MANUFACTURE AND PERFORMANCE OF FULL-SIZE STRUCTURAL FLAKEBOARDS FROM DOUGLAS-FIR FOREST RESIDUES

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Abstract

The Forest Products Laboratory manufactured and assessed the performance of 4- by 8-foot structural flakeboard panels from Douglas-fir forest residues after target performance goals were developed. The 42 pcf, three-layer boards were 1/2 inch thick with high quality disk cut flakes for the faces and lower quality flakes processed through a ring flaker in the core. More than 200 panels were produced. Basic mechanical and physical properties were evaluated, as well as durability and performance under concentrated and impact loading, racking strength of wall and floor sections, and fire exposures. Bending strength and stiffness were both below the target goals. Most other goals were met; including those for shear and nailholding properties, internal bond, and hardness. Panels used as wall sheathing exceeded specified acceptance standards for full-size walls. Under concentrated load, panels met maximum load and deflection recommendations of the Uniform Building Code for roofs and floors. Under fire exposure, the panels had a class B flame spread rating and exceeded the fire endurance requirement for exterior walls of one- and two-family dwellings.

Introduction

Forest residues which have been, at times, estimated to amount to 9.6 billion cubic feet annually, can be grouped into three primary categories: timber damaged by insects, disease and fire; logging residues: and precommercial thinning. Logging residues alone offer more than three times the volume of raw material used annually in the plywood industry (7).

To improve the utilization of these residues, the U.S. Forest Service set up a national research program to develop a structural flakeboard that could be manufactured from this presently unused material (8).

The-goals of the research at the Forest Products Laboratory (FPL) were to provide the technology and procedures that would enable industry to produce a panel product made primarily from softwood logging residues that would be fully adequate as an exterior-grade construction material. This paper is a summary of the following reports prepared as part of the Forest Service National Structural Flakeboard Program.

1. Manufacture of full-size structural flakeboards - William F. Lehmann.
2. Small specimen properties of full-size structural flakeboards from Douglas-fir forest residues - Matti J. Hyvarinen and Michael J. Superfesky.
3. Dimensional stability of FPL structural flakeboard - William F. Lehmann.
4. Concentrated and impact load testing of FPL's structural flakeboard - J. Dobbin McNatt and Michael J. Superfesky.
5. Racking strength of panels sheathed with Forest Service structural flakeboard - William J. McCutcheon.
6. Fire performance of structural flakeboard from forest residues - Carlton A. Holmes, Herbert W. Eichner, John J. Brenden, and Robert H. White.

Manufacture of Full-Size Panels

The raw materials used were primarily Douglas-fir forest residues gathered from logging operations on the western slopes of the Cascade Mountains in Washington State and shipped to the Forest Products Laboratory, Madison, Wisconsin. These were primarily broken logs of diameters varying from about 5 to 24 inches and containing variable amounts of decay.

The materials were segregated for conversion into flakes such that they contained approximately 75 percent sound wood larger than 6 inch diameter, 12-1/2 percent wood with decay, 6-1/4 percent sound wood less than 6 inches in diameter, and 6-1/4 percent bark. The overall flakeboard manufacturing process is outlined in Figure 1.

The better residues were selected for face flake material and debarked. Face flake material was then cut into billets 2 inches along the grain and 1 inch in width. These billets then were flaked in the laboratory disk f`laker.

The remaining residues were cut into 12 to 13 inch lengths. These lengths were fed into a drum chipper constructed to produce chips of 1/4 to 318 inch thickness and 2 to 2-1/2 inches in length. The large chips were further processed

[1]Symposium paper prepared from six reports listed in the Introduction.

through a ring flaker. The following factors remained constant during manufacture:

Raw material--Douglas-fir forest residues
Panel size--0.5 x 50 x 108 in.
Panel density--43 pcf (target), based on oven dry weight and nominal volume
Face flakes--0.02 x 1 x 2 in. disk flakes
Core flakes--0.05 x 2 x random width ring flakes
Face: core flake ratio--30:70% by weight of flakes
Resin binder and amount--liquid phenolic resin, 5% resin solids based on ovendry weight of flakes
Wax type and amount--wax emulsion, 1% wax solids based on ovendry weight of flakes
Mat moisture content--10 ± 1%
Press cycle--10 min at 305°F, press closed to stops in 1 min
Trimmed panel size--48 x 96 in.

Phenolic resin and wax were blended together and applied to the flakes by air spray at 3 to 4 oz/min/spray gun at 40 psi atomizing air pressure.

Immediately following blending, the flakes were formed into the three-layered, 50- by 108-inch mats using a simple mechanical forming device. Because of the press size, 4 by 20 feet, two mats were required for each press load. The formed mats were placed end-to-end and loaded into the 54- by 250-inch, steam-heated, 3,000-ton-capacity hot-press. The press was immediately closed and the pressure cycle shown in Figure 2 was followed. Press temperature was 350°F. The pressure-time step sequence shown was used to approximate as closely as possible the press cycle normally used with small-size laboratory panels. The short delay at the beginning allowed the surface flakes to heat prior to the rapid application of high pressure. This then provided a high density surface to promote high stiffness. The step pressure decreases used after reaching the desired thickness provided a means of maintaining thickness while reducing the transfer of pressure to the stop bars.

In total, 216 panels were produced in this study, of which the final 151 panels were randomly assigned to the various strength, fire, stability, and durability tests. The initial 65 panels were produced to develop the procedural sequences needed to manufacture efficiently a consistent and high-quality panel product.

Basic Engineering Properties From Small Specimen Tests

Specimen Preparation and Testing

Basic engineering properties of the full-size Douglas-fir structural flakeboards were determined using small-specimen tests to compare their quality with target performance goals established early in the Forest Service Structural Flakeboard program. Properties evaluated included bending, tension, compression, internal bond, shear, nail holding, hardness and impact. Tests were conducted on specimens conditioned to EMC at 65 percent RH. some tests were also conducted after 24-hour water-soak and after accelerated aging. Overall density and density gradient were also determined. Tests were performed according to applicable ASTM Standards (2,3). Sixty-five of the final 151 panels were randomly selected for small specimen tests and the small specimens were cut both parallel to and perpendicular to the panel length from randomly selected areas of each of the 65 panels.

Results

The static bending and nail-holding properties are summarized in Tables 1 and 2; the hardness, impact resistance (falling ball tests), internal bond strength, strength in tension and compression parallel to surfaces, and shear in Table 3.

Equilibrium moisture content at 65 percent relative humidity averaged 8.0 percent, and density averaged 41.6 pcf as determined from static bending specimens. Density gradient through the panel thickness is shown in Figure 3, as determined from selected specimens.

