and re-conditioning
1	Urea	4	0.5	34	.496	493	2,620	27	259	92	20	12	14	48
2	do	4	.5	42	.492	707	4,396	37	391	62	27	17	25	33
3	do Wax	4 1	.5	44	.492	713	4,926	107	465	15	12	7	97	9
4	Urea Melamine	2 2	.5	33	.493	522	2,896	26	292	87	15	8	340	30
5	Urea	8	1.0	37	.497	552	3,456	117	416	70	15	8	103	12
6	Phenolic	3	.4	33	.494	519	2,670	22	108	71	15	7	10	54
7	do	3	.4	40	.490	734	4,150	55	310	68	22	13	30	46
8	do	6	.8	35	.493	615	3,723	51	184	76	14	6	47	8

¹ Values are the averages of 3 specimens.

² Values are the average for 4 specimens.

³ The tension-perpendicular strength values after water soak are higher than the values for the unsoaked control specimens, which indicates that the values for the unsoaked No. 4 variable specimen are too low. The reason for this is not known.

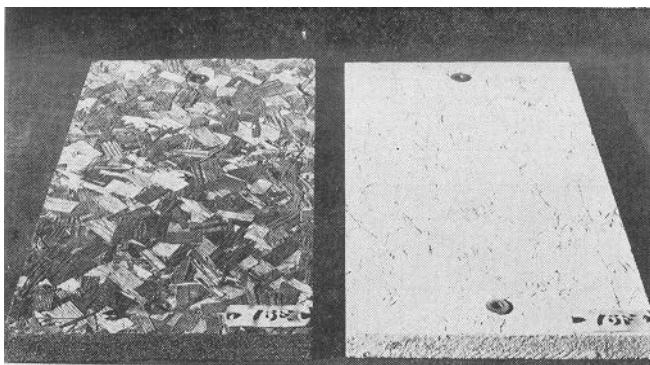


Fig. 3. - Unprotected and painted specimens of variable number 7 (3 percent phenolic-resin binder, 40 pounds per cubic foot density) after 3 years of test fence exposure.

In the 24-hour-water-soak test on unexposed specimens, as shown in Table 2, the amount of thickness swelling and internal bond strength loss was reduced by increasing resin content or by adding wax to the boards. Other studies^{2,3,4} have shown that wax repels liquid water very effectively; this was verified in this work where the addition of wax reduced the water absorption value. From 62 percent in variable 2 to 15 percent in variable 3. However, increasing the resin content from 4 percent in variable 1 to 8 percent in variable 5 did not greatly reduce water sorption.

The melamine resin-fortified urea-resin binder combination was very similar to the straight 4 percent urea-resin binder in original properties.

By increasing resin content from 4 to 8 percent, bending strength, internal bond strength, and shear strength of an urea-bonded board were improved. This result was expected since an increase in resin content will cause an increase in the total bond area.

In boards bonded with phenolic resin, increases in density and resin content (variables 6, 7, and 8) also improved the properties. However, the internal bond and shear strengths of low-density boards bonded with 3 and 6 percent phenolic resin are not as high as would be expected when compared to high-density boards bonded with 3 percent phenolic resin or 4 percent urea resin.

³ Talbot, T. W., and Maloney, T. M. 1957. Effect of several production variables on modulus of rupture and internal bond strength of boards made with green Douglas-fir planer shavings. For. Prod. J. XII: 10 395. Oct.

It is possible that the low density in the phenolic-resin-bonded boards did not require enough compression of the flakes to form good bonds with this resin at such low resin contents.

The amount of springback – the thickness increase remaining after the specimen was water soaked for 24 hours and then reconditioned to 65 percent relative humidity – was about 50 percent of the total swelling after soaking for all variable combinations.

