Lateral Bearing Strength of Fasteners in Lumber-Plywood Joints Treated with Fire Retardants

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ABSTRACT

Joints were fabricated from different combinations of untreated and fire-retardant-treated (FRT) Douglas-fir dimension lumber and 3/8-inch plywood. Eight types of fasteners and three fire-retardant treatments were tested. Joint specimens were exposed 2 and 7 years in cold, standard, and warm-humid conditions, then tested in lateral bearing. Best overall performance was from joints made with 6d hot-dipped galvanized nails; 6d monel nails were next best. Although results from several types of fasteners used in treated wood and exposed in cold and standard conditions were as good as results obtained from untreated controls, most specimens exposed in warm, humid conditions were reduced in strength; some were reduced to zero strength.

LATERAL BEARING STRENGTH OF FASTENERS IN LUMBER–PLYWOOD POINTS TREATED WITH FIRE RETARDANTS

INTRODUCTION

The objective of this study was to develop data on the lateral bearing ability of eight different fasteners in fire-retardant-treated (FRT) lumber and plywood exposed to different conditions of temperature and humidity for several years. When this study began in 1965, FRT wood was rated as having a 10-percent reduction in holding capacity of nails and other fastenings. Further reductions were assigned if possibilities of corrosion existed. The reductions were applied because of limited test data available. The Western Wood Preservers Institute and the technical staff of the American Plywood Association encouraged us to make this study and helped in the initial work.

Much research has been done to assess factors that influence wood-metal reactions and corrosion. Graham and Wilson (Wood-Metal Corrosion, a Survey. Unpublished report, School of Forestry, Oregon State University, Corvallis, August 1969.) summarized literature from 96 sources concerning the effect of untreated wood, treated wood, and wood-preserving chemicals on metals and the effect of metals and chemicals on wood. Six of the 96 sources included FRT wood, but none refers to the holding power of fasteners in FRT wood.

In this study, we tested eight fasteners, several of which are commonly used in construction, three fire retardants, three conditions of exposure, and two periods of exposure. Joints were fabricated with Douglas-fir dimension lumber and one thickness of plywood (3/8-inch), all taken from mills in western Oregon. Specimens totaled 4,704.

PROCEDURE

Materials and Specimens

All fasteners were about 2 inches long; width of staples was ½ inch. A number was assigned to each type of fastener, for convenience (Table 1).

Table 1. Types of Fasteners and the Number Assigned to Each.

Fastener	Treatment	Diameter or size		Shank area
		Shank	Head	
		In.	*In.*	*Sq in.*
Nails				
1. 6d common	none	0.113	17/64	0.040115
2. 6d box	none	.099	17/64	0.030791
3. 6d	hot-dip galvanized	.107	1/4	0.035968
4. 6d T-nail	electrogalvanized	.113	0.322 x 0.113	0.040115
8. 6d monel	none	.109	1/4	0.037325
Staples				
5. 16-gauge	electrogalvanized	0.068 x 0.052	--	0.003536
6. 16-gauge	nylon-coated	0.065 x 0.058	--	0.003770
7. 14-gauge	electrogalvanized	0.084 x 0.070	--	0.005880

Table 2. Exposure Conditions for 64 Groups of Lumber-Plywood Joints, Treated (T) and Untreated (U) with One of Three Fire Retardants.[1]

Exposure (years)	Humid Lumber:plywood	Standard Lumber:plywood	Cold Lumber:plywood
UNTREATED			
0	---	U:U	---
7	U:U	U:U	U:U
TREATED WITH NON-COM			
0	---	T:U	---
7	T:T	T:T	T:T
7	T:U	T:U	T:U
7	U:T	U:T	U:T
TREATED WITH PYRESOTE			
0	---	T:U	---
7	T:T	T:T	T:T
7	T:U	T:U	T:U
7	U:T	U:T	U:T
TREATED WITH BORAX-BORIC ACID			
0	---	T:U	---
7	T:T	T:T	T:T
7	T:U	T:U	T:U
7	U:T	U:T	U:T

[1]Data taken at 2-year exposure, which were identical to that taken at 7-year exposure, are omitted here but are available in the supplement.

Sixty-four groups of lumber-plywood joints were required for the study, with different conditions for each group. There were 8 replications in groups of lumber treated with NON-COM or Pyresote, and 10 replications in groups of lumber untreated or treated with borax-boric acid (Table 2). To minimize variability among lumber of the groups, we took time to "match" the groups by specific gravity (oven-dry weight and volume of small discs) as much as possible. Some FRT lumber was salvaged from a previous study (3), and it had been matched then. Additional lumber for this study was chosen and divided so that each of the 64 groups was similar in specific gravity, which ranged between 0.40 and 0.50. Moisture content of the lumber was about 10 percent when joints were fabricated.

Each specimen consisted of a plywood cleat, 3/8-inch thick, nailed or stapled to two pieces of 2- by 6-inch dimension lumber with one fastener in each end of the cleat. See Figure 1 for nailing distances and other details. A specimen joint could fail under the lateral bearing load because of fasteners breaking off, fasteners pulling out of lumber, fasteners pulling through plywood, plywood breaking, or some combination of these failures. Dimension lumber was 4 feet long, and each pair had 16 specimens nailed to them, with 8 (one for each type of fastener) attached to each of the two narrow faces of the lumber. Knots were avoided; otherwise, location of fasteners in the lumber was random (Figure 2).

Plywood was C-D sheathing grade with exterior glue, but knots and knotholes in the nailing area of the two outer plies were avoided so that plywood thickness would be constant and fasteners flush (not protruding above nor cutting into the plywood). Considerable care was

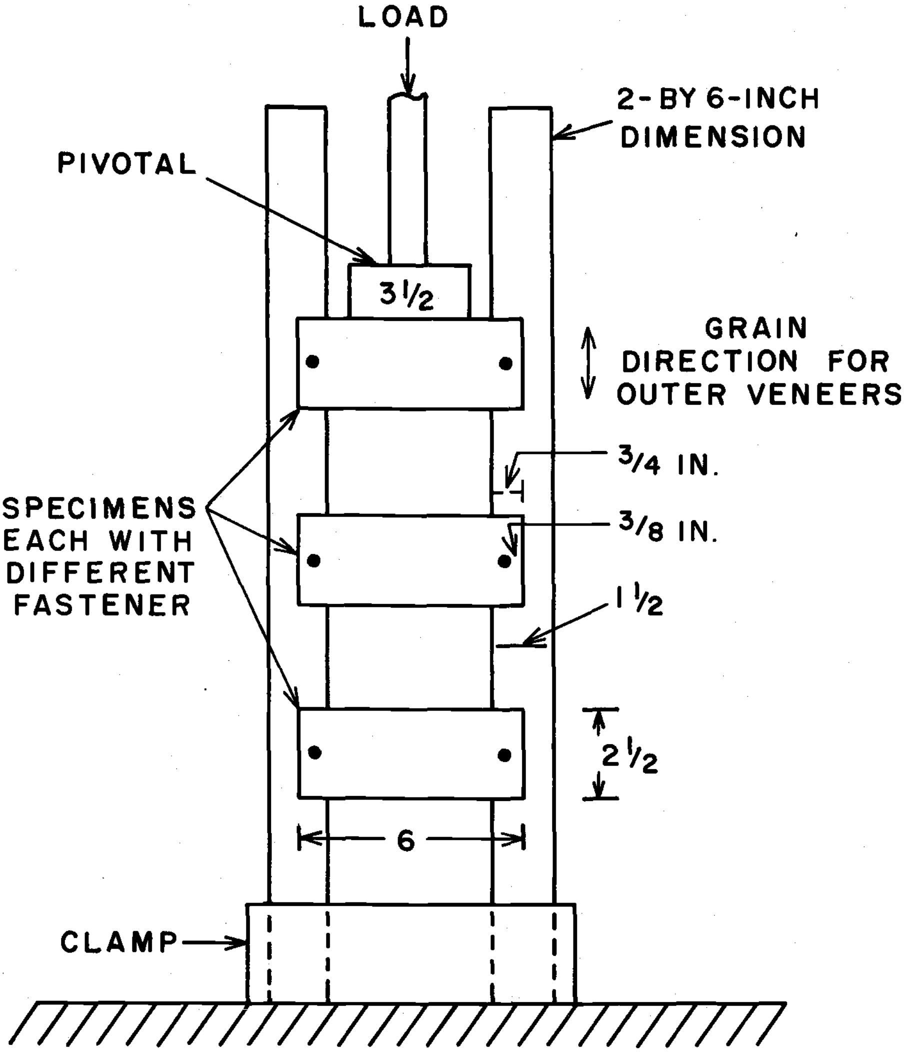

Figure 1. Sketch of specimens and test apparatus. The steel load head, 3½ inches wide along the specimen and 1 inch deep, was pivoted to allow tilting in one direction.

taken to set fasteners flush. Plywood cleats were chosen randomly and oriented with the grain of outer plies parallel to edges of the lumber (Figure 1). We thought this orientation would result in weakest (most conservative) and most realistic values.

