Racking Strength of Walls Sheathed With Structural Flakeboards Made From Southern Species

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Abstract

Ten types of structural flakeboards and two types of southern pine plywood were evaluated. Racking loads were applied to full-size racking panels (8 by 8 ft., according to ASTM E 72) and small panels (2 by 2 ft.). When subjected to a 1,600-pound racking load, 8- by 8-foot panels sheathed with flakeboards containing a mixture of hardwood and pine flakes were slightly stiffer than southern pine plywood (0.10-in. vs. 0.12-in. deflection). Yet, plywood-sheathed panels provided slightly higher strengths for the full-size racking test (6,000 lb. vs. 5,500 lb.). The highest average racking strength, 6,200 pounds, was obtained with the 1/2-inch yellow-poplar-sheathed panels. After a 24-hour water soak, small panel racking resistances and lateral nail strength decreased. The racking strength decrease ranged from 4 percent (5/8-in. oriented mixed high density) to 18 percent (1/2-in. oriented mixed low density). All panel types had racking strength reductions within limits allowed under current standards. The nail strength decrease ranged from 9 percent (5/8-in. random mixed high-density flakeboard) to 27 percent (1/2-in. southern pine plywood). Theoretical racking strengths (derived from a linear mathematical model based on lateral nail resistance) were close to, but consistently higher than, test values.

THE SOUTHERN FOREST EXPERIMENT STATION (SFES) of the U.S. Forest Service has developed a structural flakeboard and has manufactured boards in various thicknesses and densities from several species of trees found in the southern United States (4). For each of 10 combinations of thickness, density, and panel-type variables, a group of 27 flakeboards was fabricated and randomly segregated into 4 test subgroups: 1) basic flakeboard properties (8 boards), 2) time and environmental effects (7 boards), 3) impact resistance (6 boards), and 4) racking strength (6 boards). The study reported here evaluated flakeboards in the racking-strength subgroup.

ASTM E 72 (1) contains a test procedure for determining the in-plane shear, or racking strength, of an 8- by 8-foot wall segment. Results of this test are currently used in conjunction with specified strength requirements (3) to evaluate the racking performance of structural sheathing materials. The test is used to evaluate newly developed exterior sheathing materials for resistance to racking. The SFES, which has developed an exterior sheathing material, and the Forest Products Laboratory (FPL), which has developed an equation to predict the racking strength of sheathing material and designed a small-scale (2- by 2-ft.) loading apparatus (5), initiated a cooperative study to evaluate both the sheathing material and the strength-prediction equation.

The objectives of this study were to investigate the racking (in-plane shear) resistance of several designs of exterior flakeboards, to obtain the lateral nail resistance of the sheathing, and to correlate the full-scale and small-scale racking tests with lateral nail strength. Performance of these flakeboards was compared to that of southern pine plywood, a commonly used exterior sheathing material.

Test Materials

Commercially produced southern pine CDX plywood (two groups), obtained from building suppliers in central Louisiana, and 10 groups of structural flakeboard were evaluated for racking resistance. The oriented flakeboards were produced in Potlatch Corporation's pilot plant in Lewiston, Idaho, while the random flakeboards were produced at FPL. The 12 sheathing material groups were derived as follows:

1. Random flakeboard, 1/2-inch and 5/8-inch thicknesses, constructed with a mixture of 20 percent of each of southern pine, sweetgum, red oak, white oak, and hickory species at two densities (four groups).

2. Oriented flakeboard (same thicknesses and species) (four groups).

3. Random flakeboard, 1/2 inch thick, constructed with all pine or all yellow-poplar flakes (two groups).

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4. Southern pine CDX plywood, three ply, 1/2 inch thick, and four ply, 5/8 inch thick (two groups).

Procedures

Full-Scale Racking Tests

Thirty-six 8- by 8-foot wood frames were constructed from No. 1 kiln-dried southern pine framing lumber. After the sheathing was conditioned for 4 to 6 weeks in a 10 percent equilibrium moisture content environment, it was nailed to the frames. The nailing regime was to space 8d common nails 6 inches apart around the perimeter of each sheet and 12 inches apart on the interior framing members. Nails were placed 3/8 inch from the edge on the center common stud and 3/4 inch elsewhere. The 8- by 8-foot sheathed frames, referred to as panels, were stored indoors before the racking tests. Tests were conducted in accordance with the standard procedure, ASTM E 72 (1). Two anchor bolts secured the bottom of the wood frame to a timber attached to the loading frame. The horizontal load was applied at a rate of 0.2 inch per minute through a timber attached to the double top plate. Load and deflection were continuously monitored to failure, both for the ASTM E 72 three-gage system (uplift, slip, and horizontal racking displacement) and the extensional diagonal displacement. Before continuously loading to the maximum load, we took residual deflections, or set readings, after applying and removing (arbitrarily decided upon) 800-, 1,600-, and 2,400-pound loads.

