CREEP BEHAVIOR OF FLAKEBOARDS MADE WITH A MIXTURE OF SOUTHERN SPECIES

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ABSTRACT

Deflection of oriented flakeboards, random flakeboards, and southern pine plywood was evaluated for small size bending specimens and concentrated loads applied to panels nailed on framing lumber. The flakeboards contained a mixture of southern hardwoods and pine; the plywood was 3-ply ½-inch and 4-ply ⅝-inch construction. Tests of both panel directions, all load levels and RH cycles showed plywood bending specimens with the smallest deflection increase, and both random and oriented flakeboard bending specimens showed more increases. The plywood relative creep averaged 1.76; the flakeboard relative creep averaged 2.26 and 2.30 for oriented and random construction, respectively. For the concentrated loading, oriented flakeboard panels with the smallest initial deflection had the largest creep after 32 days. Random flakeboard and plywood showed less creep.

Keywords: Deflection, flakeboard, southern pine plywood.

INTRODUCTION

Rheological properties of viscoelastic materials have been researched. These time-dependent properties are often obtained with experimental methods related to stress relaxation and creep studies (Hoyle and Adams 1975; Lyon and Schniewind 1978; Mukudai and Taguchi 1980a, b; Saito et al. 1979). Often temperature and moisture effects are incorporated into the experimental methods (Dinwoodie et al. 1981; Hirai et al. 1981; Lehmann et al. 1975). By combining simple models such as ideal elastic springs, dashpots, Maxwell elements, and Voigt elements, mathematical models of the stress-time relationship are possible. Such modeling and experimentation would relate to clear, straight grain wood intended for structural application. However, the increasing importance of composite wood materials in structural applications requires additional data bases and models.

Haygreen et al. (1975) reviewed creep behavior of composite products. Some of their conclusions are: (1) sorption generally increased relative creep in particleboard; (2) fluctuating relative humidity RH increased relative creep a considerable amount more than a constant relative humidity; (3) both adsorption and desorption phases increased the rate of creep deformation; (4) ratio of creep for whole wood : particleboard : hardboard is approximately 1:4:5; (5) flexural creep is proportional to stress (Linear) below approximately 20% of the bending strength; (6) amount of creep that develops is very sensitive to the highest RH; and (7) flexural creep behavior under concentrated load is qualitatively similar to that under simple flexural stress. Therefore, investigations related to the creep behavior of proposed structural panels should incorporate both high RH and cyclic RH treatments.

Price (1978) fabricated and evaluated large (4- by 8-foot) flakeboard panels using the procedure of Hse et al. (1975). The panel evaluation consisted of plate

TABLE 1. *Flake and panel fabrication specifications for 4- by 8-foot structural flakeboards.*

Property	Specifications
Species	20% by weight of southern pine, sweetgum, red oak, white oak, and hickory
Flake generation	From 6-in. bolt on shaping lathe
Flake length	3 in.
Core flakes	0.025-in.-thick, milled for width reduction
Face flakes	0.015-in.-thick, random bolts heated to 160 F oriented bolts at ambient temperature
Flake moisture content	3 to 4%
Mat construction	Layered with each face ¼ of total weight
Surface treatment	Sprayed 4.32 g of water/ft^2 surface area
Resin binder	6% liquid phenol-formaldehyde resin[1]
Wax	1% wax solids from wax emulsion

[1] A commercially available resin was employed for the random panels, while a resin based on a laboratory formulation and prepared in a commercial plant was used for the oriented panels.

shear, small specimens in bending, internal bond, concentrated loading, distributed loading, and impact loading. Tests showed that larger panel properties would meet or exceed existing standards or performance criteria for structural sheathing. However, the rheological behavior of the large panels or small laboratory panels

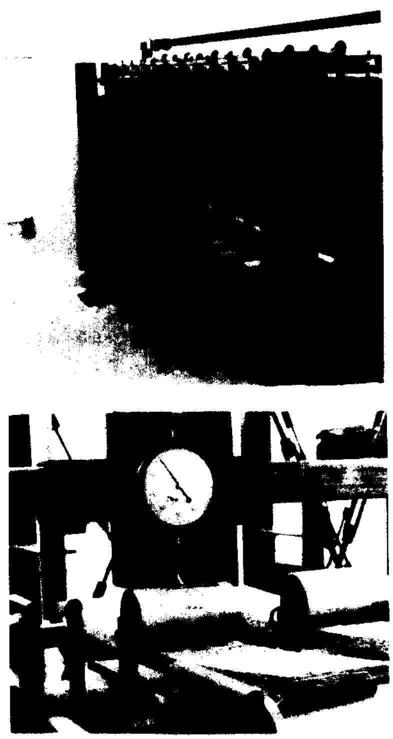

FIG. 1. Creep loading and measuring device for small bending specimens.

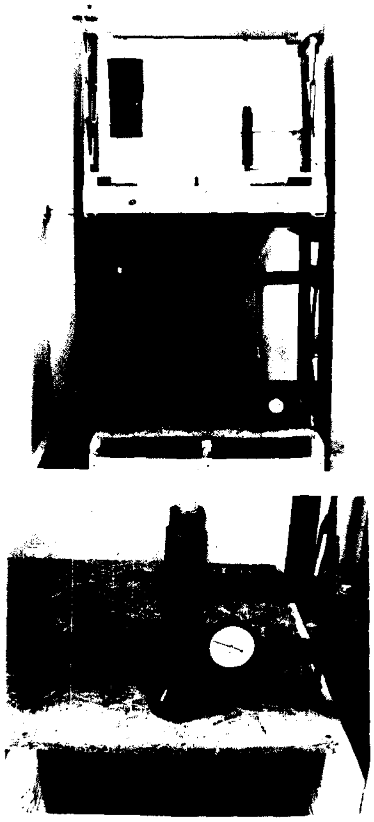

FIG. 2. Creep loading and measuring device for concentrated loads applied on panels nailed to framing lumber.

was not evaluated. The objective of this present study was to provide a data base on the creep characteristics of structural panels made with a furnish containing a large percentage of southern hardwoods.

PROCEDURE

Panels fabricated by Price (1978) and two groups of locally purchased southern pine plywood were selected for creep evaluation in both flexural loading of small specimens and concentrated loads on panel sections nailed to framing lumber. The panel types consisted of the following panel groups:

(1) Random flakeboard constructed with mixed species at two densities and two thicknesses (4 groups).

(2) Oriented flakeboards constructed with mixed species at two densities and two thicknesses (4 groups).

