Interaction of CCA preservative treatment and redrying: effect on the mechanical properties of southern pine

J.E. Winandy
R.S. Boone
B.A. Bendtsen

Abstract

Preservative treatment with chromated copper arsenate (CCA) and kiln redrying can adversely affect the mechanical properties of southern pine. To assess the extent of the effect, we treated small clear specimens to CCA target retentions of 0.25, 0.40, 3.60, 1.0, or 2.5 pounds per cubic foot (pcf) and dried at maximum dry-bulb temperatures of 80°, 140°, 180°, or 220°F. A highly significant interaction existed between the level of CCA treatment and redrying temperature. When southern pine treated to CCA retentions of up to 1.00 pcf was dried at temperatures of ⩽140°F and compared to similarly dried controls, neither maximum crushing strength (MCS), modulus of elasticity (MOE), modulus of rupture (MOR), or work to maximum load (WML) were affected; when dried at ⩾180°F, MCS and MOE were not affected, MOR was reduced 11 percent, and WML was reduced 37 percent. When pine treated to a CCA retention of 2.5 pcf was dried at temperatures of ⩽140°F, MCS was increased by 15 percent, MOE and MOR were not affected, and WML was reduced 27 percent; at 180°F, MCS was increased 9 percent, MOE was not affected, MOR was reduced 12 percent, and WML was reduced 46 percent. At 220°F, MOE was still not affected while MCS was reduced 9 percent, MOR was reduced 30 percent, and WML was reduced 68 percent. Statistical models were developed to quantify the response between CCA retention and the kiln-drying temperature. These models were used to establish guidelines for current Forest Products Laboratory studies on the response of CCA-treated southern pine dimension lumber.

Of all the wood pressure treated with preservatives in the United States, approximately 28 percent is treated with waterborne inorganic arsenical preservatives, mostly chromated copper arsenate (CCA) (12). CCA's cleanliness, paintability, and resistance to environmental leaching and biological deterioration are prime reasons it is often the preferred treatment for lumber. Southern pine is often a preferred species because it is readily available and easily treatable. However, it has long been suspected that the treatment and subsequent redrying has adverse effects on the wood's properties. Intuitively, we expect the degradative effects of CCA on strength to be critically influenced by the temperature and the duration of the redrying process. Our objective is to evaluate the effect of CCA preservative treatments and subsequent drying on the mechanical properties of southern pine.

To do this, small clear specimens were treated to six CCA retention levels and redried at four drying temperatures; the effects on the bending and compression properties were assessed.

To evaluate and predict such effects and their interactions on a broader basis we derived mathematical models that represent these relationships.

Background

For effective CCA treatment, the wood must first be dry ($\lesssim$20% moisture content (MC)). During typical CCA treatment using the full-cell (Bethell) process, the wood becomes thoroughly saturated. Accordingly, treated wood is often redried to 1) reduce shipping weight, 2) promote dimensional stability, and 3) complete the CCA fixation process which occurs with the wood.

The effects of CCA treatments and subsequent redrying on the mechanical properties of wood are not

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The authors are, respectively, Research Forest Products Technologists and Supervisory Research Forest Products Technologist, USDA Forest Serv., Forest Prod. Lab., One Gifford Pinchot Dr., Madison, WI 53705. This paper was received for publication in December 1984.

thoroughly understood. Because of the acidic nature of CCA, hydrolytic degradation may occur when CCA-treated material is kiln-redried, especially at higher temperatures. This is important because redrying temperatures of >212°F (i.e., high-temperature drying (HTD)) are sometimes employed by the treating industry.

HTD is economical and has little effect on the strength of untreated southern pine (10, 15). However, CCA-treated material is apparently affected at redrying temperatures as low as 190°F. The bending strength of No. 1 and Better 2 by 6 southern pine lumber, treated with CCA to a retention of 0.3 pound per cubic foot (pcf) was significantly reduced when redried at 190° or 240°F, when compared to untreated lumber controls (4). No difference was found between the treated lumber dried at 190° or 240°F.

There is limited mechanical property data available in which both the CCA retention level and the drying level were controlled over a broad range of the other. Evaluation of the interaction between CCA retention and redrying temperatures over a broad range of retentions and temperatures may explain the diverse results reported in the literature which has recently been reviewed (14).

