THE EFFECTS OF CCA PRESERVATIVE TREATMENT AND REDRYING ON THE BENDING PROPERTIES OF 2 × 6 SOUTHERN PINE LUMBER

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ABSTRACT

Southern pine dimension lumber (commercially graded No. 2 loblolly pine 2 × 6s) was treated with chromated copper arsenate (CCA) preservative (0.4 or 0.6 pcf) and then air-dried or kiln-dried (160, 190, or 240 F). CCA treatment significantly reduced average bending strength, but no discernible differences were found between controls and CCA-treated groups in the extreme lower portions (< 10th percentile) of the bending-strength distributions. When these same specimens were then considered solely on the basis of strength-reducing characteristics, there were obvious differences in how the CCA treatments and subsequent redrying affected these various strength-ratio grades of 2 × 6 lumber; higher grades appeared to be less affected than lower grades. Similar to the trend shown when commercially graded, the middle and upper portion of each strength-ratio grade bending-strength distribution than did drying at 240 F affected a broader range of the bending-srength distribution than did drying at 160 F. The broadened range of significant effects noted after high-temperature redrying indicates that posttreatment kiln-drying temperatures higher than 190 F should be avoided.

The effects of CCA treatment and redrying were highly interactive with strength-ratio grade and the presence or absence of pith. CCA treatment reduced the strength of lumber containing pith and having a strength ratio of <0.65 to a greater extent than pith-free lumber of any strength-ratio grade. Lumber having a strength ratio of ≥0.65 and containing pith was not affected by CCA treatment. The magnitude of this pith-related interaction demands recognition.

Keywords: Mechanical properties, bending strength, CCA, treatments, preservatives, kiln-drying, redrying, lumber, southern pine, pith.

INTRODUCTION

Although treatment with chromated copper arsenate (CCA) preservative reduces the strength of many types of wood products, the National Design Specification (NDS) does not currently require reduction in allowable design stresses (10-yr loading) for lumber treated with CCA or other waterborne preservatives (National Forest Products Association 1986). This strength loss seems to be caused by both the hydrolytic chemical (pH = 1.5–3.0) and the temperature sustained in kiln-drying after treatment (KDAT). Recent research results (Barnes and Mitchell 1984; Bendtsen et al. 1983; Knuffel 1985; Mitchell and Barnes 1986; Winandy et al. 1985) force us to question the appropriateness of unmodified allowable design stresses (ADS) for CCA-treated material. Except for work by Barnes and Mitchell (1984) and Knuffel (1985), most research on the effects of CCA has

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[1] The Laboratory is maintained in cooperation with the University of Wisconsin in Madison.

utilized small clear specimens and has dealt mainly with average property values, whereas ADS values are based on fifth percentile estimates.

Considering the limited lumber data available, we cannot satisfactorily estimate the effects of CCA preservative treatments and subsequent redrying on ADS values. Our study was an attempt to understand better how CCA treatment affects the distributional characteristics of lumber bending properties and ADS values. The primary objective was to define these effects throughout the entire bending strength distribution for 2 × 6 southern pine lumber. Secondary objectives were (1) to explore the ability of various drying temperatures to redry CCA-treated lumber without significantly reducing mechanical properties, (2) to identify relationships between strength-related characteristics (i.e., knots, slope-of-grain), CCA retention, drying temperature, and lumber strength, and (3) to identify the relationship between pith and the same characteristics.

EXPERIMENTAL

The southern pine dimension lumber used in this study consisted of 1,536 loblolly pine (*Pinus taeda* L.) 2 × 6s, 10 feet long. Each specimen was commercially graded as No. 2-Ongrade as defined in the national grading rule (NGR). NGR grade assignments are based on both strength-reducing characteristics (e.g., knots, slope-of-grain) and utility characteristics (e.g., warp). After all specimens had equilibrated at controlled conditions of 74 F and 65% relative humidity, the flatwise stiffness of each specimen was determined using a Metrigard[2] E-computer. The presence of pith was noted. Finally, the two worst knots and the maximum slope of grain of each specimen were identified, and the specimens were assigned to secondary strength-ratio grades based solely on strength-reducing characteristics (Fig. 1).