(3) Southern pine plywood, 3-ply, ½-inch thick and 4-ply, ⅝-inch thick (2 groups).

Species mixture, flake types, and panel specifications are listed in Table 1. The random panel construction contains both random face and random core flake distribution; the oriented panels had oriented face flakes and core flakes oriented

TABLE 2. *Properties of small creep specimens.*

Panel	RH cycle	Density[1]	Internal bond	Bending strength 4 ft dir.	Bending strength 8 ft dir.	Modulus of elasticity 4 ft dir.	Modulus of elasticity 8 ft dir.	Nondestructive MOE ratio[2] 4 ft dir.	Nondestructive MOE ratio[2] 8 ft dir.	Nondestructive MOE/MOE[3] 4 ft dir.	Nondestructive MOE/MOE[3] 8 ft dir.
	Days	*pcf*	.... *psi*			..... *1,000 psi*					
				½-INCH THICK PANELS							
Random flakeboard	4	45.3	69	3,900	5,400	552	746	1.01	1.03	1.39	1.32
	8	46.6	69	4,400	5,600	585	808	1.08	1.10	1.40	1.28
	32	44.8	66	4,200	5,700	560	739	1.03	1.13	1.49	1.31
	4	47.5	75	3,900	5,500	573	775	1.02	1.00	1.43	1.36
	8	47.3	66	4,500	5,800	631	774	1.08	1.07	1.38	1.37
	32	47.4	64	4,400	5,700	589	763	1.01	1.01	1.45	1.40
Avg.		46.5	68	4,200	5,600	582	768	1.04	1.06	1.42	1.34
Oriented flakeboard	4	44.8	57	3,000	5,300	382	925	1.01	1.00	2.27	1.09
	8	44.7	56	3,200	5,800	378	985	1.10	1.09	2.27	1.08
	32	45.2	55	3,300	5,400	392	935	1.02	1.01	2.32	1.14
	4	47.4	53	3,600	5,500	401	974	0.99	0.99	2.41	1.08
	8	47.7	61	3,800	5,800	408	981	1.07	1.07	2.40	1.11
	32	47.8	60	3,600	6,000	385	999	1.02	1.02	2.57	1.13
Avg.		46.3	57	3,400	5,600	391	967	1.04	1.03	2.37	1.11
Pine plywood	4[4]	34.9	84	1,800	8,600	99	1,321	0.96	0.96	7.58	1.47
	8[4]	34.4	94	1,900	9,300	96	1,416	1.07	1.09	7.98	1.32
	32	35.3	101	2,100	8,500	103	1,554	0.99	1.00	7.17	1.26
Avg.		34.9	93	1,900	8,800	99	1,430	1.01	1.02	7.58	1.35
				⅝-INCH THICK PANELS							
Random flakeboard	4	41.0	44	3,200	4,100	506	629	1.05	1.16	1.34	1.32
	8	41.2	37	3,300	4,500	515	655	1.04	1.06	1.33	1.33
	32	40.9	43	3,500	4,000	492	622	1.05	1.05	1.41	1.36
	4	43.1	62	3,500	4,500	529	708	1.02	1.01	1.34	1.31
	8	43.3	53	3,900	4,500	547	666	1.06	1.05	1.39	1.34
	32	44.0	54	3,900	4,500	563	674	1.01	1.02	1.38	1.37
Avg.		42.3	49	3,600	4,400	525	659	1.04	1.06	1.37	1.34
Oriented flakeboard	4	43.0	32	2,200	4,800	292	858	1.01	1.00	2.67	1.25
	8	43.8	33	2,400	5,500	287	940	1.08	1.08	2.83	1.23
	32	43.0	34	2,500	5,200	311	887	1.01	0.99	2.66	1.30
	4	47.1	59	3,100	6,000	370	941	1.00	1.00	2.42	1.20
	8	46.8	52	3,000	5,900	347	944	1.06	1.08	2.61	1.25
	32	47.8	62	3,200	6,500	379	1,016	1.02	1.07	2.58	1.19
Avg.		45.3	45	2,700	5,700	331	931	1.04	1.04	2.63	1.24
Pine plywood	4	34.2	77	3,900	8,300	307	1,181	0.95	0.87	3.64	1.51
	8	33.7	70	4,700	7,900	437	1,081	1.12	1.07	3.21	1.46
	32	33.7	89	4,400	7,700	441	1,040	1.00	0.99	3.25	1.61
Avg.		33.9	79	4,300	8,000	395	1,001	1.02	0.98	3.37	1.53

[1] Based on weight and volume at 50% RH.
[2] Initial nondestructive MOE/final nondestructive MOE.
[3] Final nondestructive MOE/bending MOE (nondestructive MOE was obtained by timing a sound or stress wave. Bending MOE was obtained from quasistatic loading to failure).
[4] Properties for 4-foot direction are based on an average of 10 specimens instead of 12.

perpendicular to the face flakes. Although panels were made ½- and ⅝-inch thick for both oriented and random fabrication, the panel density varied slightly with thickness and method of fabrication.

For each flakeboard panel type, at least twenty-seven flakeboards were fabri-

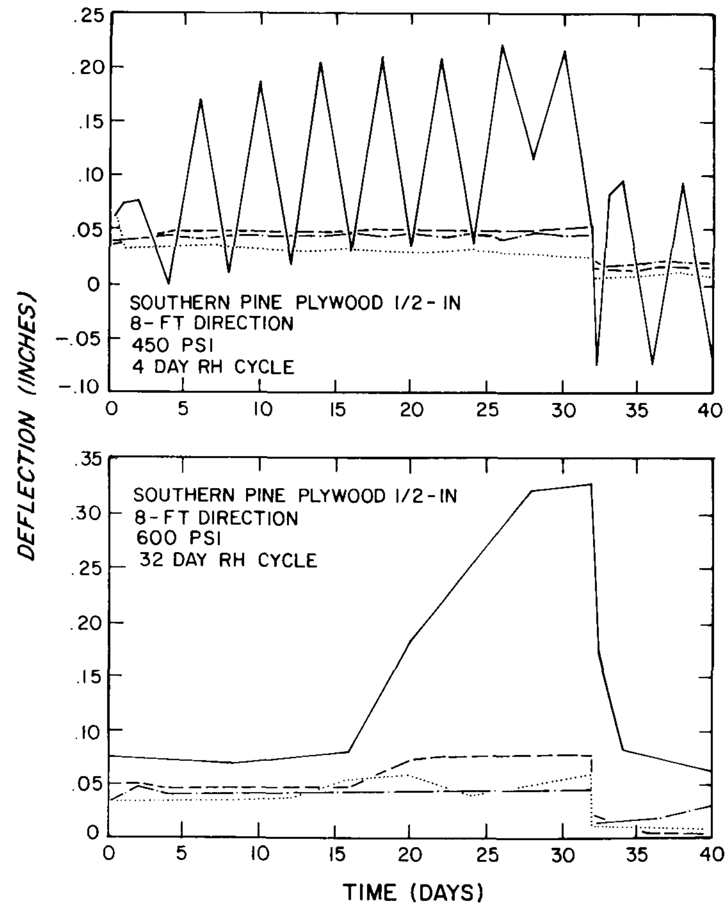

FIG. 3. Deflection curves for four different southern pine plywood specimens subjected to 450 psi (top) and 600 psi (bottom) stresses.