Methods and material

Design

Two experiments were run concurrently—one on the bending properties and the other on the compression properties of clear specimens of southern pine. The mechanical properties studied in bending were modulus of elasticity (MOE), modulus of rupture (MOR), and work to maximum load (WML), and in compression, maximum crushing strength (MCS). The statistical designs of both experiments were 6 by 4 factorials having 24 sets of specimens, one at each combination of the six retentions and four drying levels. A water-treated control and five levels of CCA treatment (0.25, 0.40, 0.60, 1.00, and 2.50 pcf) were chosen. The CCA treatment levels correspond to American Wood-Preservers' Association (2) CCA retention levels for various end uses. The four levels of drying (80°, 140°, 180°, and 220°F) represent arbitrarily chosen air, conventional (both low and high), and high-temperature kiln-drying regimes. There were 34 replications per set for the bending experiment and 24 for the compression experiment.

Material

The experimental material was obtained from 26 trees cut from the USDA Forest Service Harrison Experimental Forest near Gulfport, Miss. Trees were longleaf pine (*Pinus palustris* Mill.) and slash pine (*P. elliotii* Engelm.), between 25 to 35 years of age, with diameters at breast height of 9 to 16 inches and heights of 50 to 70 feet.

Processing

The trees were cut into 6-foot logs (about five logs per tree), end-coated to retard drying, and shipped for processing to the Forest Products Laboratory (FPL) in Madison, Wis. The logs were sawn into 1-1/4-inch-thick flitches and then ripped into 1-1/4-inch-square sticks. The sticks were air-dried to approximately 12 percent MC, surfaced to 1 inch square, and crosscut to 18-inch lengths.

It is often desirable to reduce variability in mechanical property estimates from small clear specimens. Thus, it is common that the growth rings be oriented parallel to a face. Because our goal is ultimately to apply this information to dimension lumber and because the rings in lumber are randomly oriented, no attempt was made to control ring orientation in processing this material, other than to produce clear straight-grained specimens. With this being the case, the mechanical property estimates discussed hereafter should be assumed to apply only to material having comparable randomized ring orientations.

Of the 1- by 1- by 18-inch specimens, 960 having all sapwood, no visible defects, and between 6 to 10 rings per inch were selected. They were randomly sorted into the 24 sets of 40 each (6 for compression tests and 34 for bending tests) and allowed to equilibrate at 80°F/65 percent relative humidity (RH) (~ 12% equilibrium moisture content (EMC)).

Treating

CCA-type C (oxide) formulations were used for the treatments. The concentrations for the individual CCA-treating solutions used at each retention level were determined from the solution (water) uptake of the water-treated controls (0.0 pcf).

Each full-cell treatment was performed at ambient temperature and consisted of 1/2 hour of vacuum (27 in. Hg) and 2 hours of pressure (150 psi). FPL’s 4-foot treating cylinder required 3 to 4 minutes to apply or remove either the vacuum or the pressure.

Each specimen was weighed immediately before and after treatment, and dimensions were recorded before treatment. Retentions for individual specimens were calculated from this information and the treating solution concentration.

The 24 sets of specimens were then sealed in polyethylene bags and held for 7 days. This assisted in completion of the CCA fixation process (3, 8) and corresponded to what we thought to be a representative time period for which treated lumber might be close-piled between treatment and drying (14).

Drying

After the 7-day holding period, the specimens designated for the 80°F (air-dried) treatment were removed from their bags, stickered, and dried at 80°F and 90 percent RH for 7 days. They were then placed in the 80°F and 65 percent RH room until they equilibrated (≅12% EMC conditions).

For kiln-drying small clear specimens, a technique was needed to simulate the drying of full-size 2-inch nominal dimension lumber because we felt that the effect of CCA on strength is a time-temperature-MC effect. This technique would keep the small specimens at the required temperature for the same length of time as the full-size 2 by 4’s, but would retard excessive moisture movement. This prevents the small specimens from being overdried at the end of comparable drying periods (6). This was accomplished by 1) removing the saturated specimens from the polyethylene bags where they had been held since the CCA treatment, 2) stacking the specimens on 314-inch-square stickers in a pile about 1 foot wide, 3) kiln-drying at the designated temperature to an average MC of 20 ± 5 percent, 4) rebagging the still-stickered specimens, and 5) heating at the designated temperature for the same duration required for full-sized 2 by 4's. The 20 ± 5 percent MC of the small specimens is retained because of the non-drying conditions (i.e., high RH, no airflow) within the polyethylene bags during this final heating period.

