Preservative-treated Structural Wood Composites For Durable Home Construction

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Abstract

Structural wood composites panel and engineered lumber are being increasingly used to replace solid lumber products and plywood in home construction. This evolution is being driven by the changes in wood supply and the development of new composite manufacturing technologies. Among the products, treated structural composites with decay and insect resistance are of growing importance due to increasing demand for treated wood products for exterior applications. Technologies are being developed to incorporate the preservatives into the product during its manufacture and/or to use chemically modified wood furnish. Many factors affect the suitability of a preservative for use in this type of application and its efficacy in the final products. This paper summarizes current preservation technologies and future research directions for protecting wood-based panel and engineered wood products.

Keywords: bio-degradation, composites, durability, preservation, wood.

Introduction

Nearly all of the 1.5 million homes constructed in the United States each year have light frames made of wood, the world's most sustainable building material. Wood-based composites, including structural panels and engineered lumber, are being increasingly utilized in both interior and exterior applications and frequently are the principal structural elements in buildings. These applications include sheathing, floor, I-beams, door and window components, joists, and molded wall panels as both skin and structural elements (Wu et al. 2002).

The exterior application of wood composites has led to increased exposure of the materials to wetting, and consequently, to decay fungi and insects (primarily termites). For example, widespread infestations of the Formosan termite (*Coptotermes formosanus*) in southern Louisiana have caused damage estimated in the hundreds of millions of dollars (Ross et al. 2003, Lee et al. 2004). Formosan termites pose a major threat to all cellulosic building materials because they consume wood much faster than native subterranean termites, and they grow colonies that can be ten times larger than those of native termites. It is the most destructive insect in Louisiana (Gran Jr. 2003). Other states recording infestations include Alabama, California, Florida, Georgia, Hawaii, Mississippi, North Carolina, South Carolina, Tennessee, and Texas. Mould, decay, and other moisture-related problems have also led to significant economical losses in the building industry. Wood composites are particularly vulnerable to these biological attacks, if unprotected (Laks and Palardy 1993, Lee 2003).

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For solid lumber, durability concerns have historically been addressed through the use of chemical treatments employing a variety of application methods including pressure impregnation, immersion, diffusion, and vacuum-assisted treatments (Evan 2003, Freeman et al. 2003). With the exception of pressure-treated plywood, traditional methods with waterborne preservatives have not proven to be practical or effective enough for treating structural composite panels such as oriented strandboard (OSB), and engineered lumber such as laminated veneer lumber (LVL). This is primarily due to the undesirable swelling and strength reduction of the treated panel and the need for a post-treatment drying step involving cost and the potential for initiating technical degradation of the products (Murphy et al. 1993).

In response to these factors, significant effort has been made to develop new treatments and treating methods to meet the challenge of enhancing the durability of composite building materials. The purpose of this paper is to provide a summary of current treatment methods, treating chemistries, and future research directions for protecting wood-based panels and engineered wood products. Discussion is directed primarily to the strand-based structural composites.

Current State of the Art

Structural wood composites are manufactured by heat and pressure consolidation of wood furnish (i.e., strands) coated with adhesive and wax. The modern manufacturing process represents a fine balance of raw material (i.e., wood, resin, wax, and other additives) and production variables (e.g., mat forming, pressing temperature, and time) in terms of cost and product performance. The addition of a preservative component or the use of chemical modified furnish may have a major effect on product properties and often requires change of the manufacturing process. A number of factors need to be taken into account when developing such a system (Laks and Palardy 1993, Freeman et al. 2003). These factors include nature of the preservative (e.g., heat stability, diffusivity during consolidation, solid or liquid), nature of wood furnish (e.g., species and dimension), natural of adhesives (e.g., phenol formaldehyde -PF versus diphenylmethane diisocyanate - MDI), interaction of preservative with adhesive and wood, and methods of preservative incorporation.

