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Bending Properties of Southern Pine Treated With Waterborne Copper Naphthenate

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Abstract: Southern pine treated with a waterborne copper naphthenate (CuN) preservative at 0.04, 0.075, and 0.13 pcf Cu (as metal) was tested in static bending. Comparison was with control samples treated with water only and samples treated with CCA type C at 0.1, 0.2, and 0.4 pcf (total oxide). Comparison of the treatments showed no deleterious effect of treatment on most bending properties for either CuN- or CCA-treated wood at the retentions tested. Work-to-maximum load at the higher retentions for CuN were the only calculated values lower than the controls. The critical design values modulus of rupture and modulus of elasticity were the same as control values as were fiber stress and longitudinal shear.

Keywords: waterborne copper naphthenate, southern pine, bending strength, stiffness, work, CCA

Introduction: For a wood preservative or fire retardant to have utility, it must not have a deleterious effect on wood properties. It is a requirement for all systems standardized by AWPA. Therefore, all data packages presented for consideration must include the effects on mechanical properties. Many studies have been conducted on the effect of various treatments on the mechanical properties of wood. Research by Winandy and others (Winandy et al. 1992; Winandy and Barnes 1991; Barnes et al. 1990; Barnes and Winandy 1989) resulted in drying temperature limitations for CCA-treated wood and for design factors for fire retardant-treated wood (Barnes 1993, 1994; Winandy et al. 1991; Winandy, Ross and LeVan 1991). Other work has shown ACQ and other treatments not to cause significant reductions in mechanical properties (Barnes, et al. 1993; Barnes and Winandy 1986). This paper reports on the testing of southern pine treated with a new generation, waterborne copper naphthenate system.

Methods and Materials

Materials—All sapwood, defect-free southern pine samples were cut from commercial dimension stock. Samples were randomly assigned to seven treatment groups such that each group would have a similar density range, ring count, and earlywood/latewood ratio. Both CCA-type C and waterborne copper naphthenate (CuNWB) concentrates were used to prepare treating solutions by water dilution.

Treatment—All samples were treated using a full-cell cycle consisting of 30 minutes of vacuum at -88 kPa, introduction of treating solution under vacuum, increasing to 1035 kPa in five minutes and holding for one hour, venting to atmospheric pressure in five minutes, and removal of samples from the treating solution. Samples were weighed before treatment and after the wiping of excess solution following treatment in order to determine preservative retention by weight gain. Three CuNWB retentions (0.04, 0.075, 0.13 pcf Cu as metal) and three CCA type C retentions (0.1, 0.2, 0.4 pcf total oxide basis) were tested. Comparison was with untreated southern pine controls which had been treated with water only. Thirty samples at each retention level were treated. Samples were allowed to equilibrate at 75° F in a constant moisture content room before testing.

Testing and analysis—Samples were tested in static bending with center-point loading according to D143 (ASTM International 2004). Specimen size was one-in x one-in in cross-section x 16-in long with a 14-in span. A machine speed of 0.109 in/min was employed. Moisture content and specific gravity were determined on small samples cut from near the break of the bending samples. Modulus of elasticity (E), modulus of rupture (R), work-to-maximum load (W_{ml}), work-to-proportional limit (elastic resilience, W_{pl}), fiber stress at proportional limit (FS_{pl}), and greatest calculated longitudinal shear were computed for each sample. The data were analyzed using covariate analysis and mean separation techniques (SAS Institute 2001).

Results and Discussion

A cumulative distribution curve for modulus of rupture values is shown in Figure 1. This family of curves is typical of the distribution in property values for the samples in this study and indicate no deleterious impact of treatment on modulus of rupture. Descriptive statistics for the various treatment groups are given in Table 1. Note that these are mean values and differ from the least square means presented in the graphs and in Table 2. The analysis of covariance showed specific gravity to be a significant covariate in the statistical analysis.

Least square means for modulus of rupture, modulus of elasticity, and fiber stress at proportional limit are shown in Figure 2. None of these mean values were significantly lower than the control values. Modulus of rupture averaged 93-104% of the control value with samples treated with CCA slightly higher and CuN slightly lower than the controls. For modulus of elasticity, CCA values averaged 9% higher and CuN values 4% higher than controls. CuN treatments averaged 1% higher and CCA treatments 4% higher than controls in fiber stress.

Work values are compared in Figure 3. Work-to-proportional limit values ranged from 94% to 107% of the control values depending on treatment but were not significantly different from control values. Only with work-to-maximum load were significant decreases found compared to control values. In this instance, CuN treatment averaged 83% of the control value while CCA treatment averaged 93% of the control. A similar result was found with ACQ-treated 2 x 6s reported in 1993 (Barnes *et al.* 1993) in which the treated material averaged 68% of the control value.

