Direct withdrawal and head pull-through performance of nails and staples in structural wood-based panel materials

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Abstract

In both the nail and staple direct withdrawal resistance tests, l/2-inch thick waferboard and two OSBs performed equal to or better than CD-grade plywood sheathing in all three exposures, but the veneered composites performed as well as plywood only in the dry and 24-hour soaked conditions. The ASTM 24-hour soaking and 6-cycle accelerated-aging exposures reduced the average nail withdrawal resistance value in roof sheathing specimens about 30 and 40 percent, respectively; and reduced the staple withdrawal resistance about 55 and 8 percent, respectively. The staples showed higher withdrawal resistance values than the nails in the dry and 24-hour water-soaked conditions, while nails showed much better results in the 6-cycle accelerated-aged condition. The nailhead pull-through and staple-crown pull-through resistance tests yielded similar average values in all wood-based materials (except the l/2-in. thick waferboard) in all exposure conditions. The difference between the ASTM nailhead pull-through and nailhead push-through are relatively small in all exposure conditions. The newly developed nailhead push-through test appears to be a good substitution for the ASTM nailhead pull-through method. The average values of nail and staple withdrawal and pull-through resistance of most of the nine wood-base materials tested meet the minimum requirement of various specifications or current standards.

An average home takes as many as 70,000 nails, which require about 300,000 hammer blows to drive them in place. For efficiency, the use of power-driven staples for the fastening of wood materials has increased in recent years (14). In addition, some new types of wood-based panels, which have a density or hardness similar to some dense hardwood lumbers, can pose greater hammer-driven nailing problems than those encountered in the use of softwood plywood panels. To overcome this difficulty, a widespread adaptation of a proper power-driven fastening system may be the possible solution. New information on the performance of staples in these new sheathing and siding products is needed for comparative purposes (10).

Direct withdrawal resistance of nails and staples is the force required to pull imbedded fasteners from the wood. The holding power of fasteners is especially important when applying shingles or siding materials to roof or wall sheathing (14).

A standard ASTM nailhead pull-through test has been used to determine the resistance of a wood material by pulling the head of a nail through the thickness of the specimen (2,3). This test is meant to simulate the conditions encountered when wind or earthquake forces pull sheathing or siding from a wall. It was reported that the problem of maintaining a firm grip on the nail shank has frequently been encountered in the course of nailhead pull-through using the method described in ASTM D 1037. The nail-slip problems encountered in the use

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TABLE 1. — *Existing direct nail withdrawal and nailhead pull-through performance standards (1/2-in.-thick board tested with 6-penny nail).*[a]

Standard and method		Exposure condition	Minimum direct nail withdrawal	Minimum nailhead pull-through
			(lb.)	
ASTM D 2277 1/2-in. fiber insulation board sheathing using ASTM D 1037 tests		Dry	40	--
		Wet	25	--
FHA Circular No. 12		Dry	--	200
Voluntary Product Standard PS 60-73, hardboard siding		Dry	--	150
APA S-4 test method for plywood sheathing (6d nail)	Roof	Dry	20	--
		Wet/redry	15	--
	Subfloor	Dry	20	--
		Wet/redry	15	--
USDA Forest Service target goal for flakeboard		Dry	40	250
		Wet	25	--
		ASTM 6-cycle aging	20	120
Can. Standards Assoc. Can 3-0188.2-M78 for waferboard		Dry	20	--
FHA UM-32, 1961 for exterior particleboard (1/2-in. board)		Dry	30	250
		ASTM 6-cycle aging	20	125

[a] See references 1, 2, 7-9, 11, and 12.

of the present standard test often lead to unreliable test results (5). Table 1 lists the existing direct nail withdrawal and nailhead pull-through performance standard for some panel products.

Previous study determined the effects of test methods and accelerated aging on lateral fastener resistance in wood-based products (6). However, little information is available on the fastener direct withdrawal and head pull-through resistance performance of new structural wood-based sheathing panels. The objectives of this study were to: 1) develop data on the maximum direct nail and staple withdrawal, and the pull-through performance of nine commercial structural wood-based sheathing and siding panels compared to conventional plywood sheathing material; and 2) determine the effects of severe exposure on the nail and staple performance by conducting accelerated-aging tests.