Test Fence Exposure: The most apparent result of the test fence exposure was that all unprotected specimens deteriorated in strength markedly. This strength loss was associated with thickness swelling and occurred primarily during the first year. It is probable that the pressures used to fabricate the particleboards led to compression recovery when the moisture content was increased during exposure. Binders, on the average, would bond highly compressed particles with particles that were less compressed and reduce recovery from compression set. Therefore, high resin contents would be expected to reduce the overall thickness swelling and increase apparent durability, at least during early stages of deterioration. Fabrication variables that improve internal bond strength should therefore reduce the amount of thickness swelling. The results show that the amount of thickness swelling and strength loss on exposure were influenced by the amount of resin and also by the board density.

⁴ Olson, D. E. 1960. Studies to improve the dimensional stability of particleboard. A thesis submitted in partial fulfillment of the requirements for the degree of Master of Sci. (Chem. Engrg.). Univ. of Wis. July.

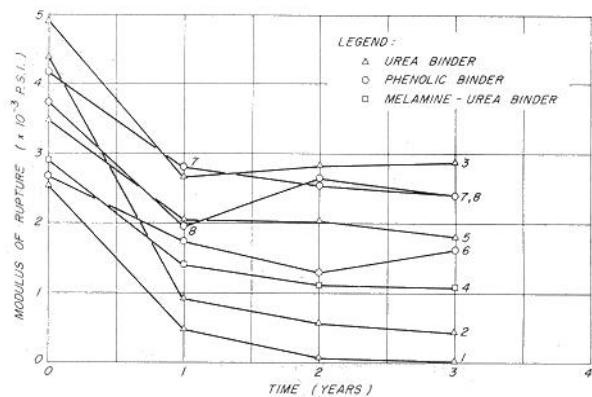


Fig. 4. - The effect of test fence exposure time on the modulus of rupture of unprotected specimens. Code numbers refer to fabrication variables listed in Table 1.

Boards that were bonded with 4 percent urea resin deteriorated rapidly and were essentially useless after 2 years' exposure. With the addition of 1 percent wax or an increase in resin content to 8 percent, the urea-bonded boards became much more weather resistant. The effect of wax was studied by Olson⁴ who showed that wax reduces the capillarity of particleboard and thus retards the movement of liquid water into the board. Wax appeared to have no effect on water-vapor movement. Boards that contain wax will not be easily wet by rain so only the surface of such boards will be exposed to the extreme moisture content changes that may occur in exterior exposure. The board containing wax became very rough on the surface but experienced little thickness swell. Also, as mentioned previously, wax appeared to improve internal bond strength by some unexplained mechanism. Improving internal bond strength should, as discussed above, improve a board's durability.

The increase in durability that resulted from increasing the urea-resin content from 4 to 8 percent may be due to the need for additional resin to resist internal stresses. Because of the variability of the data, after 3 years' exposure, it is impossible to determine if the boards bonded with 8 percent urea resin are still deteriorating or if the rate of deterioration is now almost zero. Since urea-resin adhesives are not normally durable when exposed to exterior conditions, it is likely that some adhesive deterioration is still occurring.

The boards bonded with a 2 percent urea-2 percent melamine-resin binder seemed to be somewhat more durable than similar boards bonded

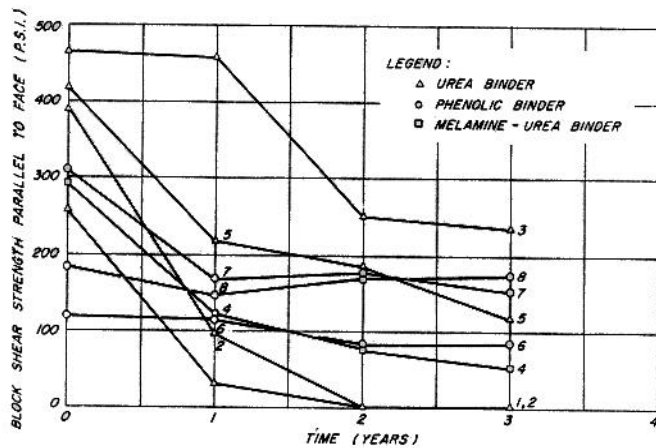


Fig. 5. - The effect of test fence exposure time on the shear strength of unprotected specimens. Code numbers refer to fabrication variables listed in Table 1.