The specimens were then sorted into nine treatment-drying groups having nearly equivalent E-computer stiffness profiles (Table 1). One group of specimens remained untreated to serve as true controls. Two other groups were treated with water, and the remaining groups were treated with either of two levels of CCA retention, 0.4 or 0.6 pound per cubic foot (pcf). These levels of CCA retention were chosen to represent the American Wood-Preservers' Association (1986) specified retentions for structural lumber intended for use in Ground Contact situations (0.4 pcf CCA) or in Permanent Wood Foundations (0.6 pcf CCA). After treatment, the CCA- and water-treated 2 × 6s were either air-dried or kiln-dried at 160, 190, or 240 F. These drying temperatures were chosen to represent a range of commonly used industrial redrying temperatures. The specimens were then tested to failure using ASTM D 198 static bending tests (American Society for Testing and Materials 1984).

Because of certain characteristics of the NGR, No. 2 lumber actually contains many pieces that would actually qualify as Select Structural or No. 1 if only knots or slope of grain were considered. Examples of these characteristics include limits

[2] The use of trade or firm names in this publicaton is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

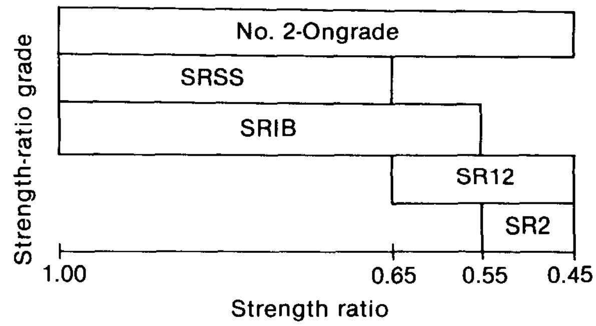

FIG. 1. Range of strength ratios in commercially graded No. 2-Ongrade and in each of the four strength-ratio grades. SRSS = Select Structural, SR1B = No. 1 and better, SR12 = No. 1 and No. 2, and SR2 = No. 2. (ML87 5438)

for wane, warp, and manufacturing defects in excess of those allowed in Select Structural or No. 1. In many cases these limits are intended to assure the utility rather than the strength of a piece of lumber. Possibly the most significant NGR limit is that decay in a knot automatically downgrades a piece to No. 2, regardless of the knot size, despite the fact that in most instances decay "within" a knot has only a limited influence on strength of that piece. Consequently, commercially graded No. 2 lumber has a range of strength ratios from 0.45 to nearly 1.00.

The commercial grade, which allowed for both strength-reducing factors and utility factors, and the secondary strength-ratio grade provided us with two schemes for studying the same experimental data. One scheme, with a high number of specimens in each of its treatment-drying groups, provided for precise identification of "treatment" and/or "redrying" effects throughout the entire bending property distribution for commercially graded No. 2 lumber (No. 2-Ongrade). The second scheme, with multiple strength-ratio levels, provided a method of assessing the interaction between treatment- and/or drying-induced effects and lumber quality. Because the first method of analyzing the experiment was deemed most important, the specimens were assigned to treatment groups solely on the basis of pretreatment stiffness to assure virtually identical modulus of elasticity (MOE) distributions for each of the nine No. 2-Ongrade groups (Table 1). Because MOE correlates with strength, this procedure helped assure equivalent strength distributions too. Thus, for the analysis involving the strength-ratio levels, the number of specimens in each treatment group was uncontrolled, even though sorting by pretreatment stiffness tended to balance the distributions (Table 1).

Treatment

CCA treatments were done commercially using a Type C oxide formulation (American Wood-Preservers' Association 1986) and a modified full-cell process. Target retentions were 0.4 or 0.6 pcf. For each of the two charges, a 20-boring sample was taken for subsequent analysis of CCA penetration and retention.

TABLE 1. *Experimental design showing the number of graded specimens according to treatment and drying method.*

Treatment/drying method	Graded specimens[1]				
	No. 2-Ongrade	SRSS	SR1B	SR12	SR2
No treatment (controls)	190	77	125	113	65
Water treatment					
Air-dried	—	—	—	—	—
Kiln-dried					
160	192	109	141	83	51
190	—	—	—	—	—
240	192	99	144	93	48
CCA treatment, 0.4 pcf					
Air-dried	—	—	—	—	—
Kiln-dried					
160	128	59	91	69	37
190	—	—	—	—	—
240	128	64	88	64	40
CCA treatment, 0.6 pcf					
Air-dried	127	58	88	69	39
Kiln-dried					
160	190	89	139	101	51
190	191	90	141	101	50
240	190	100	135	90	55

[1] Specimens were graded as No. 2-Ongrade as defined by the National Grading Rule, or as Select Structural (SRSS), No. 1 and Better (SR1B), No. 1 and No. 2 (SR12), or No. 2 (SR2) according to strength ratio.