All kiln-dried specimens were then placed in a room controlled at 80°F and 65 percent RH and allowed to equilibrate.

Testing

After coming to equilibrium in the controlled environment, the six 1- by 1- by 18-inch specimens from each retention-drying set were each cut into four compression specimens (1 by 1 by 4 in.). This yielded the 24 compression specimens from each set as previously indicated.

Compression and bending tests were performed in accordance with the secondary methods outlined in ASTM D 143 (1), except that the bending specimens were loaded at a rate of 0.10 inch per minute, twice the standard rate. All bending specimens were tested in such a manner as to maximize stress on the face having the most radial orientation of the annual rings simply for uniformity of procedure.

Analysis

Statistical analysis was conducted using analysis of variance (ANOVA) and quadratic (least squares) modeling techniques (7,9). The bending experiment, being a completely randomized factorial design, was analyzed using a two-way classification for ANOVA. Because the 24 compression specimens of each set were prepared from 6 larger specimens, each compression replication was not a "true" independent observation; thus, blocking was employed. The compression experiment, being a blocked factorial design, was analyzed using a three-way classification (retention-drying temperature-block number).

Mathematically derived response surface models were developed using least squares techniques. These models were then used to generate predicted mechanical property values over the entire range of the variables being studied. When these predicted values are plotted, they clearly illustrate the joint functional dependence of the highly interactive data.

Results and discussion

The analysis of the bending and compression data indicates that the effects of the CCA retention level and the drying temperature level are highly dependent (interactive) upon each other.

Experimental results

The average CCA retention and its standard deviation for each level of treatment are listed in Table 1. The average EMC (80°F-65%RH) for each level of treatment is also shown in Table 1. Note that the average EMCs of the bending specimens, in general, increase with retention level and that the average EMCs for the smaller compression specimens are noticeably lower than the average EMCs for the longer bending specimens (Table 1). Since all specimens were maintained in identical environments for identical periods, the comparative differences in specimen lengths must be in part responsible.

TABLE 1. —*Average retention in small clear specimens of southern pine after treatment to various levels with CCA, and resultant equilibrium moisture content.*

Target retention	Property	No. of specimens	Avg. calculated retention	Standard deviation	Equilibrium moisture content[a]
(pcf)			----------- (pcf)	-----------	(%)
0.00	Bending	135	0.0	—	13.61
	Compression	24	0.0	—	12.03
0.25	Bending	136	0.277	0.024	14.28
	Compression	24	0.275	0.021	12.25
0.40	Bending	136	0.421	0.037	14.12
	Compression	24	0.421	0.022	12.07
0.60	Bending	135	0.648	0.054	14.26
	Compression	24	0.643	0.041	12.43
1.00	Bending	136	1.014	0.099	13.83
	Compression	24	0.991	0.132	12.28
2.50	Bending	129	2.791	0.221	14.99
	Compression	24	2.816	0.178	12.80

"When held at 12% EMC conditions.

It is well known that strength is a function of MC, but less well known is that the EMC of CCA-treated wood is a function of retention (5). Adjusting mechanical property data to comparable MCs would, in part, mask the effects of the treatment on strength. However, the results of analyses in which all strength property estimates were adjusted to an MC of 12 percent were comparable to the results of analyses using unadjusted strength property estimates. Thus, unadjusted mechanical property estimates for each level of CCA retention and drying were used throughout the remainder of our analyses and are shown in Table 2.

Considering the highly interactive nature of these experiments, certain CCA treatment and drying levels were grouped because they exhibited similar mechanical property responses. Duncan's multiple range tests (Table 3) of the main effects of drying temperature showed that, with the exception of the differences between the 180" and 220°F drying levels for MOR and WML at the 2.50 pcf retention level, the 80" and 140°F drying levels and the 180" and 220°F drying levels each reacted in statistically equivalent manners. Accordingly, two drying level groupings will usually be considered—the LOW (80° and 140°F) and the HIGH (180° and 220°F)—but individual drying levels will still be used in instances where consideration of the individual levels is more informative and appropriate.