Fire-Retardant Treatments

Three fire retardants were used with the lumber and plywood. In addition, some of the material was untreated (Table 2). Lumber and plywood were pressure-treated with NON-COM

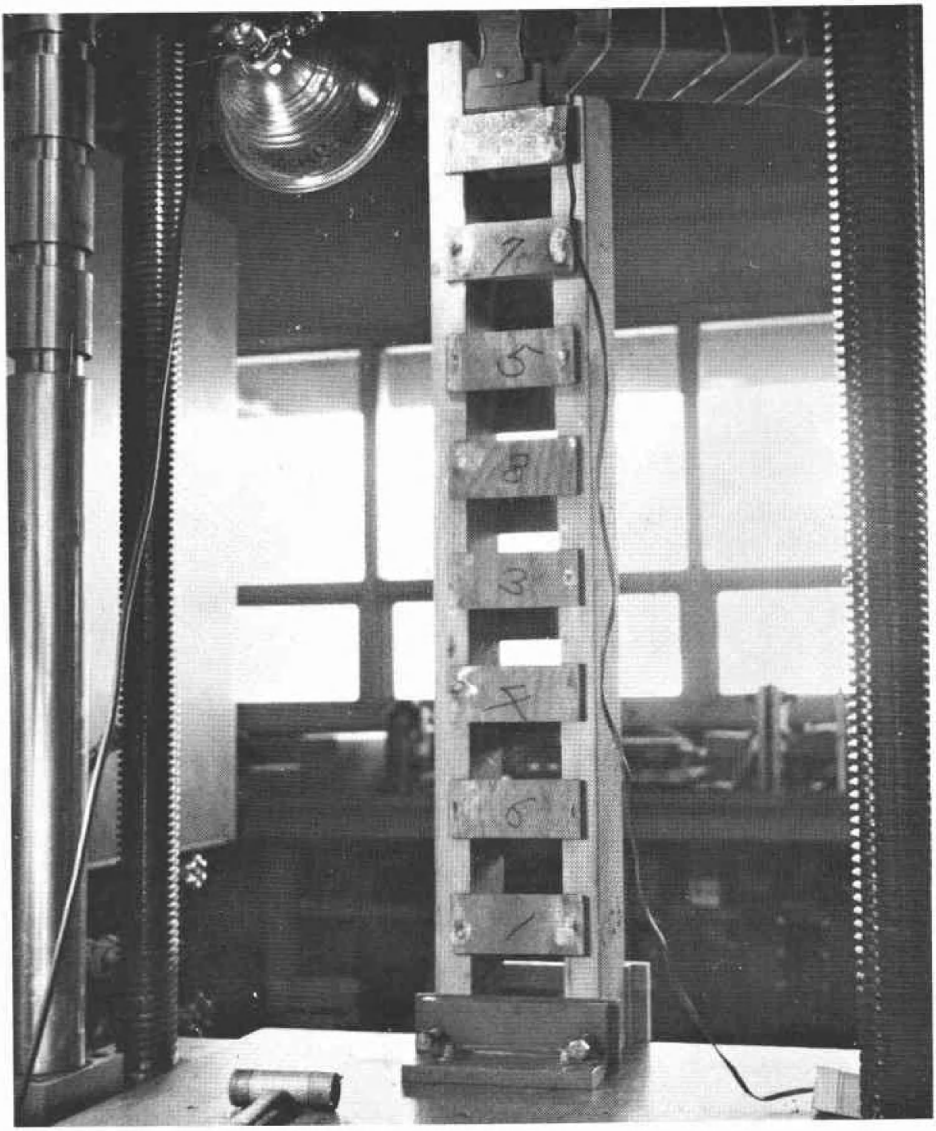

Figure 2. Random orientation of plywood cleats, each with different fasteners, on dimension lumber; eight were attached in staggered, ladder-like manner to other edge of lumber also. Note identification number of fasteners on cleats.

by Koppers Company, Inc., with Pyresote by J. H. Baxter and Company, and at our laboratory with borax-boric acid (FR-28) supplied by U.S. Borax and Chemical Corporation. Only lumber treated with NON-COM and Pyresote bore an Underwriter's label. The solution of borax and boric acid was used because it has shown promise as a noncorrosive fire-retardant. Dry salt retention of FR-28 was 6.0 pounds per cubic foot in lumber and 7.6 in plywood.

Pyresote contained zinc chloride, ammonium sulfate, boric acid, and sodium bichromate. FR-28 contained oxides of boron, calcium, and sodium. The composition and retention of NON-COM was unknown, as was the retention of Pyresote.

Exposure of Specimens

Specimens were exposed to three different conditions (in three rooms) for 2 and 7 years. In addition, four groups were fabricated and tested immediately (Table 2). Two of the rooms–standard (70 F, 65 percent relative humidity) and cold (35 F, 70-80 percent relative humidity)–represented conditions of use for FRT lumber and plywood. FRT wood was not recommended for use in conditions above 80 percent relative humidity (1), but specimens were put in the warm, humid room (90 F, 90 percent relative humidity) to study effects of such conditions on strength of the eight fasteners. Since this study began, some fire retardants have been developed for exterior use.

Specimens were stacked randomly within each of the three rooms; about every 6 months each stack was rotated in the event conditions within the room were not uniform. Throughout all preparation and subsequent testing of specimens, we tried to treat each type of fastener equally.

Testing

Lateral bearing load was applied to each joint specimen at a speed of 0.25 inch per minute on the Tinius Olsen universal testing machine (Figures 1, 2). Speed was doubled from standard (ASTM-D1761) because of the numerous tests, and because previous work (2) indicated no significant difference in results between speeds of 0.125 and 0.25. Load-deflection curves were drawn for all specimens, although these data are not presented in this report. Plans are to report on load-slip patterns later. Types of failure were recorded also.

Specimens were not removed from a conditioning room until just before testing and were put back into the room immediately if something disrupted the continuity of testing, so that moisture content did not change significantly during tests. We did not attempt to determine the moisture content of FRT wood, but untreated wood was at equilibrium moisture content for the three rooms.

RESULTS AND DISCUSSION

The primary reason for tests after 2 years of exposure was to determine whether strength of joints would deteriorate in a short time. In most instances (exception, joints with Pyresote in humid conditions), strength loss was not that rapid. (Tables and graphs showing results of exposure for 2 years are not included in this report but are available upon request, from Oregon State University, Forest Research Laboratory, Corvallis, Oregon 97331.) In relation to actual construction, results after exposure for 7 years are more useful.

Results after 7 years, obtained from the many combinations of variables, are presented in graphs and tables. Extensive statistical analyses (5 percent level of significance) were made, and tables contain guidelines for comparing much of the data. More general views of the data are given in graphs. Many comparisons that could have been isolated and discussed are not included. This presentation will serve both the reader with a general interest and one who desires to study a particular factor, such as a type of fastener, in more detail. Probably, results will be more meaningful if types of failures are discussed first.

Failures

After exposure for 2 years, most nails and staples pulled partly out of the dimension lumber and bent under lateral bearing load; then the heads pulled through the 3/8-inch plywood with increased load. After 7 years, the majority of failures were of the same type, but other types of failure occurred. Many joints failed after corrosion caused nails to break. In the most humid conditions, some fasteners corroded until the plywood fell off the pieces of lumber (Figure 3). In the tables, these are identified by average loads of zero, or less than 100 pounds, in which perhaps five, six, or seven out of eight replications were zero. In some joints, only one of two fasteners failed; in a minor number, fasteners held and the plywood broke.

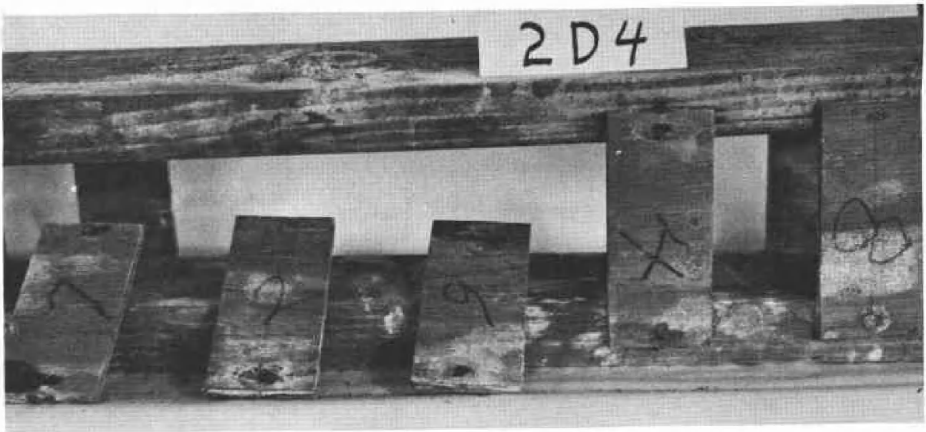

Figure 3. Some fasteners in warm, humid conditions corroded away entirely, leaving plywood cleats unattached.

Considerable corrosion residue developed on the heads of some fasteners (Figure 4), but most corrosion was at the interface between dimension lumber and plywood. Generally, corrosion was worst in joints in which both lumber and plywood were treated.

Fasteners

Average maximum values for lateral bearing load for the eight types of fasteners are shown in Figures 5, 6, and 7 and Tables 3, 4, and 5; each graph and table contains data for a particular fire-retardant treatment. Values for untreated lumber and untreated plywood controls are repeated for ease in comparison. In Tables 3-5, results for fasteners are ranked in numerical order and are classified according to statistical analyses. Values connected by ticks off vertical lines were not significantly different at the 5-percent level. Ranks were determined by a series of tests using individual degrees of freedom.

In several groups, separations by statistical analyses were not definite, and overlapping occurred (some values were in more than one class within the group). Overlapping is not unusual when eight values are to be separated; statements concerning several groups must be general or qualified. The following statements are based on the occurrence of each fastener in the upper, intermediate, or lower class of each group (Tables 3, 4, 5).

No fastener was superior in every condition, but the 6d hot-dip galvanized nail (No. 3) was nearly so; it was in the top class in most groups. The 6d monel nail (No. 8) was next best under all conditions, and was best in warm, humid conditions for 7 years and in lumber and plywood treated with Pyresote (Table 3). The 6d common nail (No. 1), 14-gauge electrogalvanized staple (No. 7), and 6d box nail (No. 2) were classified intermediate in performance, with results from the 6d box nail not quite as good as the other two. The 6d