Both modulus of rupture (MOR) and modulus of elasticity (MOE) in bending indicated that the Forest Service structural flakeboard had some directional properties despite the random flake orientation. Averages along and across the forming direction were 4,700 and 4,260 psi in MOR and 714,000 and 673,000 psi in MOE, respectively.

Forest Service Flakeboard and Target Values

The target values (Table 4) were met or exceeded for modulus of rupture after aging (the actual value was 84 percent of the dry value vs. the target value of at least 50 percent), lateral nail-holding dry (503 vs. 300 pounds) and wet (332 vs. 150 pounds), nail-head pull-through (460 vs. 250 pounds), near minimum[2] Janka ball hardness (765 vs. 500 pounds), internal bond strength dry (111 vs. 70 psi), edgewise shear strength (1,630 vs. 1,000 psi), interlaminar shear strength (395 vs. 250 psi), direct nail withdrawal resistance dry (73 VS. 40 pounds) and wet (58 vs. 25 pounds).

However, the target values were not met for the density range, from near minimum to near maximud (36.9 to 46.2 pcf actual vs. 37.0 to 43.0 target), near minimum modulus of rupture in static bending (3,030 vs. 4,500 psi), modulus of elasticity in static bending (693,000 vs. 800,000 psi), near maximum Janka ball hardness (1,481 vs. 1,200 pounds), and internal bond strength after aging (43 vs. 50 percent).

Cyclic Humidity Exposure

Specimen Preparation

Randomly-selected 2- by 4-foot sections of 65 full-size panels were each cut into twelve

[2] 5 percent laver exclusion limit.

[3] 5 percent upper exclusion limit

3- by 12-inch specimens for determination of dimensional stability and strength retention after cyclic moisture exposure.

The 780 3 by 12 inch specimens were randomly assigned to three groups of 260 specimens with the restriction that each group received an equal number of specimens from each panel and each major panel dimension.

The three groups of 260 specimens then were subjected to the following exposures and determinations of dimensional stability (water absorption (WA), thickness swelling (TS), and linear expansion (LE)) and related properties:

1. Ovendry exposure. 260 specimens were oven-dried at 216 ± 4°F and weighed and measured.
2. Relative humidity (RH) exposure. 30 to 50 to 90 percent RH followed by 12 cycles of 30 to 90 percent RH. Specimens were placed in conditioning rooms at 80°F and appropriate humidity and maintained for 30 days during each step of the initial 30 to 50 to 90 percent RH exposure. Succeeding cycles of 90 to 30 to 90 percent RH were in 21-day increments at each step of the cycle. Specimens were weighed and measured at cycles 1, 3, 6, and 12; then 65 specimens representing both major panel dimensions were removed, dried at 120°F for 3 days and tested without further conditioning for retention of bending stiffness, strength and internal bond strength. Testing procedures conformed to ASTM D 1037-72a4 and bending property calculations were based on initial specimen thickness.

3a. Watersoak exposures. 24-hour watersoak (WS) in 70°F water followed by 24 cycles of 1-hour soaking in 150°F water and 22 hours of drying at 160°F. Specimens were weighed and measured at cycles 1, 3, 6, 12, and 24; after each cyclic series 26 specimens were removed, dried for 3 days at 120°F and tested without further conditioning for retention of strength All watersoak tests were performed with specimens in a horizontal position under 1 inch of water.

3b. Ovendry-vacuum-pressure-soak exposures. 24 hour WS in 70°F water followed by 24 cycles consisting of 30 minutes submerged in 70°F water under a vacuum of 26 inches of Hg, 60 minutes at 50 psi pressure and 22 hours drying at 160°F. Specimens were weighed and measured at cycles 1, 3, 6, 12, and 24; after each cyclic series 26 specimens were removed, dried for 3 days at 120°F and tested without further conditioning for retention of strength.

Results

Results of these evaluations are illustrated graphically in Figures 4 to 9 and indicate that structural flakeboards as prepared in this study can undergo prolonged and reasonable exposures to cyclic wet and dry conditions with minimal loss of strength and bond integrity and with reasonable changes in dimensions. If exposures are limited to cyclic humidity conditions, there appears to be little, if any, loss in up to 12 cycles of exposure, indicating good product durability in long-term exposures to either liquid or water vapor.

Concentrated and Impact Load Testing

Specimen Preparation

Concentrated load tests were conducted on 65 randomly-selected 2 by 4 foot panels; 55 were tested "dry" after conditioning at 65 percent relative humidity, and 10 were tested "wet" after soaking in water for 24 hours. Tests were also conducted on 20 randomly-selected 4 by 4 foot panels nailed to joists after conditioning at 65 percent RH. The 2 by 4 foot panels were simply supported along the 4-foot-long sides by 4-inch-diameter steel pipes spaced 16 inches on center and resting on glued-laminated beams. A concentrated load was applied at the center of each panel, first by a 4-inch-diameter disk up to a maximum of 300 pounds; and then by a 1-inch-diameter rod up to failure. Deflection was measured relative to the supports, under the load point by a LVDT. The 4 by 4 foot flakeboard panels were nailed to 2 by 4 inch joists spaced 16 inches on center using 8-penny common nails spaced 6 inches apart. The 2 by 4 joists rested on glued-laminated beams. The concentrated load was applied to the center of one of the end spans, first by a 3-inch-diameter disk up to a maximum of 300 pounds; and then by a 1-inch-diameter rod up to failure.

For all concentrated load tests, load deflection ratios were calculated from the slope of the initial portion of the load deflection curves. Also recorded was the load at failure when loading with the 1-inch-diameter rod.

Impact load tests were conducted on 20 randomly selected 2 by 4 foot panels, 10 each "wet" and "dry" as defined above. Impact tests were also conducted on the other end span of the 20 "dry" 4 by 4 foot panels subjected to concentrated loads. An additional 5 "wet" 4 by 4 foot panels were tested. The 60-pound leather sandbag described in ASTM E 72 (5) was used in all impact tests. The 2 by 4 foot panels were simply supported along the 4-foot-long edges on the rounded tip edge of 2 by 8 inch members spaced 16 inches on center. The supports were bolted to glued-laminated girders to hold them in position during impact. The sandbag was dropped on the center of the panel.

The 4 by 4 foot panels nailed to 2 by 4 inch joists also were bolted to the glued-laminated beams to hold the panel in position during impact. The sandbag was dropped on the center of the end span of the "dry" panels not subjected to concentrated load testing and on the center of each of the two end spans of the "wet" panels.

The procedure for dropping the sandbag and measuring deflectian was the same for both size panels. The bag was initially dropped from a height of 6 inches, and the height was successively increased in increments of 6 inches until failure occurred. Failure was considered to have occurred when the residual deflection exceeded 1/8 inch. After initial impact on each drop the sandbag was restrained with a rope and pulley to prevent additional impacts from the same drop. Prior to each test the sandbag was rolled on the floor to loosen the sand since packing of the sand would change the energy absorption behavior of the bag.