Experimental design and method

Part one

A. Dependent variable: maximum direct fastener withdrawal resistance (lb.).

B. Independent variables:

1. Materials: A_1= commercial CDX plywood sheathing, l/2-inch; A_2= larch veneered strandboard composite plywood, 1/2-inch; A_3= oriented strandboard (OSB-1), sanded l/2-inch; A_4= oriented strandboard (OSB-2), l/2-inch; A_5= waferboard, l/2-inch; A^6= embossed hardboard siding, 7/16-inch; A_7= waferboard roof sheathing, 7/16-inch; A_8= oriented strandboard roof sheathing (OSB-1), 7/16-inch; and A_9= oriented strandboard roof sheathing (OSB-2), 7/16-inch;

2. Exposure conditions: B_1= dry; B_2= 24-hour water-soaked (ASTM D 1037); and B_3= accelerated aging (ASTM, 6 cycles);

3. Fastener type: C_1= 6-penny common wire nail (0.113-in. shank diameter and 0.250-in. head); C_2= l/2-inch crown, 16-gauge power-driven staple (0.056-in. diameter and 2 in. long); C_3= roof sheathing aluminum nail (0.121-in. shank diameter and 0.4-in. head); and C_4 = 15/16-inch crown, 16-gauge power-driven staple for roof sheathing (0.057-in. diameter and 1-1/4 in. long).

The roof sheathing fasteners C_3 and C_4 were used to test materials A_1, A_7, A_8, and A_9 only.

C. Constant factors:

1. Specimen size (3 by 6 in.) and test follow methods described in ASTM D 1037;

2. Two Paslode power-driven staple guns were used to attach staple to specimen;

3. The source of the nails was a single manufacturer;

4. Nails were all hammer-driven into specimens using a specially designed new nailing jig.

Part two

A. Dependent variable: maximum fastener pull-through resistance (lb.).

B. Independent variables:

1. Materials: same as Part one, factor A;

2. Exposure condition: same as Part one, factor B;

3. Test method: ASTM D 1037 pull-through using 6-penny nail (1/4-in. head); nailhead push-through using 6-penny nail (1/4-in. head); steel rod punch-through using l/4-inch diameter steel rod; and staple crown (1/2 -in.) pull-through.

C. Constant factors: same as Part one, factor C.

Materials and procedures

Seventy-two sheets (4 by 8 ft.), eight sheets each of nine commercial wood-based panels (including three 7/16-in. -thick roof sheathing materials) were received from five manufacturers. All panels were randomly selected, one panel from each production day or shipment. Table 4 shows the average density and thickness of all nine panel products.

Replication

Thirty specimens (3 by 6 in.) were randomly selected from each type of material. Preliminary nail withdrawal resistance tests were conducted to determine the variability of this property in each material. In order to detect a real difference of 10 percent of the maximum nail withdrawal resistance value, the required number of replications for plywood, composite plywood, sanded OSB-1, OSB-2, waferboard, and embossed hardboard were found to be 24, 32, 14, 19, 39, and 34, respectively (13). For both statistical and practical reasons, a replicate size of 50 tests was used throughout this experiment. This design called for 3,900 direct fastener withdrawal resistance tests and 5,400 fastener head pull-through resistance tests.

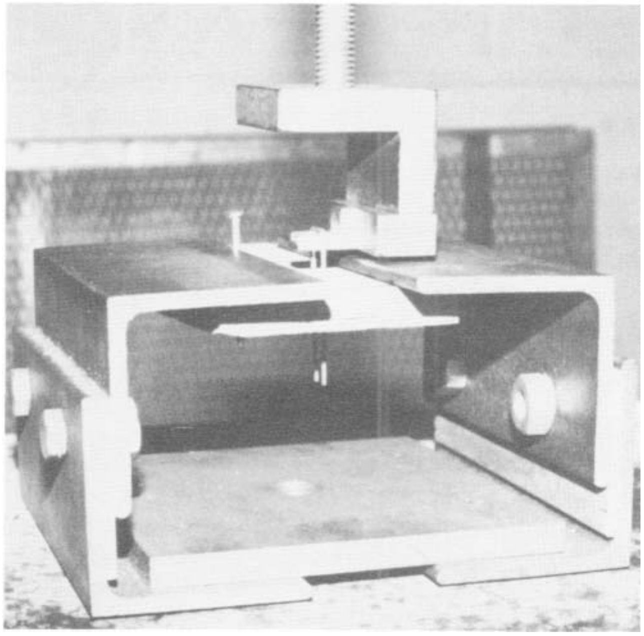

Figure 1. — A 2-inch-long, l/2-inch crown, 16-gauge staple will be vertically withdrawn from a specimen.