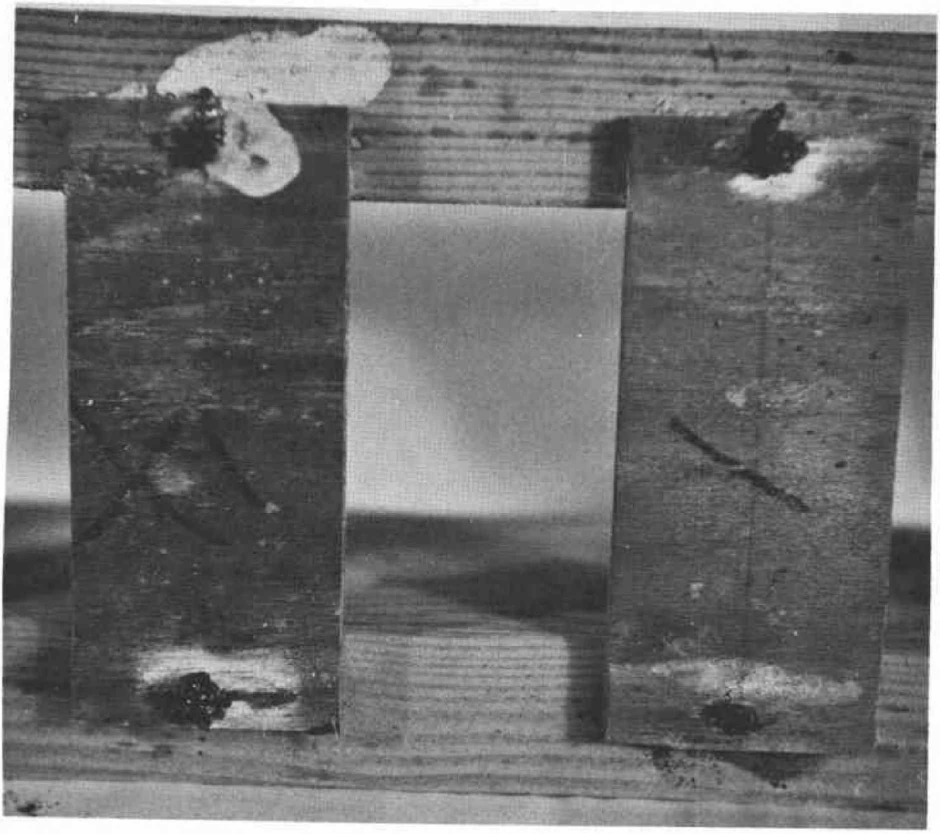

Figure 4. Buildup of corrosion residue on heads of fasteners; many had little residue.

electrogalvanized T-nail (No. 4), 16-gauge electrogalvanized staple (No. 5), and 16-gauge nylon-coated staple (No. 6) were in the lowest class, with performance of the nylon-coated staple lowest of the 8 types of fasteners.

Fire-Retardant Treatments

Comparative performances of each fastener on lumber and plywood treated with three fire-retardants are shown in Figures 8-15. None of the three treatments was consistently best or worst in all conditions or for all eight fasteners. Considering all fasteners as a group, no significant difference was found among the three treatments except for specimens exposed in warm, humid conditions, where those treated with Pyresote were of least strength.

Exposure Time and Condition

Effects of time and condition of exposure on each type fastener are shown in Figures 8-15; average values listed in Tables 6-8 aid in comparing conditions and time. Specimens were affected more in warm, humid conditions than in either cold or standard rooms, especially after exposure for 7 years. Type of treatment of lumber and plywood was a factor also.

About 75 percent of the average values for Pyresote-treated specimens exposed in the warm, humid room for 2 years were significantly lower than values for specimens exposed in the standard or cold room. After 7 years' exposure, all values from Pyresote-treated specimens exposed to high humidity were lower; most were zero or near-zero in strength. For material treated with NON-COM and exposed 2 years, about 13 percent of the average values from specimens in the humid room were significantly lower than those obtained from the standard or cold room; after 7 years, the percentage was 62.

High humidity had less drastic effect on specimens treated with borax-boric acid. After 2 years' exposure, little difference appeared in specimens exposed in humid, standard, and cold rooms. After 7 years' exposure, about 20 percent of the average values from borax-boric acid specimens in the humid room were significantly lower than those from borax-treated specimens in the standard and cold rooms.

Significant differences were found between about 20 percent of the average values obtained from standard and cold room for specimens treated with NON-COM or borax-boric acid, but differences were not consistent. In some periods of exposure and types of treatment, results from the standard room were best; in other situations, results from the cold room were best. In 80 percent of the comparisons, no significant difference was found between the two rooms. For specimens treated with Pyresote, significant differences were found in about 35 percent of the comparisons between standard and cold rooms, with about 9/10 of the differences indicating better results from the standard room.

Table 3. Average[1] Maximum Lateral Bearing Load per Specimen[2] in Pounds, and Ranking[3] of Eight Fasteners Used with Various Combinations of 2- by 6-Inch Douglas-fir Dimension Lumber and 3/8-Inch Sheathing Grade Plywood Untreated and Treated with NON-COM Fire-Retardant and Exposed in Three Different Conditions Up to Seven Years.

No exposure[4]		Exposed 7 years in rooms					
Standard		Warm, humid[6]		Standard[7]		Cold[8]	
Fast.[5]	Load	Fast.	Load	Fast.	Load	Fast.	Load
a. UNTREATED LUMBER AND UNTREATED PLYWOOD (Controls)							
7	624	1	734	3	672	1	783
3	618	7	676	7	657	2	728
8	564	2	671	8	650	3	704
1	549	3	669	1	622	7	653
2	511	8	642	2	588	8	637
4	473	4	562	4	495	4	598
6	453	5	447	5	467	5	547
5	435	6	437	6	367	6	376
b. UNTREATED LUMBER AND TREATED PLYWOOD							
-	---	3	542	3	772	3	801
-	---	7	535	7	721	1	783
-	---	8	481	2	698	2	697
-	---	5	478	8	677	7	667
-	---	2	476	1	661	8	667
-	---	4	476	5	616	4	618
-	---	1	437	4	526	5	473
-	---	6	335	6	333	6	338

These results strengthen the general warning against using FRT wood in warm, humid conditions (1). With judgment, perhaps some selected fasteners could be used with certain FRT wood.

Combinations of Untreated and FRT Lumber and Plywood

Several control groups of specimens were made of untreated lumber and plywood so that results could be compared to specimens with different combinations of treated and untreated lumber and plywood. Some control specimens were tested within 2 weeks (zero exposure in standard conditions) and others were exposed for 2 and 7 years in three conditions—warm and

Table 3. (Continued)

No exposure[4]		Exposed 7 years in rooms					
Standard		Warm, humid[6]		Standard[7]		Cold[8]	
Fast.[5]	Load	Fast.	Load	Fast.	Load	Fast.	Load
c. TREATED LUMBER AND UNTREATED PLYWOOD							
8	744	7	590	3	836	3	787
3	705	3	589	1	806	2	777
1	701	8	546	2	745	1	754
7	695	5	504	8	745	8	743
2	614	1	498	7	683	4	696
4	552	4	494	5	563	7	647
5	550	6	420	4	559	5	538
6	373	2	397	6	453	6	353
d. TREATED LUMBER AND TREATED PLYWOOD							
-	---	3	489	3	782	3	676
-	---	7	487	8	782	1	651
-	---	8	458	2	729	2	650
-	---	4	429	1	680	8	641
-	---	1	384	7	641	7	634
-	---	5	347	4	579	4	515
-	---	2	313	5	510	5	337
-	---	6	270	6	355	6	234

[1]Average of 10 replications in sets a and b and 8 in sets c and d.

[2]Each specimen consisted of a plywood cleat fastened to 2 pieces of lumber, 1 fastener in each piece, and load applied laterally. See Figure 1.

[3]Values connected by ticks off vertical lines were not significantly different at 5% significance level.

[4]Specimens tested within 2 weeks. Conditions similar to standard room.

[5]Fasteners were: 1, 6d common nail; 2, 6d box nail; 3, 6d hot-dip galvanized nail; 4, 6d electrogalvanized T-nail; 5, 16-gauge electrogalvanized staple; 6, 16-gauge nylon-coated staple; 7, 14-gauge electrogalvanized staple; and 8, 6d monel nail. All were about 2 inches long; staples were about 1/2-inch wide.

[6]Relative humidity 90%, temperature 90°F.

[7]Relative humidity 65%, temperature 70°F.

[8]Relative humidity variable (70-80%), temperature 35°F.

humid, standard, and cold. Average values for controls are shown as solid circles in Figures 8-15 and are among initial values in each of the tables.

For all fasteners except the nylon-coated staple (No. 6), lateral bearing strength values increased (compared to controls) for specimens tested soon after fabrication in which only lumber was treated; many of the increases were significant. Probably, treatments increased density of the lumber. If all seven fasteners are considered as a group, no significant differences occur among the three fire retardants. For some unknown reason, borax-boric acid treatment increased, and Pyresote and NON-COM decreased the strength of joints fabricated with nylon-coated staples and tested within 2 weeks.

Results from several types of fasteners used in FRT lumber and plywood were as good as, or better than, results from the same fastener used with untreated lumber and plywood (controls). When all eight types of fasteners in three rooms for the 2 and 7 years' exposure periods were considered as a group, however, significant differences in average results did appear among specimens fabricated with different combinations of treated and untreated lumber and plywood (Figures 6, 7, 8). The different combinations, plus untreated controls, are ranked in descending order in Table 9 according to significant differences (5 percent level) within each treatment.

Results from all three treatments indicated that joints with untreated plywood gave best results. Apparently, treatments affected the strength of plywood. This is consistent with failures that occurred in the majority of specimens in which fasteners pulled part way out of the lumber, and heads of fasteners pulled through the plywood. Results were affected less

Table 4. Average[1] Maximum Lateral Bearing Load per Specimen[2] in Pounds, and Ranking[3] of Eight Fasteners Used with Various Combinations of 2- by 6-Inch Douglas-fir Dimension Lumber and 3/8-Inch Sheathing-Grade Plywood Untreated and Treated with Pyresote Fire-Retardant and Exposed in Three Different Conditions Up to Seven Years.

No exposure[4]		Exposed 7 years in rooms					
Standard		Warm, humid[6]		Standard[7]		Cold[8]	
Fast.[5]	Load	Fast.	Load	Fast.	Load	Fast.	Load
a. UNTREATED LUMBER AND UNTREATED PLYWOOD (Controls)							
7	624	1	734	3	672	1	783
3	618	7	676	7	657	2	728
8	564	2	671	8	650	3	704
1	549	3	669	1	622	7	653
2	511	8	642	2	588	8	637
4	473	4	562	4	495	4	598
6	453	5	447	5	467	5	547
5	435	6	437	6	367	6	376
b. UNTREATED LUMBER AND TREATED PLYWOOD							
-	---	8	368	8	687	3	685
-	---	3	338	7	683	1	659
-	---	4	64	1	670	8	658
-	---	1	29	3	659	2	624
-	---	7	18	2	577	7	621
-	---	2	11	5	565	4	579
-	---	6	9	4	529	5	542
-	---	5	0	6	379	6	306

when only the lumber was treated. Joints tended to be of least strength when both lumber and plywood were treated.

SUMMARY AND CONCLUSIONS

Lumber-plywood joints were fabricated from different combinations of untreated and FRT Douglas-fir dimension lumber and 3/8-inch plywood. Eight types of fasteners and three treatments were tested. Joint specimens were exposed 2 and 7 years in cold, standard, and warm, humid conditions and then tested for lateral bearing.