Treatment Preservatives

Preservative treatment of wood has a long history in the United States. The preservatives for wood and wood products are designed considering health, safety and environmental properties in relation to manufactures and customers, product life cycle, compatibility and adaptability with process, resin and additive systems, stability and consistency to the manufacturing process, final board properties and durability, and other related issues (Ross et al. 2003). The history of wood preservative development in the U.S. can be traced back to early 1800. Two comprehensive reviews were recently made by Evan (2003) and Freeman et al. (2003) on wood preservatives, treating process, and emerging protection technologies for wood and wood composites.

To provide structural composite panels with required biological resistance, inorganic borates are being used as an additive during panel manufacturing (Laks et al. 1988, Knudson 1998, Brunette et al. 1999, Lee 2003). Among the products, disodium octaborate tetrahydrate (DOT, Timbor) has ability to diffuse into engineered wood products, making it useful as components of penetrating barrier surface treatments. However, Tim-Bor had an appreciable negative effect on the properties of composite boards bonded with phenolic resins (Laks et al. 1988). The use of MDI resin can help reduce the negative impact of Tim-Bor, but leaching of the chemical under wet conditions still poses a significant problem for the chemical. In this regard, zinc borate, which has low water solubility, has been used for structural composite manufacturing to provide decay and insect resistance with reduced interference to the manufacturing (i.e., adhesive bonding) process (Knudson 1998, Lee et al. 2002, Lee 2003).

Recent research on durability analysis of borate-treated structural panels at the Louisiana State University (Wu et al. 2002, Lee et al. 2004, Lee 2003) showed that calcium borate can also be used in this application. Figures 1 to 4 show comparative mechanical, termite resistance, leaching, and long-term creep properties of zinc and calcium borate-treated OSB from southern pine and mixed hardwoods. Calcium borate with an appropriate particle size can be successfully used to protect OSB bonded with PF resin with required mechanical strength and biological resistance. Leaching (Figure 3) for both zinc and calcium borate treated OSB under the direct water exposure is still a problem (Wu and Lee 2002). Thus, it is desirable to develop non-leachable borate systems for exterior application. Hydrated sodium calcium borate hydroxide ($NaCaB_5O_6(OH)_6$-$5H_2O$), often known as Ulexite, has also been studied for treating wood composites. Both calcium borate and Ulexite are not at this time registered as a wood preservative with the U.S. Environmental Protection Agency (EPA).

Long-term structural performance under sustained loading conditions of borate-treated structural composites is one of the major concerns for structural application. It was shown that boards bonded with both phenolic and isocyanate adhesives display a reduction in bending strength upon the incorporation of borate. Thus, durability issues of borate-treated composites will arise both in load-bearing (e.g., OSB shear wall, roof, and I-beams) and non-load-bearing (e.g., OSB siding and sheathing) situations. It has been reported that high temperatures that occur within roof structures can cause a degradation in the wooden roof components that is probably catalyzed by acids derived from the chemical (LeVan and Winandy 1990). Also, the influence of cyclic environmental exposure can affect the extent of degrade. Because the borate is inorganic salts, it diffuses throughout the wood with moisture movement. In some situations, such as roofs, elevated temperatures and humidity changes cause shifts in the equilibrium moisture content of the wood. As the moisture moves, so do the inorganic salts. This cycling could cause migration of the salts within the wood. At each new site, the acidic salt can cause further degradation. The study reported by Wu and Lee, J.N. (2002) demonstrated creep performance of zinc and calcium borate-treated OSB under both constant and varying moisture conditions. In the study, the influence of initial borate content, wood species, and stress level on the creep deformation was studied. Under the constant moisture condition, there was practically no difference in creep for boards at various borate levels for both types of borate. The creep data were fitted well with a spring-dashpot model. Predicted fractional creep validated the current adjustment factor up to a 30-year duration under a constant moisture content level. Under the varying moisture condition, however, large creep deflection developed due to the mechano-sorptive effect (Figure 4). The effect of borate on wood deformation became significant for both zinc and calcium borate treated OSB, indicating a reduced load carrying capacity of the OSB at higher borate levels. This result indicates the need for studying long-term duration of load properties of the modified OSB under combined mechanical and moisture loadings.