Specimens were cut randomly from 72 panels (4 by 8 ft.) and coded and conditioned at a relative humidity (RH) of 65 percent and a temperature of 68°± 6°F. A total of 9,300 tests were conducted in accordance with the method described in ASTM D 1037 (2).

Test conditions

Three groups of randomly selected specimens were subjected to three exposure condition tests: dry, 24-hour soak, and 6-cycle aging. A batch of nailed and stapled specimens were delivered to the USDA Forest Products Laboratory, Madison, Wis, to be subjected to a 6-cycle aging treatment. The specimens were returned to the University of Illinois and reconditioned at 68° ± 6°F and 65 ± 6 percent RH prior to the tests. Specimens for the 24-hour water-soak treatment were nailed and stapled directly before soaking. The dry specimens did not receive their fasteners until immediately before testing.

Direct withdrawal resistance test

Each of the fasteners was driven through the thickness of the specimen; at least 1/2 inch of the fastener top was left protruding above the surface of each specimen using special jigs. The 6-penny common wire nail tests were performed using the apparatus specified by the ASTM standard. The roof nail withdrawal tests were performed using a newly made metal box that has a slot cut into it to fit the 7/16-inch diameter head of the roofing nail. A newly designed test jig was made to fit the universal testing machine for conducting the staple withdrawal test (Fig. 1).

Two heavy-duty power-driven staple guns were used to drive the l/2-inch crown staple and the 15/16-inch crown roofing staple into the specimens. The former type of staple has been commonly used for wood-based wall sheathing attached to wood members by the factory-built house and prefabricated panel industries. The latter type of staple has been used for attaching shingles onto roof sheathing materials.

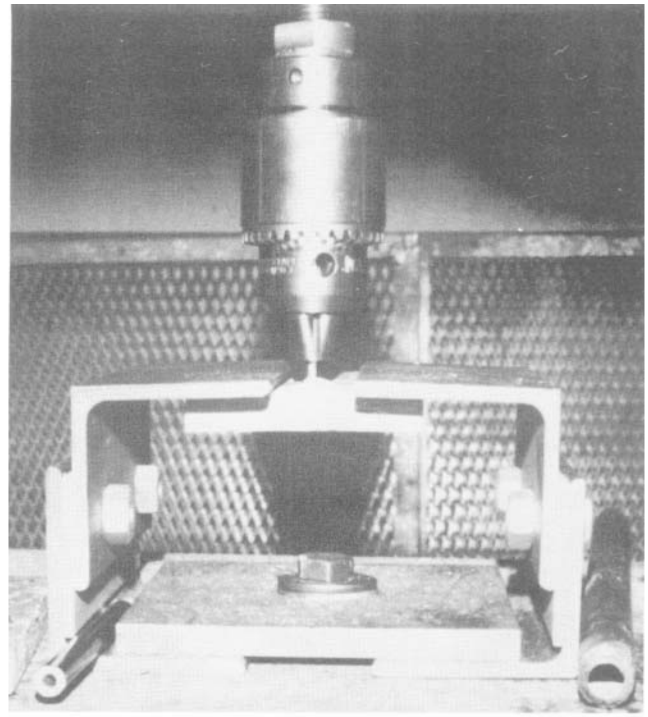

Figure 2. — The nailhead pull-through test method uses a drill chuck to hold the 6-penny nail shank.

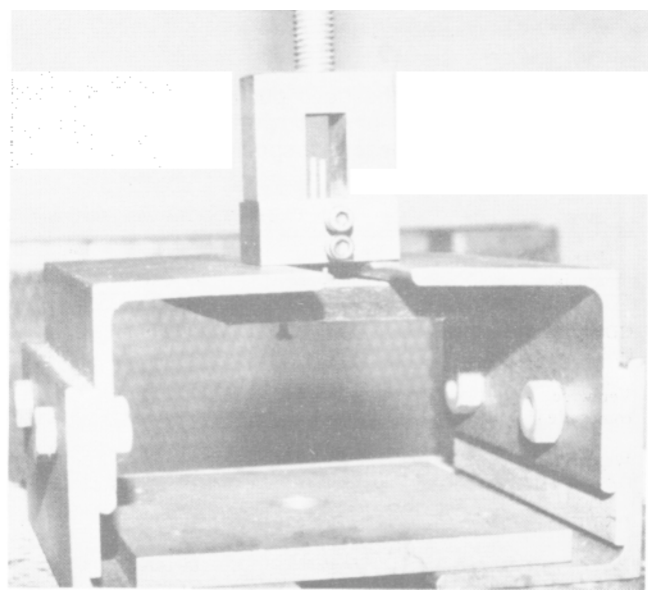

Figure 3. — A new jig was made to hold two legs of a staple for conducting the staple crown pull-through test.