cated and randomly segregated into four test groups. The study reported here evaluated flakeboards in the time and environmental effects subgroup (seven panels). The seven panels were cut into four 2- by 4-foot sections with the 4-foot direction the same as the original 8-foot panel direction. Six sections from different panels were dissected to obtain six small flexural test specimens per panel direction. Twelve sections, with the maximum number of sections obtained from different panels, were selected for concentrated load test.

Small flexural specimens were evaluated at three stress levels and three RH cycles; concentrated load specimens were evaluated at two load levels and three RH cycles. Relative humidity cycles consisted of 2, 4, or 16 days at 50% RH plus an equivalent number of days at 85% RH with a constant dry bulb of 72 F. Since the loads were applied for 32 days, specimens were subjected to 8, 4, and 1 complete RH cycle. After 32 days, the loads were removed and RH cyclic rate continued, deflect recovery measurements being taken for 8 days.

No standards exist for selection of stress levels for small flexural creep evaluations. Stress values for small flexural tests were selected for one stress value (450

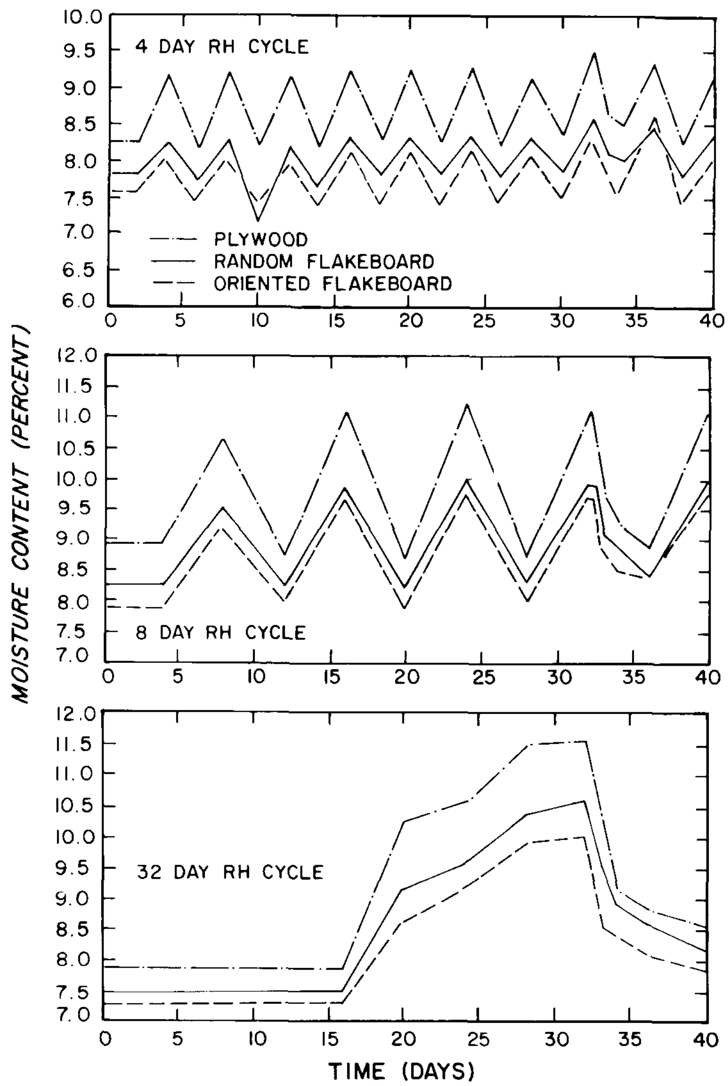

FIG. 4. Moisture content fluctuation for plywood, random flakeboard, and oriented flakeboard when subjected to a cyclic 50–85% relative humidity change every 4, 8, and 32 days.

psi) applied in both panel directions. According to the original panel direction, the stress level was increased 150 psi if in the 8-foot direction or decreased 150 psi if in 4-foot direction. No creep failure was anticipated, but sufficient creep occurred to allow analysis. Specimens obtained parallel to the 8-foot panel direction were subjected to 0, 450, and 600 psi stress, while specimens obtained perpendicular to this direction were subjected to 0, 300, and 450 psi stress level.

The creep loading and measuring equipment (Fig. 1) was such that deflection measurements included the effect of thickness change. To minimize the effect of thickness change and water absorption, all edges were wax coated prior to loading.

These bending specimens, 3 inches wide and 18 inches long, were then centerpoint loaded over a 15-inch span. Specimens not subjected to a load, zero stress level, received the same environmental treatment as loaded specimens. After completion of a test cycle, specimens conditioned 30 days at 50% RH, were destructively evaluated in bending.

Data for concentrated loads applied to panels over 16- and 24-inch spans and loads applied through 3- and 1-inch diameter disks were available (Price 1978). Using these established loading locations, panel creep behavior for concentrated loads of 300 pounds applied through a 3-inch-diameter disk and 200 pounds on a 1-inch disk was obtained. The loads were applied at mid-span, 2½ inches from the unsupported edge only on a 16-inch span. The load frame and measuring device consisted of a two tier load frame and an instrument to measure the disk deflection of the panel top over the framing members (Fig. 2). Relative humidity cycle schedules and the measuring sequence for the concentrated loads were equivalent to the flexural specimens. Two replications per variable combination for the concentrated loads and four specimen replications for small specimens were obtained.

As panels varied in origin, resin, and density, no statistical analysis was performed. Consequently, implied differences are based on professional judgment instead of statistical testing.