Considering all factors, greatest strength values were obtained from joints made with 6d hot-dip galvanized nails. The 6d monel nail was next best overall, and was best in warm, humid

Table 4. (Continued)

No exposure[4]		Exposed 7 years in rooms					
Standard		Warm, humid[6]		Standard[7]		Cold[8]	
Fast.[5]	Load	Fast.	Load	Fast.	Load	Fast.	Load
c. TREATED LUMBER AND UNTREATED PLYWOOD							
8	755	8	443	1	877	3	777
2	749	3	191	2	828	1	768
1	730	4	19	3	798	2	685
3	717	1	0	7	716	8	665
7	703	2	0	8	697	4	618
4	589	7	0	4	608	7	575
5	529	5	0	5	538	5	413
6	389	6	0	6	372	6	388
d. TREATED LUMBER AND TREATED PLYWOOD							
-	---	8	362	2	775	3	654
-	---	3	71	8	763	8	569
-	---	1	12	3	755	7	558
-	---	2	0	1	741	2	527
-	---	7	0	7	713	4	515
-	---	4	0	4	656	1	508
-	---	5	0	5	591	5	422
-	---	6	0	6	351	6	348

[1]Average of 10 replications in sets a and b and 8 in sets c and d.

[2]Each specimen consisted of a plywood cleat fastened to 2 pieces of lumber, 1 fastener in each piece, and load applied laterally. See Figure 1.

[3]Values connected by ticks off vertical lines were not significantly different at 5% significance level.

[4]Specimens tested within 2 weeks. Conditions similar to standard room.

[5]Fasteners were: 1, 6d common nail; 2, 6d box nail; 3, 6d hot-dip galvanized nail; 4, 6d electrogalvanized T-nail; 5, 16-gauge electrogalvanized staple; 6, 16-gauge nylon-coated staple; 7, 14-gauge electrogalvanized staple; and 8, 6d monel nail. All were about 2 inches long; staples were about 1/2-inch wide.

[6]Relative humidity 90%, temperature 90°F.

[7]Relative humidity 65%, temperature 70°F.

[8]Relative humidity variable (70-80%), temperature 35°F.

conditions. Least strength was obtained from specimens made with 16-gauge nylon-coated staples.

When exposed in cold and standard conditions, about equal results were obtained from joints treated with NON-COM, Pyresote, and borax-boric acid. In warm, humid conditions, however, specimens treated with Pyresote were lowest in strength.

The warning against using FRT wood exposed in warm, humid conditions for prolonged periods should be followed, or considerable judgment should be exercised regarding types of fasteners to be used. Although some joints did not lose strength after 2 years' exposure in warm, humid conditions, nearly all lost strength after 7 years; in many joints, the fasteners corroded away, resulting in zero strength.

For each of the eight fasteners, many joints fabricated from different combinations of treated and untreated lumber and plywood gave results as good as those for untreated control specimens. In general, however, greatest values were obtained from untreated specimens; those joints with untreated plywood were next best; those with both lumber and plywood treated were lowest in strength.

Should results from specimens that were exposed in warm, humid conditions be eliminated from these analyses, differences between untreated controls and treated specimens would be reduced considerably.

Different results might be found in a similar study if thicker plywood were used, because final failure in the majority of these tests was fastener heads pulling through plywood.

Table 5. Average[1] Maximum Lateral Bearing Load per Specimen[2] in Pounds, and Ranking[3] of Eight Fasteners Used with Various Combinations of 2- by 6-Inch Douglas-fir Dimension Lumber and 3/8-Inch Sheathing-Grade Plywood Untreated and Treated with Borax-Boric Acid Fire-Retardant and Exposed in Three Different Conditions Up to Seven Years.

No exposure[4]		Exposed 7 years in rooms					
Standard		Warm, humid[6]		Standard[7]		Cold[8]	
Fast.[5]	Load	Fast.	Load	Fast.	Load	Fast.	Load
a. UNTREATED LUMBER AND UNTREATED PLYWOOD (Controls)							
7	624	1	734	3	672	1	783
3	618	7	676	7	657	2	728
8	564	2	671	8	650	3	704
1	549	3	669	1	622	7	653
2	511	8	642	2	588	8	637
4	473	4	562	4	495	4	598
6	453	5	447	5	467	5	547
5	435	6	437	6	367	6	376
b. UNTREATED LUMBER AND TREATED PLYWOOD							
-	---	3	521	3	691	3	674
-	---	8	509	7	650	7	651
-	---	4	465	8	636	8	640
-	---	7	454	1	585	1	624
-	---	5	401	2	572	2	577
-	---	6	384	4	511	4	546
-	---	1	352	5	407	5	402
-	---	2	276	6	379	6	319

LITERATURE CITED

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2. JOHNSON, JAMES W. and THOMAS J. ALBERT. "Tests of Power-Driven Fasteners for Plywood." For. Prod. J. 12:589-595. December 1962.

3. JOHNSON, J. W. Bending Strength for Small Joists of Douglas-fir Treated with Fire Retardants. Oregon State University, School of Forestry, Forest Research Laboratory, Corvallis, Oregon. Report T-23. August 1967.

Table 5. (Continued)

No exposure[4]		Exposed 7 years in rooms					
Standard		Warm, humid[6]		Standard[7]		Cold[8]	
Fast.[5]	Load	Fast.	Load	Fast.	Load	Fast.	Load
c. TREATED LUMBER AND UNTREATED PLYWOOD							
3	809	3	746	3	837	1	878
7	676	7	706	2	789	2	813
8	674	2	695	8	716	3	798
1	655	1	674	1	701	8	687
2	598	8	647	7	684	4	660
4	561	4	629	4	502	7	659
6	559	5	605	5	473	5	543
5	461	6	512	6	423	6	406
d. TREATED LUMBER AND TREATED PLYWOOD							
-	---	3	677	3	727	1	750
-	---	7	606	7	691	7	656
-	---	4	569	1	660	3	639
-	---	1	555	8	654	2	594
-	---	2	549	2	631	8	563
-	---	5	538	4	495	4	515
-	---	8	538	5	479	5	488
-	---	6	437	6	395	6	453

[1]Average of 10 replications.

[2]Each specimen consisted of a plywood cleat fastened to 2 pieces of lumber, 1 fastener in each piece, and load applied laterally. See Figure 1.

[3]Values connected by ticks off vertical lines were not significantly different at 5% significance level.

[4]Specimens tested within 2 weeks. Conditions similar to standard room.

[5]Fasteners were: 1, 6d common nail; 2, 6d box nail; 3, 6d hot-dip galvanized nail; 4, 6d electrogalvanized T-nail; 5, 16-gauge electrogalvanized staple; 6, 16-gauge nylon-coated staple; 7, 14-gauge electrogalvanized staple; and 8, 6d monel nail. All were about 2 inches long; staples were about 1/2-inch wide.

[6]Relative humidity 90%, temperature 90°F.

[7]Relative humidity 65%, temperature 70°F.

[8]Relative humidity variable (70-80%), temperature 35°F.

Table 6. Average[1] Maximum Lateral Bearing Load per Specimen[2] in Pounds, of Eight Fasteners Used with Various Combinations of 2- by 6-Inch Douglas-fir Dimension Lumber and 3/8-Inch Sheathing-Grade Plywood Untreated and Treated with NON-COM Fire-Retardant and Exposed in Three Different Conditions Up to Seven Years.

Exposure		Fastener number[4]							
Years	Room[3]	1	2	3	4	5	6	7	8
	a. UNTREATED LUMBER AND UNTREATED PLYWOOD (CONTROLS)								
0	Std.	549	511	618	473	435	453	624	564
	b. TREATED LUMBER AND UNTREATED PLYWOOD								
0	Std.	701	614	705	552	550	373	695	744
	c. UNTREATED LUMBER AND UNTREATED PLYWOOD (CONTROLS)								
7	Humid	734	671	669	562	447	437	676	642
7	Std.	622	588	672	495	467	367	657	650
7	Cold	783	728	704	598	547	376	653	637
	d. UNTREATED LUMBER AND TREATED PLYWOOD								
7	Humid	437	476	542	476	478	335	535	481
7	Std.	661	698	772	526	616	333	721	677
7	Cold	783	697	801	618	473	338	667	667
	e. TREATED LUMBER AND UNTREATED PLYWOOD								
7	Humid	498	397	589	494	504	420	590	546
7	Std.	806	745	836	559	563	453	683	745
7	Cold	754	777	787	696	538	353	647	743
	f. TREATED LUMBER AND TREATED PLYWOOD								
7	Humid	384	313	489	429	347	270	487	458
7	Std.	680	729	782	579	510	355	641	782
7	Cold	651	650	676	515	337	234	634	641
Sig. Diff.[5]		100	100	110	80	105	110	100	95

[1]Average of 10 replications in sets a, c, d; 8 in sets b, e, f.

[2]Each specimen consisted of a plywood cleat fastened to 2 pieces of lumber, 1 fastener in each piece, and load applied laterally. See Figure 1.

[3]Humid room: relative humidity 90%, temperature 90°F; standard room: relative humidity 65%, temperature 70°F; cold room: relative humidity variable (70-80%), temperature 35°F.

[4]Fasteners were: 1, 6d common nail; 2, 6d box nail; 3, 6d hot-dip galvanized nail; 4, 6d electrogalvanized T-nail; 5, 16-gauge electrogalvanized staple; 6, 16-gauge nylon-coated staple; 7, 14-gauge electrogalvanized staple; and 8, 6d monel nail. All were about 2 inches long; staples were about 1/2-inch wide.

[5]An approximate number, based on variance of fasteners in each group, estimating the difference required between 2 average values to show significance (5% level). Probable range ±5, depending on the values compared.

Table 7. Average[1] Maximum Lateral Bearing Load per Specimen[2] in Pounds, of Eight Fasteners Used with Various Combinations of 2- by 6-Inch Douglas-fir Dimension Lumber and 3/8 Inch Sheathing-Grade Plywood Untreated and Treated with Pyresote Fire-Retardant and Exposed in Three Different Conditions Up to Seven Years.