Fastener pull-through test methods

1. A standard ASTM nailhead pull-through test was used to determine the resistance of specimens to having the head of a 6-penny common nail pulled through the thickness of a specimen. Figure 2 shows that the point of the nail is gripped by a specially made large-size Jacob's type drill chuck attached to the upper portion of the testing machine. The specimen is inserted un-

der the holding fixture with the point of a 6-penny nail at the lower platen.

2. The staple crown pull-through resistance test was performed using a newly designed jig. The legs of the l/2-inch crown staple were placed in 16-gauge-size holes in the steel block, which has two allen screws on two sides. The four allen screws are then tightened to hold two legs in place, while the staple crown is pulled through the specimen (Fig. 3).

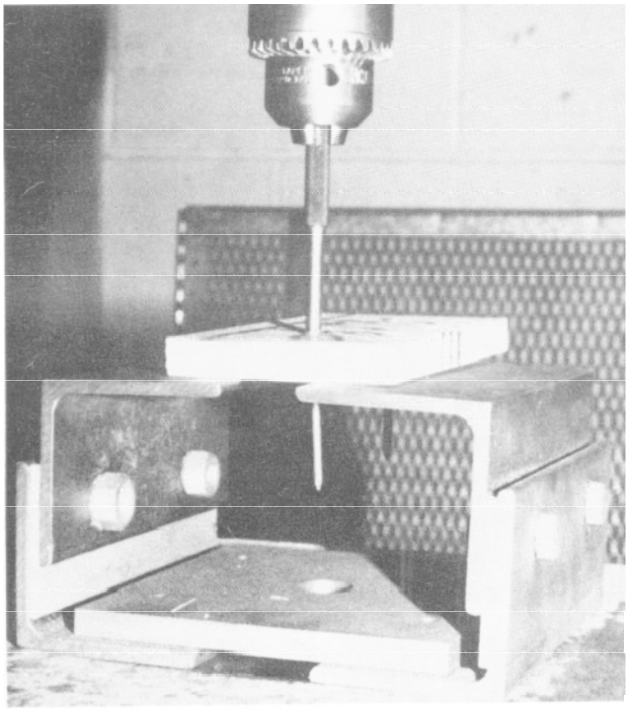

Figure 4. — The new nailhead push-through test used a 7/32-inch Starrett drive-pin to push the head of a 6-penny nail through the thickness of a specimen.

3. The nailhead push-through test is shown in Figure 4. In this photo, a nailed specimen is resting on the top of a holding fixture plate located at the middle of the loading table or the testing machine. The nail point faces downward and centers at the opening of the holding plate. A vertically aligned Starrett 7/32-inch driven pin is fixed at the lower portion of the bottom platen. The test can be achieved by lowering the steel pin onto the center of the nailhead which has a l/4-inch diameter.

4. The steel rod punch-through test was developed to simulate nailhead performance in new wood-based sheathing panels. A 1/4-inch steel rod was driven directly through a specimen without the use of a nail.

It should be noted that neither roofing nails nor roofing staples were used in the fastener pull-through test. The nailhead diameter of the roofing nail is almost twice that of the 6-penny common nail, therefore, the nailhead pull-through failure is almost nonexistent in the roof sheathing materials in practical use.

Results and discussion

Tables 2 and 3 and Figures 5 through 7 show the average fastener resistance values and the variability of nine different wood-based structural materials. The results of the analysis of variance for two experiments (maximum fastener direct withdrawal and pull-through resistance) show that all main factors (material type, exposure condition, fastener type, and test method) significantly affected both the direct withdrawal and pull-

TABLE 2. — *Average maximum fastener withdrawal and pull-through values.*[a]