Deflection of the panel during impact and residual deflection after each impact was measured by an LVDT attached to the underside of the panel directly under the load point by means of a ball and socket arrangement. Time-deflection data were recorded and stored in a digital storage oscilloscope. Time deflection curves for each drop were drawn by means of a digital-to-analog converter whereby the oscilloscope memory was played back to an X-Y recorder at a slower sweep rate. Peak dynamic deflection, time to peak deflection, and residual deflection were read off the oscilloscope.

Results

Results of concentrated and impact load tests are given in Tables 5 and 6 and can be summarized as follows:

Concentrated Load

1. Load-deflection ratios were increased by increasing the area under load from 1 inch in diameter to 4 inches in diameter.
2. Load-deflection ratios decreased when the flakeboard panels were soaked in water for 24 hours. However, load at failure changed little
3. Load-deflection ratios were about the same for the 2 by 4 foot simply-supported panels and the 4 by 4 foot panels nailed to joists when the 4-inch-diameter loading disk was used. However, the ratios were somewhat larger for the 4-foot-square panels than for the smaller panels when the 1-inch-diameter rod was used.
4. Performance of the panels exceeded the maximum load and allowable deflection values recommended by the Uniform Building Code for floor and roof sheathing (9).

Impact Load

1. Neither height of drop at failure or time to maximum deflection were affected by soaking the panels in water for 24 hours.
2. Height of drop at failure was greater and time to maximum deflection was less for the 4 by 4 foot panels nailed to joists 16 inches on center than for the 2 by 4 foot panels simply-supported over a 16-inch span.
3. The sand bag produced a flexure failure along the length of the 2 by 4 foot panels, but produced a puncture failure in the 4 by 4 foot panels.

Racking Strength of Walls

Seven full-size 8 by 8 foot walls were sheathed with FPL structural flakeboard and tested in racking according to ASTME 72 (5). Four were tested dry and three were tested after being subjected to wetting cycles specified in ASTM E72. Dry racking strength averaged just over 6,200 pounds and wet strength averaged just under 5,900 pounds. Both these values are well above the generally accepted standards of 5,200 pounds dry and 4,000 pounds wet (6).

Fire Performance

Flame spread properties of the FPL structural flakeboard were determined by the 25-foot tunnel furnace test of ASTM E 84-70 (1).

The flame spread clsssification (FSC) values obtained in the two tests with the FPL structural flakeboard in the 25-foot rating furnace were 70 and 72 with an average of 71. This meets the acceptance flame spread criteria under building codes for class B material--75 or under flame spread. This classification will permit its use in many building occupancies, and applications where flame spread of building materials is limited; for example, in exitways and corridors.

The FPL flakeboard was also tested in load-bearing wood-frame walls for fire endurance in the Forest Products Laboratory large vertical furnace. Two tests were conducted according to ASTM Standard E 119-73 (1) except the panel height was limited to 8 feet and the applied load was 1,250 pounds per linear foot (the computed maximum loading for the first floor wall of a two-story house of average size). This was 27 percent higher than design load based on allowable compression perpendicular to grain stress at the plate and only 2 percent less than design load based on allowable compression parallel-to-grain stress in the studs. For one wall the interior facing was 3/8-inch gypsum wallboard panels which were vertically applied to the frame with 1-inch-long, fourpenny gypsum wallboard nails, spaced 8 inches on center. All joints were taped and covered with joint compound and nailheads were indented and covered with joint compound. One coat of latex paint was applied. For the second wall, the interior facing was the 1/2-inch-thick flakeboard panels vertically attached to the framing with sixpenny nails spaced 8 inches on center at edges and 12 inches at intermediate locations.

For the wall with gypsum wallboard interior facing, burnthrough occurred after 33 minutes, 20 seconds. The wall with flakeboard interior facing burned through after 31 minutes, 35 seconds. Both are in excess of the 20 minutes required for exterior walls in the Minimum Property Standards for Single- and Double-Family Dwellings of the Department of Housing and Urban Development (10). Details on these and other fire performance tests conducted on the FPL flakeboard are given in paper No. 6 listed in the introduction.

Summary

The Forest Products Laboratory produced more than 200 full-size (4- by 8-foot) three-layer structural flakeboards from Douglas-fir forest residues and evaluated their potential as an exterior-grade construction material. Results of tests were compared with target goals for certain basic properties which had been developed earlier. Target goals were not met for some basic properties (bending strength and stiffness and retention of internal bond strength after accelerated aging, for instance), but were surpassed for other properties (nailholding, shear, hardness).

The following results from performance-type testing help indicate that the panels would be acceptable as an exterior sheathing product:

1. Under concentrated load, the panels surpassed the maximum load and allowable deflection values recommended by the Uniform Building Code for floor and roof sheathing.

2. Racking strength of full-size wall sheathed with the panels exceeded the accepted FHA standard.

3. Under fire exposure, panels met the acceptance flame spread criteria under building codes for class B material. Fire endurance for load-bearing walls sheathed with the panels exceeded the 20 minutes required for exterior walls in the HUD minimum Property Standards for Single- and Double-Family Dwellings (10).

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Table 1.—STATIC BENDING PROPERTIES FOREST SERVICE STRUCTURAL FLAKEBOARD

Property	Mean	Standard Deviation	Minimum	Maximum	Coefficient of Variation	Sample Size
					%	
Original thickness, in.						
Specimens for dry series[1]	0.514	0.016	0.469	0.563	3	390
Original density, pcf						
Specimens for dry series	41.6	2.81	33.8	51.2	7	390
Moisture content, pct						
Dry (65% RH)	8.0	.7	6.0	9.6	9	390
Wet (24 hr soak)	25.5	4.0	16.1	42.5	16	130
Aged (65% RH)	9.6	.3	8.9	11.1	3	130
Modulus of rupture, psi						
Dry ‖[2]	4,700	942	2,360	7,180	20	195
⊥[3]	4,260	759	2,650	6,310	18	195
All	4,480	881	2,360	7,180	20	390
Wet ‖	3,620	785	2,060	6,490	22	65
⊥	3,300	637	1,930	5,100	19	65
All	3,460	730	1,930	6,490	21	130
Aged ‖	3,860	686	1,670	5,070	18	65
⊥	3,540	691	2,250	5,460	20	65
All	3,700	705	1,670	5,460	19	130
Modulus of elasticity, thousand psi						
Dry ‖	714	117	404	1,057	16	195
⊥	673	96	445	972	14	195
All	693	109	404	1,057	16	390
Wet ‖	548	105	378	976	19	65
⊥	493	93	326	788	19	65
All	521	102	326	976	20	130
Aged ‖	676	87	386	827	13	65
⊥	614	91	440	858	15	65
All	645	94	386	858	15	130

1 Dry specimens: Conditioned to EMC at 73° F, 65% RH.

2 ‖ Specimen length parallel to 8-ft dimension of panel.