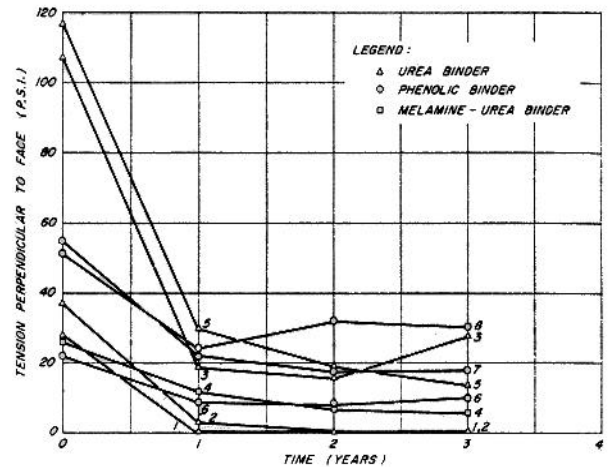


Fig. 6. - Effect of test fence exposure time on the strength in tension perpendicular to the face of unprotected specimens. Code numbers refer to fabrication variables listed in Table 1.

with urea resin only. This is not surprising since wood products bonded with melamine resin are generally more durable than wood products bonded with urea resin.

After the decline in strength during the first year of exposure, the phenolic-bonded boards have shown no apparent increase in deteriora-

tion. Since phenolic resin is known to be very durable when used as an adhesive in other wood products, the loss of strength and associated thickness increase during the first year of exposure is probably due to release of compression of the wood, and, perhaps, some adhesive bond fracture caused by swelling stresses.

The painted specimens of all boards were in very good condition after 3 years of test fence exposure (Figures 2 and 3). This was expected because the thick paint film prevented rainwater from penetrating the boards and also undoubtedly decreased the moisture vapor transmission to and from the boards. In

Table 3. - COMPARISON OF THE FLEXURAL PROPERTIES OF VARIOUS PARTICLEBOARD SPECIMENS AFTER EXPOSURE ON TEST FENCE WITH UNEXPOSED SPECIMENS

Board variable No.	Variables in board composition			Control specimens ¹ p.s.i.	Modulus of rupture Test fence specimens ²			Control specimens ¹ p.s.i. × 10 ⁻³	Modulus of elasticity Test fence specimens ²		
	Binder Type	Amount percent	Density lb. per cu. ft.		After 1 year p.s.i.	After 2 years p.s.i.	After 3 years p.s.i.		After 1 year p.s.i. × 10 ⁻³	After 2 years p.s.i. × 10 ⁻³	After 3 years p.s.i. × 10 ⁻³
Unprotected Specimens											
1	Urea	4	34	2,620	470	90	0	493	83	13	0
2	do	4	42	4,396	900	550	440	707	140	80	59
3	do	4	44	4,926	2,650	2,830	2,860	713	375	411	398
	Wax	1									
4	Urea	2	33	2,896	1,400	1,110	1,090	522	242	214	195
	Melamine	2									
5	Urea	8	37	3,456	2,030	2,040	1,800	552	316	296	277
6	Phenolic	3	33	2,670	1,740	1,300	1,640	519	313	265	304
7	do	3	40	4,150	2,800	2,550	2,370	734	383	368	363
8	do	6	35	3,723	1,950	2,630	2,350	615	339	385	406
Painted Specimens											
1	Urea	4	34	2,620		2,200		493		391	
2	do	4	42	4,396		3,430		707		518	
3	do	4	44	4,926		3,960		713		562	
	Wax	1									
4	Urea	2	33	2,896		3,100		522		479	
	Melamine	2									
5	Urea	8	37	3,456		3,590		552		543	
6	Phenolic	3	33	2,670		2,200		519		420	
7	do	3	40	4,150		4,710		734		674	
8	do	6	35	3,723		2,980		615		488	

¹ Tested after 1 month of conditioning in a room maintained at a temperature of 80° F. and 65 percent relative humidity.