Organic waterborne water-repellent preservative systems similar to those used to protect solid lumber have also been developed and tested for composite products (Baileys et al. 2003). The biocides (i.e., fungicides based on iodocarbamates, triazoles, and isothiazalones, and insecticides based on synthetic pyrethriods and nicotinimides) can be introduced as furnish treatments during manufacturing to provide water and fungal resistance of structural composites (Ross et al. 2003). The active ingredients however, must be capable of withstanding processing temperatures of up to 220?C as commonly experienced during hot pressing. Surface treatments of finished products utilize many of the same chemistries.

Treatment Methods

There are three primary methods for manufacturing treated wood composites, based on the manufacturing process of the composite material. These methods include pretreatment of wood furnish, in-line treatment, and post treatment of finished products.

a) Pretreatment of Wood Furnish

In this process, wood furnish is treated with a preservative through either pressurized (Quinn et al. 1993) or non-pressurized (i.e., spraying or dipping) processes (Roos et al. 1993). The treated furnish is then dried and used for composite manufacturing. With an appropriate combination of preservative and adhesive, this process can provide a product with a constant loading of preservative throughout its thickness. Development of such manufacturing process can also help recycle treated wood (e.g., chromated-copper-arsenate or CCA-treated wood) through a composite process. Concerns with the process include emissions from the driers and pressing operation, and disposal of treated waste products (e.g., trimmings and sawdust) and preservative.

Chemical modification of wood furnish with polymer systems provides a way of producing composite products with improved decay, insect, and dimensional performance properties (Rowell 1982). Among the polymers, isocyanates have proven to be the most effective modifying agents and react with the wood constituents to form cross-linkages. This crosslinking reduces the adsorptive nature of wood and makes it less susceptible to attack from biotic agents. The challenge is to produce modified wood with low weight gain and without losses in properties common to many of current methods such as acetylation. Wood modification has the potential for lessening the environmental impact found with conventional systems of wood protection.

b) In-line Treatment

In-line treatment refers to the process whereby the active preservative ingredients are combined with dry wood furnish before mat forming and hot pressing (Laks et al. 1988, Knudson 1998, Brunette et al. 1999, Lee 2003). Active ingredients can include fungicides, insecticides and water repellents, either singly or in combination. The preservatives can be applied to wood in two ways:

- Spraying the preservative directly to dry wood furnish in blenders. This is often done for strand-based composites such as OSB and parallel strand lumber (PSL) with powder type preservatives (e.g., zinc borate).
- Premixing the preservative with resin and spraying the mixture to wood furnish. This process is often referred to as glueline treatments and is mainly applied in products made from veneers such as LVL and plywood.

In both methods, it is critical to assure good distribution throughout the treated component. Ingredients must be capable of withstanding the processing temperatures associated with production, and they must be compatible with the resins used. Since they are distributed throughout the thickness of the substrate, the treatments can offer long term protection against decay, mould, insect attack and water intrusion.

c) Post Treatment of Finished Products

Post manufacturing treatments are applied to wood-based composite products either through immersion or spray applications. These provide an envelope of protection to the substrate and are mainly designed to provide short-term resistance to mold, decay and water intrusion. They are often utilized to protect building materials through transportation, storage and the construction process (Ross et al. 2003). Their major advantage is that they are relatively easy to apply and are very cost effective.

The use of surface treatments combined with diffusible preservatives such as borates offers deeper protections by forming a "penetrating barrier" of protection (Ross et al. 2003, Baileys et al. 2003). In these systems, the face components remain at the surface where they are most needed to form a protective barrier against mold, insects and surface moisture. The diffusible components penetrate to provide deeper protection against decay and insects. Penetrating barrier treatments are also relatively easy to apply to most wood composites and they are very cost-effective compared to other methods of treatment.

Vapor boron treatments offer another way to post treat wood composites. The methods involve exposing wood products to a vapor of volatile boron compound, trimethyl borate (TMB), which lead to hydrolysis of the ester and deposition of the active preservative ingredient boric acid in the wood (Murphy et al 1993). Most born esters are hydrolytically unstable and the reaction proceeds very rapidly with any water present within the wood product.