Further Duncan's multiple range tests (Table 4) of the effect of CCA retention level showed that with the

TABLE 2. — ***Effects of preservative treatment with CCA and subsequent redrying on the mechanical properties of small clear specimens of southern pine. The values for MCS and MOR are reported as psi, for MOE as 1000 × psi, and for WML as in.-lb./in.^{3}.***

		Property values and standard deviation at drying temperatures of									
		80°F		140°F		180°F		220°F		All temperatures	
CCA retentions	Mechanical property	Property avg.	Standard deviation	Property avg.	Standard deviation	Property avg.	Standard deviation	Property avg.	Standard deviation	Property avg.	Standard deviation
(pcf)											
		[b]*n* = 33		*n* = 34		*n* = 34		*n* = 34		*n* = 135	
0.0	MCS[a]	7,738	461	8,012	1,370	7,835	734	9,012	1,142	8,149	1,101
	MOE	2,120	323	2,173	330	2,176	416	2,327	414	2,200	378
	MOR	14,948	1,932	15,165	2,433	15,289	2,619	16,140	2,808	15,389	2,487
	WML	13.3	4.4	11.4	3.5	12.1	3.6	12.0	4.2	12.2	4.0
		n = 34		*n* = 34		*n* = 34		*n* = 34		*n* = 136	
0.25	MSC[a]	8,578	449	7,795	626	7,912	769	8,291	523	8,129	662
	MOE	2,117	359	2,191	427	2,208	355	2,251	411	2,192	388
	MOR	15,293	2,280	15,473	2,838	14,154	2,287	14,162	3,112	14,770	2,696
	WML	12.9	3.9	11.7	4.0	8.7	2.6	7.9	3.7	10.3	4.1
		n = 34		*n* = 34		*n* = 34		*n* = 34		*n* = 136	
0.40	MCS[a]	8,237	1,001	7,343	1,234	8,144	1,059	9,057	1,060	8,195	1,236
	MOE	2,278	366	2,203	339	2,118	386	2,268	381	2,217	370
	MOR	15,785	2,294	15,393	2,035	13,239	2,742	13,647	3,034	14,516	2,755
	WML	12.4	4.0	11.6	3.6	7.5	3.2	6.5	3.3	9.5	4.4
		n = 34		*n* = 33		*n* = 34		*n* = 34		*n* = 135	
0.60	MCS[a]	8,123	453	8,358	1,091	7,146	736	8,275	980	7,975	970
	MOE	2,148	459	2,121	360	2.162	395	2,351	380	2,196	407
	MOR	15,469	2,667	14,679	2,130	13,061	2,730	14,373	2,596	14,419	2,651
	WML	11.6	3.5	10.4	2.9	7.1	2.9	7.8	3.6	9.2	3.7
		n = 34		*n* = 34		*n* = 34		*n* = 34		*n* = 136	
1.00	MCS"	8,371	1,255	8,324	812	6,959	1,124	9,030	1,075	8,171	1,304
	MOE	2,209	296	2,117	391	2,251	367	2,272	407	2,212	368
	MOR	15,937	1,781	14,891	2,518	14,370	2,621	14,516	2,489	14,929	2,428
	WML	12.4	3.0	10.1	3.5	8.1	3.1	7.5	3.3	9.5	3.7
		[c]*n* = 32		*n* = 33		[d]*n* = 32		*n* = 32		*n* = 129	
2.50	MCS[a]	8,936	778	[e]9,236	[e]1,413	8,572	524	[e]8,213	[e]1,627	8,739	1,209
	MOE	2,223	374	2,228	391	2,177	376	2,331	316	2,240	366
	MOR	15,541	2,323	15,227	2,595	13,475	2,835	11,238	2,303	13,881	3,027
	WML	9.4	2.9	8.7	2.5	6.5	2.5	3.9	1.8	7.1	3.2
		n = 201		*n* = 202		*n* = 202		*n* = 202		[f]*n* = 807	
All	MCS[a]	8,320	864	8,170	1,249	7,761	1,004	8,649	1,158	8,225	1,122
	MOE	2,182	367	2,172	372	2,182	381	2,300	384	2,209	379
	MOR	15,498	2,227	15,140	2,426	13,953	2,716	14,040	3,069	14,657	2,710
	WML	12.0	3.8	10.7	3.5	8.4	3.5	7.6	4.1	9.7	4.1

[a] MCS value for six levels of CCA treatment and four levels of drying (24 total groupings) are derived from 24 (1- by 1- by 4-in.) blanks per grouping cut from six randomly selected (1-by 1-by 18-in.) specimens unless otherwise noted.

[b] *n* = sample size.

[c] Two specimens were discarded because they were found to exhibit physical defects.

