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Section 4 Processes and properties

Performance of Fasteners in Treated Wood: A Comparative Study

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ABSTRACT

Fastener performance is an important property for treated wood. Published data on screw and nail performance for different preservative systems currently on the market are, however, limited. In this study, screw and nail withdrawal strength for southern pine wood treated with ACQ (above ground and ground contact), MCQ (above ground and ground contact), borate (disodium octaborate tetrahydrate – DOT), and untreated southern pine control were tested at air dry and water-soaked conditions based on ASTM standard D1037. Individual sample density and surface hardness were also measured. The relationship among screw and nail withdrawal strength, density, hardness, and moisture content was established for various preservative systems.

Keywords: nail, screw, ACQ, MCQ, borate, solid wood, hardness

1. Introduction

Treated wood is widely used in wood structures, which are composed of interconnected components. The performance of the system is directly related to the performance of the fastening elements (i.e., nails and screws). Therefore, withdrawal strength of nail and screw for wooden building elements is useful information for determining the durability and stability of the whole system. Several studies have been reported on determining corrosion resistance of treated wood for nails and screws (e.g., Jermer and Andersson 2005, Zelinka et al. 2008.). These studies showed different corrosion rates of the fasteners tested with wood treated with different preservative systems. However, none of the studies has actually dealt with fastener withdrawal strength in relation to different wood preservatives and moisture conditions.

AWPA E12-94 deals with fastener corrosion properties of treated wood, but does not specify actual fastener withdrawal strength tests (AWPA 1994). ASTM Standard D 1037 (ASTM 1996) was developed to evaluate the engineering performance of wood-based panels and includes fastener tests for nail withdrawal, nail-pull through, and screw withdrawals. The ASTM D1037 method has been used to test solid wood and wood plastic composite materials (e.g., Falk et al 2001). The objectives of the study was 1) to develop nail and screw pull and withdrawal strength data for treated wood and 2) to study effect of density and moisture content level on the measured data using ASTM D1037 method. Initial study included wood samples at air dry and soaked conditions as specified in the ASTM D1037; and on-going work includes testing of matched wood samples after exposing to high temperature and humidity treatment conditions.

2. METHODS

2.1 Material Selection.

The raw material used included southern pine wood treated with ACQ for ground contact use (ACQ-GC: 1), ACQ for above ground use (ACQ-AG: 2), MCQ for ground contact use (MCQ-GC: 3), MCQ for above ground use (MCQ-AG: 4), borate (disodium octaborate tetrahydrate – DOT: 5), and untreated southern pine control (6). Lumber from each group was purchased from local home building material retailer. Care was taken in selecting the materials with similar density and grain orientation. Forty samples with a size of 6x3.5x1.5 inch were machined from each group. For each group, they were divided into 8 subgroups with five samples in each subgroup for tests of nail withdrawal, nail pull through, sheet metal screw withdrawal and coated screw withdrawal at both dry and soaked conditions. The samples were conditioned at room condition for several weeks prior to testing. Initial weight and sample dimension was measured to determine air dry density and moisture content.

2.2 Nail Withdrawal and Nail head Pill-Through

Nail withdrawal test determines the peak load required to pull a six-penny common nail (0.117-inch diameter) free from the sample. The nails actually used were 2-3/8" 8d coated sinker nails. Nails were hand-driven before testing. One nail was driven ½ inch deep from wide surface and another nail was driven ½ inch deep from one side for each sample. Half of the samples were tested at air dry condition and half of the samples were soaked for six days before being tested. Tests were done with an Instron machine at a loading rate 0.06 in/min.

Nail head pull-through test was used to determine the force needed to pull the nail head through the sample. The nails actually used were 2-3/8" 10d zinc plated molding/trim nails. One nail was driven through the sample thickness at a center position of each sample (nail head flush with surface of board). Half of the samples were tested at air dry condition and half of the samples were soaked for six days before being tested. Tests were done with an Instron machine at a loading rate 0.06 in/min.

2.3 Screw Withdrawal

The screw withdrawal test determines the load needed to pull a standard size screw from the sample. Two types of screws were used. One was No 10 stainless sheet metal screw (Pan Philips Zinc) specified in ASTM D 1037-96a. The other was coated screw (PrimeGuard Philips Exterior Screw). Two 1/8 inch diameter pilot holes were drilled 0.5 inch deep into each sample (one from surface and one from the side). One screw was threaded into the board 2/3 inch deep from one wide surface and another one from the side. Half of the samples were tested at air dry condition and half of the samples were soaked for six days in water before being tested. Tests were done with an Instron machine at a loading rate 0.06 in/min.