Future Research Directions

Wood composites and engineered lumber will be the future. The durability of these products needs to be improved. The successful incorporation of preservatives to wood composites must consider the effect of the chemical on the chemical interaction with the resin used, the physical properties of the composite, the distribution of biocide within the composites, the efficacy of the treated composite, and the effect of manufacture on composite properties (Freeman et al. 2003). Some of specific research needs are listed as follows:

1) Development of new generations of preservatives applicable to wood composites. The emerging technology includes copper and zinc-based systems to replace CCA.
2) Development of information database on fungal flora and insects as related to wood species, resin type, and service situations. This information would permit more useful laboratory testing of products and preservatives.
3) Understanding of moisture relations in panel products in conjunction with finishes and overlayments. This information would permit more understanding on moisture requirement for common rot fungi development in panel products.

4) Understanding of micro-distribution of preservatives within the treated panel products. For borate system, low molecular weight of boron makes it very difficult to determine its distribution within the glue line and wood with traditional method (e.g., EDAX-SEM system).
5) Assessment of structural performance of treated composites under combined mechanical and moisture loading for structural applications.
6) Development of useful and reproducible test methods to assess decay, leaching, mould, and termite resistance properties of treated composite products. Existing AWPA and ASTM test methods are mainly for solid wood. The unique properties of composite materials (e.g., swelling) require new test methods to be established and evaluated.

Conclusions

Treated wood composites panels and engineered lumber have a strong future. As the type of timber available for use in forest products continues to change and the demand for exterior-use products continues to grow, there will be a growing need for fungal and insect-resistant structural composites. The development of protected structural panels and engineered lumber is especially important since these materials are critical to almost all wood structures. Successful commercialization of treated composite products depends on development of a cost-effective manufacturing process and establishment of a market base for the products.

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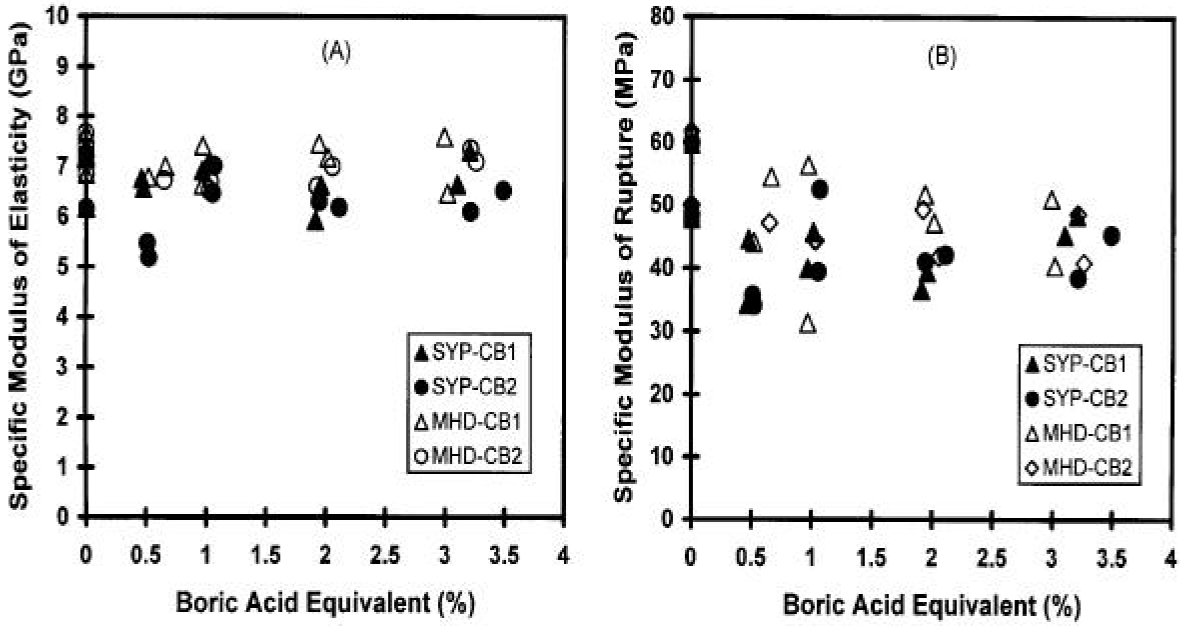

Figure 1. Bending Properties of Calcium Borate OSB (A: Bending Modulus of Elasticity/Specific Gravity and B: Bend Modulus of Rupture/Specific Gravity). MHD-mixed hardwood, SYP-southern pine, ZB-Zinc borate, CB-calcium borate.