3 ⊥ Specimen length parallel to 4-ft dimension of panel.

Table 2.—NAIL-HOLDING PROPERTIES[1]

Property and Condition	Mean	Standard Deviation	Coefficient of Variation	Minimum Value	Maximum Value
	Lb	Lb	%	Lb	Lb
Lateral nail resistance [2]					
Dry[3]	503	82	16	209	710
Wet[4]	332	77	23	190	615
Aged[5]	381	88	23	195	650
Nail-head pull-through					
Dry	460	88	19	280	790
Wet	410	88	21	225	640
Aged	374	94	25	188	688
Direct nail withdrawal					
Dry	73	19	26	35	124
Wet	58	19	33	12	128

1 Sixpenny common wire nail used. All values are averages of 130 specimens.
2 1/2-in. edge distance used.
3 Dry: Conditioned to EMC at 73° F and 65% RH.
4 Wet: Soaked in water 24 hr and tested wet.
5 Aged: Subjected to 6 cycles of accelerated aging.

Table 3.--HARDNESS, IMPACT RESISTANCE, INTERNAL BOND STRENGTH, STRENGTH IN TENSION AND COMPRESSION PARALLEL TO SURFACE, SHEAR PROPERTIES AND SAG MODULUS OF ELASTICITY OF FOREST SERVICE STRUCTURAL FLAKEBOARD

Property	Mean	Standard Deviation	Minimum	Maximum	Coefficient of Variation	Sample Size
					%	
Janka ball hardness, lb	1,122	215	680	1,640	19	65
Falling ball impact, failure height, in.	65	6.5	48	74+	10	65
Internal bond strength, psi						
Dry	111	28	59	176	25	130
Aged	49	20	10	106	41	130
Tension parallel to surface, Modulus of elasticity, thousand psi[1]						
∥	615	178	126	999	29	111
⊥	539	175	70	980	32	115
All	577	180	70	999	31	226
Tension strength, psi[1]						
∥	2,024	396	1,260	3,290	20	129
⊥	1,723	309	1,090	2,630	18	130
All	1,873	385	1,090	3,290	21	259
Compression parallel to surface Modulus of elasticity, thousand psi						
∥	603	114	333	885	19	130
⊥	455	89	290	702	20	130
All	529	126	290	885	24	260
Compressive strength						
∥	2,690	459	1,620	4,040	17	130
⊥	2,270	377	1,450	3,340	17	130
All	2,480	469	1,450	4,040	19	260
Shear properties						
Edgewise shear strength, psi	1,630	251	1,210	2,390	15	65
Interlaminar shear strength, psi	395	73	244	641	18	65
Interlaminar shear modulus, thousand psi	44	7	31	68	16	65
Plate shear modulus, thousand psi	287	30	226	362	10	65

[1] 19 ∥ and 15 ⊥ MOE values omitted from average due to malfunction of deformation gage. One tensile strength value omitted because specimen failed in grips.

Table 4.--ACTUAL AND TARGET GOALS FOR PROPERTIES OF DOUGLAS-FIR STRUCTURAL FLAKEBOARDS

Property	Target	Actual
Density, pcf		
Near minimum[1]	37	36.9
Near maximum[2]	43	46.2
Modulus of rupture, psi		
Near minimum[1]		
Dry (65 % RH)	4,500	3,030
After accelerated aging[3]	2,250	2,530
Modulus of elasticity, psi		
Mean	800,000	693,000
Hardness[4], lb		
Near minimum[1]	500	765
Near maximum[2]	1,200	1,480
Internal bond		
Mean		
Dry, psi	70	113
After accelerated aging[3], % dry	50	43
Edgewise shear strength, psi		
Mean (dry)	1,000	1,630
Interlaminar shear strength, psi	250	
Mean (dry)		395
Lateral nail resistance[5],[6], lb		
Mean		
Dry	300	503
After accelerated aging[3]	100	332
Nailhead pullthrough[5]		
Mean		
Dry	250	460
After accelerated aging	125	374
Direct nail withdrawal[5]		
Mean		
Dry	40	73
After 24-h soaking	25	58
After accelerated aging	20	--

1 5% lower exclusion limit.
2 5% upper exclusion limit.
3 ASTM D1037-72a, Sec. 118-122. (2)
4 Janka Ball.
5 6-penny common wire nail.
6 1/2-in. edge distance.

Table 5.—CONCENTRATED LOAD BEHAVIOR OF FPL STRUCTURAL FLAKEBOARD

Panel Type	Number	Panel Density[1]	Load-Deflection Ratio: 4-inch dia. disk[2]	Load-Deflection Ratio: 1-inch dia. rod.	Load at Failure: 1-inch dia. rod.
		Pcf	Lb/in.	Lb/in.	Lb.
2 x 4 foot, dry[3]	44				
Average		44.8	2,693	2,168	789
Range		38.5–50.1	2,083–3,333	1,705–2,752	520–975
2 x 4 foot, wet[4]	10				
Average		44.6	2,084	1,712	781
		40.6–47.1	1,648–2,381	1,339–1,935	645–935
4 x 4 foot, dry[3]	20				
Average		44.3	2,621	2,387	826
Range		41.6–46.3	2,069–3,030	1,863–2,703	665–960

[1] Density is based on weight and dimensions at 65% RH.

[2] 3-in.-diameter disk for 4- by 4-ft. panels.

[3] "Dry" panels were as conditioned to EMC at 65% RH.

[4] "Wet" panels were soaked in water for 24 hr.

Table 6.—RESULTS OF IMPACT LOAD TESTING OF FPL STRUCTURAL FLAKEBOARD

Panel Type	Number	Panel Density[1]	Height of Drop at Failure	Time to Maxium Deflection
		Pcf	In.	Ms
2 x 4 foot, dry[2]	10			
Average		44.8	27	18
Range		38.6–48.5	24–30	16–20
2 x 4 foot, wet[3]	10			
Average		44.8	29	18
Range		40.4–49.0	24–36	16–20
4 x 4 foot, dry[2]	20			
Average		44.3	36	14
Range		41.6–46.3	30–42	13–16
4 x 4 foot, wet[3]	10[4]			
Average		45.1	38	15
Range		43.0–47.2	30–42	14–16

[1] Density is based on weight and dimensions at 65% RH.

[2] "Dry" specimens were conditioned at 65% RH.

[3] "Wet" specimens were soaked under 1 in of water for 24 hr.

