ROOFING NAIL PERFORMANCE IN STRUCTURAL FLAKEBOARDS

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ABSTRACT

Phenolic structural flakeboard might be commonly used as roof and wall sheathing and as subfloor panels in housing. Important in the acceptability of such flakeboard as roof sheathing is the ability to hold the shingles in place. Failure of the roofing nails to perform this function is exhibited by nail "pop"—the slow natural withdrawal of a nail due to shrinkage and swelling of the panel and shingles. Such tendency of 1-inch roofing nails that had been driven into and through commercial and experimental flakeboards was compared with that in 5-ply exterior grade Douglas-fir plywood. Cyclic moisture conditions (including freeze-thaw) were generated employing an ASTM accelerated aging procedure. Nail pop was not evidenced in any of the panels. Rather, the nailheads were observed to subside further into shingle and panel surfaces with increasing exposure. This subsidence was highly correlated to the thickness swell of the panels. It can be concluded that nail pop will not be a problem with nails driven through the flakeboard.

Keywords: Panels, plywood, flakeboard, fasteners, roof sheathing, nail withdrawal, durability, accelerated aging.

INTRODUCTION

Considerable research has been done on development of phenolic flakeboard for sheathing and subfloor in housing. Important in the acceptability of such flakeboard for roof sheathing is maintaining the integrity of a shingle surface by minimizing nail popping.

This paper reports the movement of roofing nails driven into commercial and experimental phenolic flakeboards that had been exposed to a severe environment, as compared to nail movement in similarly exposed 5-ply exterior grade Douglas-fir plywood. An accelerated aging procedure was used to generate cyclic moisture conditions. This procedure included freeze-thaw conditions (ASTM D 1037 six cycle).

BACKGROUND

Nail "pop," "creep," or "backout" are synonymous terms used to describe increased protrusion of the nailhead (Fig. 1) which was originally driven flush with a surface (Suddarth and Angleton 1956). The phenomenon is initially associated with drying of wood into which a nail is driven, but repeated cycling between high and low moisture content causes additional outward movement, or "pop," of the nails driven into lumber (Suddarth and Angleton 1956; Stern 1951; Giese and Henderson 1947). Though special surfacing or shaping of nail

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[1] Retired.

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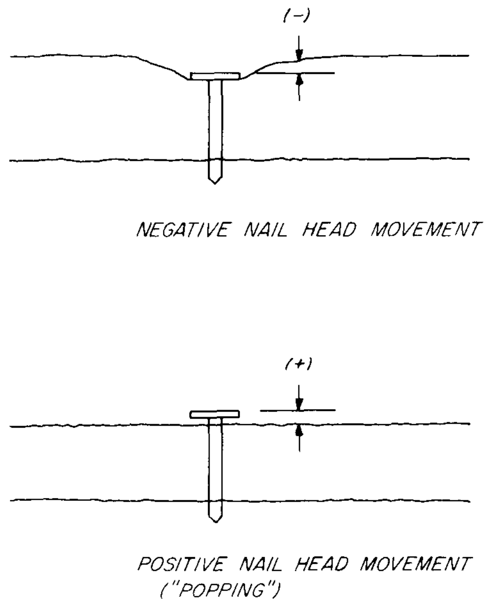

FIG. 1. Illustration of nail popping positive nail movement in panels, as contrasted with negative nail movement.

shanks is believed to aid in the elimination of nail popping (Stern 1950, 1951, 1954a, b), Suddarth and Angleton (1956) found the nail shape, surface condition, or diameter influence amount of pop very little. Of major influence was depth of penetration of the nail tip. Nail pop was found directly proportional to the depth of penetration; the shrinkage occurring over half the board thickness was the upper limit to the maximum amount of pop to be expected (Suddarth and Angleton 1956). Completely penetrating nails in roof sheathing popped less than nails not driven to full penetration.

EXPERIMENTAL PROCEDURE

Specimens consisting of a section of ½-inch exterior flakeboard and plywood sheathing material, standard weight (240 lb. per 100 sq. ft.) and 1-inch galvanized roofing nails were fabricated as shown in Fig. 2. Panel materials evaluated included:

1. Commercial phenolic flakeboard A.
2. Commercial phenolic flakeboard B.
3. FS-structural flakeboard (Douglas-fir residues).
4. Lodgepole pine 3-layer flakeboard (nonsteam stabilized).
5. Cottonwood particleboard.
6. Lodgepole pine 3-layer flakeboard (steam stabilized).
7. Plywood, exterior (5-ply) Douglas-fir.