2.4 Surface hardness

After nail and screw withdrawal tests, hardness test was done from one wide surface and one edge for each sample According to ASTM D1037.

2.5 Data Analysis

Since wood density significantly affects nail and screw withdrawal strength, the measured strength data from each sample was corrected for density effect by dividing measured strength value with air dry specific gravity of each sample. The obtained data, called specific nail or screw withdrawal strength, was plotted among various wood groups. A statistical ranking test was done to test if the treatments were significantly different from each other at the 5% significance level.

3. RESULTS AND DISCUSSION

3.1 Nail Withdrawal Strength

Table 1 lists specific nail withdrawal strength for various groups of wood samples. Also shown in Table 1 are the specific hardness data from sample surface and edge. In Table 1, data values in a given column followed by the same letter show no significant difference at the 5% significance level Figure 1 shows specific nail withdrawal strength plotted for various sample groups. There was a significant variability in sample density among various groups, and sample density was a leading factor that affected the measured nail withdrawal strength values. In particular, high density samples had higher withdrawal values. There was no any trend of measured nail withdrawal

Table 1. Specific nail withdrawal strength and hardness data

Sample Group	Air-dry Specific Density		Nail withdrawal strength-surface (lb)		Nail withdrawal strength-edge (lb)		Surface Hardness (lb)		Edge Hardness (lb)
	dry	soaked	dry	soaked	dry	soaked	dry	soaked	soaked
ACQ-GC (1)	0.57 (0.05)	0.55 (0.03)	254.5 (55.1) ab	175.5 (39.4) a	191.7 (48.7) ab	198.1 (34.3) ab	1011.1 (142.7) a	617.7 (136.7) bc	1307.5 (123.9) b
ACQ-AG (2)	0.68 (0.03)	0.68 (0.02)	210.1 (69.9) b	205.8 (43.4) a	192.4 (32.6) b	207.7 (38.4) ab	846.3 (122.5) a	647.1 (54.2) abc	1201.7 (140.2) bc
MCQ-GC (3)	0.50 (0.05)	0.60 (0.06)	177.6 (78.2) b	128.5 (25.7) a	167.4 (58.9) c	238.6 (53.0) b	705.1 (93.3) b	592.6 (93.3) ab	1259.2 (103.3) c
MCQ-AG (4)	0.46 (0.03)	0.45 (0.00)	315.3 (24.1) a	75.4 (25.1) a	227.7 (88.6) b	179.5 (35.6) a	1097.5 (211.7) c	675.3 (102.1) bc	1509.2 (267.7) a
Borate (5)	0.57 (0.04)	0.55 (0.02)	317.2 (66.6) a	79.1 (43.5) a	206.2 (116.2) a	166.4 (72.6) a	1194.0 (143.3) c	780.5 (105.8) c	1435.6 (118.2) ab
Control (6)	0.45 (0.00)	0.44 (0.02)	178.1 (36.0) b	190.3 (28.0) a	168.2 (43.0) b	265.3 (25.0) ab	1171.3 (100.6) a	708.1 (70.2) a	1728.0 (199.9) a

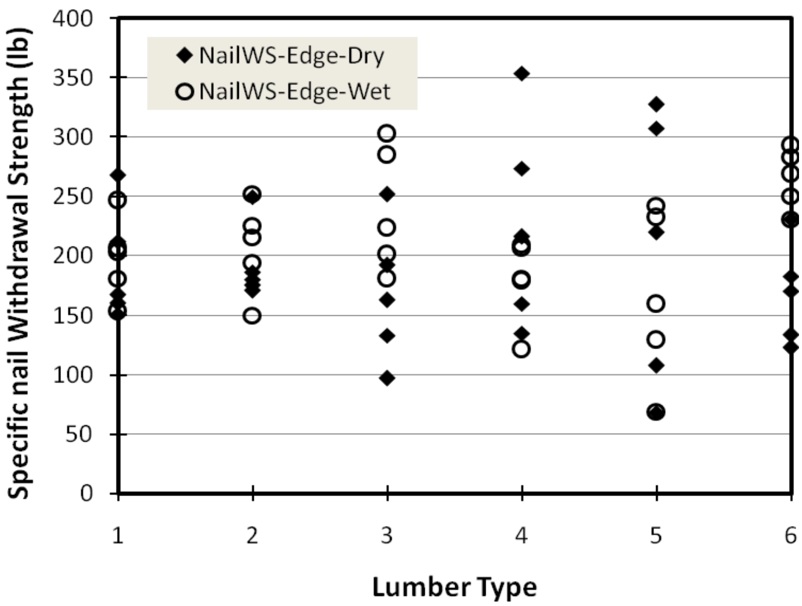

Figure 1. Specific nail withdrawal strength from sample edge for various samples.