[d] One specimen was discarded because it was found to exhibit physical defects.

[e] Only 23 specimens were used to compute this MCS estimate of mean or standard deviation because of missing data.

[f] The mechanical property values of six specimens could not be calculated because of missing data.

TABLE 3. — ***The effect of redrying temperature at each level of CCA retention as compared by a Duncan's multiple range test of mean values at a = 0.05.***[a]

	Effects of temperature on individual properties[b]															
CCA	MCS				MOE				MOR				WML			
(pcf)	(low			high)	(low			high)	(low			high)	(low			high)
0.0	80	180	140	220	80	140	180	220	80	140	180	220	140	220	180	80
0.25	140	180	220	80	80	140	180	220	180	220	80	140	220	180	140	80
0.40	140	180	80	220	80	220	140	180	180	220	140	80	220	180	140	80
0.60	180	80	220	140	140	80	180	220	180	220	140	80	180	220	140	80
1.00	180	80	140	220	140	80	180	220	180	220	140	80	220	180	140	80
2.50	220	180	80	140	180	80	140	220	220	180	140	80	220	180	140	80

[a] Each bar represents mean values equivalent at a 95% level of significance.

[b] Each property value increases as temperature is read from left to right.

TABLE 4. — *The effect of CCA retention level at each level of redrying temperature as compared by a Duncan's multiple range test of means at a = 0.05.*[a]

Temperature (°F)	Effect of retention on individual properties[b] (low					high)	Temperature (°F)	Effect of retention on individual properties[b] (low					high)
	MCS							MOE					
80	0.0	0.6	0.4	1.0	0.25	2.5	80	0.4	2.5	1.0	0.6	0.0	0.25
140	0.4	0.25	0.0	1.0	0.6	2.5	140	2.5	0.4	0.25	0.0	0.6	1.0
180	1.0	0.6	0.0	0.25	0.4	2.5	180	0.4	0.6	0.0	2.5	0.25	1.0
220	2.5	0.6	0.25	0.0	1.0	0.4	220	0.25	0.4	1.0	0.0	2.5	0.6
	MOR							WML					
80	0.0	0.25	0.6	2.5	0.4	1.0	80	2.5	0.6	1.0	0.4	0.25	0.0
140	1.0	0.6	0.0	2.5	0.4	0.25	140	2.5	1.0	0.6	0.0	0.4	0.25
180	0.6	0.4	2.5	0.25	1.0	0.0	180	2.5	0.6	0.4	1.0	0.25	0.0
220	2.5	0.4	0.25	0.6	1.0	0.0	220	2.5	0.4	1.0	0.6	0.25	0.0

[a] Each bar represents mean values equivalent at a 95% level of significance.
[b] Each property value increases as read from left to right.

exception of WML at the 140°F drying level, the 0.25, 0.40, 0.60, and 1.00 pcf retention levels reacted in an equivalent manner. Thus, only three CCA retention levels will be considered—the CONTROL (0.0 pcf), the LUMBER[1] (0.25, 0.40, 0.60, and 1.00 pcf), and the MARINE (2.50 pcf).

Using these groupings, the effects of CCA treatment and drying on MCS (Table 5) are consistent with the literature. MCS is unchanged at the LUMBER retention levels. At the MARINE level MCS is increased when dried at 180°F or below, but is decreased at a drying temperature of 220°F.

MOE is not affected by any combination of CCA treatment and drying. This is quite consistent with the literature and shows that CCA has a negligible effect upon the stress-strain relationships below the proportional (elastic) limit.

The effects of CCA treatment on MOR are also, to a lesser degree, consistent with the literature. MOR is not affected by CCA treatment at LOW drying temperatures. But when dried at HIGH, the degradative effect of CCA treatment becomes quite significant.

WML is not affected at the LUMBER levels by LOW drying temperatures, but at HIGH temperatures the effect of CCA on WML is significant. At the MARINE levels, WML is significantly reduced by drying temperatures of 140°F or higher.

For both the LUMBER and MARINE levels the negative effects of CCA treatments on WML are far more pronounced than are the comparable effects on MOR. Because WML is a measure of the energy (work) required to deform (strain) a material to its maximum load (stress) capacity, it is a function of stress and strain, whereas MOR is solely a function of stress. Accordingly, the reason WML is reduced to a greater degree than MOR is that the ability of the treated material to dissipate energy via strain is dramatically reduced, especially beyond the proportional limit. This reduction in strain capability is embrittlement (decreased ability to deform or strain under load) and it represents the most significant structural effect of CCA treatments.

