Challenges in accelerated testing of durable wood products

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The types of durable wood products are changing rapidly, but predicting their long term durability with our short term tests remains a serious challenge. Improved understanding and interpretation of our test methods is needed to provide greater confidence in our durability evaluations.

Introduction

As societal expectations and economic conditions change, there is increasing pressure to develop and market new types of durable wood products. The last few years have seen the introduction and rapid acceptance of micronized copper preservative formulations as well as the introduction and commercialization of metal-free organic preservative systems. Preservative retentions have been lowered to lessen environmental concerns and lower cost. Numerous other types of preservative formulations are rumored to be on the near horizon, and there is renewed interest in the use of naturally durable wood species. Non-preservative approaches to durability such as thermal treatments and modified wood have been commercialized in European countries, and their potential is being explored in the United States. The rapid evolution of durable wood products has further highlighted an old problem in wood protection… how do we evaluate long term durability with short term tests? This challenge is further complicated by the wide range of exposure environments, types of structures and service life expectations. There are also vast differences in the consequences of premature failure.

Over the last century numerous laboratory and field test methods have been developed to evaluate durability, and many of these methods have gained broad acceptance in Europe, Australia, Asia and the United States. In the United States

the American Wood Protection Association (AWPA) has over 20 preservative evaluation standard methods, and other organizations, such as ASTM International, have applicable methods as well. These methods detail the testing procedures, and in some cases suggest or prescribe the manner of presenting the results. However, the methods generally provide little guidance on how to interpret the results in terms of expected service life or in terms of "pass/fail" criteria. In other words, what is the significance of an average stake rating of 9.0 after 3 years exposure? Does this rating demonstrate efficacy of a preservative in ground-contact? A similar problem in data interpretation exists in European countries, where there is a need for a harmonized system for durability classification.

Figure 1. Soil block (or soil-bottle) decay test.

Accelerated laboratory tests

The most widely used laboratory test in the United States is the soil-block (also called soil bottle) decay test. In this test a cube of the wood product is placed into a bottle that contains moist soil and a feeder-strip that has been pre-inoculated with a specific decay fungus. Sterile technique is used to ensure that only the fungus of interest is present in the bottle. The intent of the method is to provide the fungus with ideal conditions for colonizing the test material, and to evaluate the ability of the wood product to resist colonization. The method can perhaps be best understood as a measure of resistance to fungi that are known to be tolerant of a specific preservative. However, the relationship between the results of the soil-block test and in-service durability are poorly understood. One of the drawbacks of the method is that the fungi evaluated many not be relevant for in-service conditions. The standard fungi have been selected for their known resistance to some of the conventional preservatives, and are not necessarily those found degrading wood products. The vigor of the fungi also varies greatly between laboratories, and the results appear to depend on factors such as the age

of the fungal culture, soil properties, and moisture content. Perhaps a larger concern with this method is that the sterilization process eliminates other organisms, such as bacteria, that may play a role in degrading and detoxifying organic preservatives. Thus, although the soil-block test does provide some insight on the ability of a wood product to resist colonization by certain fungi, it does not offer great promise for predicting the service life of a wood product used either in ground contact or above the ground.

Ground contact stake tests

Stake tests continue to be the primary method of evaluating products intended for use in ground contact. However, there are several factors that can interact to affect the results of these tests. Perhaps the most important of these factors are site conditions and duration of the test. It has long been recognized that deterioration is more rapid in warm, moist climates than in cool or dry climates. In the US, the AWPA standards recognize that climate affects the rate of deterioration, stating that while the minimum exposure time is 3 years in high decay hazard areas such as southern Mississippi, longer exposure times are required for lower decay hazard test sites such as Wisconsin. It is left up to the discretion of the subcommittee evaluating the proposal to determine whether the length of the exposure is adequate, but in the past, 3–5 years of data have generally been considered to be sufficient. However, results derived from northern climates are potentially misleading, even with longer exposures. For example, stakes that perform well in Wisconsin for over 5 years can be nearly destroyed in less than three years Mississippi.

Figure 2. Stake test plot in Mississippi, USA.

Similar challenges in interpreting data from different sites are encountered in European countries. It has been proposed that the site differences can be partially accounted for by creating adjustment factors based on the relative performance of reference materials at various sites. While this approach would remove some of the subjectivity in determining the required length of exposure, it is not a perfect solution because the effect of test site on preservative performance is a function of the formulation (or type of product) being evaluated. Thus, one cannot always assume that exposure for a certain number of years in a moderately severe site is equivalent to exposure for a certain number of years in a more severe location. Perhaps the most practical solution is to require data from at least one test site that has demonstrated a severe deterioration hazard.