Shear values are shown in Figure 4. No significant differences due to treatment were noted. Treated samples averaged 94% to 104% of control values.

Summary and Conclusions

The data obtained in this study would indicate that little to no deleterious effect on bending properties was seen with treatments using waterborne copper naphthenate. This result is similar to results obtained with other waterborne preservative systems. While no data are presented, it would seem prudent to restrict redrying of stock treated with waterborne copper naphthenate to the same 160° F limit applicable to other waterborne systems until a definitive redrying study can be done.

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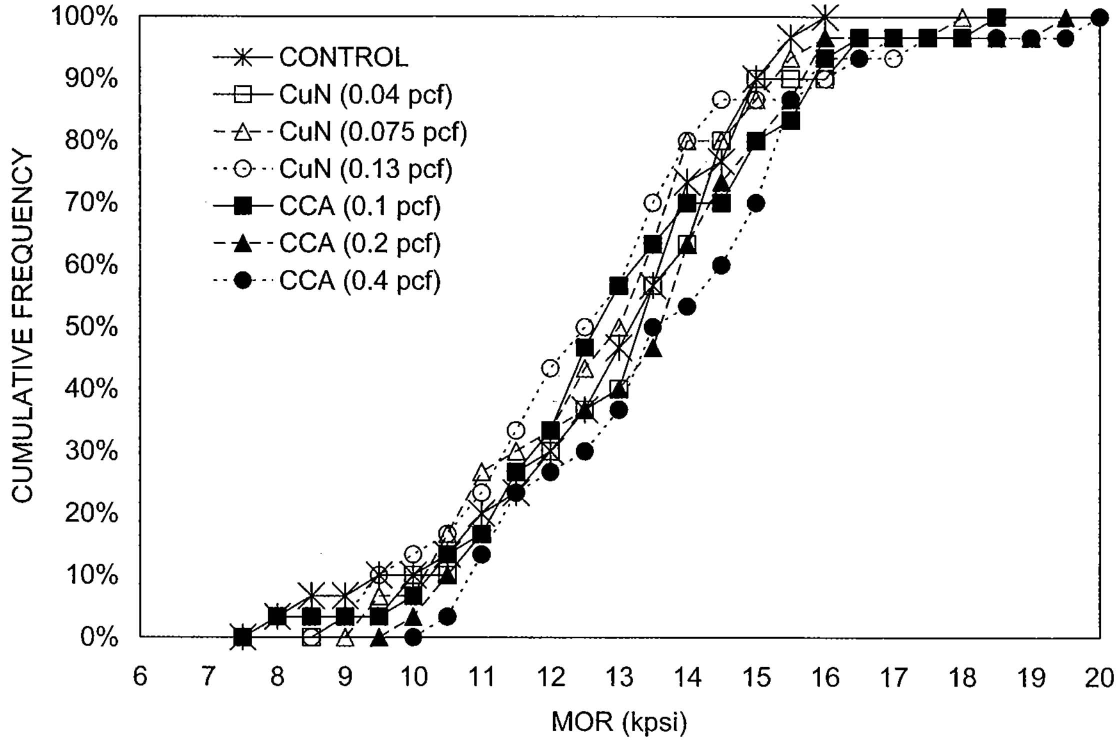

Figure 1. Cumulative frequency diagram of modulus of rupture (MOR) for the various treatment groups in this study.