Panel properties are described in the Appendix. Six specimens were cut from each panel and subjected to five full exposure cycles (Suddarth and Angleton

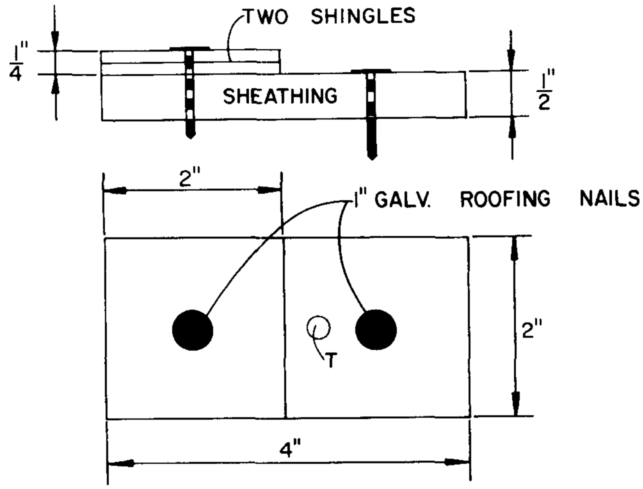

FIG. 2. Panel-shingle specimen employed in accelerated aging tests. Point "T" on specimen indicates location of thickness swell measurement.

1956) as specified by Paragraph 120 on accelerated aging, ASTM D 1037. Each cycle of this procedure consists of:

(1) Immersion in water at 120 F for 1 hour.
(2) Spray steam and water vapor at 200 F for 3 hours.
(3) Store at 10 F for 20 hours.
(4) Heat at 210 F in dry air for 3 hours.
(5) Spray again with steam and water vapor at 200 F for 3 hours.
(6) Heat in dry air at 210 F for 18 hours.

Deformation of the nailhead upward or downward with respect to shingle surface and panel surface was measured at the end of the third and sixth steps of each

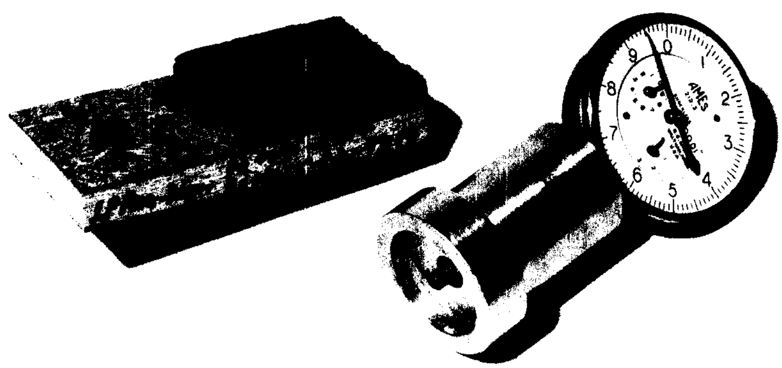

FIG. 3. Panel-shingle specimen and deformation gage employed to detect nailhead movement with respect to adjacent surfaces.

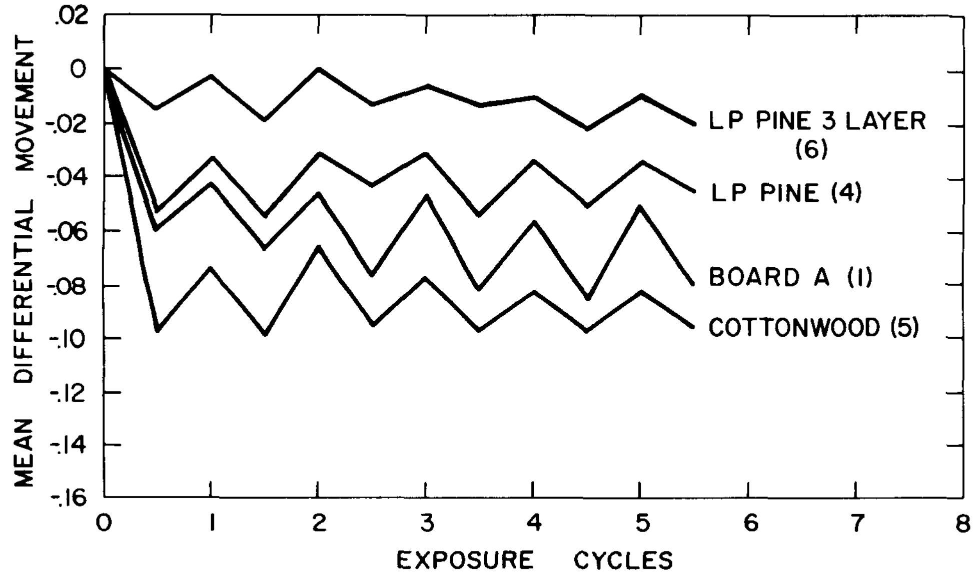

FIG. 4. Mean differential movement of nailheads with respect to panel surfaces for four panel types.

accelerated aging cycle. Change in thickness of the panel was recorded at these times as well. The deformation gage is illustrated in Fig. 3.