Length of exposure is also a concern even within high decay hazard areas. It is far from clear that the three years specified in AWPA standards is sufficient. For example, consider the ratings of stakes in one of the USDA, Forest Products Laboratory's plots in southern Mississippi. This plot contains over 100 treatment groups, each of which was replicated with 20 stakes (19 by 19 by 457 mm). The stakes in these plots have been rated for 11 years. The data was analyzed to compare how well a treatment group with a perfect rating (all 20 stakes rated as perfect) at 1 through 9 years faired after 11 years. The analysis revealed that only about half of the groups with a perfect rating after three years performed as well as the reference preservative (average rating of 9.10) after 11 years. Thus, perfect ratings or equivalent performance to a reference preservative after three years does not provide a high degree of confidence that a test system will be performing similarly to the reference preservative over the longer term. These data indicate that when evaluating preservatives intended for use in ground contact in high hazard areas, a minimum of at least 5 years of exposure data is needed, and that the average rating of the test preservative should be at least as high as that of the reference preservative. Even slight evidence of vulnerability after 5 years appeared to be a strong indicator of poor future performance.

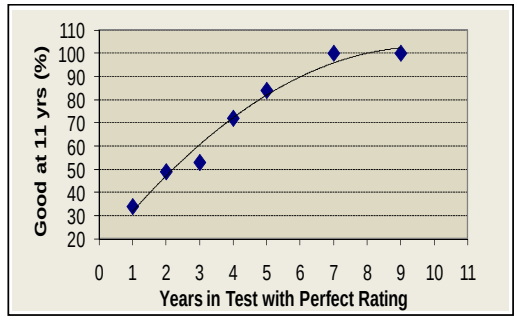

Figure 3. Only about 50% of groups with perfect ratings at three years perform well after 11 years.

The European Standard EN 252 for ground contact exposure does require a minimum of 5 years of testing before results can be interpreted. However, similar concerns have been expressed about the use of 5 year data from Nordic test plots to predict long term performance. Researchers in Norway compared the average ratings of over 700 treatment groups (approximately 10,000 total stakes) at 5 and 10 years to their median life and concluded that even treatment groups with no signs of decay after 5 or even 10 years may have a relatively short median life. One treatment group with no evidence of decay after 10 years had a median life of only 14 years.

Stake size effect

Often stakes with relatively small dimensions are used in tests because they are thought to have accelerated deterioration relative to larger stakes or commodity-size stakes. Small stakes do generally fail more rapidly, and so provide accelerated information on the relative efficacy of a test formulation in comparison to a reference preservative. However, it is unclear how their ratings or durability correspond to the service life of larger commercial members. In a recent study, the years to reach average ratings corresponding to loss of 10% of the cross section or complete failure were compared for 53 sets of matched 19- by 19-mm and 38- by 89-mm stakes exposed in plots in Mississippi. The larger stakes required an average of 2.1 times longer to reach an average rating corresponding to loss of 10% of the cross section, but this ratio ranged from as low as 1.0 to as high as 8.0. It took an average of 2.2 times longer for the larger stakes to fail, with maximum and minimum ratios of 3.5 and 1.4, respectively. Linear regression of average years to loss of 10% of the cross section or failure for the two stake sizes yielded R^2 values of

0.60 and 0.69, respectively. The data indicates substantial uncertainty in using the durability of 19- by 19-mm stakes to predict the durability of 38- by 89-mm stakes, and by extension, the durability of in-service members.

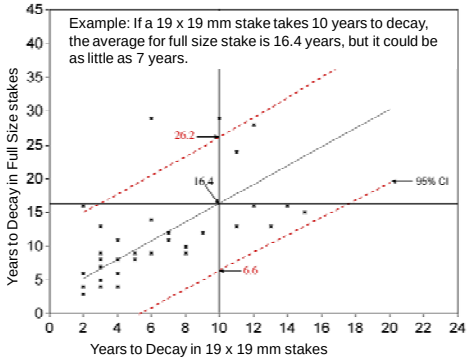

Figure 4. The relationship between the durability of these two stake sizes varies greatly.

Above-ground durability evaluations

Evaluation of wood products intended for use above-ground has proven even more difficult than ground contact evaluations. Although it is recognized that the decay environment presented by stake tests is very severe for products intended for use above-ground, the selection of an appropriate above-ground test method has been problematic. The greatest source of difficulty appears to be the wide variations in severity of exposure for wood used above-ground. The severity of above ground exposure does vary with climate but it also varies greatly with construction practices and localized site conditions that influence moisture, temperature and UV exposure. In areas where organic debris can collect in connections, the above-ground decay hazard may be higher than anticipated.