Small-Scale Racking Tests

After completion of each full-scale racking test, four 1- by 2-foot sections of sheathing were removed from the large sheets (two from each 4- by 8-ft. sheet). We assumed that the sheathing properties of the small specimens were not significantly affected by the full-scale racking test. Two small-scale (2- by 2-ft.) racking frames were sheathed with this material (Fig. 1). Type and spacing of nails and load rate were the same as for the full-scale tests.

For these tests, load and extensional diagonal displacement were recorded continuously to failure. One of the 2- by 2-foot racking panels was tested without any additional environmental conditioning and designated as the dry test. The other panel was soaked in ordinary tap water at room temperature (the nailed sheathing was under a 1-in. water head for 24 hr.). These panels, designated as the wet tests, were tested between 2 and 4 hours after being removed from the soaking tub.

Lateral Nail Resistance Tests

Specimens for evaluation of lateral nail resistance were also obtained from the panels after the full-scale tests. To simulate the joint in a racking panel, we used a modified form of a standard test procedure (2) to evaluate lateral nail resistance (single shear type). Sheathing and lumber removed from the racking test frames were overlapped 4 inches and fastened by a single nail (8d common) driven either 3/8, 1/2, or 3/4 inch from the edge of the sheathing. Preliminary tests had indicated these distances were acceptable for evaluation of failure modes and maximum lateral nail loads. Although these tests indicated no difference in strength in vertical or horizontal sheet direction, half of the specimens were cut in each direction.

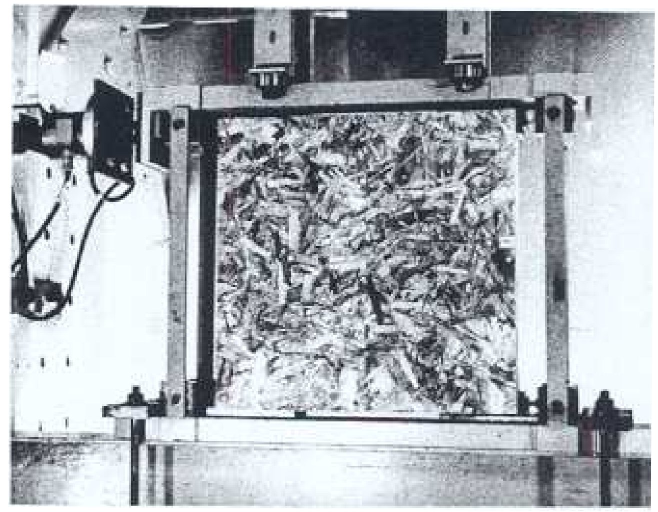

Figure 1. — A 2- by 2-foot test frame subjected to a racking load.

As in the small-scale racking tests, the lateral nail tests were run "dry" and "wet."

All lateral nail resistance specimens were loaded in tension at a constant displacement rate of 0.1 inch per minute. Load and slip were plotted to 0.12 inch of slip, and maximum loads were also recorded.

Analytical Racking Model

As discussed by Tuomi and Gromala (5), racking resistance of sheathing material mechanically fastened to a stud frame can be calculated for a given nail spacing as a function of the ultimate lateral load of the fastener. The equation derived for the calculation is based on an energy expression whereby the externally applied load is resisted by the internal energy offered by the fasteners. The frame is assumed to distort like a parallelogram while the sheathing remains rectangular. The equation for racking strength *(R)* of panel is:

$$R = N \times S \times K + F$$

where

N = number of sheets in series,
S = ultimate lateral load of a single fastener (lb.),
K = racking coefficient,
F = racking strength of the basic frame (lb.).

Racking coefficients are tabulated in reference (5). For this theoretical racking strength equation, values for the racking strength of the frame and lateral nail resistance at ultimate load are required.

Theoretical racking strengths based on the equation were calculated assuming frame racking resistance of 450 pounds for an 8- by 8-foot frame and 250 pounds for a 2- by 2-foot frame (5) with the proper racking coefficients and lateral nail test results. Experimental racking strengths were then compared with the theoretical values.