RESULTS

Small specimens

Four ½-inch-thick plywood specimens obtained from the 4-foot direction failed, perhaps from variability. One of the four, stressed at 300 psi, survived the 32-day loading with a 4-day RH cycle regime, but it failed in handling prior to destructive evaluation. The specimen data were included in the creep data but not the specimen property data (Table 2). Another specimen similarly loaded under the 8-day RH cycle failed 8 days after being loaded. The other two specimens, one scheduled for a 4-day RH cycle and one for an 8-day RH cycle, failed during loading with sufficient weight for the 450 psi stress level. Averages for these groups excluded specimens that failed under creep loads.

The plywood decreased in deflection measurements as relative humidity increased (Fig. 3). The decrease more reflected moisture absorption and bowing action than creep behavior. This bowing could have resulted either from stress level insufficient to prohibit upward movement of the specimens, end support prohibiting longitudinal changes, or uneven moisture absorption on the two surfaces of the specimen. Despite data collection problems, some statements about RH cycles, moisture content, panel thickness, panel type, and stress level can be made.

The moisture content (MC) in relation to relative humidity (RH) was similar for all panel types. Plywood, generally slightly higher in initial MC, maintained a slightly higher MC during evaluation. Random flakeboard generally had an MC between the plywood and oriented flakeboard. However, panel types usually differed less than 1% (Fig. 4). Although each RH cycle had equivalent exposure to high humidity for the 32-day test schedule, the RH cycles produced some MC

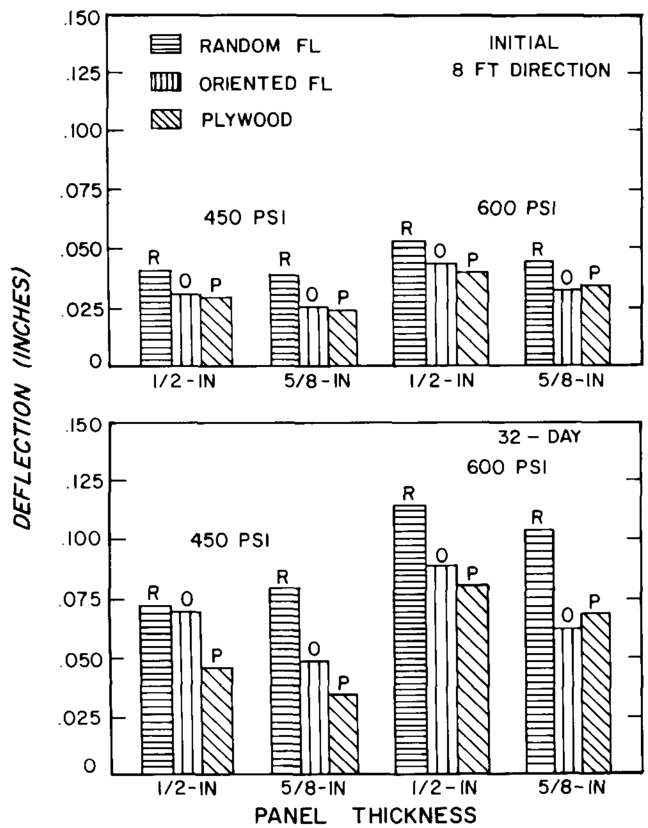

FIG. 5. Relationship between deflection of plywood, random flakeboard, and oriented flakeboard, ½-inch and ⅝-inch thick, when initially loaded (top) and after 32 days of a continuous load (bottom) at 450 psi and 600 psi bending stress on small bending specimens obtained from the 8-foot panel direction.

differences. For instance, all specimens subjected to the 4-day RH cycle initially averaged 8% MC and finally 9%; the 8-day and 32-day cycle specimens changed from 8.4 to 10.3% and 7.7 to 11.0%, respectively.

Although the ½-inch and ⅝-inch flakeboard and plywood panels had slightly different density and modulus of elasticity values MOE (Table 2), similar panel type yielded similar creep behavior (Fig. 5). For instance, the relative creep (final deflection/initial deflection) value (Table 3) for all ½-inch panels averaged 2.15, while the ⅝-inch panel average was 2.19. Because both panel thicknesses were evaluated on a 15-inch span, the small relative creep difference may be attributed to the span to depth ratio. The four stress level-panel thickness combination averages showed that an increase in the stress level increased relative creep in three of the four cases. The only relative creep decrease occurred for the ⅝-inch-thick panels obtained for the 4-foot direction, i.e., 2.37 for 300 psi stress to 2.29 for 450 psi stress level. However, the panel thickness did not appear significant for additional investigations for these low stress levels.

Properties of both panel directions are important, but the 8-foot panel direction properties are often considered more significant for many end-use applications.

TABLE 3. *Small specimen creep data.*

Panel type	RH cycle	4-foot direction, 300 psi stress: 0 day	16 day	32 day	Recovery[1]	Relative creep	4-foot direction, 450 psi stress: 0 day	16 day	32 day	Recovery	Relative creep	8-foot direction, 450 psi stress: 0 day	16 day	32 day	Recovery	Relative creep	8-foot direction, 600 psi stress: 0 day	16 day	32 day	Recovery	Relative creep
		0.001 inch					0.001 inch					0.001 inch					0.001 inch				
½-INCH THICK PANELS																					
Random flakeboard (45.6 pcf)	4	29	60	64	26	2.21	56	123	127	61	2.27	41	72	74	28	1.81	51	94	95	36	1.86
	8	38	87	91	60	2.40	52	131	134	82	2.58	48	99	103	61	2.15	57	125	131	75	2.30
	32	37	51	85	51	2.30	54	76	142	84	2.63	40	58	99	56	2.48	57	83	127	72	2.23
(47.4 pcf)	4	43	77	81	36	1.88	50	92	94	36	1.88	27	50	60	10	2.22	52	92	92	33	1.77
	8	32	72	76	40	2.38	44	107	112	60	2.55	39	80	82	47	2.10	60	139	141	90	2.35
	32	28	41	62	27	2.21	45	68	125	70	2.78	42	56	80	42	1.91	46	63	113	59	2.46
Oriented flakeboard (44.9 pcf)	4	51	103	108	56	2.12	78	168	174	81	2.23	33	53	55	18	1.67	40	72	73	27	1.83
	8	55	136	148	97	2.69	69	201	216	135	3.13	33	64	68	39	2.06	39	90	94	54	2.41
	32	57	80	136	85	2.39	75	106	194	121	2.59	42	53	68	39	1.62	41	70	92	52	2.24
(47.4 pcf)	4	53	100	105	49	1.98	71	157	163	77	2.30	36	60	63	21	1.75	42	70	80	21	1.91
	8	51	118	128	81	2.51	77	181	196	117	2.55	34	73	75	45	2.21	44	93	97	58	2.21
	32	54	77	147	95	2.72	75	118	194	113	2.59	26	39	60	24	2.31	46	63	93	48	2.02
Pine plywood	4	212	173	171	27	0.81	219	356	364	127*	1.66	35	39	45	13	1.29	33	48	57	17	1.73
	8	242	358	359	204	1.48*	217	456	511	268*	2.36	33	53	53	27	1.61	45	64	61	28	1.36
	32	175	239	346	180	1.98	312	413	571	278	1.83	25	30	45	18	1.80	40	56	127	86	3.18