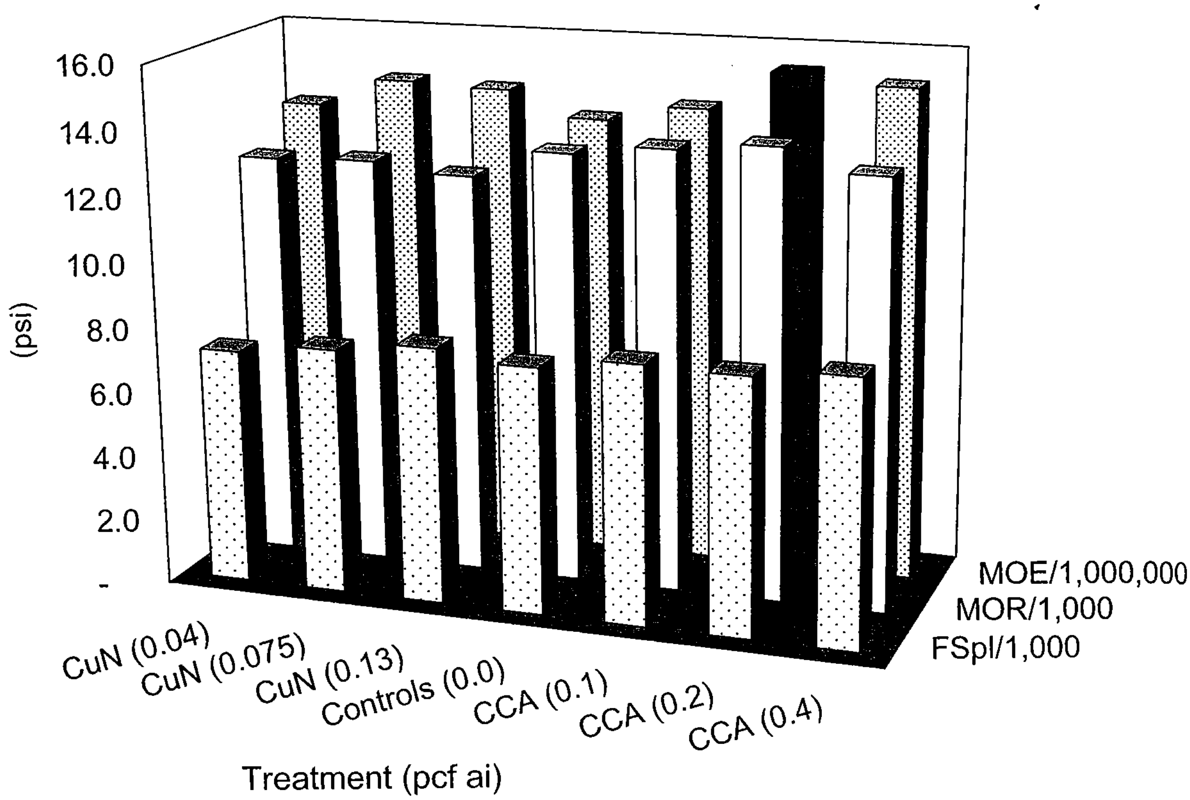

Figure 2. A comparison of least square means adjusted for specific gravity for modulus of rupture (MOR), modulus of elasticity (MOE), and fiber stress at proportional limit (FS_{pl}) by treatment (darkened bar indicates a mean value significantly different from the control).