values among various sample groups. Thus, preservative treatments had little effect on the nail withdrawal strength value at these two moisture conditions. Soaked groups had similar nail withdrawal strength value as these of air dry group.

3.2 Nail Pull Strength

Table 2 lists specific nail pull strength withdrawal strength for various groups of wood samples. Also shown in Table 2 are the hardness data from sample surface for the corresponding samples. Figure 2 shows specific nail withdrawal strength plotted for various sample groups. Similar to the nail withdrawal strength, there was no any trend of measured nail pull strength values among various sample groups. Thus, preservative treatments had little effect on the nail pull strength value at these two moisture conditions. Soaked groups had similar nail pull strength values as these of the air dry groups.

Table 2. Specific nail pull strength and hardness data

Sample Group	**Air-dry Specific Density**		**Nail Pull Strength-Dry (lb)**		**Surface Hardness (lb)**	
	dry	soaked	dry	soaked	dry	soaked
ACQ-GC (1)	0.58 (0.08)	0.61 (0.04)	350.7 (89.4) ab	313.5 (60.0) ab	1148.4 (263.2) ab	731.1 (144.4) a
ACQ-AG (2)	0.68 (0.03)	0.68 (0.04)	351.2 (15.0) ab	295.4 (41.7) b	969.3 (100.0) ab	599.1 (102.6) ab
MCQ-GC (3)	0.52 (0.04)	0.60 (0.03)	349.3 (79.3) ab	271.5 (41.7) c	778.4 (118.6) b	545.4 (53.2) b
MCQ-AG (4)	0.56 (0.02)	0.47 (0.02)	364.0 (29.2) ab	288.2 (38.0) b	1103.5 (70.8) ab	725.7 (174.8) a
Borate (5)	0.58 (0.04)	0.59 (0.03)	409.1 (135.7) a	354.3 (50.7) a	1321.3 (104.4) a	713.2 (33.4) a
Control (6)	0.43 (0.02)	0.43 (0.02)	283.0 (91.7) b	312.5 (71.9) b	1071.1 (89.7) ab	719.4 (99.9) a

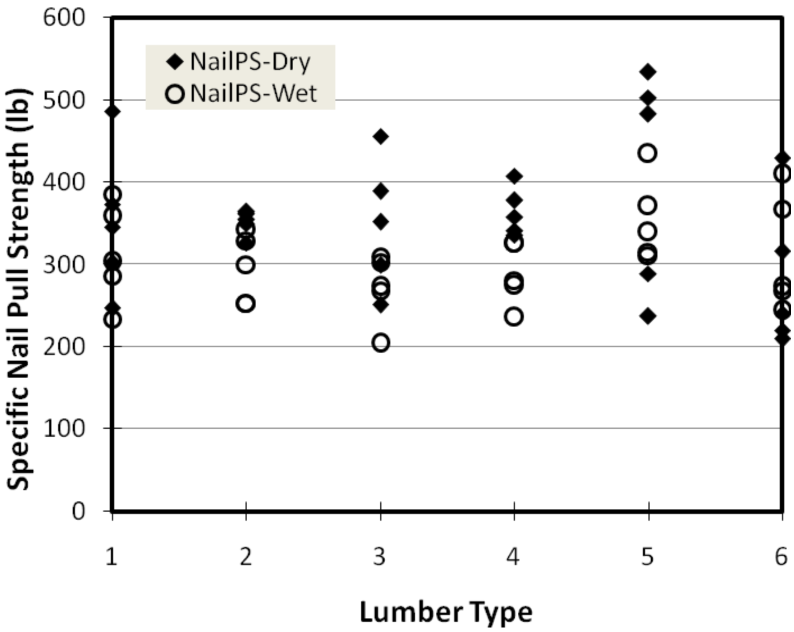

Figure 2. Specific nail pull strength from sample surface and edge for various samples.