TABLE 3. *Continued.*

		4-foot direction										8-foot direction									
		300 psi stress					450 psi stress					450 psi stress					600 psi stress				
Panel type	RH cycle	0 day	16 day	32 day	Recovery[1]	Relative creep	0 day	16 day	32 day	Recovery	Relative creep	0 day	16 day	32 day	Recovery	Relative creep	0 day	16 day	32 day	Recovery	Relative creep
⅝-INCH THICK PANELS																					
Random	4	26	56	55	25	2.12	54	99	106	40	1.96	34	73	75	29	2.21	59	95	101	40	1.71
flakeboard	8	37	91	97	63	2.62	54	130	139	92	2.57	43	101	104	69	2.42	51	120	126	73	2.47
(41.0 pcf)	32	33	63	108	68	3.27	36	59	104	52	2.89	29	51	72	39	2.48	50	73	132	72	2.64
(43.5 pcf)	4	31	77	78	41	2.52	53	93	96	44	1.81	41	73	81	29	1.98	43	74	78	26	1.81
	8	33	75	73	47	2.21	50	113	122	79	2.44	41	81	79	41	1.93	43	105	113	59	2.63
	32	26	43	64	35	2.46	47	79	126	77	2.68	35	50	80	41	2.29	50	82	121	63	2.42
Oriented	4	44	109	116	61	2.64	82	155	164	72	2.00	27	45	54	17	2.00	30	59	61	16	2.03
flakeboard	8	61	164	173	118	2.84	73	204	220	47	3.01	32	68	65	41	2.03	34	76	81	45	2.38
(43.3 pcf)	32	45	70	109	61	2.42	71	122	193	117	2.72	28	43	57	27	2.04	37	60	81	42	2.19
(47.7 pcf)	4	44	94	95	47	2.16	74	122	125	42	1.69	27	45	54	18	2.00	38	60	59	22	1.55
	8	42	99	104	68	2.50	84	191	206	129	2.45	26	54	51	27	1.96	29	67	71	35	2.45
	32	44	71	124	75	2.82	73	105	188	110	2.58	22	39	44	20	2.00	31	42	53	18	1.71
Pine	4	59	88	86	17	1.46	104	147	157	38	1.51	22	−1	4	−25	0.18	33	45	57	10	1.73
plywood	8	59	87	94	32	1.59	114	188	203	92	1.78	24	44	43	21	1.79	37	60	61	34	1.65
	32	41	58	80	30	1.95	91	109	212	118	2.33	23	38	56	22	2.44	34	45	88	46	2.59

* Based on average of three specimens instead of four.

[1] Recovery is the amount of deflection recovered after 8 days with no load applied.

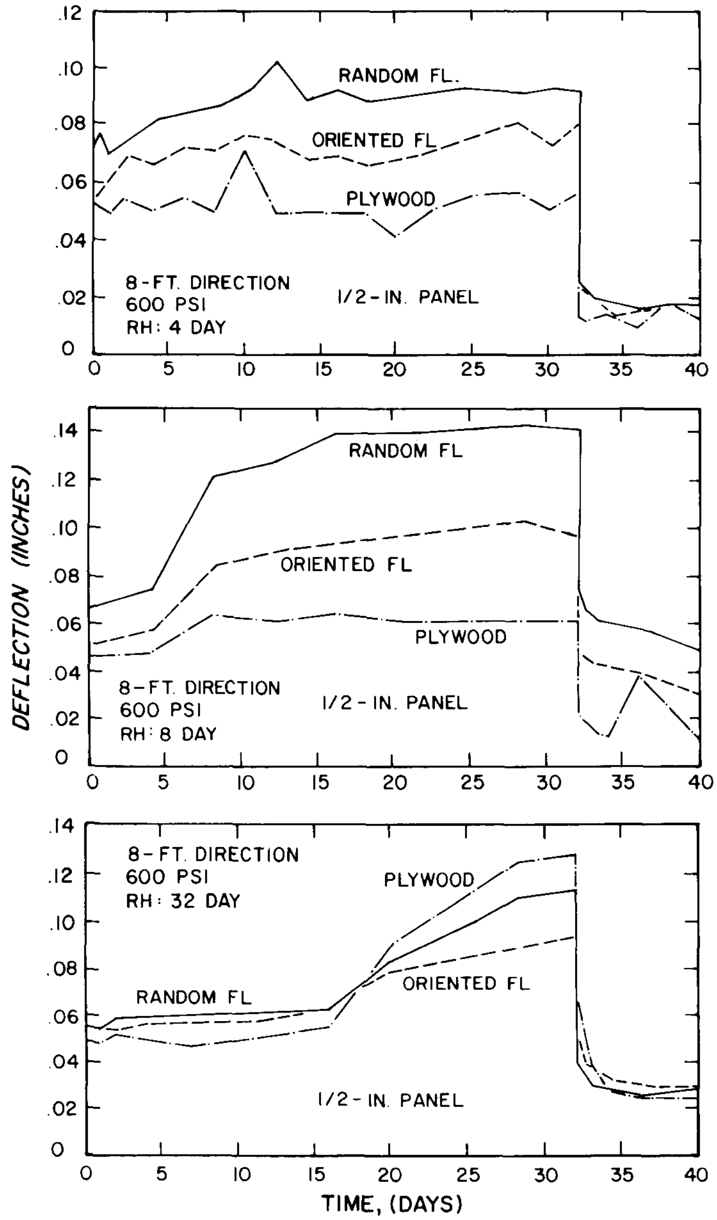

FIG. 6. Deflection versus time relationship for ½-inch-thick random flakeboard, oriented flakeboard, and plywood specimens obtained from the 8-foot panel direction and subjected to 600 psi continuous stress for 32 days under a 4-, 8-, and 32-day relative humidity cycle of 50 to 85%.