Panel materials	Exposure conditions	Direct withdrawal: 6d nail[b]	Direct withdrawal: 1/2-inch staple[c]	Pull-through: ASTM 6d nail	Pull-through: 1/2-inch staple	6d nail push-through	6d rod[d] punch-through
		(lb.)					
CD-plywood (1/2-in.)	Dry	49 (31)[e]	95 (28)	343 (15)	272 (20)	364 (19)	464 (20)
	24-hour	35 (22)	54 (22)	252 (16)	240 (20)	245 (20)	477 (19)
	6-cycle	25 (57)	19 (42)	254 (20)	270 (20)	261 (22)	397 (17)
Veneered composite (1/2-in.)	Dry	68 (24)	131 (24)	309 (17)	291 (20)	353 (16)	397 (17)
	24-hour	31 (30)	56 (26)	207 (21)	224 (18)	212 (20)	414 (20)
	6-cycle	45 (42)	12 (30)	205 (22)	250 (36)	211 (22)	323 (22)
Waferboard (1/2-in.)	Dry	74 (31)	162 (20)	344 (23)	340 (17)	397 (22)	485 (21)
	24-hour	52 (42)	99 (44)	332 (30)	341 (22)	332 (23)	508 (22)
	6-cycle	62 (49)	16 (32)	238 (25)	238 (25)	283 (27)	354 (22)
OSB-1 (1/2-in.)	Dry	73 (28)	146 (25)	332 (15)	305 (20)	394 (18)	448 (15)
	24-hour	35 (27)	63 (34)	212 (21)	208 (18)	217 (18)	330 (20)
	6-cycle	90 (42)	22 (40)	284 (13)	270 (16)	300 (16)	371 (16)
OSB-2 (1/2-in.)	Dry	77 (33)	182 (22)	343 (18)	341 (20)	413 (19)	475 (19)
	24-hour	50 (35)	92 (34)	290 (20)	277 (19)	293 (22)	471 (18)
	6-cycle	80 (44)	23 (26)	286 (19)	282 (18)	282 (15)	377 (17)
Waferboard (7/16-in.)	Dry	58 (33)	131 (32)	313 (20)	303 (24)	312 (23)	451 (22)
	24-hour	24 (39)	57 (44)	216 (29)	258 (26)	212 (32)	351 (23)
	6-cycle	28 (43)	11 (25)	196 (23)	205 (22)	192 (19)	290 (26)
OSB-1 (7/16-in.)	Dry	61 (34)	109 (40)	303 (19)	333 (20)	349 (20)	432 (24)
	24-hour	26 (27)	55 (46)	241 (26)	218 (27)	273 (30)	423 (24)
	6-cycle	55 (53)	13 (47)	205 (24)	229 (20)	214 (23)	312 (17)
OSB-2 (7/16-in.)	Dry	58 (34)	91 (49)	321 (20)	321 (20)	337 (22)	428 (22)
	24-hour	31 (30)	54 (35)	210 (26)	199 (24)	208 (21)	314 (26)
	6-cycle	65 (57)	16 (37)	230 (21)	227 (18)	230 (23)	299 (21)
Embossed hardboard (7/16-in.)	Dry	32 (31)	57 (17)	110 (11)	102 (9)	114 (15)	156 (8)
	24-hour	34 (23)	34 (20)	102 (13)	97 (8)	98 (15)	149 (6)
	6-cycle	38 (19)	12 (59)	81 (11)	72 (8)	92 (13)	125 (6)

[a] Each value is an average for 50 tests.
[b] The 6-penny common wire nails were used.
[c] Staples of 16-gauge wire, 2 inches long, with a 1/2-inch crown, were used.
[d] A steel rod about 0.262 inch in diameter was used.
[e] Numbers in parentheses represent: coefficient of variation (%) = $\frac{\text{standard deviation}}{\text{average}} \times 100$.

TABLE 3. — *Average maximum direct fastener withdrawal in roof sheathing materials.*[a]

Materials	Roof nail withdrawal					Roof staple (15/16-in.) withdrawal				
		24-hour soak		6-cycle aged			24-hour soak		6-cycle aged	
	Dry	Average	Dry	Average	Dry	Dry	Average	Dry	Average	Dry
	---------- (lb.)	----------	(%)	(lb.)	(%)	---------- (lb.)	----------	(%)	(lb.)	(%)
Waferboard	61 (23)[b]	37 (24)		26 (72)		126 (25)	44 (38)		13 (39)	
(7/16-in.)	23 to 86[c]	19 to 58	61	4 to 70	43	60 to 197	14 to 114	35	4 to 23	10
OSB-1	74 (28)	53 (29)		46 (70)		137 (31)	71 (42)		15 (45)	
(7/16-in.)	22 to 121	23 to 89	72	8 to 135	62	70 to 222	20 to 139	52	5 to 35	11
OSB-2	80 (24)	45 (26)		62 (58)		134 (28)	59 (32)		17 (41)	
(7/16-in.)	38 to 114	27 to 71	56	9 to 131	78	71 to 249	20 to 110	44	6 to 43	13
CD-plywood	85 (26)	56 (20)		21 (59)		116 (22)	59 (18)		18 (33)	
(1/2-in.)	23 to 126	21 to 82	66	2 to 57	25	44 to 171	32 to 87	51	9 to 35	16