[4] Two tests on each of five panels.

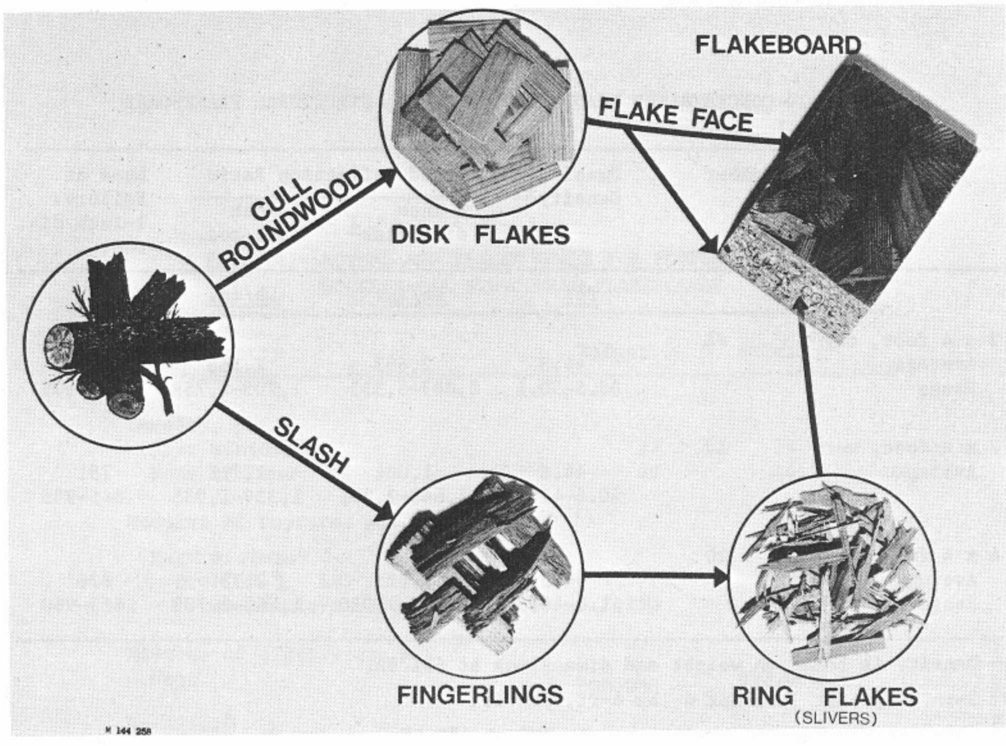

Figure 1.--The forest residues-to-structural flakeboard process.

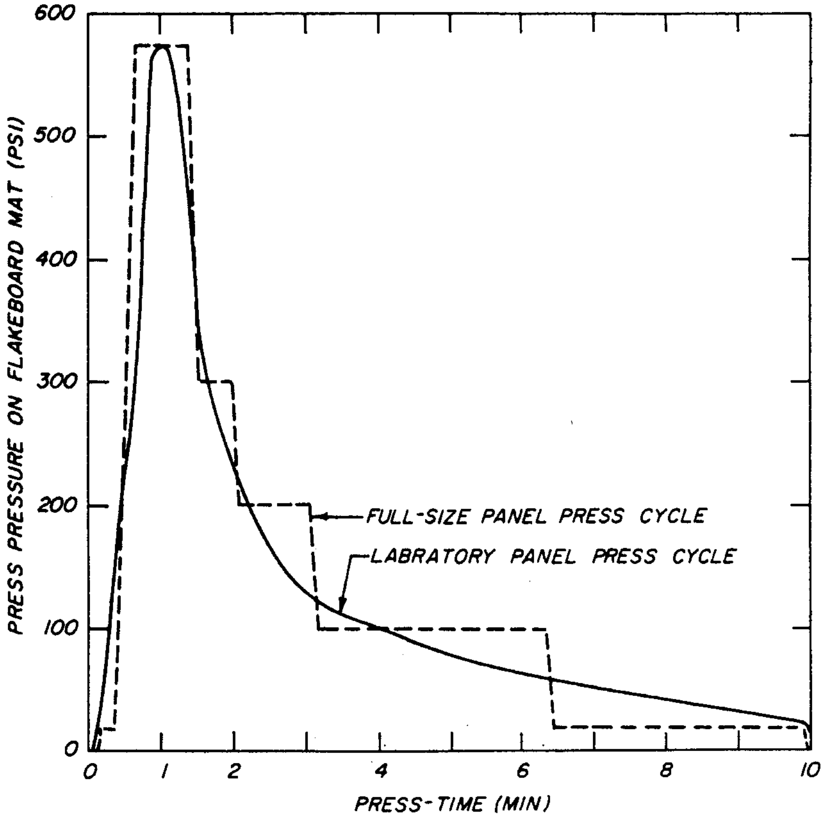

Figure 2.--Comparision of press cycles used in manufacture of laboratory and full-size structural flakeboards.

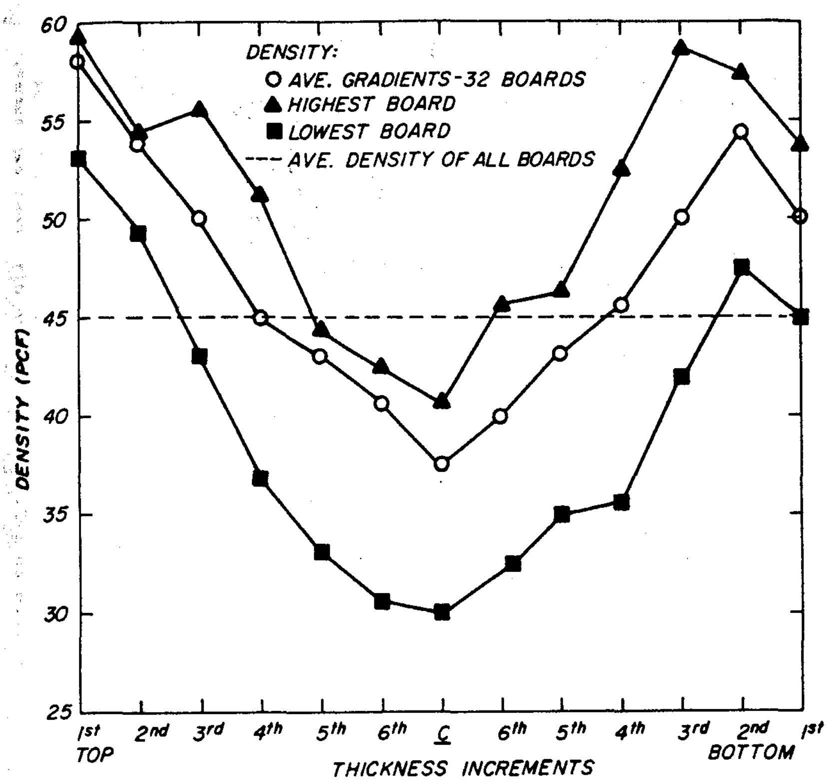

Figure 3.–Density gradients through panel thickness in FS structural flakeboards. Density is based on weight and dimensions at 73°F, 65 percent RH.