Thus, as 8-foot test results show (Fig. 6), the three panel types exhibited similar deflection trends for all three RH cycles. The figure illustrates the observed phenomenon of the deflection rate increasing during the adsorption phase of the RH cycle except for the 4-day cycle. Random flakeboard with the lowest MOE exhibited the largest deflection for the 4-day and 8-day RH cycles. Since one of the

TABLE 4. *Properties of small specimens after continuous loading at three stress levels.*

Panel	Stress level[1]	Density	Internal bond	Bending strength		Modulus of elasticity	
				4-ft dia.	8-ft dia.	4-ft dia.	8-ft dia.
		pcf		*psi*		*1,000 psi*	
½″ random flakeboard	0	46.1	67	4,200	5,600	584	754
	1	46.5	68	4,400	5,700	575	766
	2	46.9	68	4,100	5,500	586	784
	Avg.	46.5	68	4,200	5,600	582	768
½″ oriented flakeboard	0	46.5	59	3,500	5,700	400	974
	1	45.8	51	3,400	5,500	388	957
	2	46.5	60	3,400	5,700	386	970
	Avg.	46.3	57	3,400	5,600	391	967
½″ pine plywood	0	33.9	95	1,900	7,700	96	1,320
	1	34.8	100	2,000	9,100	103	1,339
	2	35.8	90	1,900	9,700	91	1,632
	Avg.	34.8	95	1,900	8,800	97	1,430
⅝″ random flakeboard	0	42.5	47	3,700	4,400	542	657
	1	42.1	47	3,400	4,500	521	676
	2	42.0	51	3,500	4,300	512	644
	Avg.	42.2	48	3,500	4,400	525	659
⅝″ oriented flakeboard	0	45.2	46	2,700	5,600	329	943
	1	45.0	44	2,800	5,600	329	933
	2	45.4	45	2,700	5,700	336	917
	Avg.	45.2	45	2,700	5,600	331	931
⅝″ pine plywood	0	34.0	79	5,300	8,300	517	1,075
	1	34.0	86	4,400	7,700	362	1,039
	2	33.5	76	3,300	7,900	306	1,187
	Avg.	33.8	80	4,300	8,000	395	1,100

[1] The 0 stress implies no previous creep loading; stress level 1 is 300 psi in 4-foot direction, 450 psi in the 8-foot direction; and stress level 2 is 450 psi in 4-foot direction and 600 psi in the 8-foot direction.

four plywood specimens (Fig. 3, bottom) exhibited considerably more deflection than the other specimens, plywood had the largest deflection for the 32-day RH cycle. Using the relative creep values as an indication of the panel direction effect, all panel types subjected to the 450 psi stress had a relative creep value of 2.35 for the 4-foot direction and 1.96 for the 8-foot direction. As expected, the 4-foot direction stressed at a higher percentage of the bending strength exhibited the larger creep. This higher relative creep value for the 4-foot direction occurred for all panel types, with oriented flakeboard exhibiting the highest value and plywood the lowest. Random flakeboard did have the lowest percentage of relative creep increase in the 4-foot direction over the 8-foot direction.

Relative humidity cycle seemed to have a significant effect on the relative creep. The average relative creep values for all panel types were 1.86, 2.28, and 2.38 for the 4-day, 8-day, and 32-day RH cycles. This same order of RH cycles occurred at all stress levels. In general, the 8- and 32-day RH cycles had similar values that were higher than the 4-day cycle values, likely a reflection of the moisture content changes related to each RH cycle.

Excluding the few plywood specimens that failed while under load, the remaining plywood specimens had the lowest relative creep average of any panel group. The plywood relative creep averaged 1.76, oriented panels relative creep

TABLE 5. *Concentrated load test.*

Panel type	RH cycle	200-pound load[1]					300-pound load[1]				
		Initial	16 days	32 days	Recovery	Relative[2] creep	Initial	16 days	32 days	Recovery	Relative[2] creep
	Days			*In.*					*In.*		
				½-INCH THICK PANELS							
Random	4	0.113	0.192	0.203	0.040	1.80	0.150	0.276	0.293	0.070	1.95
flakeboard	8	0.105	0.239	0.260	0.086	2.48	0.120	0.235	0.251	0.084	2.09
45.6 pcf	32	0.105	0.147	0.210	0.029	2.00	0.154	0.213	0.266	0.077	1.73
47.4 pcf	4	0.107	0.140	0.145	0.026	1.36	0.156	0.230	0.246	0.044	1.58
	8[3]	0.095	0.161	0.190	0.051	2.00	0.153	0.262	0.307	0.081	2.01
	32	0.097	0.148	0.213	0.075	2.20	0.138	0.203	0.263	0.088	1.91
Oriented	4	0.091	0.148	0.154	0.027	1.70	0.142	0.217	0.226	0.045	1.59
flakeboard	8[3]	0.121	0.284	0.305	0.141	2.52	0.140	0.290	0.307	0.141	2.19
44.9 pcf	32	0.090	0.127	0.155	0.034	1.72	0.139	0.218	0.265	0.078	1.91
47.6 pcf	4	0.098	0.237	0.259	0.099	2.64	0.142	0.378	0.408	0.166	2.87
	8[3]	0.063	0.116	0.137	0.034	2.18	0.140	0.243	0.295	0.067	2.11
	32	0.097	0.159	0.251	0.081	2.59	0.116	0.210	0.307	0.077	2.65
Pine	4	0.093	0.180	0.188	0.068	2.02	0.116	0.183	0.192	0.048	1.66
plywood	8[3]	0.130	0.186	0.204	0.024	1.57	0.159	0.220	0.236	0.035	1.48
	32	0.114	0.125	0.163	0.024	1.43	0.162	0.229	0.285	0.042	1.76
				⅝-INCH THICK PANELS							
Random	4	0.087	0.146	0.164	0.049	1.89	0.101	0.162	0.177	0.047	1.75
flakeboard	8	0.068	0.168	0.184	0.075	2.71	0.121	0.262	0.283	0.129	2.34
41.0 pcf	32	0.085	0.146	0.210	0.069	2.47	0.111	0.185	0.247	0.081	2.23
43.5 pcf	4	0.076	0.122	0.130	0.035	1.71	0.092	0.130	0.134	0.024	1.46
	8	0.068	0.149	0.164	0.060	2.41	0.096	0.213	0.235	0.094	2.45
	32	0.073	0.108	0.174	0.053	2.38	0.093	0.134	0.202	0.059	2.17
Oriented	4	0.057	0.103	0.110	0.031	1.93	0.081	0.134	0.149	0.031	1.84
flakeboard	8	0.050	0.124	0.144	0.048	2.88	0.070	0.138	0.148	0.058	2.11
43.3 pcf	32	0.071	0.110	0.223	0.099	3.14	0.088	0.134	0.222	0.098	2.52
47.7 pcf	4	0.051	0.113	0.127	0.035	2.49	0.075	0.154	0.170	0.056	2.27
	8	0.047	0.114	0.131	0.031	2.79	0.069	0.139	0.156	0.045	2.26
	32	0.059	0.093	0.164	0.054	2.78	0.113	0.172	0.298	0.140	2.64
Pine	4	0.065	0.100	0.119	0.027	1.83	0.095	0.142	0.153	0.020	1.61
plywood	8	0.078	0.151	0.170	0.060	2.18	0.110	0.188	0.213	0.061	1.94
	32	0.074	0.112	0.162	0.061	2.19	0.117	0.159	0.212	0.071	1.81