Exposure		Fastener number[4]							
Years	Room[3]	1	2	3	4	5	6	7	8
	a. UNTREATED LUMBER AND UNTREATED PLYWOOD (CONTROLS)								
0	Std.	549	511	618	473	435	453	624	564
	b. TREATED LUMBER AND UNTREATED PLYWOOD								
0	Std.	730	749	717	589	529	389	703	755
	c. UNTREATED LUMBER AND UNTREATED PLYWOOD (CONTROLS)								
7	Humid	734	671	669	562	447	437	676	642
7	Std.	622	588	672	495	467	367	657	650
7	Cold	783	728	704	598	547	376	653	637
	d. UNTREATED LUMBER AND TREATED PLYWOOD								
7	Humid	29	11	338	64	0	9	18	368
7	Std.	670	577	659	529	565	379	683	687
7	Cold	659	624	685	579	542	306	621	658
	e. TREATED LUMBER AND UNTREATED PLYWOOD								
7	Humid	0	0	191	19	0	0	0	443
7	Std.	877	828	798	608	538	372	716	697
7	Cold	768	685	777	618	413	388	575	665
	f. TREATED LUMBER AND TREATED PLYWOOD								
7	Humid	12	0	71	0	0	0	0	362
7	Std.	741	775	755	656	591	351	713	763
7	Cold	508	527	654	515	422	348	558	569
Sig. Diff.[5]		100	90	105	85	105	85	100	95

[1]Average of 10 replications in sets a, c, d; 8 in sets b, e, f.

[2]Each specimen consisted of a plywood cleat fastened to 2 pieces of lumber, 1 fastener in each piece, and load applied laterally. See Figure 1.

[3]Humid room: relative humidity 90%, temperature 90°F; standard room: relative humidity 65%, temperature 70°F; cold room: relative humidity variable (70-80%), temperature 35°F.

[4]Fasteners were: 1, 6d common nail; 2, 6d box nail; 3, 6d hot-dip galvanized nail; 4, 6d electrogalvanized T-nail; 5, 16-gauge electrogalvanized staple; 6, 16-gauge nylon-coated staple; 7, 14-gauge electrogalvanized staple; and 8, 6d monel nail. All were about 2 inches long; staples were about 1/2-inch wide.

[5]An approximate number, based on variance of fasteners in each group, estimating the difference required between 2 average values to show significance (5% level). Probable range ±5, depending on the values compared.

Table 8. Average[1] Maximum Lateral Bearing Load per Specimen[2] in Pounds, of Eight Fasteners Used with Various Combinations of 2- by 6-Inch Douglas-fir Dimension Lumber and 3/8-Inch Sheathing-Grade Plywood Untreated and Treated with Borax-Boric Acid Fire-Retardant and Exposed in Three Different Conditions Up to Seven Years.

Exposure		Fastener number[4]							
Years	Room[3]	1	2	3	4	5	6	7	8
	a. UNTREATED LUMBER AND UNTREATED PLYWOOD (CONTROLS)								
0	Std.	549	511	618	473	435	453	624	564
	b. TREATED LUMBER AND UNTREATED PLYWOOD								
0	Std.	655	598	809	561	461	559	676	674
	c. UNTREATED LUMBER AND UNTREATED PLYWOOD (CONTROLS)								
7	Humid	734	671	669	562	447	437	676	642
7	Std.	622	588	672	495	467	367	657	650
7	Cold	783	728	704	598	547	376	653	637
	d. UNTREATED LUMBER AND TREATED PLYWOOD								
7	Humid	352	276	521	465	401	384	454	509
7	Std.	585	572	691	511	407	379	650	636
7	Cold	624	577	674	546	402	319	651	640
	e. TREATED LUMBER AND UNTREATED PLYWOOD								
7	Humid	674	695	746	629	605	512	706	647
7	Std.	701	789	837	502	473	423	684	716
7	Cold	878	813	798	660	543	406	659	687
	f. TREATED LUMBER AND TREATED PLYWOOD								
7	Humid	555	549	677	569	538	437	606	538
7	Std.	660	631	727	495	479	395	691	654
7	Cold	750	594	639	515	488	453	656	563
Sig. Diff.[5]		105	95	105	70	110	90	90	85

[1]Average of 10 replications.

[2]Each specimen consisted of a plywood cleat fastened to 2 pieces of lumber, 1 fastener in each piece, and load applied laterally. See Figure 1.

[3]Humid room: relative humidity 90%, temperature 90°F; standard room: relative humidity 65%, temperature 70°F; cold room: relative humidity variable (70-80%), temperature 35°F.

[4]Fasteners were: 1, 6d common nail; 2, 6d box nail; 3, 6d hot-dip galvanized nail; 4, 6d electrogalvanized T-nail; 5, 16-gauge electrogalvanized staple; 6, 16-gauge nylon-coated staple; 7, 14-gauge electrogalvanized staple; and 8, 6d monel nail. All were about 2 inches long; staples were about 1/2-inch wide.

[5]An approximate number based on variance of fasteners in each group, estimating the difference required between 2 average values to show significance (5% level). Probable range ±5, depending on the values compared.

Table 9. Different Combinations of Treated and Untreated Lumber and Plywood in Descending Order According to Significant Differences Within Each Treatment.

NON-COM			Pyresote			Borax-boric acid		
Rank	Lumber treated	Plywood treated	Rank	Lumber treated	Plywood treated	Rank	Lumber treated	Plywood treated
1[1]	Yes	No	1	No	No	1	Yes	No
1[1]	No	No	2	Yes	No	2	No	No
3	No	Yes	3	No	Yes	3	Yes	Yes
4	Yes	Yes	4	Yes	Yes	4	No	Yes

[1]Both joint combinations in first rank.

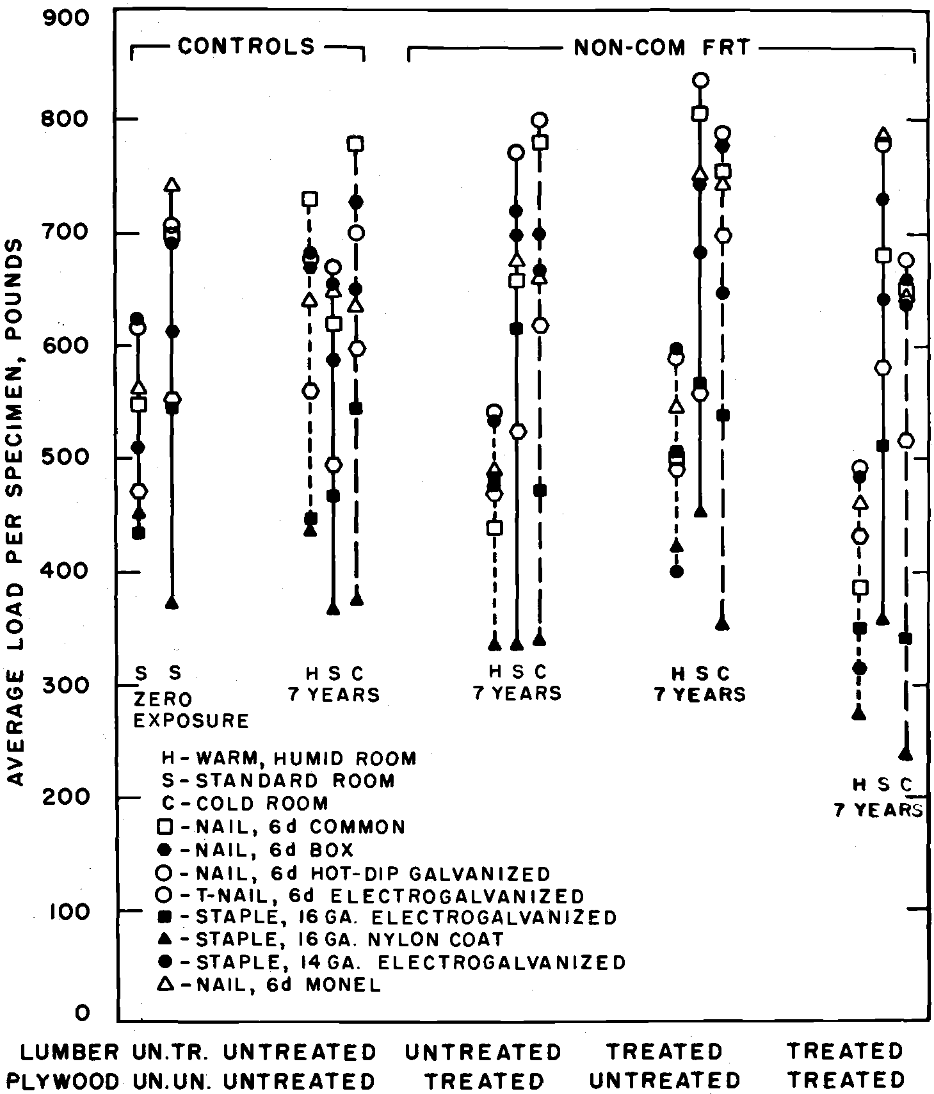

Figure 5. Overall view of average values obtained from specimens on NON-COM-treated and untreated wood exposed to different conditions.