Except for WML at the highest retention, the chemical mechanisms that reduce strength require not only the presence of CCA, but high temperatures as well. It seems that redrying temperatures of 220°F for MCS, 180°F for MOR, and 140°F for WML may represent limit values at or above which significant strength losses should be expected. The significant reductions in MCS, MOR, and WML at higher temperatures are probably attributable to the hydrolytic mechanisms of CCA fixation (8). Because of these fixation mechanisms, CCA could have destructive hydrolytic action upon both the laminar cell wall structure (11, 14) and the polymeric

TABLE 5. — *Change in various mechanical properties of CCA-treated specimens compared to water-treated specimens dried at identical temperatures.*

Mechanical property	Changes[a] at retention levels and temperatures of LUMBER (0.25%,0.40%,0.60%, and 1.00%) Low (≤ 140°F)	High (≥ 180°F)	MARINE[b] (2.5%) ≤ 140°F	180°F	220°F
	(%)				
MCS	ND	ND	+15	+9	−9
MOE	ND	ND	ND	ND	ND
MOR	ND	−11	ND	−12	−30
WML	ND	-37	−27	-46	-68

[a] The reported values reflect significant differences (a < .05). ND refers to no significant difference (a < .05) when compared to similarly dried water-treated controls.
[b] At the MARINE, the Low-High groupings have not been used because of significant differences between drying temperatures of 180°F and 220°F.

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[1] The LUMBER grouping does not coincide with AWPA standard (2) lumber levels; its purpose is merely intended to aid in explaining the experimental results.

compositional material (14), especially at higher temperatures. These degradative actions probably result in microscopic and macroscopic discontinuities with the laminar cell wall, together with an eventual solubilization and extraction of certain acid-susceptible polymeric components. The affected polymeric components could include cellulose, hemicellulose, and certain acid-susceptible lignin fractions. Chemical analysis identifying the wood components being affected is currently being planned.

Modeling

To better describe the highly interactive effects of retention and drying levels on strength and to possibly provide some insight into the discrepancies previously alluded to in the literature, response surfaces were generated from the data using quadradic (least squares) modeling techniques. The response surfaces characterize boundaries at which strength losses might be sufficient to warrant the use of less severe processing conditions. These response surfaces allow us to visualize the complex relationship of CCA treatment and subsequent redrying.

Models were developed of the type

$$P = b_0 + b_1D + b_2R + b_{11}D^2 + b_{22}R^2 + b_{12}DR$$

where

P = property (MOR, WML)
D = drying level (°F)
R = CCA retention (pcf)
b = calculated model parameters.

No models were developed for MCS and MOE because so few significant effects existed.

These models were found to have parameters of:

	MOR	WML
b_0	14,582.170	14.186
b_1	8.545	–0.0114
b_2	992.291	- 2.455
b_{11}	- 0.041	–7.295 (10^{-5})
b_{22}	50.017	0.644
b_{12}	- 9.801	- 0.012

The models included factors (boundary conditions) for specific gravity (SG) (ovendry weight/volume at test) and MC that were fixed at SG = 0.59 and MC = 15 to decrease the dimensionality of the models (9) and, thereby, allow graphic representations of these surfaces. Accordingly, the response surfaces (Figs. 1 and 2) and the estimated model parameters are appropriate only under the assumed boundary conditions and would require recalculation under different conditions. The models developed had R^2 values of 0.540 for MOR and 0.455 for WML. Simplified models such as these are not intended to predict the magnitude of the chemical effects. Higher order models and several transformations of the variables were tried; they did not substantially increase the precision of the simplified models in predicting treatment effects. When simplified models are used to illustrate trends within the data, they are easier to understand and indeed revealing.