RESULTS

Results of the exposure tests were most surprising. Nail withdrawal or pop was not observed in any specimens tested. The mean differential movement with

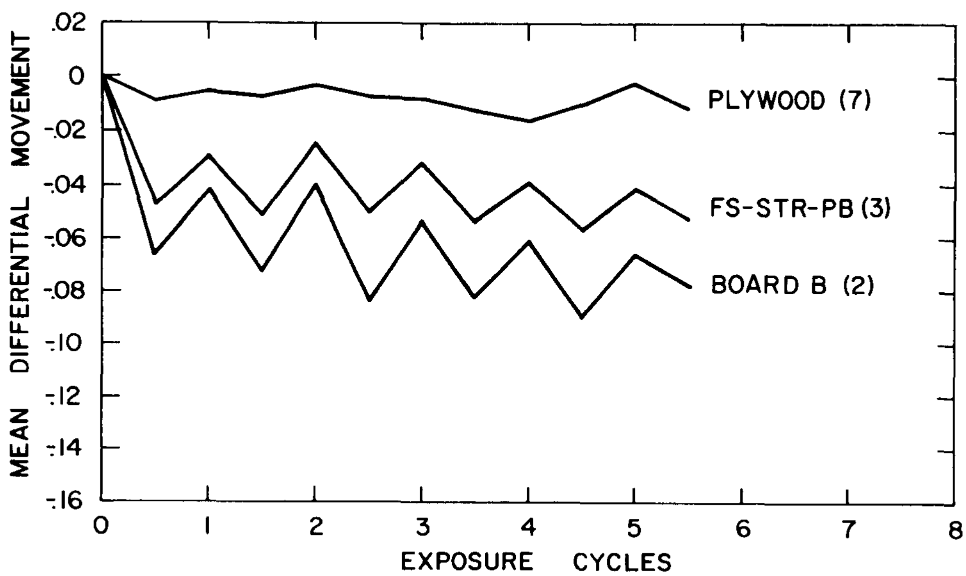

FIG. 5. Mean differential movement of nailheads with respect to panel surface for three panel types.

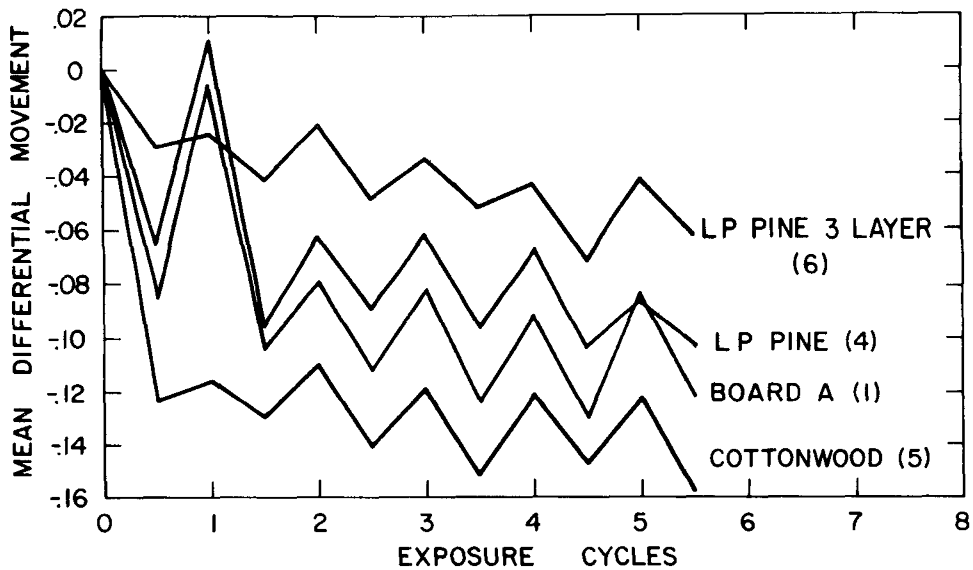

FIG. 6. Mean differential nailhead movement with respect to shingle surface for four panel types.

respect to shingle or panel surfaces was negative rather than positive (the "popping" case). This is illustrated in Fig. 1.

The mean differential movements of the nails with respect to either shingle surface or panel surface are graphed in Figs. 4–7. The mean thickness change is similarly graphed in Figs. 8–9. (Tabular means and standard deviations for each panel are included in Appendix II.)