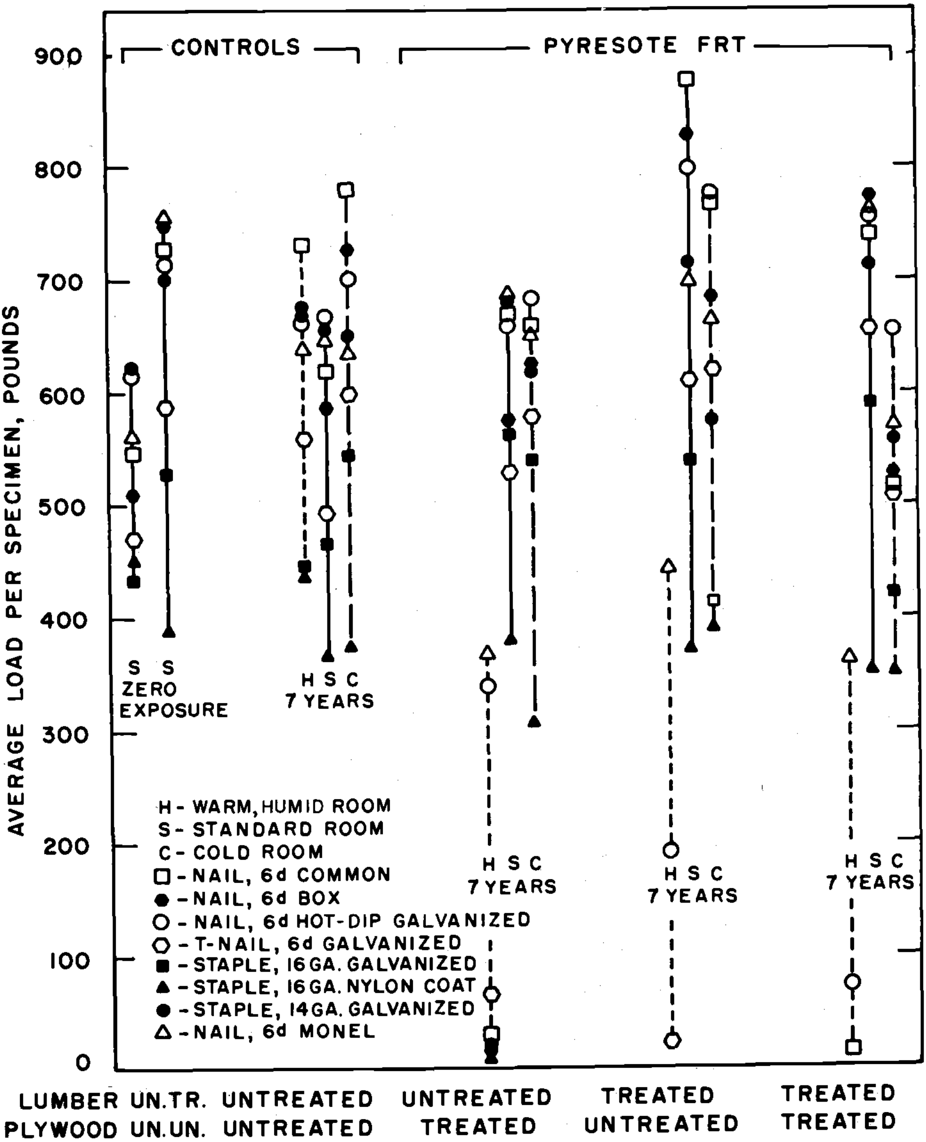

Figure 6. Overall view of average values obtained from specimens of Pyresote-treated and untreated wood exposed to different conditions.

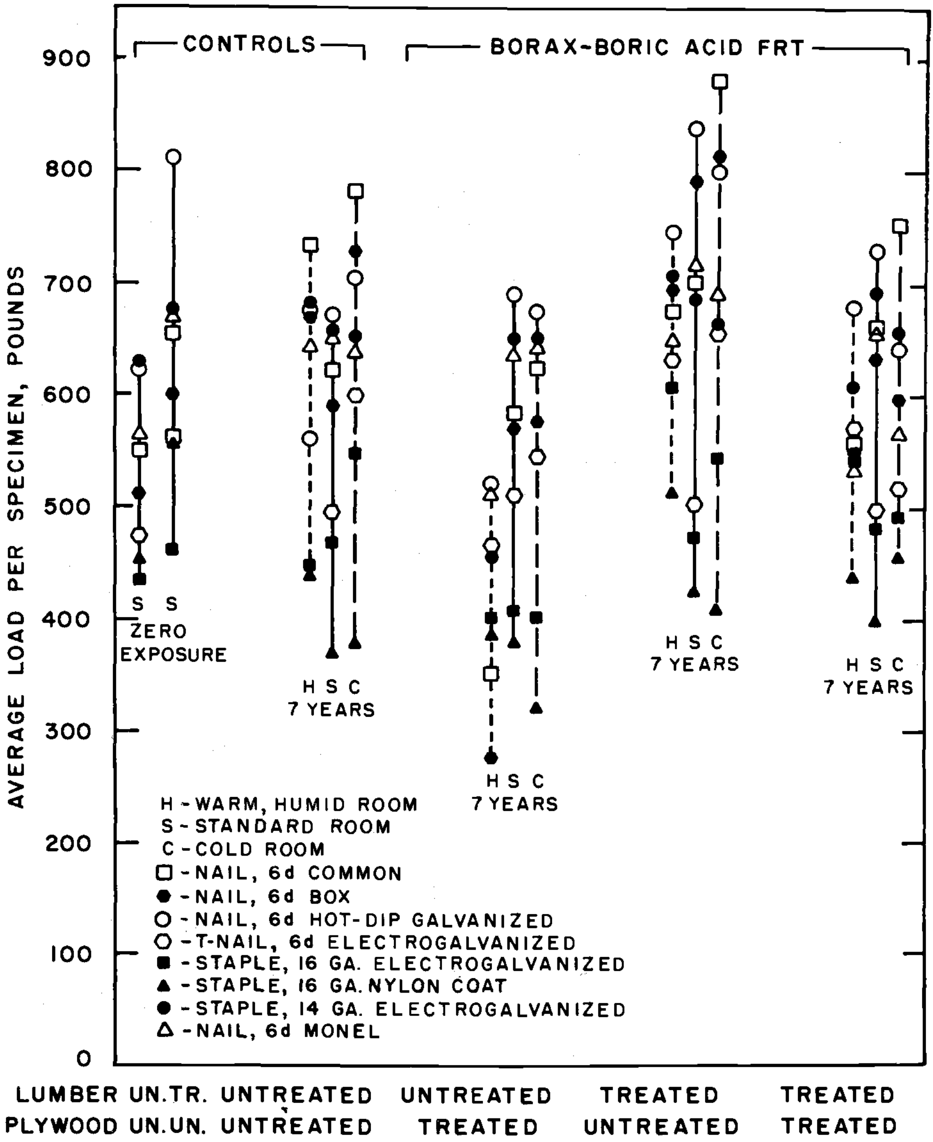

Figure 7. Overall view of average values obtained from specimens of borax-boric acid-treated and untreated wood exposed to different conditions.

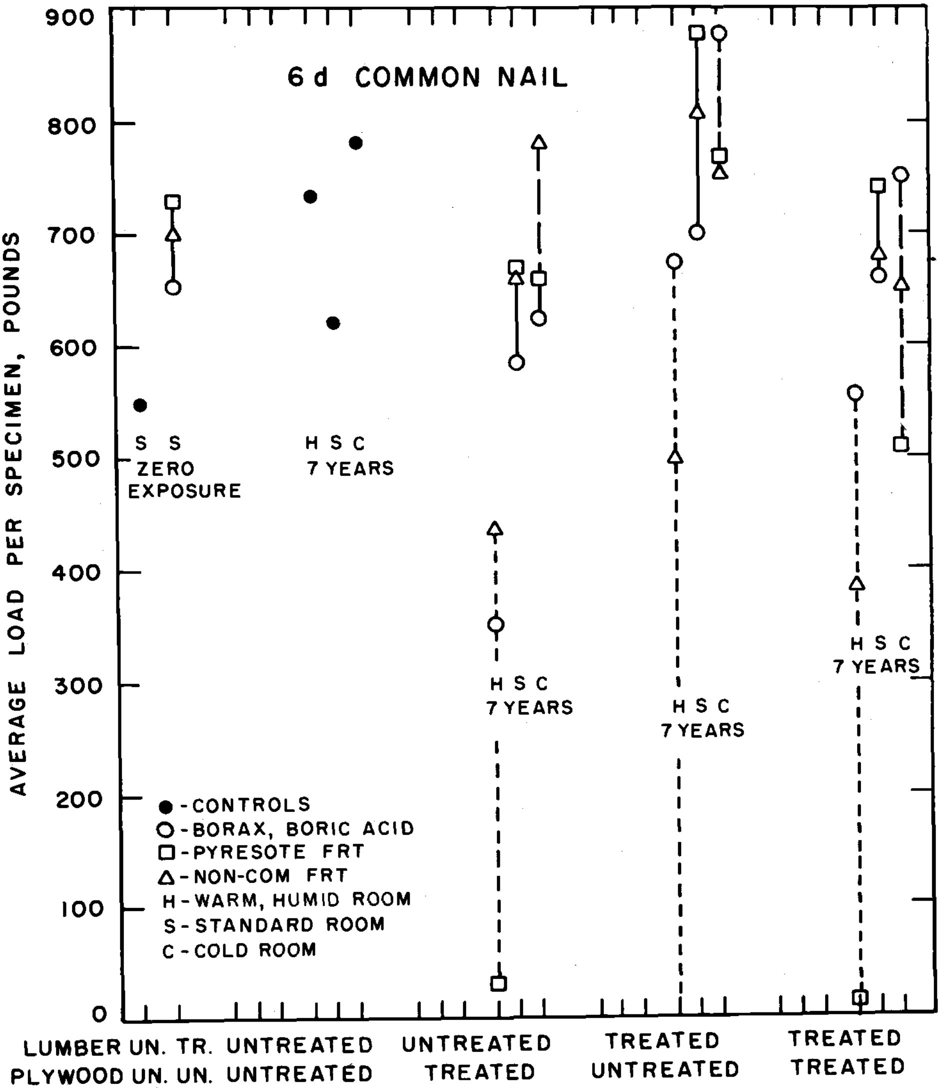

Figure 8. Average values from specimens fabricated with 6d common nails; wood untreated and treated with three fire retardants; different conditions of exposure.