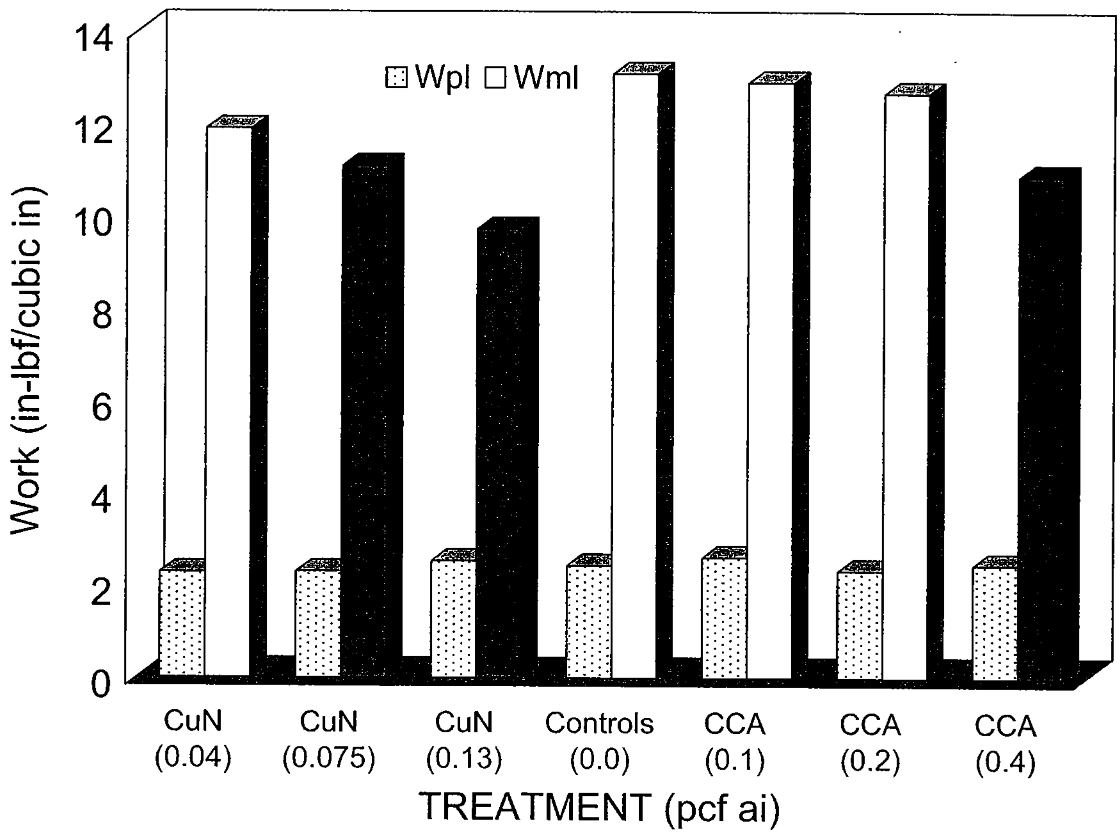

Figure 3. Least square means adjusted for specific gravity for work-to-proportional limit (W_{pl}) and work-to-maximum load (W_{ml}) by treatment (darkened bars indicate means significantly different from the control value).

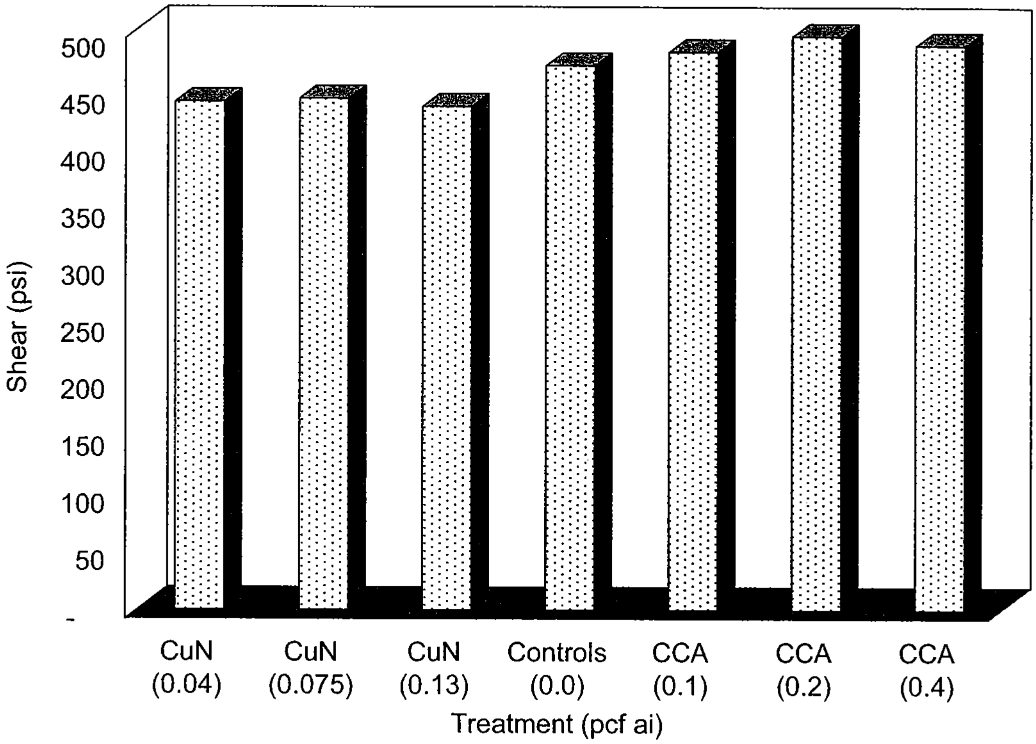

Figure 4. Least square means adjusted for specific gravity for greatest calculated longitudinal shear by treatment.

Table 1. Property values for treated specimens tested in static bending.