² Before tests were made, all specimens were removed from test fence and reconditioned to approximate constant weight in a room in which temperature was 80° F. and the relative humidity was 65 percent. Properties were calculated on the basis of reconditioned thickness and are the average for 3 specimens.

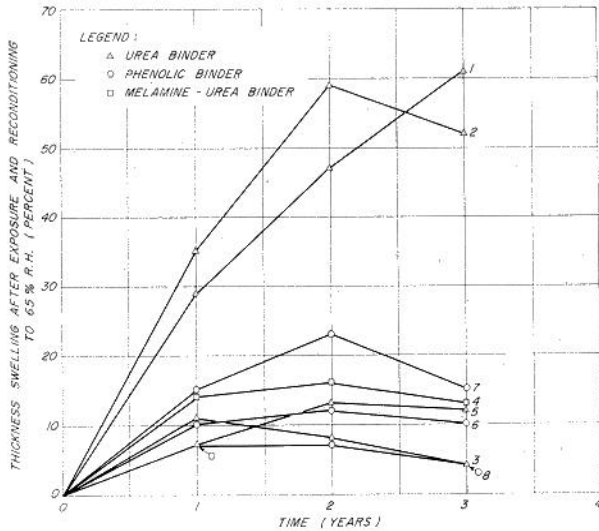


Fig. 7. - The effect of test fence exposure time on the thickness swelling of unprotected specimens. Code numbers refer to fabrication variables listed in Table 1.

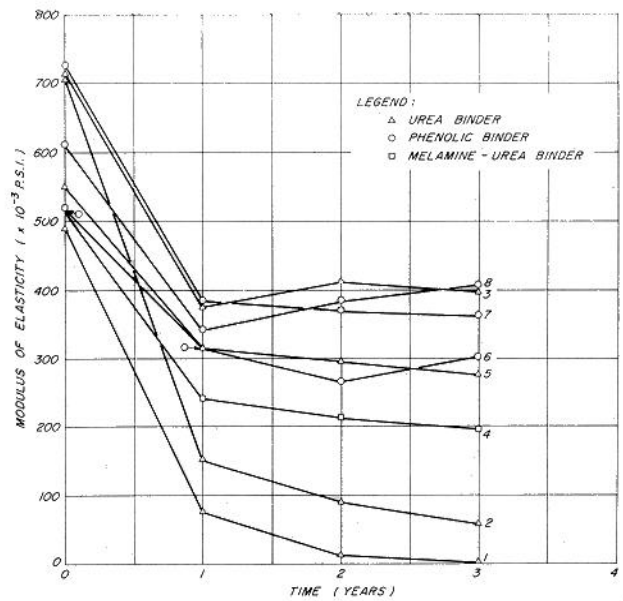


Fig. 8. - Effect of test fence exposure time on the modulus of elasticity of unprotected specimens. Code numbers refer to fabrication variables listed in Table 1.

actual practice, paint coatings must be maintained and all exposed edges must be repainted if a paint film is to be effective. Such coatings, therefore, cannot be relied on in

practice as permanent protection for particleboard.

ASTM Accelerated Aging Exposure: The ASTM Accelerated Aging Exposure is intended to simulate

long-time exterior exposure in a short time. Such short-term exposures are necessary in the evaluation of new products that are intended for exterior uses. The ASTM

Table 4. - COMPARISON OF THE STRENGTH IN SHEAR PARALLEL TO FACE AND IN TENSION PERPENDICULAR TO FACE OF VARIOUS PARTICLEBOARD SPECIMENS AFTER EXPOSURE ON TEST FENCE WITH UNEXPOSED SPECIMENS