[a] Each value is an average for 50 tests.
[b] Numbers in parentheses represent: coefficient of variation (%) = $\frac{\text{standard deviation}}{\text{average}} \times 100$.
[c] Range from minimum to maximum values.

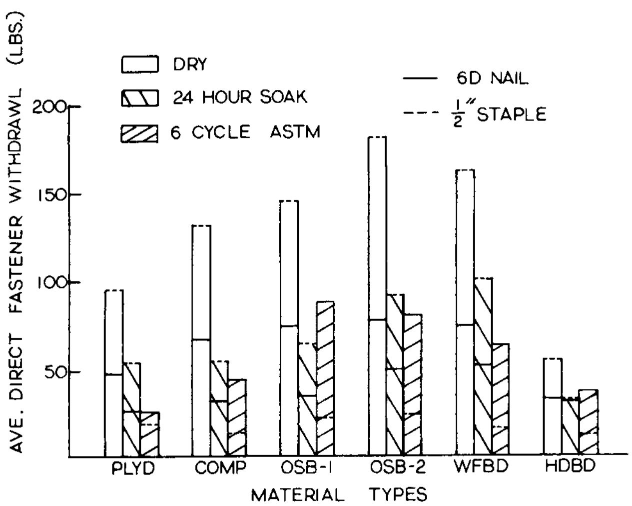

Figure 5. — The average direct 6-penny nail and 1/2-inch staple withdrawal resistance of six wood-based materials at three exposure conditions.

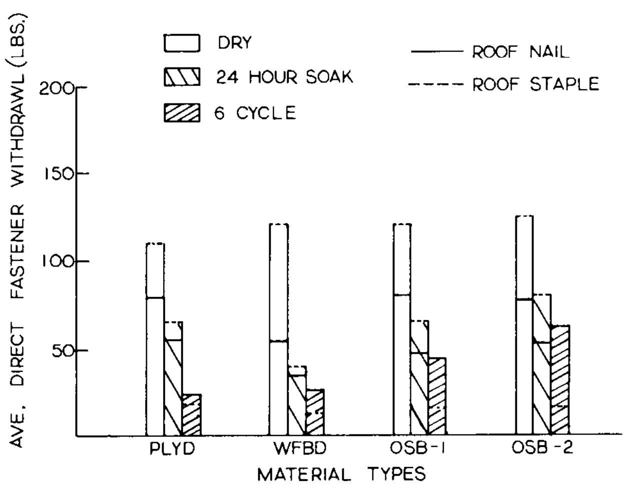

Figure 6. — The average direct roof nail and staple resistance values of four roof sheathing panels at three exposure conditions.

through strength properties of all nine wood-based panels.

Direct nail and staple withdrawal resistance

Materials

For waferboard, OSB-1, and OSB-2, the specimens with 1/2-inch thickness obtained higher direct nail and staple withdrawal resistance values than the 7/16-inch-thick roof sheathing specimens (Table 2). On the average, the composite plywood, waferboarda, and two OSB specimens performed equal to or better than CD-grade plywood when 6-penny nails and 1/2-inch staples were used at dry and 6-cycle aged conditions. The 7/16-inch-thick embossed hardboard siding outperformed the CD-plywood in the accelerated-aged condition.

The average nail direct withdrawal resistance values of all nine wood-based materials appear to meet the minimum requirement of various specifications or current standards (Table 1). The only material to come close to falling below the standard was the 7/16-inch waferboard in the water-soaked condition.

