

Do You Always Adjust Test Results to 12 Percent Moisture Content? No!

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Abstract

After conducting mechanical tests, the moisture content (MC) of the test specimens is determined. If the MC is not 12 percent, the standard procedure is to adjust the test value to equal those at 12 percent MC. With new treatments such as high-temperature heat treating, however, 12 percent MC may not be an appropriate value for adjustment. Tests were conducted using three species (southern pine [*Pinus taeda*], red oak [*Quercus* sp.], and sweetgum [*Liquidambar styraciflua*]), three temperatures (100°C, 150°C, and 200°C), and three conditioning environments (conditioning chamber, outside air, and enclosed over water). The results indicated that the higher the treatment temperature, the more difficult it was to reach 12 percent MC. For example, the MC of the samples treated at 200°C in the conditioning chamber was 7 or 8 percent, whereas the MC of the controls was 13 percent. These results imply that adjusting test values to 12 percent MC would be inappropriate if all specimens were conditioned in the same environment.

It is well known that strength properties are affected by moisture content (MC; Tang and Hsu 1972, Gerhards 1982, Green et al. 1986). The question is should a researcher always adjust the test values for differences in MC? The common practice is to place the test specimens in a conditioning chamber (CC) set at a temperature and a relative humidity that results in a nominal equilibrium MC (EMC) of 12 percent for the specimens. The specimens remain in the chamber until their weight stabilizes. If the MC values of some specimens are not 12 percent at the time of testing, then the test values of those specimens are adjusted to estimate their values at 12 percent MC using equations that were developed for untreated wood. This has been the standard procedure for many decades (Miller and Benicak 1967, Huffman 1977).

Currently, many woods that are being tested have been treated or modified in some way (e.g., at elevated temperature, with chemicals, or with radiation). These treatments can alter the moisture-holding characteristics of the wood (Chirkova et al. 2005, Kocaefe et al. 2008, Adewopo and Patterson 2011); therefore, after equalizing in a CC, the treated wood will have a different EMC than the untreated wood.

Bendtsen et al. (1983, p. 4), working with waterborne salt treatments, found that high retention levels resulted in higher EMC values after conditioning. They stated “that the significant main effects of preservative system and retention level on MOR [modulus of rupture] are apparently due to difference in MC.” Therefore, if those authors were to adjust the results for MC, they would be removing the main effect of the treatment.

We have observed that many researchers and journal reviewers insist that standard procedures be adhered to and the test values of treated specimens be adjusted to 12 percent MC. Korkut et al. (2010), after conducting mechanical tests, lowered their test values for samples treated at high temperature, which had lower MC values, to mathematically adjust the MC values up to 12 percent. This adjustment reduced the strength values for the samples treated at high temperature to below those of the controls; therefore, those authors concluded that high-temperature treating reduced the strength of the wood.

Adewopo and Patterson (2011) stated that because all of their samples were conditioned together, adjusting for MC was inappropriate. They concluded from their data that heat treating reduced some strength properties (shear and modulus of rupture) but increased others (compression parallel to grain and modulus of elasticity) when all samples were tested in the same environment (i.e., humidity and temperature).

The present study was conducted to demonstrate that adjusting the test values of wood treated at high temperature

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in essence puts it in a totally different environment and masks the effects of the treatment. Because of treated wood's lower hygroscopicity, an environment in which treated wood obtains an EMC of 12 percent could cause untreated wood to obtain a much higher EMC.

Materials and Methods

The wood for the present study was donated by three different sawmills: the first supplied southern pine lumber (*Pinus taeda*), the second red oak lumber (*Quercus* sp.), and the third sweetgum lumber (*Liquidambar styraciflua*). The sawmills supplied 2-inch nominal lumber (45 to 54 mm in thickness and 100 to 200 mm in width), which was cut into samples that were 40 by 40 by 250 mm in length, which in turn were stacked in a pile by species. Both end-by-end and side-by-side samples were generated. The samples for each treatment and environment were randomly selected from the piles and marked accordingly. All samples were dried in a kiln at 50°C to 12 percent MC. Four levels of treatment were used: controls (i.e., no additional conditioning beyond kiln drying), 100°C, 150°C, and 200°C. The duration time was 6 hours. Three conditioning environments were used, and the samples were randomly stacked in each. The first environment was an inside CC set at 21°C and 65 percent relative humidity. The second was covered outside air (OA), where the wood was protected from the sun and rain but the air could flow freely. The third was outside in a tarp-enclosed area over a pool of water (EOW). The bottom of the stack was approximately 400 mm above the water, and the top was approximately 300 mm below the tarp. The samples remained in their environments for 2 months (March and April in Arkansas). Ten replications were performed for each species, treatment, and environment, for a total of 360 samples. After conditioning, the samples were weighed, oven-dried at 103°C for 48 hours, and reweighed. The EMC values were calculated on the dry basis. The results were analyzed using a 1-way analysis of variance (ANOVA) and Tukey's studentized range test with $\alpha = 0.05$.