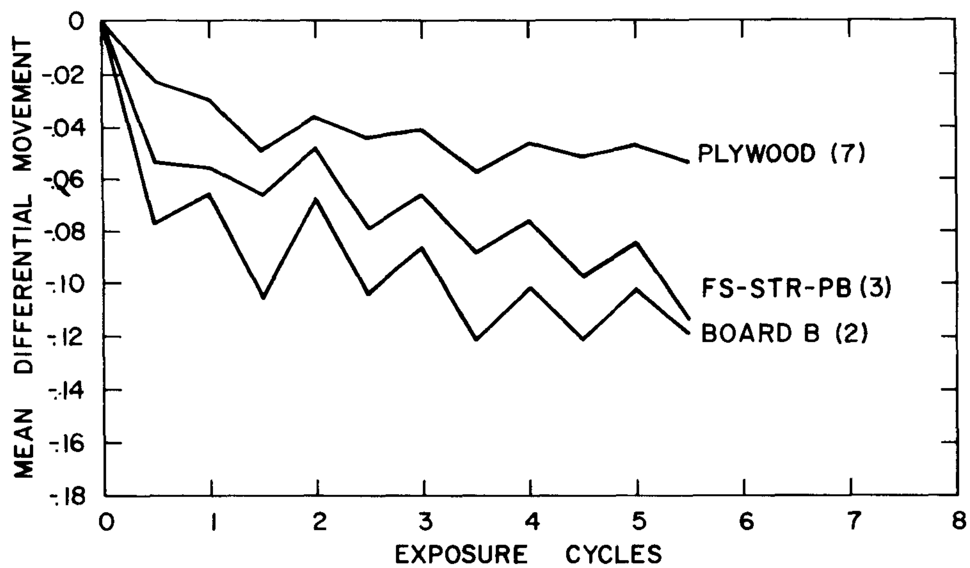

FIG. 7. Mean differential nailhead movement with respect to shingle surface for three panel types.

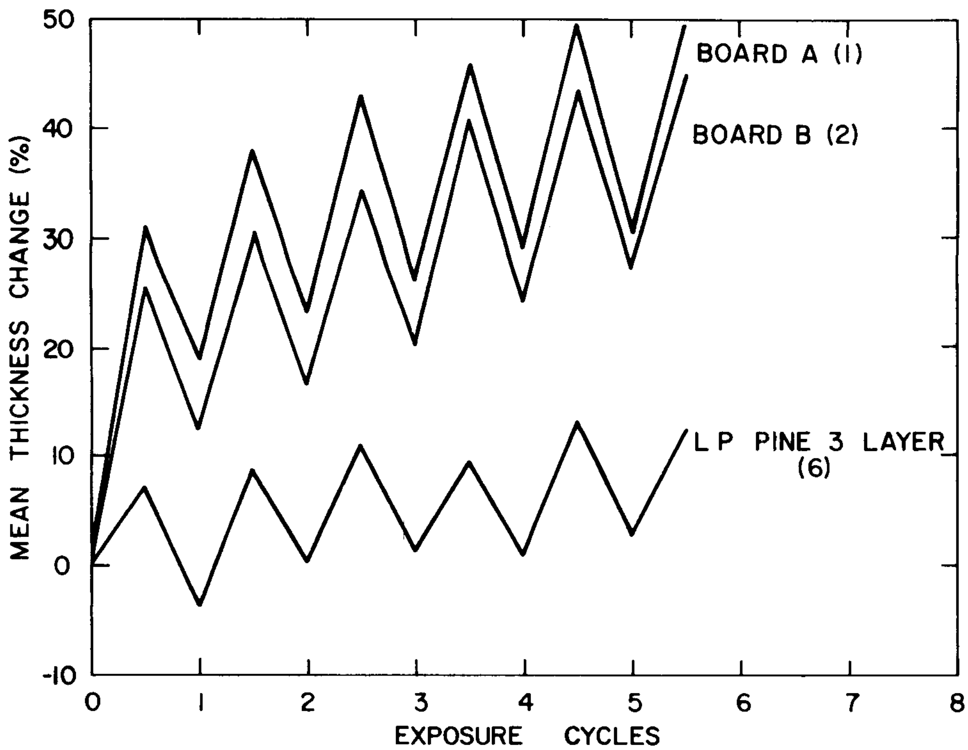

FIG. 8. Mean panel thickness change with exposure cycles for three panel types.

A representative specimen of each was photographed after the accelerated aging tests and is shown in Fig. 10. The indentation of the nailhead with respect to specimen surface is shown in Fig. 11.

All specimens maintained their structural integrity following the accelerated aging exposure even though some swelled substantially in thickness. Even though all specimens maintained their integrity, shingle pieces "cupped" substantially during treatment. This "cupping" of the shingles made accurate measurement of nailhead movement difficult, and interpretation of the results should be approached with caution.

DISCUSSION

Nail movement

The difference in dimension between panel surface and nailhead (nailhead movement) as shown in Figs. 4–5 is seen to approach a steady response level in the same way as panel thickness swell (Figs. 8–9) after five cycles of exposure to ASTM D 1037 accelerated aging. The fully penetrated nails evidently restrain local swelling of the panels during the exposure and give the nailheads the appearance of being indented (Fig. 11). Such behavior should be well correlated then to panel thickness swell. This is indeed the case as shown in Fig. 12. The correlation coefficient is 0.963 for maximum thickness change observed versus nailhead differential movement during cyclic exposures.

