A NOTE ON THE PROTECTION OF WOODEN BEAMS EXPOSED TO AN ACIDIC, HUMID ATMOSPHERE

G. M. Barton and *K. Hunt*

Research Scientists, Western Forest Products Laboratory, Canadian Forestry Service, Department of the Environment, Vancouver, British Columbia, V6T 1X2

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ABSTRACT

By means of standard lignin and carbohydrate analyses, together with pH measurements, the cause of strength losses in beams exposed to an acidic, humid atmosphere was shown to be due to acid hydrolysis of wood carbohydrates. It is recommended that wooden beams used in such an acidic environment be adequately finished with a flexible, moisture-proof coating and the finish be inspected and maintained at regular intervals.

Additional keywords: Pseudotsuga menziesii, strength, chemical degradation, chemical analysis, protective coatings.

Introduction

During the last few years, the wood chemistry activity of the Western Forest Products Laboratory has been asked by industry on several occasions to investigate "decay" in Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] wooden beams, both solid and laminated. This report summarizes the investigations of several of these beams taken from different pulp-mill bleaching plants and located where acidic vapors of chlorine dioxide and sulfurous acid were involved. Some of the beams had a protective coating of unknown composition that was in various stages of disrepair, with imperfections in the coating being common around knotholes. In none of these samples was biological decay found, although there were superficial similarities, such as a dark brown color and a friable, brittle surface.

Analyses and Results

Since acid hydrolysis of wood carbohydrates has been an important factor in several previous investigations involving deterioration of plywood due to the misuse of acidic glue accelerators and in the collapse of roofs in wooden dry kilns (Barton 1972), pH, lignin measurements (Tappi Std. T13 os-54), and carbohydrate determinations were carried out on the suspect beams (Table 1). These beams were obtained at two British Columbia locations, Prince George and Tahsis.

The low pH values of 2.8, 2.9, and 1.2, together with the higher lignin contents of 32.1, 40.9, and 61.9, respectively, of the unprotected wood exposed to strong acidic conditions were very significant. They clearly indicated that acid hydrolysis of wood hemicellulosic and/or cellulosic material had occurred. Galactose was almost completely lost and the xylan in the wood was more severely degraded than was the glucomannan. Cellulose is much less susceptible to strong-acid hydrolysis than are the hemicelluloses. The carbohydrate analyses results indicate that at least two pathways for acid degradation are possible:

1. The cellulose is untouched, while the hemicellulose fraction is greatly hydrolyzed.
2. Both the cellulose and hemicellulose are degraded, the hemicellulose fraction at a more accelerated rate.

Any effect on the cellulose was impossible to assess from the analyses in Table 1. Therefore, four additional beam samples different from those described in Table 1 were selected: (1) unexposed beam, (2) beam exposed to an acidic atmosphere (protective coat intact), (3) and (4) beams exposed to acidic moisture (protective coats

TABLE 1. *Analyses of wood samples taken from Douglas-fir beams (extractive-free, moisture-free basis)*

Description of sample*	pH	Klason lignin %	Holocellulose by difference %	Glucose %	Mannose %	Xylose %	Galactose %
Control, normal wood from unexposed beam	4.0	29.4	70.6	40.9	18.5	5.6	4.4
Beams exposed to acidic atmospheres, protective coat absent (from Prince George, B.C.)	1.2	61.9	38.1	-	-	-	-
	2.9	40.9	59.1	45.5	9.5	1.9	0.4
	-	37.8	62.2	53.0	8.8	0.1	0.1
	-	41.9	58.1	48.2	9.5	0.2	0.1
Beams exposed to acidic atmospheres, protective coat intact (from Tahsis, B.C.)	3.3	-	-	-	-	-	-
	3.2	29.7	70.3	-	-	-	-
Beam exposed to acidic atmospheres, imperfections in protective coat (from Tahsis, B.C.)	2.8	32.1	67.9	-	-	-	-

* While moisture content data of specific beams was not available, spot checks of beams and roof decking from similar locations showed ranges of 15 to 38%.

absent) which were comminuted to sawdust (40-mesh screen). Lignin was removed from the samples by the chlorite method to yield the four holocelluloses. The α-cellulose was then prepared from each holocellulose via Tappi Std. T203 os-61. The degree of polymerization (D.P.) of each sample was calculated from its α-cellulose viscosity measurement (ball-fall viscosity, 1% CED, Tappi Std. T230 su-66). The D.P. results were as follows: (1) 1200, (2) 1180, (3) 875, and (4) 735 for the above-numbered samples. Since all four samples were prepared by identical procedures, it must be assumed that any degradation due to preparation of the α-cellulose would be the same for all samples. The results show that the two samples (3) and (4) in contact with the acidic moisture and protective coat absent had a D.P. less than two-thirds that of the unexposed and protected beams.

Considering the results from Table 1 and D.P. measurements together, it would appear that the second pathway is most likely and the cellulose is degraded as well as the hemicelluloses, but at a slower rate. In the case of the sample with a 40.9% lignin content, enough hemicellulose, particularly the xylan (Kass et al. 1970), was removed and enough cellulose degraded by repeated acid hydrolysis over the exposure time of 6 years to weaken the beam sufficiently to cause it to fail in service. In appearance the broken ends were dull brown, and splinters of wood removed from the break area were quite friable.

Although the species in these investigations was Douglas-fir, other common coniferous species would behave in a similar manner. A more precise term to describe this condition would be "chemical degradation," rather than "decay," which connotes biological attack.

Clearly the higher working temperatures (above 32 C [90 F]), higher relative humidities (greater than 80%), and continuous production schedules common to pulp mills accelerated the acidic degradation of the unprotected beams. Two other important factors to be considered are imperfections in the wood surface (checks and knots) where the concentration of acidic condensate could occur during drying cycles and the exposure of new wood surfaces by mechanical abrasion.

CONCLUSIONS

1. Wooden beams exposed to acidic environments where the pH is consistently below 3 may suffer a loss of strength due to acid hydrolysis of wood carbohydrates. Other important factors that contribute to the degree of this hydrolysis are temperature and moisture content.

2. It is highly recommended that a flexible, moisture-proof coating, for example polyethylene-polyurethane, be applied to the new wood and maintained during the length of service of the beam. This coating should be carefully inspected around knotholes or other surface imperfections since these areas accumulate dilute acids that lose water during drying cycles and become concentrated acids.
3. Properly protected wooden beams used in acidic environments should give the same satisfactory life as those used in more favorable locations.

References

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Editorial

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complain that we "get no respect." I believe that is mainly because we are not well known. We can expect society to regard us as professionals only when more, much more of society recognizes that we have skills to solve problems that affect them personally. We won't do it overnight. But I predict that 5 years from now, we will be much more widely known and recognized than we are now. And, bluntly, improvement of our professional image can do much to enhance career opportunities for each of us.

This Society will do as much, or as little, for our profession as we make it do. I believe that we need to promote, sell if you will, the fact that just as wood is our one great renewable resource, so wood scientists and technologists are the best-qualified people to help the public use it effectively. We won't do this by sitting in conferences and telling each other that we are professionals. We will only do it by selling our abilities to the public. And we will be professionals only when a large segment of the public regards us as such. The Society is a potentially splendid vehicle for getting our message out; let's use it.

ALBERT N. FOULGER

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