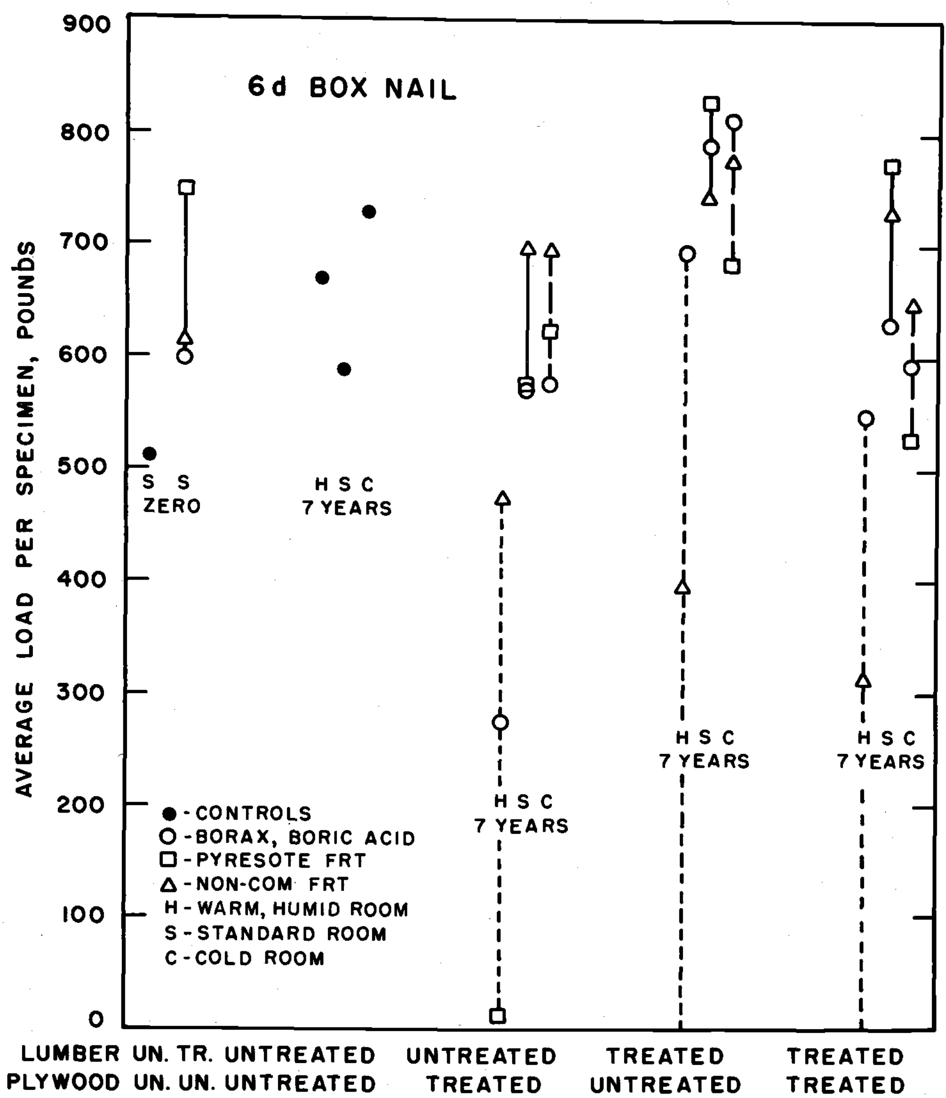

Figure 9. Average values from specimens fabricated with 6d box nails; wood untreated and treated with three fire retardants; different conditions of exposure.

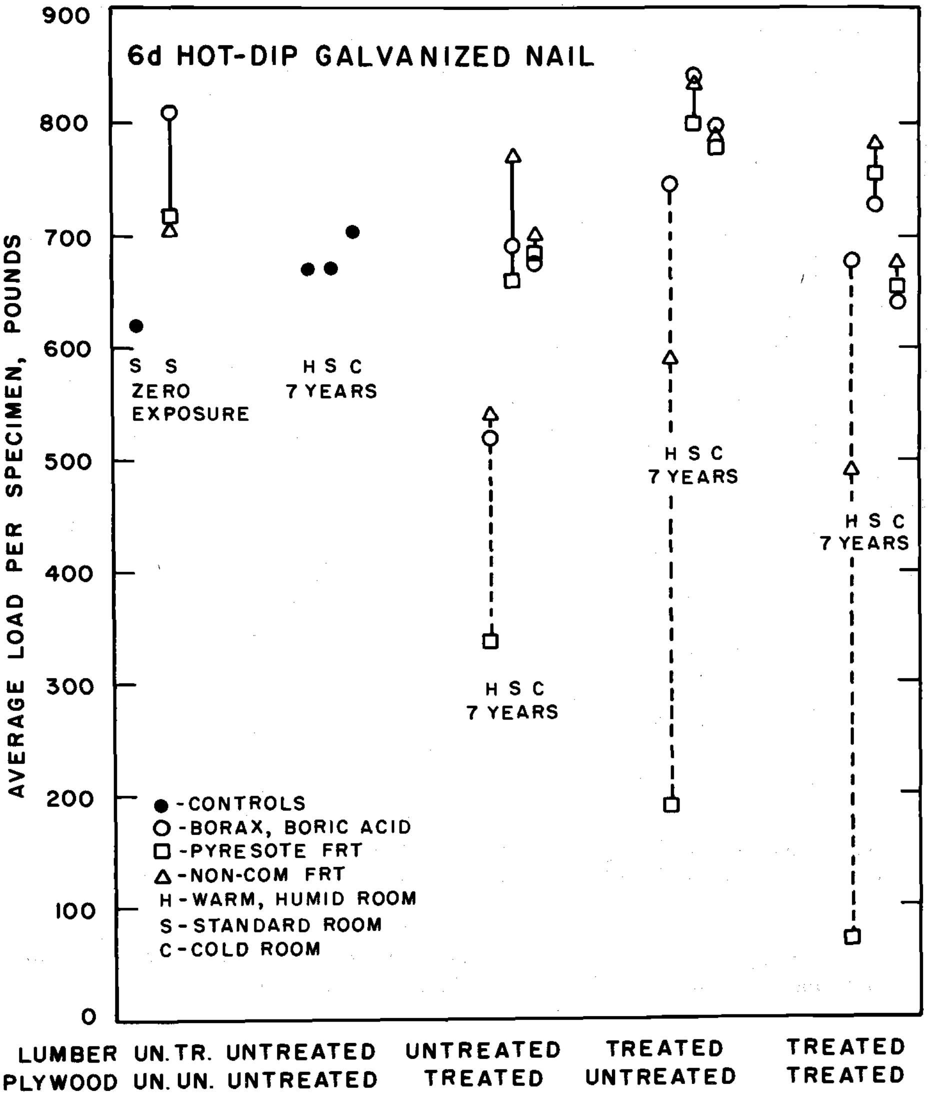

Figure 10. Average values from specimens fabricated with 6d hot-dip galvanized nails; wood untreated and treated with three fire retardants; different conditions of exposure.

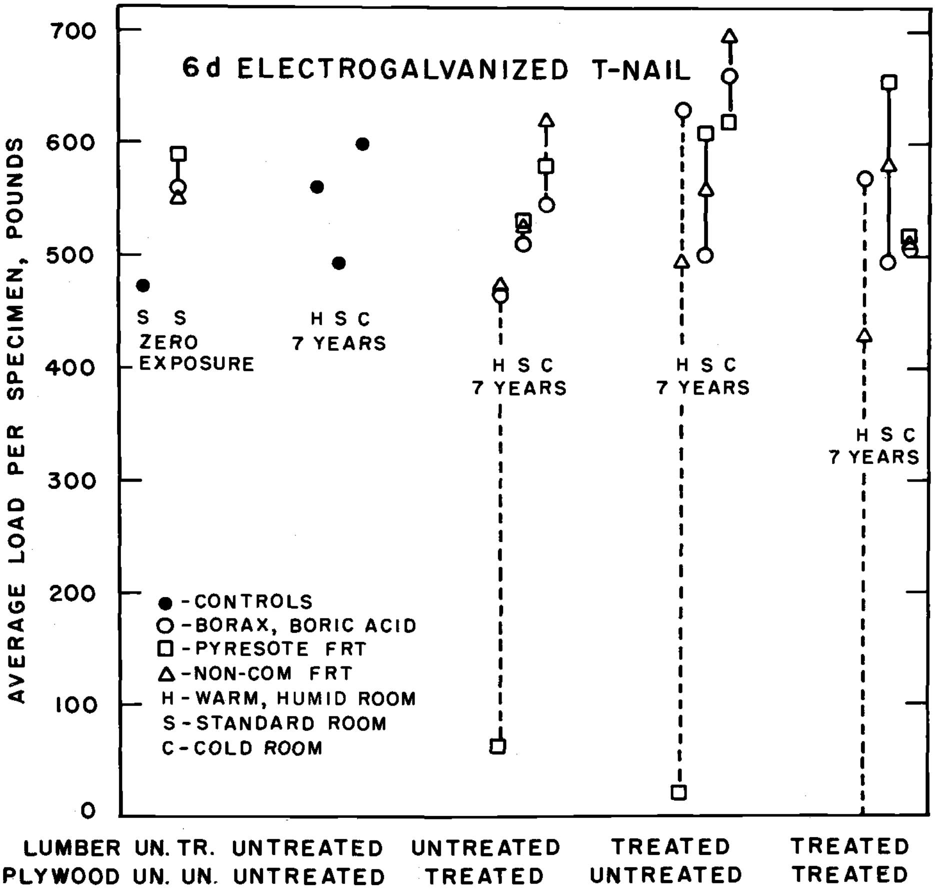

Figure 11. Average values from specimens fabricated with 6d electrogalvanized T-nails; wood untreated and treated with three fire retardants; different conditions of exposure.

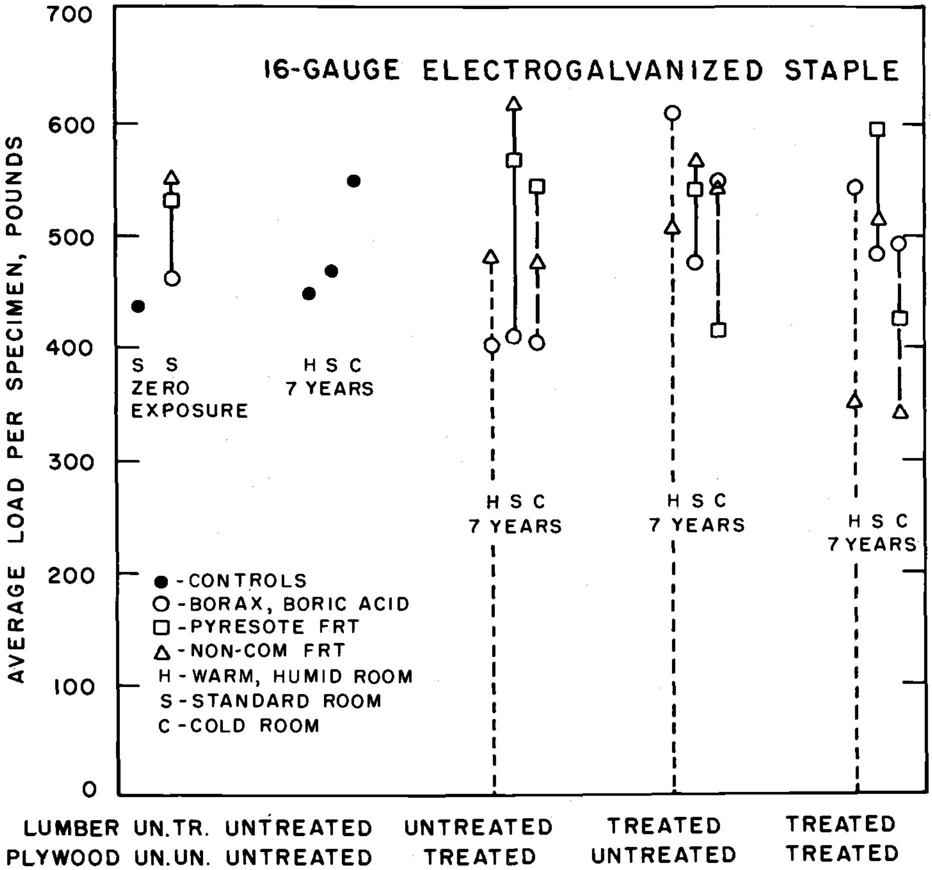

Figure 12. Average values from specimens fabricated with 16-gauge electrogalvanized staples; wood untreated and treated with three fire retardants; different conditions of exposure.