Results and Discussion

The EMC values are shown by species and treatment temperatures in Table 1 for CC, Table 2 for OA, and Table 3 for EOW. It can be seen in all three tables that a higher treatment temperature resulted in a lower EMC value. Also, the samples treated at 200°C never attained a 12 percent EMC, even after 2 months in the EOW environment.

The ANOVA analyses indicated a highly significant difference for all subsets of species and environments, with $P < 0.0001$ except for the sweetgum EOW condition, for

Table 2.—Equilibrium moisture content (EMC) after 2 months in outside air by species and treatment temperature.^a

Temp. (°C)	EMC (%)		
	Pine	Oak	Sweetgum
Control	14.1 A	12.8 A	13.7 A
100	12.9 B	11.3 B	12.6 B
150	11.6 C	8.4 C	11.6 C
200	8.7 D	5.5 D	8.7 D

^a $n = 10$. Values in a column with the same letter are not significantly different.

which $P = 0.0011$. Tukey's analyses indicated significant differences in MC by treating temperature for the CC and OA samples. Some nonsignificant differences were found in the EOW samples.

Samples treated at 100°C had a lower EMC than the controls. When oven-drying wood, a temperature of 103°C is normally used, and the duration can range from 24 hours to several days depending on specimen size. Therefore, when wood is oven-dried to determine its MC, its hygroscopicity has been reduced, so its EMC will be lower for any future environmental condition.

In a study by Patterson and Hartley (2007), the CC was calibrated using oven-dried blocks, and the chamber was adjusted until the blocks stabilized at their 12 percent EMC. After testing, the MC value of the test specimens was determined to be 14 percent. Because extra humidity had to be introduced to raise the EMC of the oven-dried blocks to 12 percent, the resulting EMC values for the air-dried test specimens were higher than desired.

The results from the EOW environment were inconsistent, and higher MC levels were expected. It appears that the tarp used to enclose the samples was more permeable than anticipated. In classroom laboratory exercises, specimens placed over water in a closed bucket attained an EMC of 20 percent. These results are statistically mixed, with some combinations being not significantly different, as shown in Table 3. If others were to duplicate the present study, we recommend using a more impermeable sheet of plastic instead of the tarp for the enclosure.

During a general discussion following a presentation of this study at the Forest Products Society's International Convention in Portland, Oregon, in June 2011, some Canadian researchers stated that their (undisclosed) wood treatment resulted in very low EMC values. They further stated that they could not publish in a European journal, because the reviewers insisted that the test values had to be

Table 1.—Equilibrium moisture content (EMC) after 2 months in conditioning chamber by species and treatment temperature.^a

Temp. (°C)	EMC (%)		
	Pine	Oak	Sweetgum
Control	14.1 A	13.0 A	13.3 A
100	12.1 B	12.0 B	11.7 B
150	10.7 C	8.0 C	10.7 C
200	8.4 D	6.1 D	8.1 D

^a $n = 10$. Values in a column with the same letter are not significantly different.

Table 3.—Equilibrium moisture content (EMC) after 2 months enclosed over water by species and treatment temperature.^a

Temp. (°C)	EMC (%)		
	Pine	Oak	Sweetgum
Control	15.3 A	12.1 A	15.0 A
100	13.9 AB	12.0 A	14.3 A
150	11.8 BC	9.5 B	12.4 AB
200	9.6 C	7.2 B	9.6 B

^a $n = 10$. Values in a column with the same letter are not significantly different.

adjusted to 12 percent. The researchers claimed their specimens could never attain 12 percent MC.

Most southern pine sawmills kiln dry their lumber in high-temperature kilns where the dry-bulb set point is approximately 120°C. The present study indicated that lumber will have a lower EMC in use compared with air-dried or lower-temperature conventional kiln-dried lumber. Lumber kiln dried at higher temperatures will perform better in service, because it will have a lower moisture-carrying capacity. In use, it will provide better dimensional stability and more resistance to fungi with minor changes in MC.

The implications of the present study are that we should reconsider the practice of forcing all test values to be reported based on 12 percent MC and ignore the effects of wood treatment. It is recommended that all specimens be conditioned in the same environment and that the test values be reported as they are. The purpose should be to determine the properties of treated wood compared with the properties of untreated wood in a set environment.

Another point to ponder is whether the equations used to adjust the strength properties of normal wood to 12 percent MC the correct equations to use for adjusting the strength properties of heat-treated wood. Winandy and Krzysik (2007) found that high temperatures used in pressing their test panels resulted in lower hygroscopicity, reduced thickness swelling, and enhanced nonground contact decay resistance. Their chemical analysis indicated that the side chains of the hemicellulose molecules were altered. Because the structure of wood is altered by heat treating, would not it also affect the amount that strength properties are changed per changes in MC?

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