[1] The 200-pound load was applied through a 1-inch disk while the 300-pound load was applied through a 2-inch disk.
[2] Relative creep is the 32-day deflection divided by the initial deflection.
[3] Data based on one specimen instead of two specimens.

averaged 2.26, and the highest average relative creep was 2.30 for the random flakeboard. Since two density groups were evaluated for the flakeboard panel types, the flakeboard panel averages are based on twice as many test specimens. Considering both panel directions, all load levels and RH cycles, the plywood specimens completing the 32-day loading had the smallest deflection increase, while both flakeboards had higher increases.

Following the creep loading, a nondestructive MOE was determined. Then, the specimens were destructively evaluated in bending and for internal bond. Since an initial nondestructive MOE was also obtained, ratio of the initial and final nondestructive MOE's and ratio of final nondestructive MOE and bending MOE

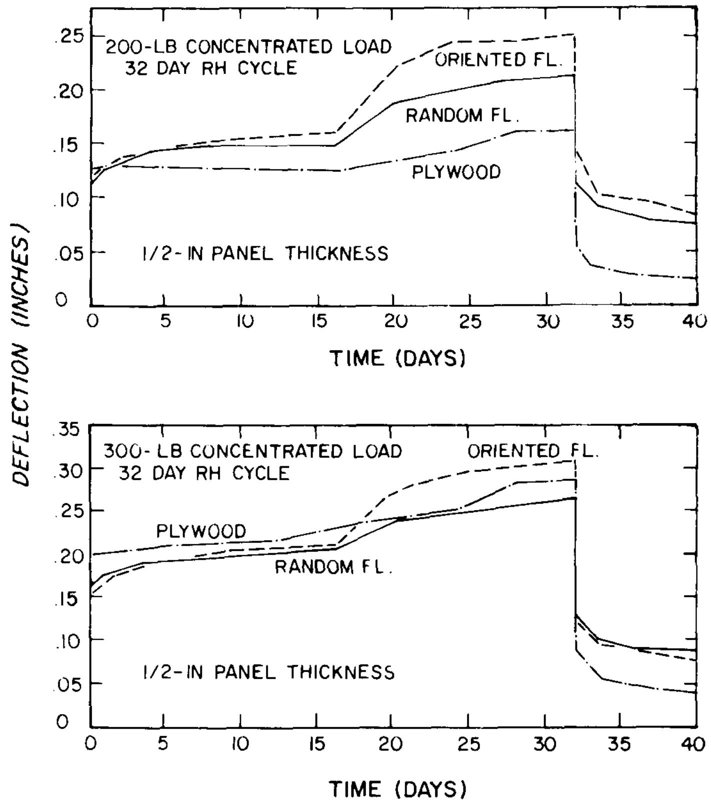

FIG. 7. Deflection versus time relationship for ½-inch-thick random flakeboard, oriented flakeboard, and plywood when subjected to 200-lb and 300-lb concentrated loads and 16 days of 50% RH plus 16 days of 85% RH.

were calculated. These ratios (Table 2) indicated that flakeboard had an initial nondestructive MOE—4.3% higher than the final nondestructive MOE. Since the flakeboard final nondestructive MOE was much larger than the final bending MOE (averages for the ratio ranged from 1.11–2.37), it could be erroneous to assume that a similar decrease in a bending-derived MOE occurred for flakeboard. For plywood, the nondestructive initial final MOE ratio for plywood was almost 1.0, while the average nondestructive final MOE/bending MOE ratio ranged from 1.35 to 7.58. This large ratio results from bending MOE on a uniform cross section instead of a transferred cross-sectional area for the laminae.

One set of specimens per panel group and RH cycle was subjected to the cyclic rate without being subjected to a creep load; then it was destructively loaded. As comparison of these final specimen properties shows (Table 4), the creep load did not decrease the internal bond, bending strength, or modulus of elasticity.

Because of the variability and failure associated with the plywood specimens, no conclusions among the panel types are valid. However, the small specimen data (Fig. 6) did indicate that, in general, each panel type exhibited a deflection increase during adsorption and desorption, deflection rate increased during adsorption and deflection was inversely related to stiffness.