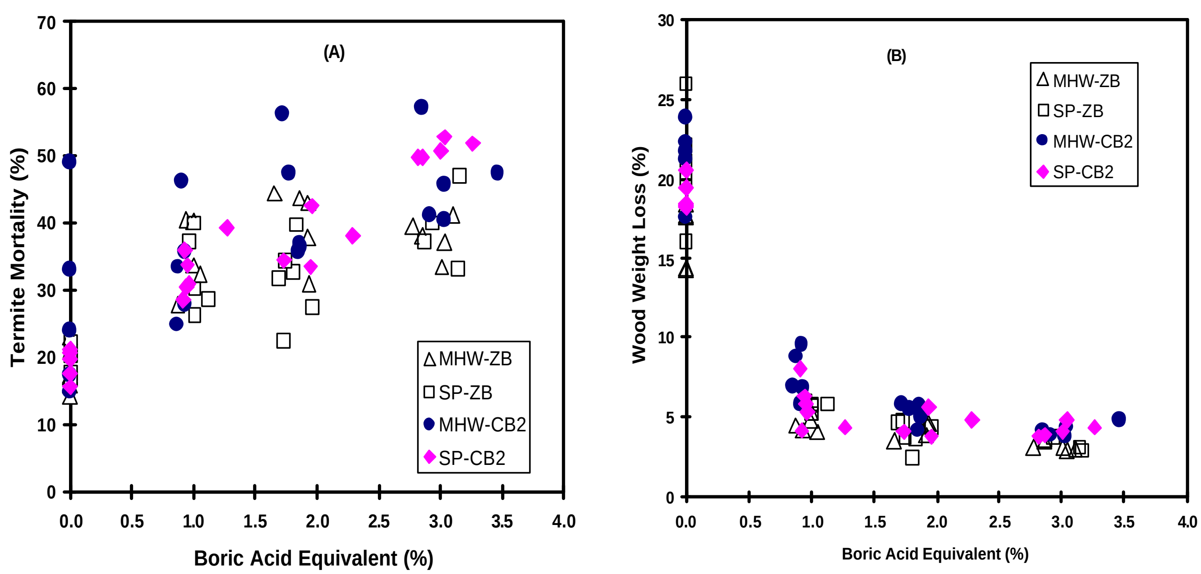

Figure 2. Termite Resistance Properties of Zinc and Calcium Borate oriented strandboard. A) Termite Mortality and B) Wood Sample Weight Loss. MHW-mixed hardwood, SP-southern pine, ZB-zinc borate, CB-calcium borate.