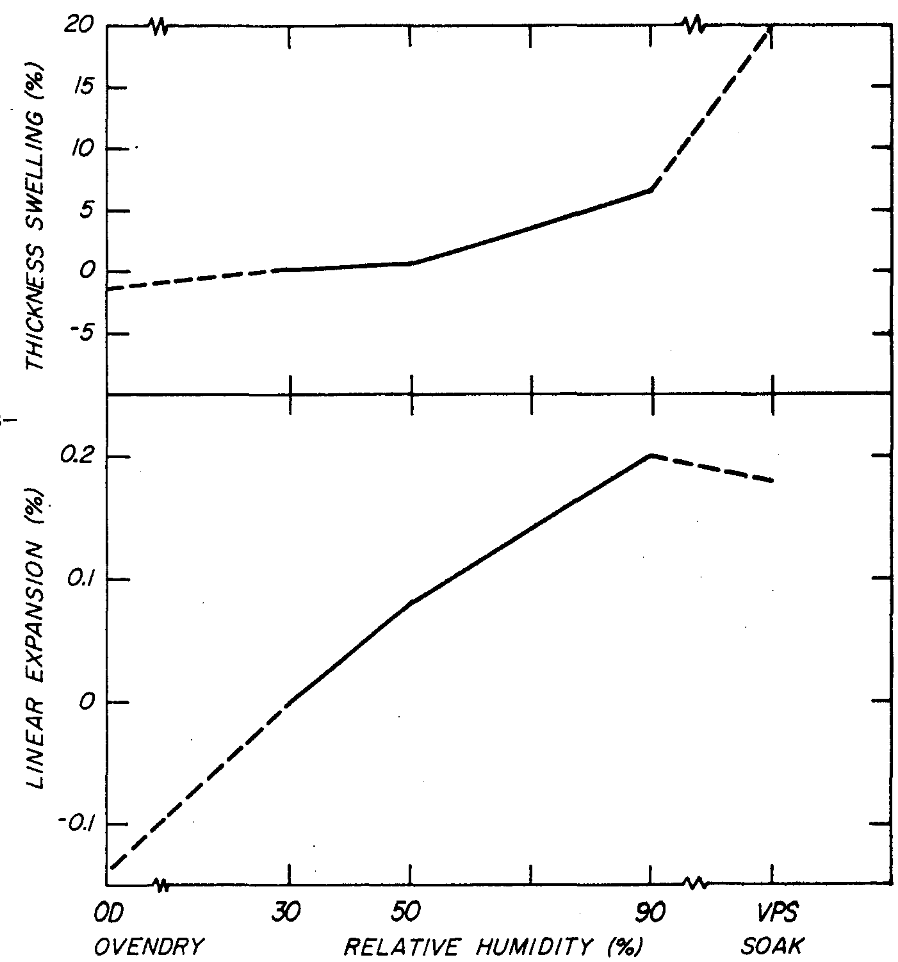

Figure 4.–Relative movement in length and thickness of FPL structural flakeboard in exposures ranging from ovendry through water saturation.

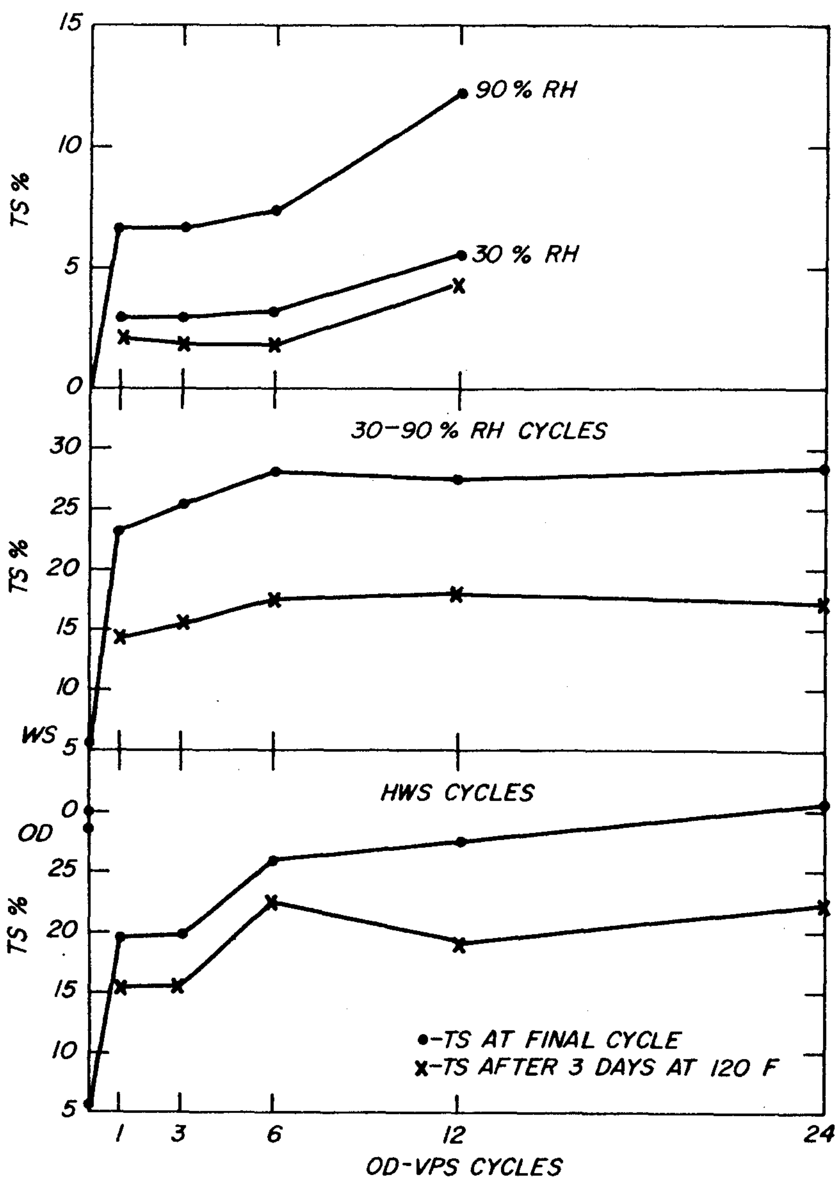

Figure 5.--Thickness swelling of FPL structural flakeboard after exposure to 1-24 cycles of three different exposures.