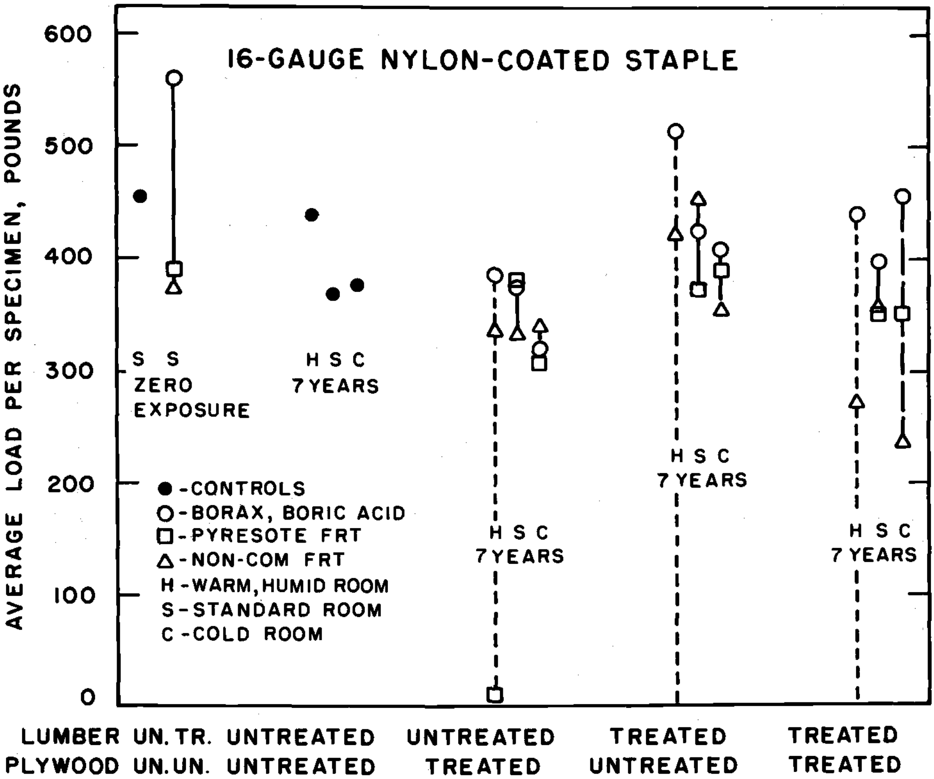

Figure 13. Average values from specimens fabricated with 16-gauge nylon-coated staples; wood untreated and treated with three fire retardants; different conditions of exposure.

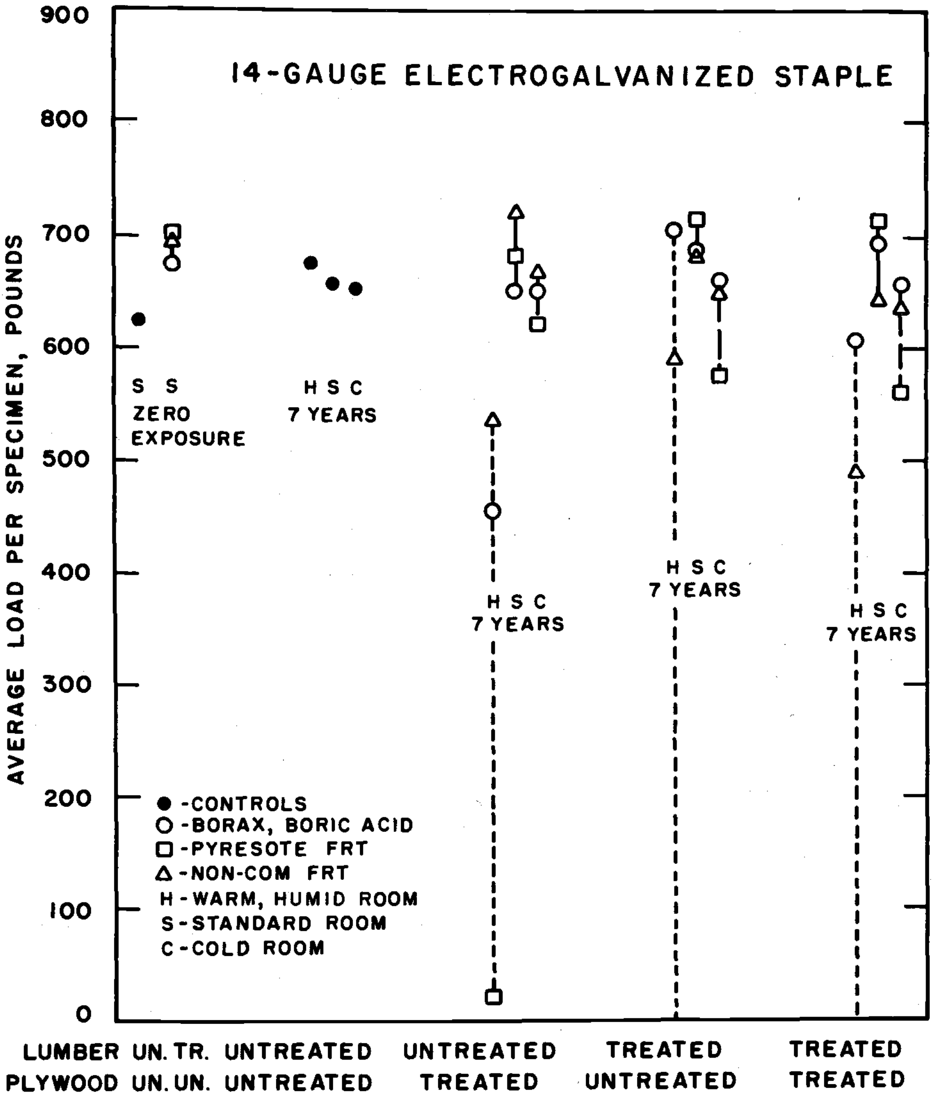

Figure 14. Average values from specimens fabricated with 14-gauge electrogalvanized staples; wood untreated and treated with three fire retardants; different conditions of exposure.

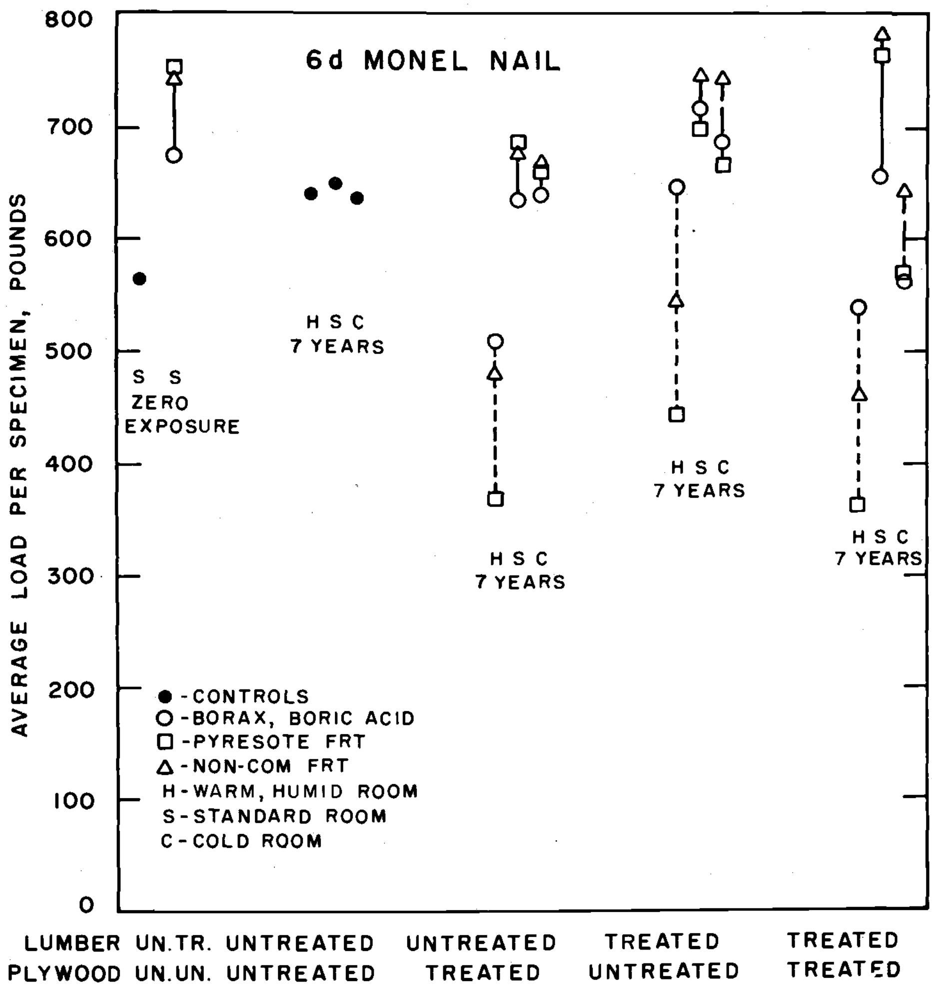

Figure 15. Average values from specimens fabricated with 6d monel nails; wood untreated and treated with three fire retardants; different conditions of exposure.