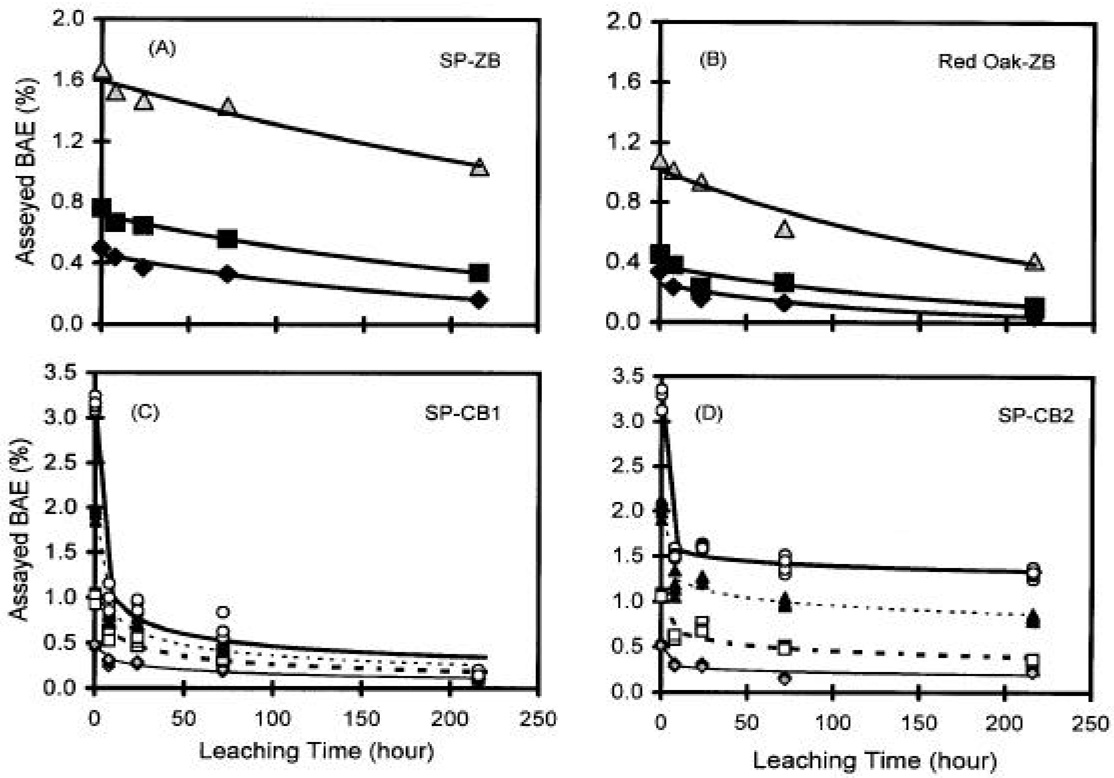

Figure 3. Leaching Properties of Zinc (A and B) and Calcium (C and D) Borate OSB. SP-southern pine.

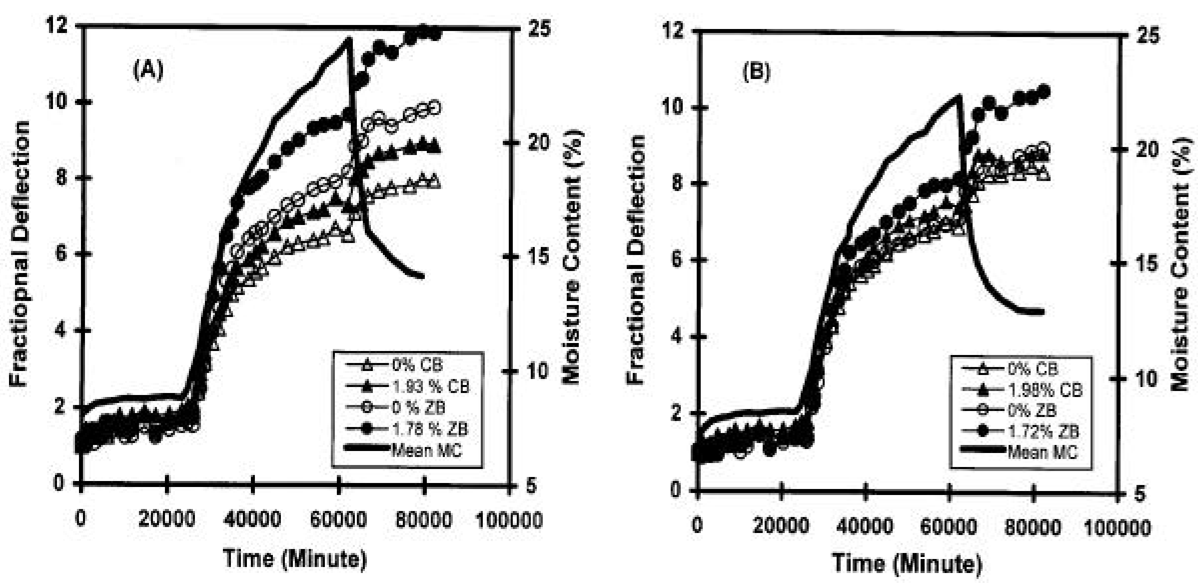

Figure 4. Mechano-sorptive Response (Fractional Deflection) of Zinc and Calcium Borate Treated OSB from Southern Pine (A) and Mixed Hardwoods (B) under the 25% Stress Level.