Results and Discussion

Full-Scale Racking Tests

For each sheathing material group, the three racking tests were averaged (Table 1). All groups exhibited an erratic change in racking resistance with a change in density. This apparent effect could have been

TABLE 1. — *Racking test results of 8- by 8-foot and 2- by 2-foot frames sheathed with various materials.*

	Sheathing material			8- by 8-ft. frame		2- by 2-ft. frame				
	Thickness			Δ @ 1,600 lb.		MC[d]		Racking load		
Type	Nominal	Actual	Density	Load/set[b]	Max. load	Dry	Wet	Dry	Wet	Loss[e]
			pcf	---- in. ----	lb.			lb.		
Flakeboard										
Mixed, oriented[a]	1/2	0.50	42.8	0.09/0.03[c]	4,720[c]	5.7	62.2	1,790	1,460	18.4
Mixed, oriented	1/2	.49	45.6	.10/ .03	5,330	5.5	35.9	1,770	1,600	9.6
Mixed, oriented	5/8	.62	43.2	.11/ .05	5,460	5.7	68.4	1,780	1,580	11.2
Mixed, oriented	5/8	.61	49.2	.07/ .03	5,580	5.9	55.7	1,750	1,680	4.0
Mixed, random	1/2	.51	47.7	.11/ .05	5,590	5.9	31.7	1,960	1,700	13.3
Mixed, random	1/2	.51	51.6	.11/ .05	5,390	6.0	26.9	1,890	1,680	11.1
Mixed, random	5/8	.62	46.2	.09/ .03	5,790	5.7	35.3	1,800	1,590	11.7
Mixed, random	5/8	.62	45.3	.08/ .04	5,780	5.9	34.4	1,820	1,660	8.8
Pine, random	1/2	.49	46.1	.10/ .04	5,710	5.9	59.4	1,700	1,500	11.8
Yellow-poplar, random	1/2	.52	41.7	.10/ .04	6,200	5.6	26.4	1,790	1,620	9.5
Plywood[f]	1/2	.47	33.3	.13/ .05	5,980	6.2	39.3	1,785	1,470	17.4
	5/8	.59	33.4	.12/ .03	6,030	6.1	38.9	1,770	1,550	12.4

[a]Mixed=southern pine, sweetgum, red oak, white oak, and hickory; oriented and random refer to flake alignment.
[b]Deflection @ 1,600-lb. load/Residual (set) after load removal.
[c]Average of three tests.
[d]Moisture content was taken only from the sheathing material.
[e](Dry-wet)/dry × 100.
[f]CDX southern pine plywood.

the result of failure mode or board fabrication variabilities. For instance, the failure mode of many panels involved bending of the nail shank, then nail withdrawal from the framing material; so the maximum sheathing resistance was not obtained. Also, the board density at the nailing area may have varied from the reported total board density.

If we assume that maximum racking load in this study was not affected by the board density or failure mode, the averages obtained indicate that flake orientation and panel thickness affected the maximum racking load. Random mixed species flakeboards, with an average of 5,640 pounds, averaged 7 percent higher (9.3% for the 1/2-in. thickness and 4.7% for 5/8-in. thickness) than oriented mixed species flakeboard. For the mixed species flakeboard, the 1/2-inch-thick board averaged 5,260 pounds while the 5/8-inch thickness averaged 395 pounds (7.5%) higher. However, the 1/2-inch, random single species panels had a higher average than the thicker mixed species flakeboards. For the plywood, maximum loads were similar for both thicknesses (a 720-lb. range in values per thickness and only a 50-lb. average difference).

The range of the average deflection values at the 1,600-pound load was 0.07 inch to 0.13 inch (Table 1). For flakeboard from randomly mixed species, increased board thickness may contribute to an increase in racking stiffness. However, the oriented flakeboard data did not have a similar relationship. Flakeboard panels were slightly stiffer than plywood. Yet, the residual deflection (deflection remaining after load removal) was similar for all sheathing materials.

Small-Scale Racking Tests

Racking strengths in the small-scale test were similar for all groups (Table 1). For all types of sheathing materials, racking strength decreased after a 24-hour water soak. For each sheathing type, the low-density group showed the largest increase in moisture content and the largest percentage of loss in racking strength after soaking.

The low-density, 1/2-inch oriented flakeboards, which lost the most strength after soaking (18%), had a wet racking strength comparable to CDX southern pine plywood (1,460 lb. compared to 1,470 lb.). For the 5/8-inch panels, the pine plywood lost slightly more strength than did the random or oriented flakeboards. The current FHA standard (3) accepts up to a 23 percent strength reduction after soaking.

Lateral Nail Tests

For all types of sheathing material, average nail resistance decreased after the 24-hour water soak (Table 2). Decreases ranged from 9 percent (5/8-in. mixed random high-density flakeboard) to 27 percent (1/2-in. southern pine plywood). The observed maximum lateral nail loads in both wet and dry tests generally increased with the distance that the nail was placed from the edge.

For the flakeboards, dry lateral nail resistance did not consistently increase as density increased. Since the high-density flakeboard groups generally lost less lateral nail resistance after water soaking than low-density groups, wet lateral nail resistance increased as board density increased. Perhaps, the high-density specimens did not absorb as much moisture as low-density samples and thus maintained better particle bonding. If so, thickness swell and density change would influence the smaller decrease in lateral nail resistance for the high-density specimens. Lateral nail resistance also increased as board thickness increased for the mixed oriented flakeboards but not for the plywood or mixed random flakeboards.