Board variable No.	Variables in board composition		Tension perpendicular to face ¹				Shear parallel to face ¹			
	Binder Type	Density lb. per cu. ft.	Control specimens ² p.s.i.	After 1 year p.s.i.	After 2 years p.s.i.	After 3 years p.s.i.	Control specimens ² p.s.i.	After 1 year p.s.i.	After 2 years p.s.i.	After 3 years p.s.i.
Unprotected Specimens										
1	Urea	4	34	27	0	0	259	31	0	0
2	do	4	42	37	3	0	391	97	0	0
3	do	4	44	107	19	16	465	457	250	235
4	Wax	1	44	107	19	16	465	457	250	235
4	Urea Melamine	2	33	26	12	7	292	123	77	52
5	Urea	8	37	117	30	19	416	217	185	119
6	Phenolic	3	33	22	9	8	108	106	82	86
7	do	3	40	55	22	18	310	168	177	153
8	do	6	35	51	24	32	184	147	174	174
Painted Specimens ⁴										
1	Urea	4	34	27		35	259		177	
2	do	4	42	37		48	391		278	
3	do	4	44	107		62	465		313	
4	Wax	1	44	107		62	465		313	
4	Urea Melamine	2	33	26		44	292		270	
5	Urea	8	37	117		136	416		413	
6	Phenolic	3	33	22		16	108		90	
7	do	3	40	55		61	310		301	
8	do	6	35	51		40	184		176	

¹ Values are the average for 4 specimens.

² Tested after 1 month of conditioning in a room maintained at a temperature of 80° F. and 65 percent relative humidity.

³ All specimens were removed from the test fence and reconditioned to approximate constant weight in a room maintained at a temperature of 80° F. and a relative humidity of 65 percent before tests were made.

⁴ The paint was sanded from the face of the specimens before tests were made.

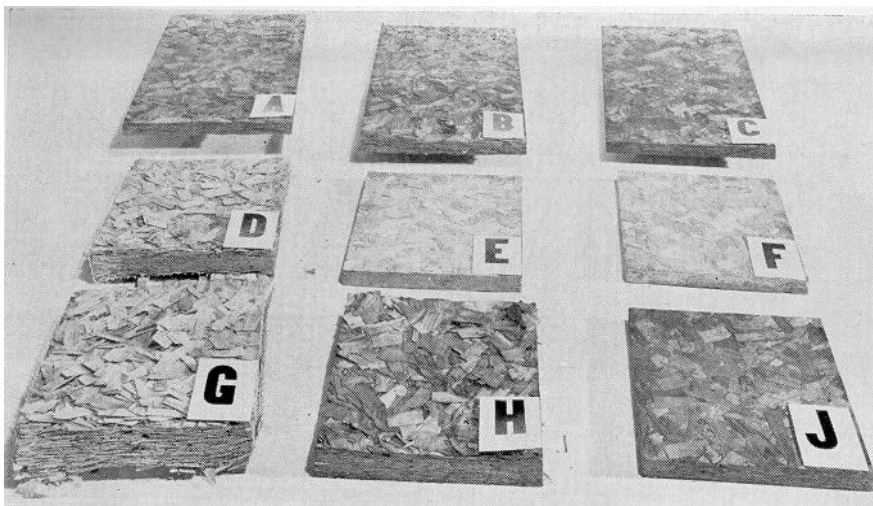


Fig. 9. - Unprotected specimens of selected variables after exposures of 3 years on the test fence and after one and four ASTM accelerated aging cycles. Specimens A, D, and G represent boards bonded with 8 percent urea resin; specimens 6, E, and H represent boards bonded with a combination of 2 percent urea and 2 percent melamine resins; and C, F, and J represent boards bonded with 6 percent phenolic resin. Specimens A, B, and C were exposed for 3 years on the fence. Specimens D, E, and F were exposed to one cycle, and specimens G, H, and J were exposed to four cycles of the ASTM Accelerated Aging Exposure. All specimens were photographed after reconditioning at 80° F. and 65 percent relative humidity.