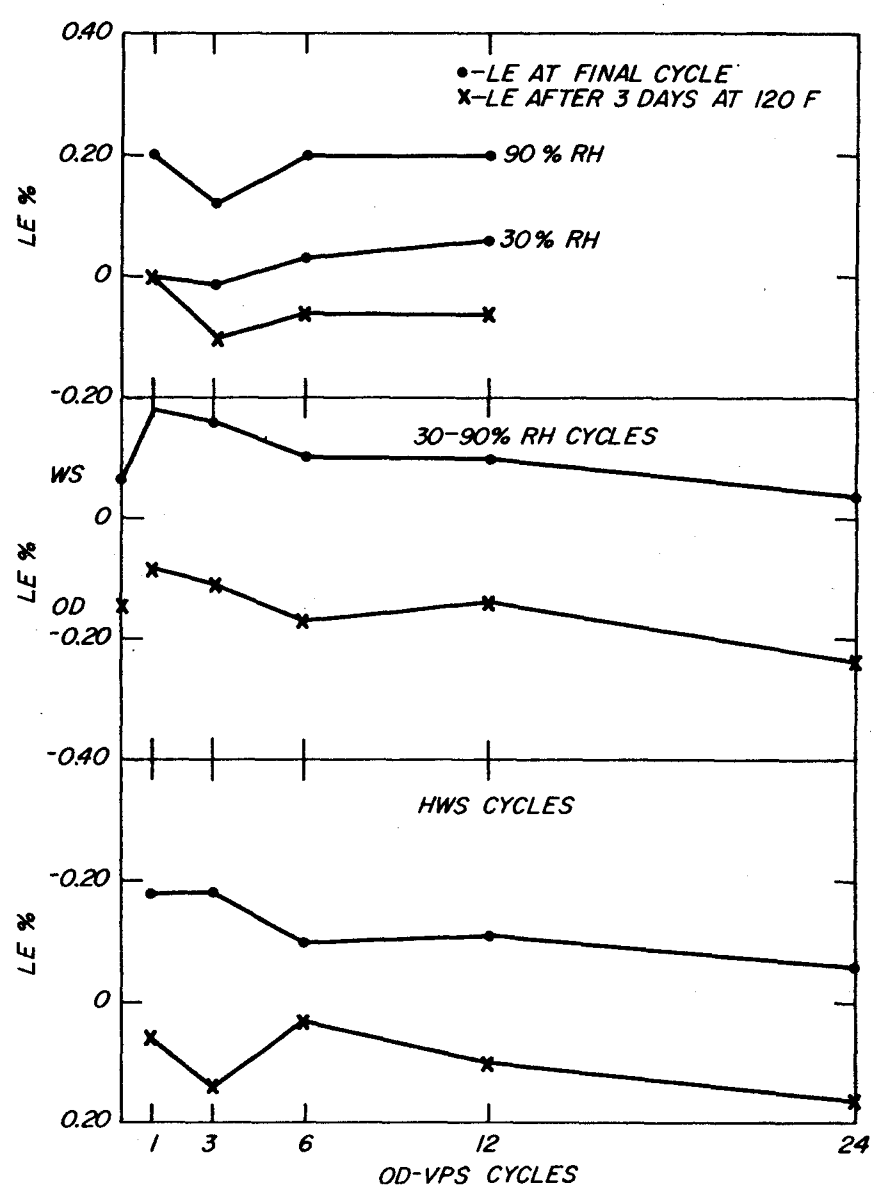

Figure 6.--Linear expansion of FPL structural flakeboard after exposure to 1-24 cycles of three different exposures.

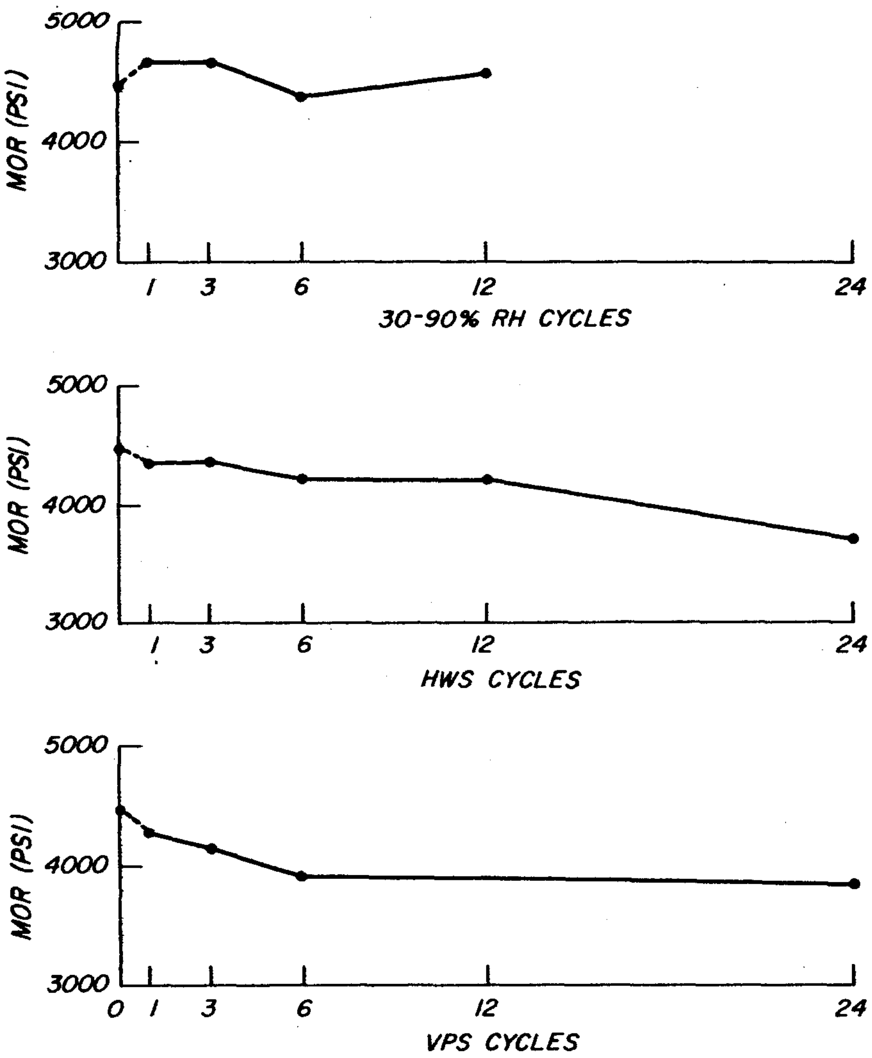

Figure 7.--Modulus of rupture of FPL structural flakeboard after exposure to 1-24 cycles of three different exposures