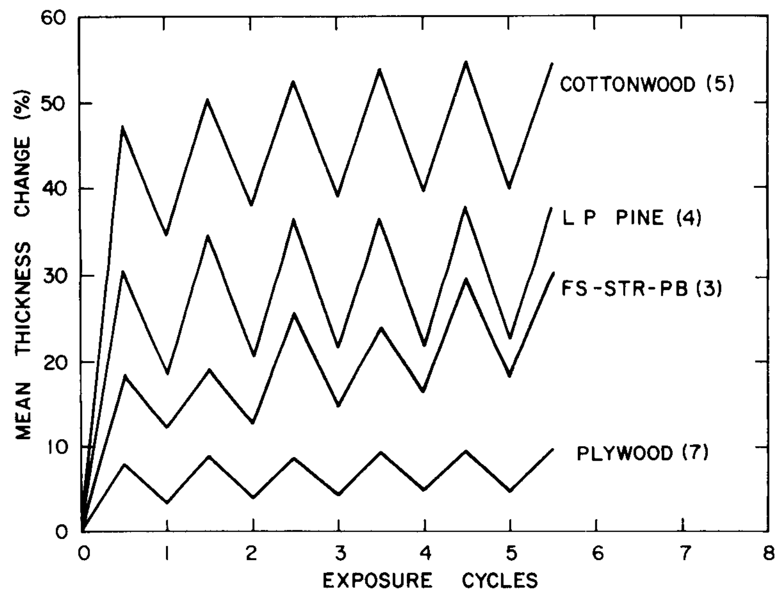

FIG. 9. Mean panel thickness change with exposure cycles for four panel types.

If the fully penetrating nail does indeed restrain local swelling of the panel, then the indentation of the head is a direct function of panel thickness swell. The equation covering this case (Fig. 13) can be approximated to be:

$$DM = \frac{1}{2}(T_S - T_0)$$

where DM = the differential movement

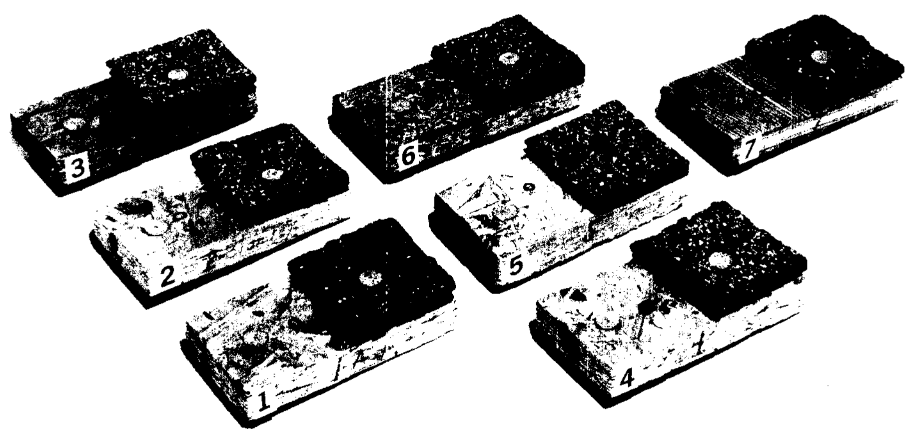

FIG. 10. Photo of typical specimens of each type after all accelerated aging cycles.

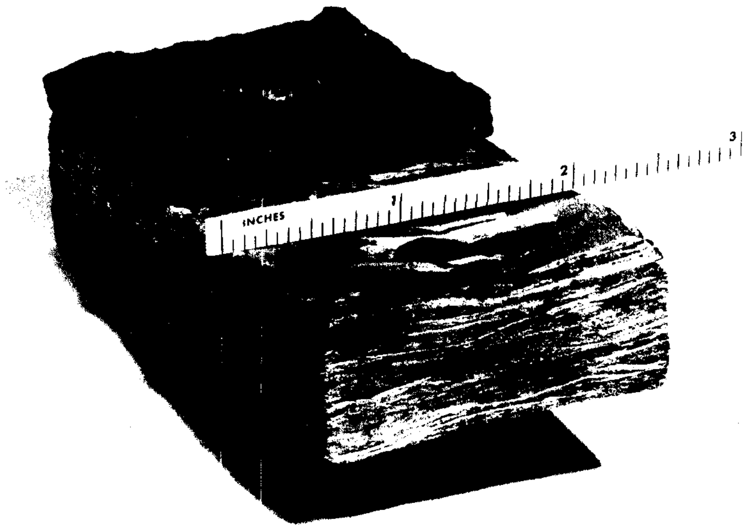

FIG. 11. Specimen after exposure to accelerated aging illustrating nail indentation with respect to specimen surface.

