

EFFECTS OF FIRE RETARDANT TREATMENTS ON WOOD STRENGTH: A REVIEW

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ABSTRACT

As evidenced by recent structural problems with fire-retardant-treated plywood, fire retardant chemicals and high temperature environments can degrade the strength properties of wood. We do not know to what extent fire retardant chemicals, thermal environment, and moisture content contribute to wood degradation. We suspect that the combination of acidic fire retardant chemicals and elevated temperatures increases the rate of acid hydrolysis in the wood, thereby causing a loss in strength. This paper presents a review of the pertinent literature on the factors influencing strength reduction in treated wood. These factors are the thermal degradation process of wood, the mechanism by which fire retardant chemicals alter wood degradation, the effect of acids on wood strength, the influence of temperature on strength, and the combined effect of fire retardant chemicals and temperature on strength. We also discuss possible long-term effects of in-service conditions on the strength of treated wood; the effects of treatment on the strength of weaker structural members and on species, size, and grade of lumber; and the application of the relationship between treatment and strength to plywood and lumber.

Keywords: Acid hydrolysis, fire retardants, plywood, strength, thermal degradation.

INTRODUCTION

When heated, wood burns by producing flammable volatiles that may ignite. To reduce flammability, wood is treated with fire retardants (FR). Such treatment drastically reduces the rate at which flames travel across the wood surface and reduces the amount of potential heat. However, some FR treatments may produce unwanted secondary side effects, such as increased moisture content, reduced strength, and increased potential to corrode metal connectors. The magnitude of the side effects depends on the particular fire retardant chemicals used, and the relative importance of these side effects depends on the intended application of the product.

Engineered roof systems are a major use of FR-treated plywood for multiple-family dwellings and for light to medium commercial construction. Treated wood is also commonly used for scaffold planking and for reducing flame spread in

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interior finishing material. The use of FR treatments in these situations is required by building codes or insurance companies for safety.

Recently, some FR-treated plywood used for roof decking has exhibited reduced strength. In these cases, the wood has become very brash and brittle, crumbles easily, and has darkened. The length of service time for the roof plywood has varied from 3 to 8 years. The mechanism of degradation in cases such as these is unknown. However, the combination of elevated temperature conditions that exist on roof systems and the acidic nature of the FR may have accelerated the rate of acid hydrolysis of the wood. Thus, the loss of strength and embrittlement of FR-treated wood could be explained by the long-term effect of acids and elevated temperatures on the composition of the wood products. The supporting evidence for this hypothesis can be found in the literature on:

- (1) chemistry of the thermal degradation process of wood,
- (2) mechanisms by which FR treatments alter the thermal degradation process,
- (3) effect of acid treatments on wood strength,
- (4) effects of temperature on wood strength, and
- (5) effect of interaction of FR chemicals and temperature on wood strength.

These five pertinent phenomena are each involved in the degradation process. Moreover, the combined effect of these phenomena may be greater than the sum of the individual effects. The purpose of this paper is to examine the factors that might influence the degradation of FR-treated wood and to expand understanding of these factors to improve design and performance of products made from treated wood.

LITERATURE BACKGROUND

Chemistry of thermal degradation

When wood is heated, chemical bonds begin to break down at about 175 C, and the reactions accelerate as the temperature increases. When heated at 100 C to 200 C in the absence of air, noncombustible products such as carbon dioxide, traces of formic and acetic acids, and water vapor are produced. Above 200 C, the carbohydrates break down and produce tars and flammable volatiles, which diffuse into the surrounding environment (Browne 1958; Shafizadeh 1984). Above 450 C, the production of flammable products is complete. The residue that remains is char (Browne 1958; Shafizadeh 1968, 1971, 1975; Shafizadeh and Chin 1977; Stamm 1955).

Cellulose decomposes in the temperature range from 260 C to 350 C (Shafizadeh 1984), and it is primarily responsible for the production of flammable volatiles. The thermal degradation of cellulose can be accelerated in the presence of water, acids, and oxygen. As the temperature increases, the degree of polymerization of cellulose decreases further, free radicals appear, and carbonyl, carboxyl, and hydroperoxide groups are formed (Broido et al. 1973; Hirata 1979; Shafizadeh 1984). The primary reaction is depolymerization caused by the cleavage of the glycosidic linkage. (The glycosidic linkages are hydrolyzable at room temperatures in the presence of strong acids.)

The hemicelluloses degrade in the approximate range of 200 C to 260 C. Hemicelluloses are less thermally stable than cellulose, and they evolve more noncom-