Exposure has been used for evaluating wood-base fiberboards for several years. Products that have retained over 50 percent of their original strength after the six cycles of the exposure have tentatively been considered as satisfactory for exterior service. It is possible, however, that the ASTM Accelerated Aging Exposure may be unrealistically severe on some types of products because of the steaming and drying at temperatures around 200° F.

When the results of the ASTM Exposure were compared with the

results after 3 years' test fence exposure, the ASTM Exposure was obviously more severe than 3 years' test fence exposure on boards bonded with urea and urea-melamine adhesives. However, the ASTM exposure on phenolic-bonded boards had about the same effect as 3 years' test fence exposure. If the ASTM Accelerated Aging Exposure can be assumed to approximate long-term exterior exposure, these phenolic-resin-bonded particleboards should remain suitable in long-term exterior use, and little additional thick-

ness swelling and strength loss should occur in specimens during the remainder of this study. By the same logic, urea-resin-bonded particleboards that are still good after 3 years' exposure should lose much strength during the remainder of the study. It is possible that the ASTM Accelerated Aging Exposure however, is a good indicator of the durability of particleboards bonded with phenolic resin, but it may not accurately indicate the durability of such products bonded with urea resin. The question of the ability of the Accelerated Aging Exposure to predict the long-term durability of particleboard cannot be answered adequately until results of longer weather exposure periods are available.

Summary

Binder variables have a major influence on the exterior durability of unprotected particleboard as indicated by strength retention after test fence exposure. Phenolic-resin binders appeared generally more durable than urea-melamine or urea resins after 3 years' exposure on the test fence, but the performance of one series of urea-resin-bonded boards containing 8 percent resin approached the performance of the phenolic-bonded boards. The addition of 1 percent paraffin wax to a 4 percent urea-resin-bonded board greatly improved both the durability and the original properties.

When the density was increased from about 34 pounds per cubic foot to about 43 pounds per cubic foot; both the original strength properties and durability were improved. The high density was probably closer to optimum than the low density for boards of this species and particle type.

All painted specimens after 3 years' exposure appeared to be in very good condition.

The ASTM Accelerated Aging Exposure caused complete failure of all urea-resin and urea-melamine-resin-bonded boards, but phenolic-resin-bonded boards remained physically intact throughout the entire exposure. Boards with 6 percent binder retained over 50 percent of their original strength in all three tests. It is not known, however, how well the ASTM Accelerated Aging Exposure simulates the effect of exterior exposure for periods longer than 3 years on particleboard bonded with different resins, and the exposures are being continued indefinitely so this question can be studied further.

Table 5. - STRENGTH PROPERTIES OF VARIOUS PARTICLEBOARD SPECIMENS AFTER ASTM ACCELERATED AGING EXPOSURE¹

Board variable No.	Variables in board composition Binder Amount Type		Strength properties ²						
			Modulus of rupture lb. per sq. in.	Tension perpendicular to face			Modulus perpendicular to face		
				lb. per sq. in.	lb. per sq. in.	per cent	lb. per sq. in.	per cent	per cent
1	Urea	4	34	0	0	0	0	0	0
2	do	4	42	0	0	0	0	0	0
3	Urea wax	4	43	0	0	0	0	0	0
4	Urea melamine	2	34	0	0	0	0	0	0
5	Urea	8	35	0	0	0	0	0	0
6	Phenolic	3	34	1,230	231,000	1	46	45	5
7	do	3	43	2,680	430,000	1	65	59	2
8	do	6	35	2,510	381,000	31	68	62	61

¹ Specimens from board variable Nos. 1, 2, 3, and 5 disintegrated after 1 cycle, while specimens from board variable No. 4 disintegrated after 4 cycles. Specimens were considered to be disintegrated when they could no longer be lifted by holding opposite corners.

² Flexural values are the average of three specimens and tension perpendicular to the face values are the average of four specimens.