Theoretical Predictions

With the average values for lateral nail resistance and the theoretical equation (5), ultimate panel racking strengths were calculated. The theoretical values were close to the experimental values for all groups, but

TABLE 2. — *Lateral nail resistance with 8d common nails spaced at various edge distances.*

Sheathing material	Max. load					
	Dry			Wet		
	3/8 in.	1/2 in.	3/4 in.	3/8 in.	1/2 in.	3/4 in.
	lb.					
Flakeboard						
Mixed, oriented (1/2 in.)[a]	305[b]	343	383	229	259	286
Low density	*15.7*	*11.2*	*18.1*	*21.0*	*15.8*	*10.9*
High density	338	335	352	271	302	326
	6.5	*16.9*	*20.1*	*18.7*	*19.6*	*14.4*
Mixed, oriented (5/8 in.)	354	411	427	298	323	327
Low density	*8.5*	*15.4*	*15.0*	*20.8*	*15.3*	*14.5*
High density	359	361	401	302	311	351
	12.0	*17.1*	*18.0*	*19.6*	*12.0*	*14.9*
Mixed, random (1/2 in.)						
Low density	319	341	381	258	309	304
	7.2	*13.7*	*8.9*	*13.4*	*23.7*	*14.8*
High density	314	338	386	294	273	316
	14.2	*11.1*	*10.4*	*14.1*	*11.2*	*11.6*
Mixed, random (5/8 in.)						
Low density	308	336	342	256	259	308
	11.7	*9.5*	*8.9*	*14.3*	*10.8*	*10.0*
High density	347	362	349	301	307	356
	8.8	*19.4*	*14.6*	*19.5*	*16.9*	*31.0*
Pine, random (1/2 in.)	314	385	388	257	288	290
	19.6	*24.7*	*12.2*	*16.6*	*23.4*	*24.2*
Yellow-poplar (1/2 in.)	351	370	406	301	290	337
	7.2	*13.9*	*23.7*	*15.3*	*15.8*	*13.9*
Plywood						
CDX southern (1/2 in.)	311	321	386	216	236	289
pine	*10.5*	*8.9*	*15.3*	*11.9*	*10.7*	*20.3*
(5/8 in.)	302	307	338	266	249	262
	9.6	*16.2*	*12.8*	*21.6*	*15.9*	*27.9*

[a]See Table 1, footnote a. Number in parentheses is nominal thickness.
[b]The first number per panel group is an average of nine tests, and the number in italics is the coefficient of variation.

calculated values consistently overestimated the racking strength (Fig. 2).

The equation may be more applicable for sheathing materials with low racking strength or for those that exhibit a pronounced corner failure. Although previous research (5) showed good correlation between nail load and racking strength, this study indicates that the use of a linear theory may not be adequate and that nonlinear prediction methods (currently under development) may be required.

Conclusions

When subjected to a 1,600-pound racking load, (1/2- and 5/8-in. thick) flakeboards made with a mixture of hardwood and pine flakes were slightly stiffer than equally thick southern pine plywood. Plywood sheathed panels provided slightly higher ultimate strengths for the full-size (8- by 8-ft.) racking frame. However, the highest racking values were obtained from the 1/2-inch yellow-poplar flakeboards.

For small-scale tests, slightly higher values were obtained from the flakeboards made with randomly mixed species than from any other type of material.

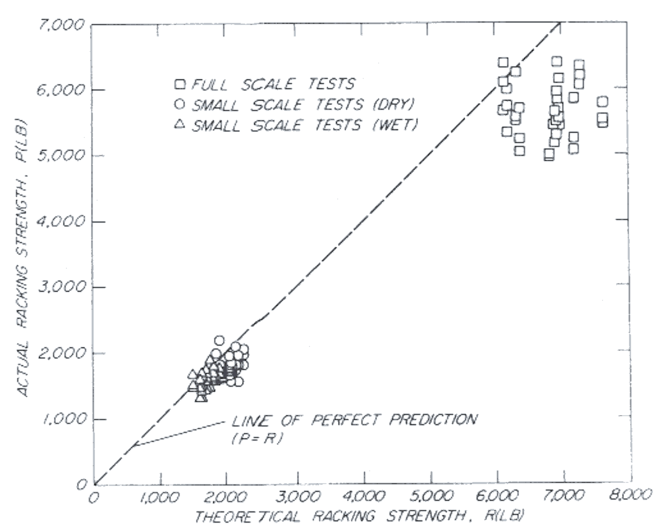

Figure 2. — Relationship of the experimentally determined racking strength and predicted racking strength.

Theoretical racking strengths computed by a linear prediction method were close to, but consistently higher than, test values.

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