T_s = swelled panel thickness
T_0 = initial panel thickness

(This is an approximation because the equation assumes (1) full restraint of swell along the length of the nail, and (2) the swelling of the panel is symmetric with respect to the center of the panel.) For further use this equation can be converted to a function of T_s in percent and DM as percent of initial panel thickness:

$$\frac{DM}{T_0} = \tfrac{1}{2}[(T_s/T_0) - 1]$$

or

$$\frac{DM}{T_0}(\%) = \tfrac{1}{2}PTC(\%)$$

where PTC is panel thickness change (%). A plot of actual differential nailhead movement versus panel thickness change is shown as a solid line in Fig. 12. The theoretical curve given by the above equation is shown by a dashed line. The difference between the two lines illustrates the error of assuming full local panel swelling restraint by the nail, and the error in the approximating equation.

Mean nailhead movement evidenced by subsidence relative to shingle surfaces is shown in Figs. 6–7. The results are generally twice that observed for movement with respect to the panel surfaces. This may be attributed to a curling and flow

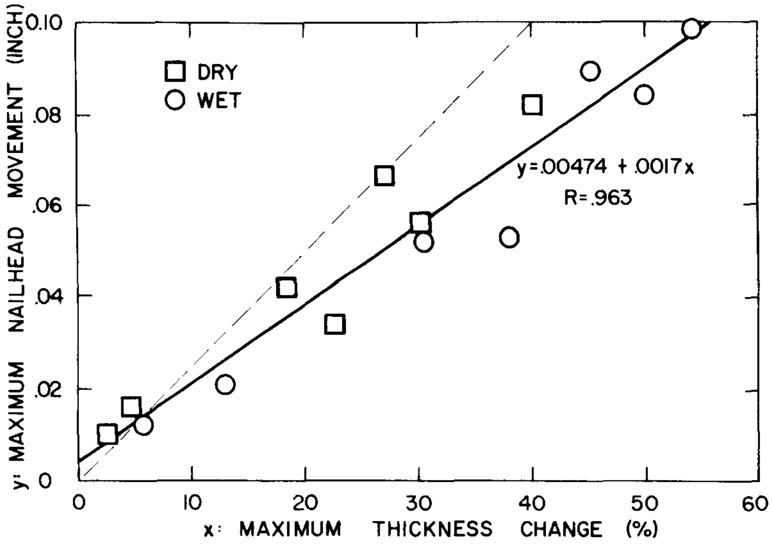

FIG. 12. Maximum recorded mean differential nailhead movements (with respect to panel surfaces) as a function of maximum mean observed panel thickness change. □: Refers to movement at end of a dry half-cycle. ○: Refers to movement at end of a wet half-cycle.

of the shingle pieces about the nailhead for a panel that is shrinking and swelling with the cyclic exposure conditions.

Panel thickness swell

The mean change in thickness of the panels during the accelerated aging is shown in Figs. 8–9. After the five cycles of aging, the steam-stabilized lodgepole pine (6), cottonwood (5), lodgepole pine (nonstabilized) (4), and plywood (7) have apparently achieved a steady thickness response to further cycles. Commercial panels (1) and (2), and the FS-flakeboard (3) appear to be continuing to swell.

Steam stabilization, as evidenced by the lodgepole pine panel (6), is effective in minimizing thickness swell. The change for a panel of this type appears equivalent to plywood.

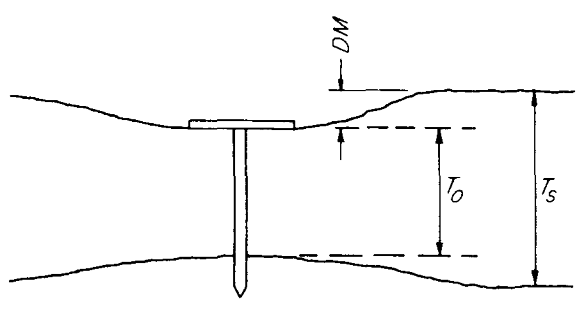

FIG. 13. Differential movement of nailhead with respect to panel thickness.

CONCLUSIONS

Nail "popping" did not occur in the structural flakeboards and exterior plywood investigated under ASTM D 1037 cyclic exposure conditions. The 1-inch roofing nails fully penetrated the ½-inch panels and shingles employed. This penetration created local restraint of the shrinking and swelling of panels giving the appearance of subsidence or indenting of the nailheads into the surface. Such behavior reaches a steady response after five cycles of exposure for all panel types except the Forest Service flakeboard and commercial panels. The close correlation of such subsidence of nailhead into panel or shingle surface and thickness swell indicates that thickness swell governs the behavior.

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APPENDIX I

Panel properties

1. Flakeboard (commercial).
2. Flakeboard (commercial).
3. FS structural 3-layer Douglas-fir residue flakeboard (Lehmann and Geimer 1974).

In constructing the three-layer boards, all material was screened on a ½-inch mesh screen. Sufficient large flakes (those retained on the screen) were used for the panel faces, and the remaining large flakes and all smaller flakes (passing through the screen) were used in the core. The face flake mixture was composed of about 85% disk flakes and 15% ring flakes. Face:core:back ratios were 15:70:15% of panel weight.