3.3 Coated Screw Withdrawal Strength

Table 3 lists specific withdrawal strength for coated screw for various groups of wood samples. Also shown in Table 3 are the hardness data from sample surface and edge for the corresponding samples. Figure 3 shows specific nail withdrawal strength plotted for various sample groups. The specific screw withdrawal strength for all groups at dry and soaked conditions was similar. Soaking led to reduced screw withdrawal strength for all groups.

Table 3. Coated Screw Withdrawal strength and hardness data

Sample Group	Air-dry Specific Density		Screw withdrawal strength-Surface (lb)		Screw withdrawal strength-Edge (lb)		Surface Hardness (lb)	Edge Hardness (lb)
	dry	soaked	dry	soaked	dry	soaked	soaked	soaked
ACQ-GC (1)	0.52 (0.03)	0.50 (0.05)	1139.0 (91.5) bc	709.4 (53.1) b	1004.5 (375.8) a	788.8 (69.5) a	724.0 (78.9) a	1428.4 (126.2) ab
ACQ-AG (2)	0.60 (0.04)	0.58 (0.03)	1255.1 (40.6) abc	780.8 (80.0) a	1374.1 (154.8) a	795.8 (49.2) a	745.9 (73.9) a	1432.9 (157.6) ab
MCQ-GC (3)	0.42 (0.03)	0.44 (0.04)	1069.3 (187.2) c	691.1 (84.0) b	1030.9 (173.9) a	662.2 (145.5) b	635.0 (69.7) a	1325.2 (328.1) b
MCQ-AG (4)	0.52 (0.08)	0.45 (0.03)	1337.1 (265.1) ab	658.4 (79.8) a	1495.4 (241.6) a	731.4 (41.2) ab	688.4 (104.9) a	1582.6 (281.8) ab
Borate (5)	0.54 (0.03)	0.57 (0.04)	1361.3 (108.5) a	715.9 (106.9) a	1481.1 (174.8) a	779.4 (75.4) a	744.0 (55.2) a	1610.4 (96.7) ab
Control (6)	0.44 (0.01)	0.42 (0.03)	1269.7 (65.9) abc	695.2 (103.8) ab	1248.7 (78.5) a	797.0 (41.1) a	750.7 (86.7) a	1652.3 (145.0) a

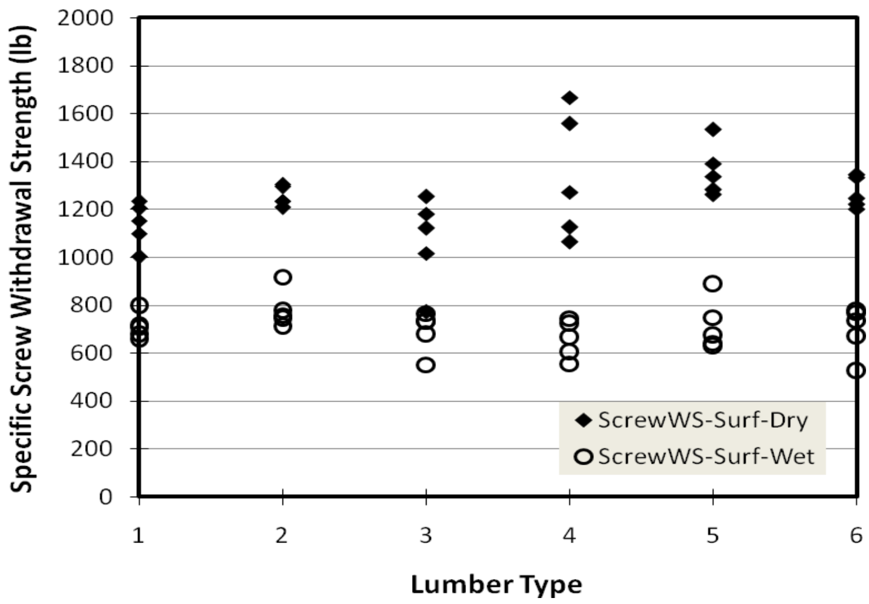

Figure 3. Specific nail pull strength from sample surface and edge for various samples.

3.4 Sheet Metal Screw Withdrawal Strength

Table 4 lists specific withdrawal strength for sheet metal screw for various groups of wood samples. Also shown in Table 3 are the hardness data from sample surface and edge for the corresponding samples. Figure 3 shows specific screw withdrawal strength plotted for various sample groups. Similar to coated screw, the specific screw withdrawal strength for all groups at dry and soaked conditions was similar. Soaking led to reduced screw withdrawal strength for all groups.