At the 6-cycle aged condition, most of the waferboard and OSB panels appeared to outperform the veneered

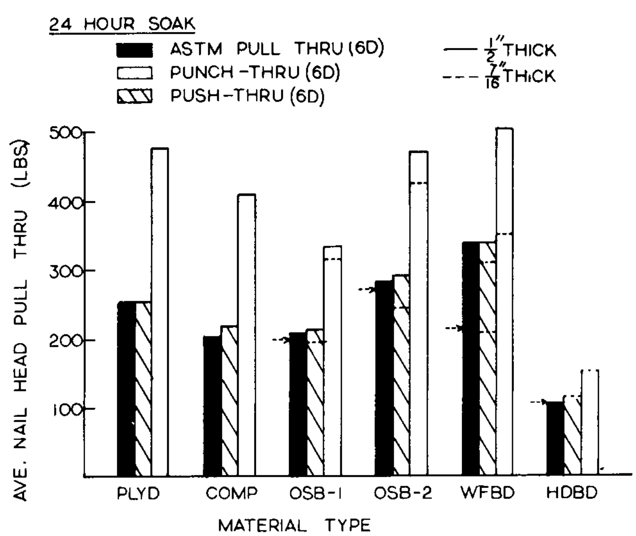

Figure 7. — The effects of three test methods on nailhead pull-through resistance of six wood-based materials with two thicknesses (24-hr. water-soaked condition).

composite and plywood panels, which had retentions of only 51 to 66 percent, respectively, of their dry 6-penny nail withdrawal strength values. All OSB and waferboard, except the 7/16-inch waferboard, retained at least 84 percent of their original values. This poor performance of the 7/16-inch waferboard could be due in part to the high swelling of the wood particle materials (Table 4) and the resulting increase in wood fiber pressure against the 6-penny nail shank.

Fasteners and exposure conditions

In comparing four different types of fasteners in three exposure conditions, the 15/16-inch crown roof staple exhibited the highest values in both the dry and 24-hour soaked conditions, followed by the 1/2-inch staple, roof nail, and 6-penny nail. In the 6-cycle aged condition, the 6-penny nail demonstrated the highest withdrawal values followed by the roof nail and two staples, which obtained about the same level of lower values.

The statistical analysis shows that the 1/2-inch crown staple withdrawal values were consistently higher than those of the 6-penny nail at the dry condition. When comparing the staple and nail values, the differences ranged from a low of 37 percent for the 7/16-inch OSB-2, to a high of 58 percent for the 1/2-inch OSB-2. In roof sheathing materials at the dry condition, the 15/16-inch crown roof staple had greater resistance values than the roof nail.

Table 3 shows that, at the dry condition, the roof staple obtained an average of 51 percent higher withdrawal resistance than the roof nail in 7/16-inch waferboard roof sheathing materials. After specimens were exposed to the 24-hour water-soak, the two types of staples also yielded higher maximum withdrawal values than the two types of nails. However, the overall difference between these two fasteners in the 24-hour soaked condition was markedly decreased, (by about one-half).

The situation in the 6-cycle aged condition was completely reversed from what was found in the dry and 24-hour soaked conditions. Tables 2 and 3 and Figures 5 and 6 show that both the 6-penny nail and the roof nail had better withdrawal resistance in accelerated-aged wood-based materials than the two staples. In specimens of two 7/16-inch OSBS, the roof nail performed about 70 percent better in direct withdrawal than the roof staple. The plywood showed a difference of only 15 percent. It seems that more wood fibers were separated from the staple legs than from the nail shank as a result of repeated shrinkage and swelling during the accelerated-aging process. Evidently, after the 24-hour water soaking, the compressive stress exerted on staple legs by wood fibers at dry condition was somewhat reduced. The compressive stress was drastically reduced when specimens were exposed to the 6-cycle aging condition. It was also noted that most of the 6-penny nails developed discoloration and rust.

It is worth pointing out that in 24-hour soaked and 6-cycle aged conditions, both the 6-penny nails and roof nails retained a greater percent of their original withdrawal resistance than did the two types of staples, although the staples had withdrawal values higher than the nails in the original dry condition.

Fastener pull-through resistance

Materials

The test results of both nailhead and staple crown pull-through on nine wood-based panel materials are shown in Table 2 and Figure 7. Significantly higher average values were obtained from 1/2-inch-thick specimens than 7/16-inch-thick specimens of waferboard, OSB-1, and OSB-2 panel products, except the OSB-1 specimens in staple test.

In nailhead pull-through, push-through, and staple crown pull-through tests, the 1/2-inch-thick unsanded OSB-2 and waferboard obtained average values equal to or better than CD-grade 1/2-inch-thick plywood at the dry and 24-hour soaked conditions. Similar trends are shown in the 6-cycle aged condition for OSB-2 specimens (Table 2). All materials except the embossed hardboard meet the current standards of minimum requirement for nailhead pull-through values (Table 1).