Screening preceded resin application; thus resin was applied separately to face and core fractions.

Boards were prepared holding the following manufacturing factors constant:

Flake size	: 0.020 inch thick by 2 inches long, variable width
Panel size	: ½ by 24 by 28 inches
Panel density	: 40 pounds per cubic foot (OD weight, volume at test basis)
Resin type and amount	: 5% phenol-formaldehyde (PF) resin solids (based on OD weight of flakes)
Wax type and amount	: 1% wax solids (based on OD weight of flakes)
Mat MC	: 10.0 ± 0.5%
Press temperature	: 350 F
Press time	: 10 minutes (1 minute to thickness)

4. Lodgepole pine 3-layer flakeboard (Heebink 1974).
   Faces (50% of panel): 0.020- by 2-inch flakes from disk flaker, 4% phenol resin, 1% wax.
   Core (50%): slivers, hammered chips, 2% phenol resin, 1% wax. Surfaces unsanded.
5. Cottonwood homogenous flakeboard, 42 pounds per cubic foot hammermilled 0.20- by 2-inch + 1/32 disk flakes screened; 3% phenolic resin, 1% wax.
   Flakes from mixed wood sections greater than 3-inch diameter including bark.
6. Lodgepole pine 3-layer flakeboard: post-treated, 40 pounds per cubic foot.
   Faces (40%): Fines passing 1/16 screen (from core material), 8% phenolic resin, 1% wax (60%).
   Core (60%): 0.020- by 2-inch ringflakes, + 1/16 screen, 4% phenolic resin, 1% wax.
   Panel steam-stabilized following fabrication (Heebink and Hefty 1969) employing 360 F steam for 10 minutes.
7. Douglas-fir 5-ply exterior grade plywood.

APPENDIX II. *Mean standard deviation values for differential nailhead movement and panel thickness change.*

Measurement*	Cycle no. 1				Cycle no. 2				Cycle no. 3			
	Wet		Dry		Wet		Dry		Wet		Dry	
	Shingle	Board	Shingle	Board	Shingle	Board	Shingle	Board	Shingle	Board	Shingle	Board
					LP PINE							
MDM	−0.065	−0.052	0.011	−0.032	−0.095	−0.053	−0.063	−0.030	−0.089	−0.042	−0.062	−0.030
SDM	−0.009	−0.009	−0.042	−0.012	−0.009	−0.012	−0.012	−0.007	−0.010	−0.017	−0.018	−0.007
MTC pct	30.67		18.57		34.77		20.60		36.64		21.74	
SDTC	2.45		1.48		2.12		1.78		2.05		1.76	
					BOARD A							
MDM	−0.084	−0.059	−0.005	−0.041	−0.104	−0.065	−0.079	−0.045	−0.112	−0.075	−0.082	−0.046
SDM	−0.014	−0.014	−0.057	−0.007	−0.017	−0.011	−0.020	−0.009	−0.023	−0.009	−0.017	−0.008
MTC pct	31.18		19.38		38.07		23.38		42.81		26.64	
SDTC	2.27		5.38		8.97		7.13		6.69		6.56	
					LP PINE 3- LAYER							
MDM	−0.029	−0.014	−0.024	−0.002	−0.042	−0.018	−0.021	−0.001	−0.049	−0.012	−0.034	−0.005
SDM	−0.007	−0.003	−0.004	−0.003	−0.006	−0.003	−0.010	−0.011	−0.011	−0.003	−0.014	−0.004
MTC pct	7.21		−3.87		8.56		0.29		10.99		1.18	
SDTC	0.93		8.69		1.65		0.21		1.30		0.86	
					COTTONWOOD							
MDM	−0.123	−0.096	−0.116	−0.072	−0.130	−0.098	−0.110	−0.065	−0.141	−0.095	−0.119	−0.076
SDM	−0.018	−0.020	−0.019	−0.015	−0.024	−0.019	−0.023	−0.017	−0.019	−0.021	−0.014	−0.015
MTC pct	47.56		34.65		50.38		38.01		52.18		38.97	
SDTC	8.72		7.06		8.59		8.20		8.55		7.86	