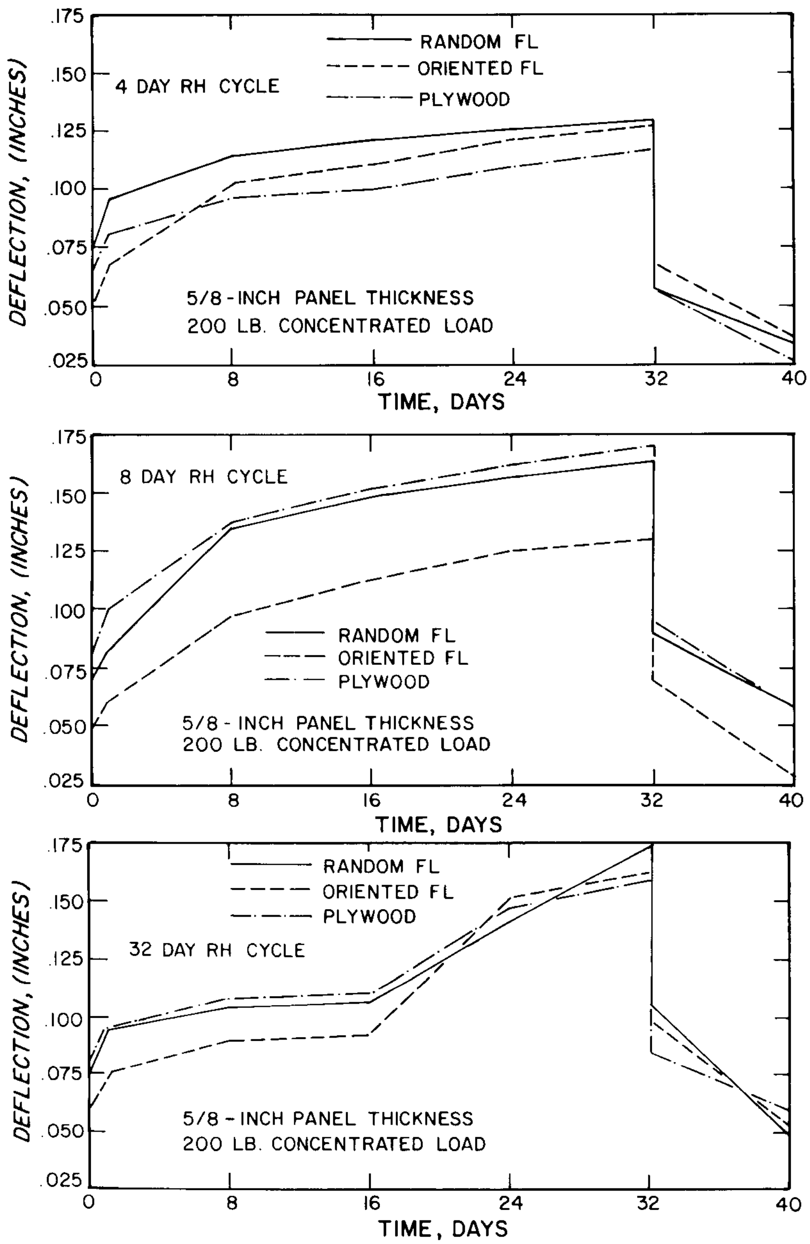

FIG. 8. Deflection versus time relationship for ⅝-inch-thick random flakeboard, oriented flakeboard, and plywood when subjected to 200-lb concentrated load and a 4-, 8-, and 32-day relative humidity cycle of 50 to 85%.

Panel test

External circumstances allowed only eight specimens to be simultaneously evaluated per relative humidity setting. During one setting, data for four specimens were incorrectly located on the data sheet and omitted from analysis. Conse-

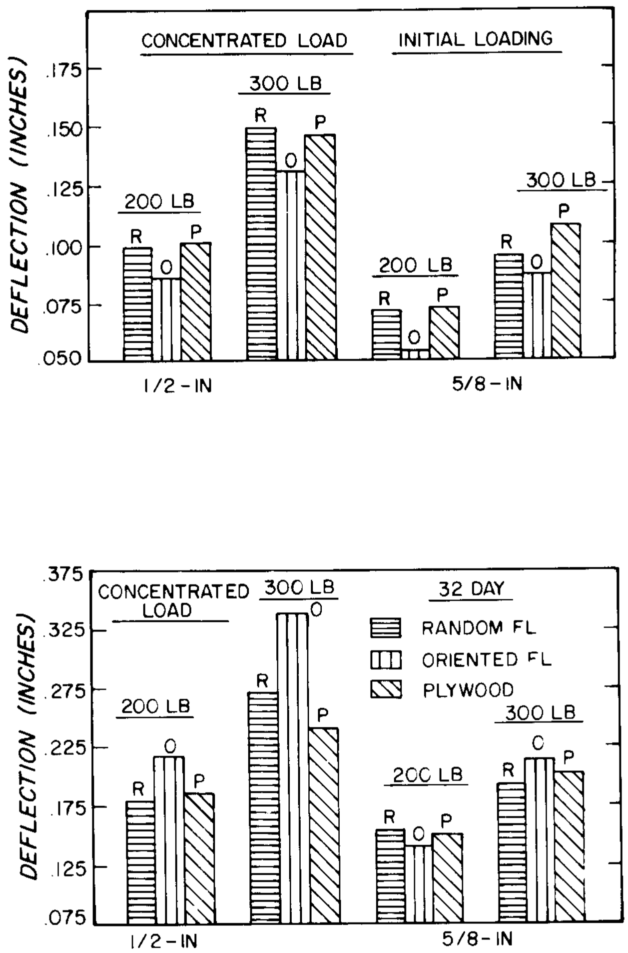

FIG. 9. Initial and 32-day deflection relationship for ½- and ⅝-inch-thick random flakeboard, oriented flakeboard, and plywood when subjected to 200- and 300-lb concentrated loads.

quently, only one specimen of those four types was evaluated, while the other results reflect an average of two specimens (Table 5). The ½-inch panels had higher deflection values than the thicker ⅝-inch panels but slightly lower relative creep values, 1.99 versus 2.25. The relative creep increase with panel thickness is most likely a result of lower panel density for the ½-inch random flakeboard and the plywood construction difference, 3 ply versus 4 ply. Similar deflection behavior occurred for both panel thicknesses, paralleling the case of the small bending specimen.

The 200-pound load did result in a slightly higher relative creep than the 300-pound load, 2.20 compared to 2.03. In fact, only the high density, ½-inch oriented flakeboard panel group had a slightly higher relative creep for the 300-pound load when the three RH values were averaged. One possibility of the lower load having a slightly higher relative creep value could be material compression under the concentrated load head. But, as illustrated in Fig. 7, neither load level exhibited any unusual creep behavior.

The average relative creep values per RH cycle for the 200-pound load are 1.94, 2.37, and 2.29 for 4-, 8-, and 32-day RH cycles, respectively. Similarly, the 300-pound values are 1.86, 2.10, and 2.13. Thus, the 8- and 32-day RH cycles exhibited similar deflection values at the end of 32 days (Fig. 8). The 4-day RH cycle, 2 days at a high humidity, probably does not allow sufficient exposure time for moisture absorption to affect the creep behavior of the wood or glue bonds.

Although the data for 200-pound load on ⅝-inch panels (Fig. 8) indicated that the oriented panels had similar or lower deflection values after 32 days, the trend was not supported by relative creep ratio on other test conditions (Table 5, Fig. 9). Oriented flakeboard panels generally had the smallest initial deflection but the largest creep after 32 days.

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