Table 4. Sheet metal screw withdrawal strength and hardness data

Sample Group	Air-dry Specific Density		Screw withdrawal strength-Surface (lb)		Screw withdrawal strength-Edge (lb)		Surface Hardness (lb)	Edge Hardness (lb)
	dry	soaked	dry	soaked	dry	soaked	soaked	soaked
ACQ-GC (1)	0.52 (0.03)	0.49 (0.02)	561.9 (146.9) a	412.2 (19.1) a	725.2 (168.9) b	495.2 (40.3) a	660.5 (52.0) bc	1554.3 (183.7) a
ACQ-AG (2)	0.60 (0.02)	0.57 (0.04)	624.4 (209.8) a	449.6 (60.9) a	862.7 (111.7) ab	418.9 (33.6) a	744.5 (84.6) ab	1309.5 (154.1) b
MCQ-GC (3)	0.44 (0.03)	0.47 (0.04)	624.7 (114.8) a	430.4 (26.6) a	658.9 (158.6) ab	434.7 (33.9) a	694.9 (58.1) abc	1331.5 (69.4) b
MCQ-AG (4)	0.54 (0.07)	0.45 (0.02)	626.8 (188.1) a	432.63 (55.7) a	702.6 (213.4) ab	483.9 (41.2) a	607.8 (142.8) c	1676.3 (200.8) a
Borate (5)	0.55 (0.03)	0.54 (0.02)	683.1 (97.0) a	420.7 (48.1) a	856.5 (221.5) ab	480.3 (97.9) a	766.9 (51.7) ab	1503.4 (101.9) ab
Control (6)	0.42 (0.02)	0.44 (0.02)	724.9 (276.4) a	480.4 (41.6) a	(870.1 (136.6) a	421.8 (126.7) a	815.3 (109.8) a	1668.6 (194.9) a

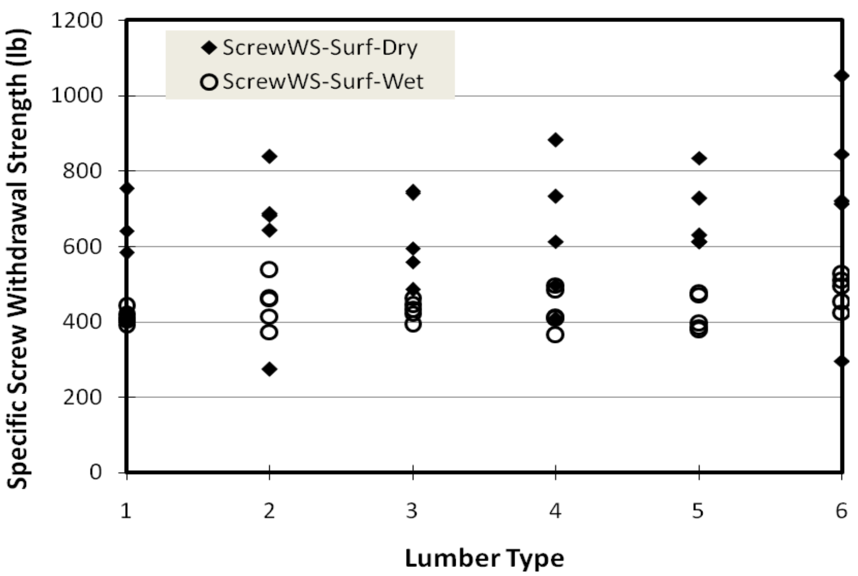

Figure 4. Specific sheet metal screw withdrawal strength from sample surface.

4. CONCLUSIONS

Nail and screw performance for southern pine wood treated with ACQ (above ground and ground contact), MCQ (above ground and ground contact), borate (disodium octaborate tetrahydrate – DOT), and untreated southern pine control were tested at air dry and water-soaked conditions based on ASTM standard D1037. At these two specific conditions, there was no noticeable difference in nail withdrawal, nail pull-through, and screw withdrawal strength among various wood groups, showing little effect of preservative treatment. The soaked groups had lower screw withdrawal strength, but similar nail withdrawal and pull-through strength compared with the air-dry groups. Tests are on-going with matched samples to demonstrate the effect of extended high temperature and humidity exposure on the nail and screw withdrawal strength among various treated wood groups in comparison with untreated materials.

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