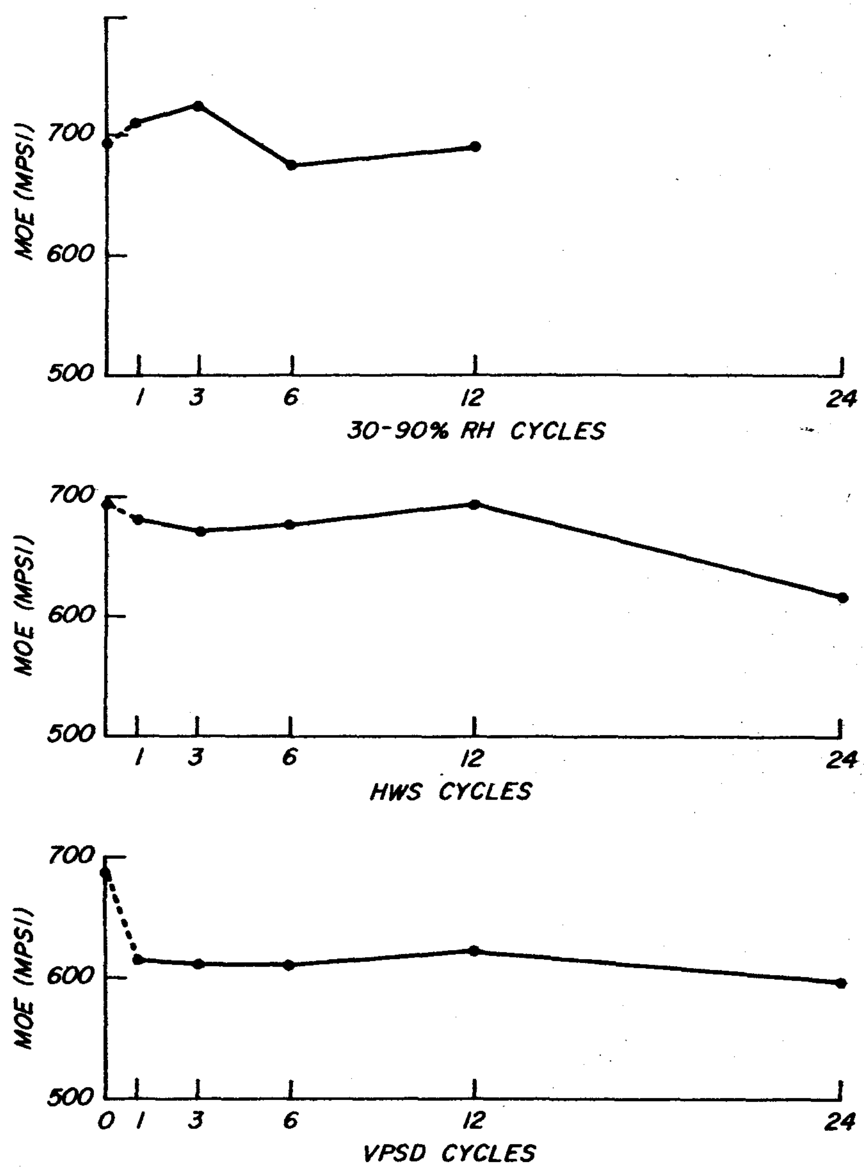

Figure 8.--Modulus of elasticity of FPL structural flakeboard after exposure to 1-24 cycles of three different exposures.

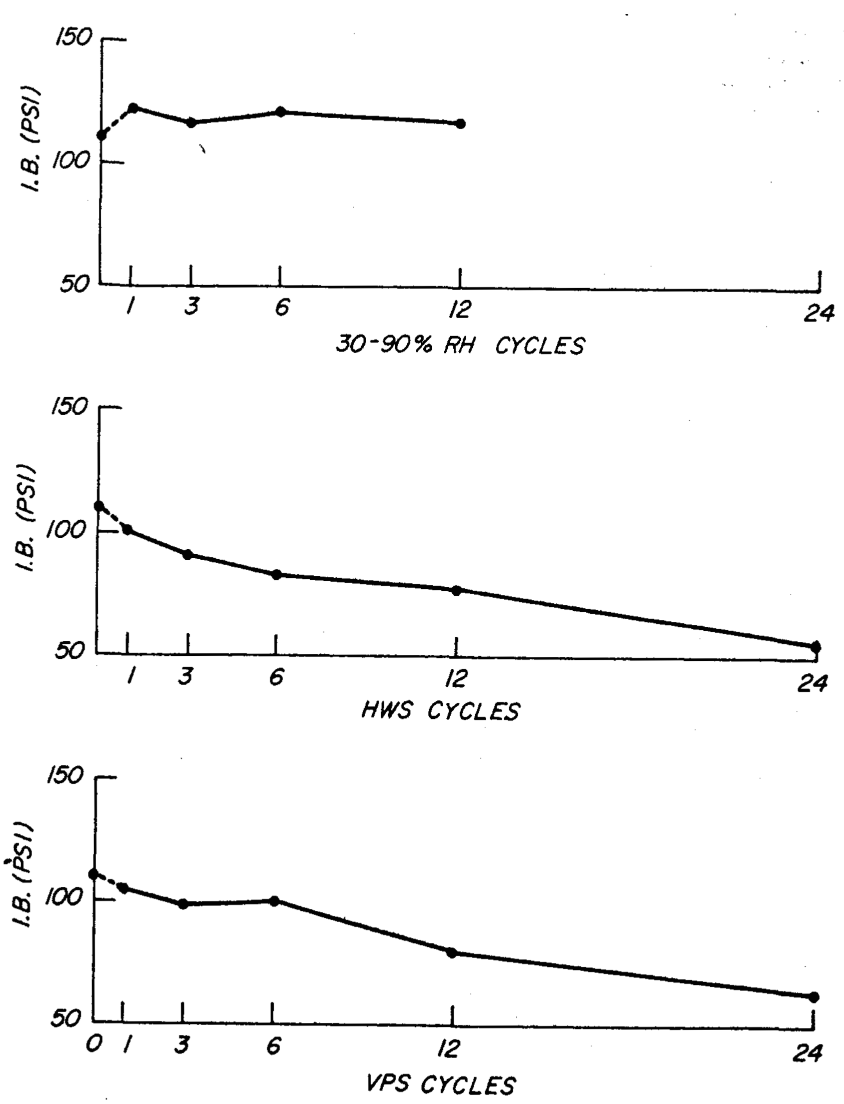

Figure 9.--Internal bond strength of FPL structural flakeboard after exposure to 1-24 cycles of three different exposures.

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PROCEEDINGS OF A SYMPOSIUM

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