Figure 5. Current above-ground test methods may not adequately account for the accumulation of organic debris that can occur in-service.

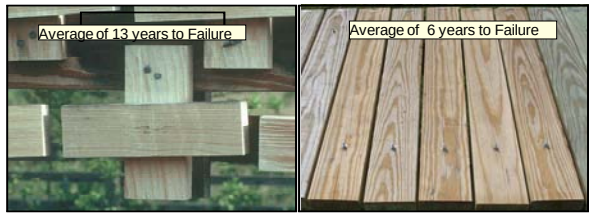

Figure 6. Small specimens used for above-ground testing may not hold sufficient moisture for sustained decay.

Substantial research on above-ground evaluations continues to take place in Europe, where the transition to use of “above-ground only” preservatives has preceded that in the United States. Despite extensive research however, it remains unclear how well above-ground tests characterize the hazard, or if they actually accelerate the rate of decay relative to in-service applications. Much of the difficulty is derived from creating test arrangements that simulate the moisture-trapping conditions present in actual structures. Most methods utilize some type of joint, connection or layering in an effort to trap moisture, but this effect can be undermined by the use of specimens with small dimensions. Although the smaller dimensions do allow more rapid detection of decay once it is present, smaller specimens dry more rapidly than dimension lumber. Smaller specimens also may be less susceptible to the formation of the checks that allow penetration and trapping of moisture in larger material. Thus, although we associate the use of small specimens with accelerated testing for wood placed in ground contact, this assumption may be misleading for above-ground evaluations. Some studies suggest that common test arrangements may actually slow the time needed for decay to develop. In a comparison of tests units of untreated southern pine sapwood exposed above-ground in southern Mississippi, the most rapid visually evident average years to failure (6 years) was achieved by simply using 102 mm thick planks. An earlier study reported that initial decay was not observed in untreated pine cross-brace units (20 x 75 x 15 mm) until after 6 years of exposure in southern Mississippi. In contrast, fruiting bodies of the brown rot fungus *Gloeophyllum sepiarium* can be observed after only three years of exposure of southern pine decking specimens (38 by 140 x 914 mm) in the lower decay hazard climate of Wisconsin. In addition to the effects of specimen dimensions, none of the commonly used test methods simulate the accumulation of decaying organic debris that often occurs in connections of treated wood used above-ground. Specimens are typically exposed in open areas to remove variability

associated with natural shading, and when organic debris does accumulate it is removed during periodic inspections. European researchers have also noted that shading alone can promote above-ground decay, possibly because of increased wood moisture content.

Both the United States and European above-ground methods do indicate that meaningful results are not obtained until the untreated specimens reach a certain level of deterioration, but AWPA guidelines for preservative evaluation also state that a minimum of only three years of data may be needed in high hazard climates. This relatively short test duration may be based on the optimistic assumption that the above-ground test arrangements provide for accelerated testing. The standard methods do not provide criteria for ratings that would be considered acceptable or "passing" for the preservative-treated specimens, and given our uncertainty about the relationship between the results of these tests and in-service performance such criteria may be difficult to develop. It is also worth noting that although we may associate above-ground treatments with decking, the same use category also applies to structurally critical support members used above-ground. Given the ramifications of failure in some of these members, such as, third story balcony supports, some consideration should be given to providing more conservative durability estimates.

Conclusions

For evaluation of products intended for use in contact with the ground, it appears that even extended durability tests conducted in less severe (northern) climates may not be adequate for estimation of durability in more severe climates. Even in severe decay hazard climates, excellent performance of stakes after only three years is not a reliable indicator of long term durability. Basing test duration or performance criteria on the durability of untreated controls also does not appear to be sufficient for ground contact evaluations. The approach used in Australia, where test duration is based on the performance of low concentrations of an established reference preservative, does appear to have some merit.

Our current methods of assessing above-ground durability may not accelerate decay in comparison to some conditions encountered for durable wood products in service, suggesting that much longer evaluation periods or more severe tests should be considered. Alternatively, above-ground uses could be further divided, with more stringent test methods utilized for products intended as above-ground structural supports. Ground-contact testing of products used in structurally criti-

cal above-ground members may be necessary until the meaning of above-ground test methods is better understood.

Interpretation of test data also remains problematic. A return to more prescriptive data presentation may be warranted, as average ratings do not always adequately characterize the performance of a durable product. In addition, methods should provide more specific guidance on the distribution of ratings that is considered to represent adequate performance.

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