The model for MOR (Fig. 1) suggests the effect due to CCA retention is negligible until drying temperatures of 120°F are reached. However, after this **120°F** redrying temperature is exceeded, a progressively increasing negative effect is apparent as either CCA retention or drying temperature is increased. Note that the model also suggests that at levels of drying below

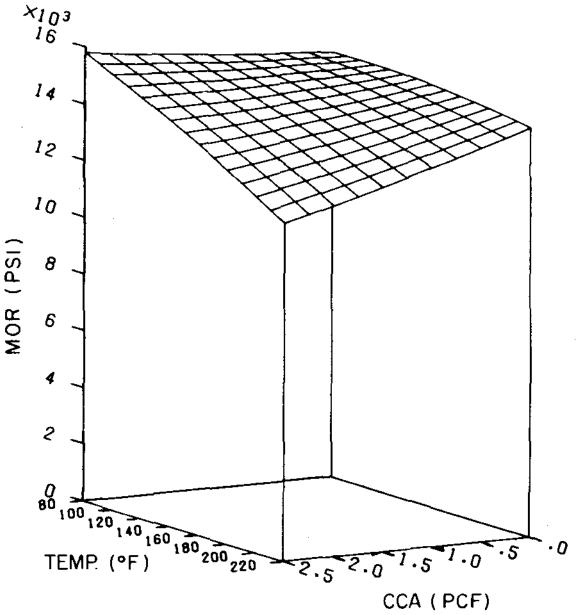

Figure 1. — The response of a model for modulus of rupture (psi) as affected by various levels of CCA retention and subsequent drying when the model is constrained to boundary conditions of 15 percent moisture content and 0.59 specific gravity (ovendry weight/volume at test).

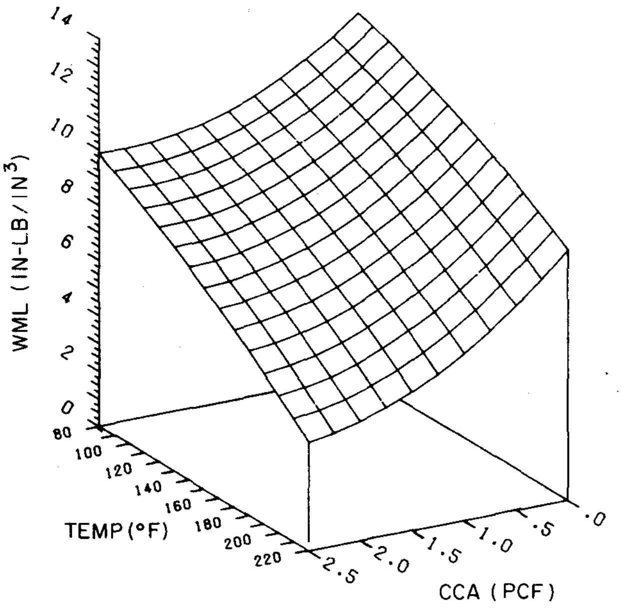

Figure 2. — The response of a model for work to maximum toad (in.-lb/in.^{3}) as affected by various levels of CCA retention and subsequent drying when the model is constrained to boundary conditions of 15 percent moisture content and 0.59 specific gravity (ovendry weight/volume at test).

100°F the effect on MOR of CCA retentions above approximately 1.5 pcf would be positive rather than negative.

The model for WML (Fig. 2) suggests a progressively increasing negative effect as either the CCA retention or the drying temperature is increased. The magnitude of this effect is much more pronounced than a comparable effect found with MOR.

Conclusions

In this experiment, small clear specimens of southern pine were pressure treated with CCA preservative, stored for 7 days, and then dried in conditions designed to simulate actual practice. At CCA retentions of up to 1.00 pcf, drying temperatures of 140°F or below have no significant degradative effects on MCS, MOE, MOR, and WML. At these same retentions, drying temperatures of 180°F or above reduced MOR by about 11 percent and WML by 37 percent.

Consistent with the literature (14), at CCA retentions of 2.5 pcf there is a distinct, although nonsignificant, increase in the MCS of the material when dried at temperatures of up to 180°F, but a decrease in MCS when dried at 220°F. MOR is significantly reduced at 180°F and above, while WML is significantly reduced at temperatures of 140°F and above.

Since WML is not a design property, the practical significance and/or relative importance of a degradative effect on WML is difficult to judge. It would, however, appear that even at low retention levels (i.e., 0.25 and 0.40 pcf) the loss in WML could present the design engineer or architect with significant problems when shock or energy absorption characteristics are important design considerations. For these reasons, care must be exercised in the design process if specification-writing or standard-setting organizations do not in some way account for the apparent embrittlement of treated material which has been redried at high temperatures.

Our analysis of the results and the models derived from those results indicate that, where strength is important, CCA-treated southern pine should not be redried at temperatures approaching or exceeding 180°F, even at low CCA retention levels. A redrying temperature limit of 160°F would appear to be a reasonable suggestion at this time.

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