Item	Treatment	Retention (pcf)	MOR (psi)	MOE (psi)	Work-to-max load (in-lbf/in3)	Work-to-prop. Limit (in-lbf/in3)	Fiber stress @ prop. Limit (psi)	Moisture content (%)	Specific gravity
Mean	CONTROLS	0.000	12,763	1,332,520	12.27	2.35	7,372	9.64	0.466
Standard Deviation			2,035	194,534	3.85	0.55	1,274	0.54	0.049
Coefficient of Variation (%)			16	15	31	23	17	6	11
Median			13,269	1,362,191	12.76	2.32	7,262	9.57	0.466
Minimum			7,965	944,600	4.09	1.42	5,034	8.80	0.380
Maximum			15,551	1,668,034	18.36	3.77	10,397	10.89	0.590
Mean	CCA-C	0.103	12,965	1,369,514	11.97	2.51	7,659	9.98	0.460
Standard Deviation		0.007	2,154	247,298	4.56	0.74	1,794	0.42	0.046
Coefficient of Variation (%)		6	17	18	38	30	23	4	10
Median		0.103	12,703	1,359,321	10.89	2.41	7,533	9.93	0.453
Minimum		0.086	7,972	945,138	3.50	0.14	1,511	9.08	0.384
Maximum		0.113	18,056	1,943,981	21.33	4.35	11,070	10.76	0.592
Mean	CCA-C	0.206	13,271	1,488,975	11.93	2.22	7,569	10.52	0.458
Standard Deviation		0.013	2,112	266,532	3.69	0.54	1,447	0.42	0.037
Coefficient of Variation (%)		6	16	18	31	24	19	4	8
Median		0.209	13,518	1,510,280	11.75	2.06	7,451	10.49	0.453
Minimum		0.172	9,702	1,000,367	4.32	1.34	5,420	9.89	0.393
Maximum		0.228	19,174	2,223,369	17.18	3.97	12,454	11.45	0.533
Mean	CCA-C	0.418	13,656	1,505,041	12.40	2.53	8,106	13.16	0.481
Standard Deviation		0.026	2,114	271,040	3.68	0.59	1,567	1.77	0.063
Coefficient of Variation (%)		6	15	18	30	23	19	13	13
Median		0.421	13,522	1,494,216	11.83	2.47	7,948	13.79	0.466
Minimum		0.351	10,089	1,100,517	6.25	1.62	5,576	9.56	0.358
Maximum		0.463	19,649	2,440,287	21.78	4.42	13,559	15.97	0.609

Table 1. Property values for treated specimens tested in static bending.

Item	Treatment	Retention (pcf)	MOR (psi)	MOE (psi)	Work-to-max load (in-lbf/in3)	Work-to-prop. Limit (in-lbf/in3)	Fiber stress @ prop. Limit (psi)	Moisture content (%)	Specific gravity
Mean	CuN	0.041	13,123	1,426,877	12.63	2.39	7,657	8.36	0.515
Standard Deviation		0.003	2,119	263,876	4.03	0.62	1,516	0.74	0.054
Coefficient of Variation (%)		7	16	18	32	26	20	9	10
Median		0.041	13,406	1,430,013	12.18	2.32	7,560	8.31	0.517
Minimum		0.034	8,755	913,944	5.90	1.40	5,032	5.91	0.419
Maximum		0.045	18,207	1,945,271	21.00	3.73	11,169	10.31	0.604
Mean	CuN	0.076	12,751	1,475,313	11.11	2.32	7,708	8.79	0.495
Standard Deviation		0.005	2,036	202,388	4.25	0.47	1,214	0.72	0.054
Coefficient of Variation (%)		7	16	14	38	20	16	8	11
Median		0.077	12,945	1,506,045	10.73	2.26	7,662	8.84	0.490
Minimum		0.065	9,119	1,184,802	4.53	1.61	5,780	6.44	0.402
Maximum		0.084	17,806	2,050,811	21.91	3.46	11,211	10.16	0.587
Mean	CuN	0.136	12,629	1,479,288	9.94	2.58	8,131	8.49	0.501
Standard Deviation		0.008	2,350	247,365	3.63	0.58	1,487	1.16	0.052
Coefficient of Variation (%)		6	19	17	37	23	18	14	10
Median		0.138	12,499	1,497,739	9.65	2.51	7,793	8.43	0.502
Minimum		0.118	8,617	1,031,244	3.89	1.60	5,829	5.88	0.389
Maximum		0.147	18,956	2,225,416	18.08	4.30	12,876	13.43	0.600

Table 2. Least square mean comparisons.

Treatment	Retention (pcf ai)	MOR (psi)	MOE (psi)	FS_{pl} (psi)	W_{pl} (in-lbf/in^3)	W_{ml} (in-lbf/in^3)	Shear (psi)
CCA-C	0.103	13,536	1,413,209	7,935	2.61	12.90	489.2
CCA-C	0.206	13,792	*1,535,571	7,838	2.32	12.67	499.7
CCA-C	0.418	13,115	1,506,188	7,957	2.45	*10.88	475.3
CONTROL	0.000	13,228	1,364,161	7,587	2.43	13.09	479.4
CuN	0.041	12,517	1,363,814	7,320	2.28	11.89	455.0
CuN	0.076	12,622	1,452,635	7,611	2.30	*11.09	455.8
CuN	0.136	12,349	1,441,950	7,954	2.53	*9.72	450.4

* indicates values that are significantly different from the control value at $p = 0.05$.