Test methods and exposure condition

Among three nailhead test methods, both the push-through and punch-through methods resulted in higher test values than the ASTM pull-through method. The difference was especially large between values obtained from the pull-through method and those obtained from the steel rod punch-through method. The 1/4-inch steel rod punch-through method gave much greater maximum resistance values than any of the other three test methods. This is probably due to the fact that the specimens for the punch-through test did not have wood fibers dam-

TABLE 4. — *Thickness swelling and density changes of nine wood-based sheathing materials exposed to 24-hour soak and 6-cycle aging conditions.*

Nominal thickness	Material type	Dry		24-hour water-soak		ASTM 6-cycle aging	
		Thickness[a]	Density[b]	Thickness swelling	Density change	Thickness swelling	Density change
(in.)		(in.)	(lb./ft.^{3})	(%)			
1/2	CD-plywood	0.479	32.8	6	+31	4	−5
1/2	Veneered composite	0.488	38.7	10	+33	14	−15
1/2	Waferboard	0.503	42.5	13	+11	36	−27
1/2	OSB-1	0.526	42.8	17	+45	21	−20
1/2	OSB-2	0.510	43.7	11	+16	20	−16
7/16	Waferboard	0.439	39.4	22	+25	43	−30
7/16	OSB-1	0.442	41.2	15	+21	28	−23
7/16	OSB-2	0.424	44.2	18	+34	28	−24
7/16	Embossed hardboard	0.396	42.3	3	+9	7	−6

[a] Each value is an average of 40 measurements made from eight 4- by 8-foot samples.
[b] Density based on volume and weight at 68°F and 65 percent RH condition.

aged by nails prior to the test, as occurred in the other three test methods, i.e., there were no broken fibers before the steel rod was punched through the specimen.

After exposure to the 24-hour soaked condition, all specimens lost between 10 and 30 percent of their fastener pull- and push-through resistance values at dry condition. The embossed hardboard showed a relatively higher degree of strength retention than many other materials.

At the dry condition, most of the staple crown pull-through values were lower than the nailhead pull-through values. At the 24-hour soaked condition, no pull-through resistance difference is shown between the 6-penny nail and the 1/2-inch staple. Less than 5 percent average value difference existed between these two fasteners in the 6-cycle aged specimens.

Table 2 also shows that the nailhead push-through and the 1/2-inch crown pull-through showed no statistical difference from each other after the 24-hour soak and 6-cycle aging. This indicates that the newly developed nailhead push-through test method is a good substitution for the ASTM nailhead pull-through method.

Summary

The panel type, exposure condition, fastener type, and test method significantly affected both the direct nail and staple withdrawal, and the nailhead and staple-crown pull-through resistance properties in five 1/2-inch-thick and four 7/16-inch-thick wood-based panel products.

In direct withdrawal resistance, both the 1/2-inch crown staple and the 15/16-inch crown roof sheathing staple showed significantly higher values than the 6-penny common nail and the roof nail, in the dry and 24-hour water-soaked conditions. However, nails performed better than staples in specimens at the 6-cycle accelerated-aged condition. Nails also retained a greater percent of their original withdrawal value than did staples, but staples had values higher than nails at the original dry condition.

On the average, in direct withdrawal resistance, with both the 6-penny nail and the 1/2-inch crown staple, veneered composites, waferboards, and two OSB specimens performed equal to or better than the 1/2-inch-thick CD-grade plywood sheathing, in both the dry and 6-cycle aged tests. In the 6-cycle accelerated-aged condition, the 7/16-inch embossed hardboard outperformed the plywood in the direct 6-penny nail withdrawal tests.

At 6-cycle aged conditions, plywood and veneered composites had a retention of only 50 to 65 percent of their 6-penny nail withdrawal value at dry conditions. The waferboard and two OSB specimens retained at least 70 percent of their original values.

For waferboard, OSB-1, and OSB-2, specimens with 1/2-inch thickness gave higher direct nail and staple withdrawal and head pull-through resistance values than 7/16-inch-thick roof sheathing specimens, at three exposure conditions.

The average nail and staple direct withdrawal and pull-through resistance values of most of the nine panel products appear to meet the minimum requirement of those specifications cited in Table 1.

In simulating the nailhead pull-through tests, both the push-through and punch-through methods resulted in higher test values than the ASTM method. But the difference was relatively small between values obtained from the ASTM method and those obtained from the push-through method, especially at 24-hour water-soaked and 6-cycle aged conditions.

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