Water treatments were performed at the Forest Products Laboratory (FPL) in a 10-foot cylinder using a modified full-cell process.

Post-treatment moisture contents ranged from 35% to 85%. Before drying, the treated specimens were close piled and covered outdoors for 5 to 8 days at ambient temperatures and humidities in Madison, WI, during July 1984. This provided a fixation period between treatment and drying (Winandy et al. 1983).

Redrying

Specimens were redried after their respective treatments in conventional or high-temperature kilns or air-dried.

Kiln redrying was performed at FPL using schedules having maximum dry-bulb temperatures of either 160, 190, or 240 F (Table 2). The lumber was dried in 4-foot-wide piles using ¾-inch stickers on 2-foot centers. A top load of concrete blocks and/or iron weights (40 psf) was used on all charges to minimize warp in the upper courses. At the end of each drying regime, an equalizing cycle was employed to insure uniform moisture content within each specimen and throughout the entire lumber stack. Moisture content was determined by monitoring sample boards placed throughout the stack. The target moisture content for individual specimens from the kiln was 15% (19% maximum).

Specimens designated for air-drying were dried at FPL in the summer of 1984. Piles were 6 feet wide with ¾-inch stickers on 2-foot centers, roofed with plywood. After 4 weeks the lumber had dried to 12% to 15% moisture content.

TABLE 2. *KDAT drying schedules.*

Maximum DB temperature (F)	Estimated initial moisture content range[1] (%)	Air speed (ft/min)	Fan reversal (h)	DB/WB settings (F)	Time (h)	Equal DB/WB settings[2] (F)	Time (h)	Total time (h)
160	35–80	300–500	6	160/130	24	160/152	24	48
190	50–80	300–500	6	190/150	20	None[3]		20
240	35–85	800–1,000	3	240/180	6	168/160	6	12

[1] From sample boards.
[2] Equalizing cycle.
[3] Equalizing not needed; variation between specimens within limits.

Equilibration

Before mechanical testing, all specimens (treated and control) were placed in a controlled environment of 74 F and 65% relative humidity. After 7 months the specimens had equilibrated.

CCA treatments can have a significant effect upon the equilibrium moisture content (EMC) of treated clear specimens (Bendtsen et al. 1983; Winandy et al. 1985). However, a comparable effect has not been reported in the limited lumber data available. The moisture content data generated after subsequent mechanical testing were used to test for the effect of CCA treatment and redrying on lumber EMC.

Mechanical testing

Edgewise static bending tests (ASTM D 198) were performed using third-point loading and a 17:1 span-to-depth ratio. The main strength-reducing defect was placed in the maximum moment area. If the main defect could not be placed within the maximum moment area, the second greatest strength-reducing defect was employed. Where neither of these defects could be placed in the maximum moment area, the one closest to the maximum moment area was employed. For each group, half of the specimens were tested with the chosen defect up and the remaining specimens with the defect down.

The rate of loading was 1 inch of head travel per minute, which is about 3.44 times faster than the standard rate. This faster rate was used because earlier results for untreated southern pine had indicated no difference between standard loading rates and rates up to 25 times faster than standard (DeBonis et al. 1980). Load was monitored using a calibrated load cell, and deflection was monitored using a linear potentiometer. Load and deflection data were recorded during testing on an interfaced microcomputer. The maximum load (PMAX), maximum center-span deflection (DMAX), modulus of rupture (MOR), MOE, and work to maximum load (WML) were calculated from these data. Since CCA treatment induces bulking (i.e., swelling), we thought that PMAX would be a valuable parameter to quantify the comparable load-carrying capacities of treated versus untreated specimens. DMAX was included because past studies have shown appreciable losses in WML without corresponding losses in MOE.

Immediately after testing, a moisture content/specific gravity block was cut from near the zone of failure on each specimen to determine moisture content and specific gravity at time of test.