APPENDIX II. *Continued.*

Measurement*	Cycle no. 1				Cycle no. 2				Cycle no. 3			
	Wet		Dry		Wet		Dry		Wet		Dry	
	Shingle	Board	Shingle	Board	Shingle	Board	Shingle	Board	Shingle	Board	Shingle	Board
					PLYWOOD							
MDM	−0.023	−0.009	−0.029	−0.005	−0.049	−0.007	−0.036	−0.003	−0.044	−0.007	−0.041	−0.008
SDM	−0.006	−0.002	−0.009	−0.004	−0.014	0.003	−0.014	−0.008	−0.013	−0.004	−0.011	−0.004
MTC pct	8.01		3.08		8.90		3.97		8.70		4.07	
SDTC	1.16		1.14		1.39		1.25		0.77		1.25	
					FS-STR-PB							
MDM	−0.053	−0.047	−0.055	−0.029	−0.066	−0.051	−0.048	−0.024	−0.079	−0.050	−0.066	−0.032
SDM	−0.005	−0.011	−0.016	−0.006	−0.014	−0.011	−0.012	−0.009	−0.017	−0.020	−0.010	−0.007
MTC pct	18.94		12.21		19.17		12.97		25.75		14.97	
SDTC	2.14		3.28		3.48		2.68		5.07		3.15	
					BOARD B							
MDM	−0.077	−0.066	−0.065	−0.041	−0.105	−0.072	−0.067	−0.040	−0.104	−0.083	−0.086	−0.054
SDM	−0.019	−0.009	−0.015	−0.008	−0.025	−0.013	−0.015	−0.010	−0.027	−0.013	−0.020	−0.010
MTC pct	25.77		12.26		30.44		16.62		34.76		20.08	
SDTC	2.50		1.56		6.49		3.85		5.22		4.49	

* MDM: Mean differential nailhead movement; SDM: Standard deviation of differential movement; MTC: Mean thickness change; SDTC: Standard deviation of thickness change.

APPENDIX II. *Continued.*

Measurement*	Cycle no. 4				Cycle no. 5				Cycle no. 6	
	Wet		Dry		Wet		Dry		Wet	
	Shingle	Board	Shingle	Board	Shingle	Board	Shingle	Board	Shingle	Board
					LP PINE					
MDM	−0.096	−0.053	−0.067	−0.033	−0.104	−0.050	−0.086	−0.034	−0.103	−0.045
SDM	−0.021	−0.005	−0.024	−0.005	−0.014	−0.007	−0.011	−0.014	−0.015	−0.014
MTC pct	36.61		22.00		37.91		22.67		37.64	
SDTC	2.21		1.63		2.24		1.95		2.10	
					BOARD A					
MDM	−0.124	−0.081	−0.091	−0.056	−0.129	−0.084	−0.084	−0.050	−0.122	−0.080
SDM	−0.007	−0.006	−0.014	−0.006	−0.014	−0.009	−0.015	−0.008	−0.015	−0.006
MTC pct	45.80		29.04		49.54		30.39		49.90	
SDTC	8.27		5.98		6.22		6.68		6.05	
					LP PINE-3 LAYER					
MDM	−0.052	−0.012	−0.043	−0.009	−0.071	−0.021	−0.041	−0.009	−0.062	−0.020
SDM	−0.017	−0.011	−0.008	−0.003	−0.009	−0.005	−0.008	−0.006	−0.017	−0.009
MTC pct	9.37		0.87		12.96		2.65		12.15	
SDTC	1.00		0.65		0.60		1.00		1.35	
					COTTONWOOD					
MDM	−0.152	−0.097	−0.121	−0.082	−0.147	−0.097	−0.122	−0.082	−0.158	−0.096
SDM	−0.028	−0.017	−0.026	−0.015	−0.023	−0.020	−0.026	−0.017	−0.025	−0.019
MTC pct	53.78		39.84		54.78		40.34		54.41	
SDTC	9.04		7.76		9.05		8.04		9.39	

APPENDIX II. *Continued.*

Measurement*	Cycle no. 4				Cycle no. 5				Cycle no. 6	
	Wet		Dry		Wet		Dry		Wet	
	Shingle	Board	Shingle	Board	Shingle	Board	Shingle	Board	Shingle	Board
					PLYWOOD					
MDM	−0.057	−0.012	−0.046	−0.016	−0.051	−0.010	−0.047	−0.002	−0.054	−0.011
SDM	−0.018	−0.004	−0.015	−0.003	−0.019	−0.004	−0.017	−0.008	−0.019	−0.004
MTC pct	9.33		4.97		9.47		4.67		9.60	
SDTC	1.35		1.54		1.25		1.72		1.60	
					FS-STR-PB					
MDM	−0.088	−0.053	−0.076	−0.039	−0.097	−0.056	−0.084	−0.041	−0.112	−0.052
SDM	−0.014	−0.011	−0.012	−0.008	−0.020	−0.010	−0.014	−0.006	−0.015	−0.013
MTC pct	24.17		16.49		29.71		18.42		30.38	
SDTC	9.56		3.04		4.42		2.29		4.17	
					BOARD B					
MDM	−0.121	−0.082	−0.101	−0.061	−0.121	−0.089	0.102	0.066	−0.119	−0.077
SDM	−0.030	−0.012	−0.028	−0.007	−0.024	−0.007	−0.032	−0.007	−0.037	−0.015
MTC pct	40.92		24.15		43.68		27.23		45.37	
SDTC	4.68		3.47		2.76		3.23		3.08	