

USE of BORATE-TREATED WOOD as PART of an IPM APPROACH for DURABLE and SUSTAINABLE CONSTRUCTION

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Abstract Wood is a common structural material, used for building most homes and some commercial buildings in North America. This widespread use is due to wood's desirable performance properties, abundance and cost effectiveness, ease of use, and favorable environmental attributes. However, wood can be degraded by various wood-destroying organisms (WDO) such as termites and decay. Since structural systems are often hidden from view and difficult to reach once put into service, infection of these systems by WDO can result in catastrophic damage, expensive repair, and the on-going use of chemical and physical methods to mitigate the problem. As a means of addressing the WDO problem, some builders and architects are specifying alternative materials such as steel and concrete where they would have otherwise used wood. These alternatives can increase the cost of construction and reduce the environmental performance of the building. In many parts of the world, borate industrially pretreated wood has been used successfully for decades to build structures that are protected against WDO. Borates have strong environmental and safety profiles, and industrial pretreatment provides for deep penetration of borates into the wood products, providing long-term durability of the structure to WDO. This paper discusses the use of borate-treated wood as part of an integrated pest management (IPM) strategy for new buildings. Issues examined are: cost comparisons and life-cycle analyses of wood, steel, and concrete building systems; distribution and economic consequences of wood-destroying organisms; an assessment of the current typical approaches of protecting buildings from wood-destroying organisms; incorporating pest management into the design and construction of buildings; the application and performance of borate-treated lumber, plywood, and OSB; approaches for protecting buildings from WDO in various parts of the world; and the environmental and safety aspects of borate wood preservatives.

Key Words Termites decay structures building home

INTRODUCTION

Wood-destroying organisms (WDO) such as termites and decay fungi have an indispensable presence within the earth's ecosystem; they recycle dead trees and other plant materials into elements essential to life. Their presence is ubiquitous and large, and it is estimated that termites have a biomass of one thousand pounds for every person on earth (Conniff, 1998).

In buildings, WDO can cause significant economic damage and challenge the integrity of structural systems, resulting in life and safety concerns. A comparison of new home-building activity statistics compiled by the U.S. Department of Commerce with termite and decay profiles found in model building codes such as the International Residential Code (IRC) shows that nearly half of all new homes are built in areas of significant termite and decay hazard (Bureau of Census, 2000; International Residential Code, 2000). For performance and cost reasons, the structural systems of most homes in North America are built of wood. As a result we find that many new homes are suffering damage from WDO. At a national level, it has been estimated by the Wood Protection Council of the National Institute of Building Sciences that the annual cost to replace wood severely damaged by decay and termites increased from \$750 million in 1988 to over \$2 billion in 1993 (Wood Protection Council, 1993). Currently the damage numbers are estimated to be \$3 billion per year, but could in fact be higher. At an individual homeowner level, there are

many known cases where WDO have caused tens of thousands of dollars of damage over a short period.

The issue of building and maintaining structures that are durable to WDO has many constituents. These include homeowners, builders, designers, entomologists, pest-control operators, building codes officials, building materials suppliers, mortgage bankers, insurance companies, and many others. Hence a thorough address of WDO in buildings requires the integrated involvement of many disciplines. This paper examines an IPM strategy that can be jointly used by entomologists and building designers to provide long-term WDO mitigation to new structures.

DISCUSSION

Wood As A Building Material

Wood is a good building material because of its desirable physical and mechanical properties; high strength-to-weight ratio; good insulating properties against heat, sound, and electricity; and ability to absorb and dissipate moisture. The abundance of wood and our ability to construct wood structures with simple equipment and readily available labor have made wood-framed buildings highly cost effective. Also, wood has the best environmental profile among building materials. It is a renewable resource. And with the ability of trees to absorb carbon dioxide and emit oxygen, wood is the only material to have a positive impact on the environment.

The environmental superiority of wood over steel and concrete as a construction material has been documented repeatedly. The Building for Environmental and Economic Sustainability (BEES) model developed under the auspices of the National Institute of Standards (NIST), shows that treated wood is superior to steel in both environmental and economic performance as a wall-framing material (Tables 1, 2) (NIST, 2001).

The ATHENA Sustainable Materials Institute has evaluated the environmental performance of wood structural systems with that of light steel framing and insulated concrete form. A life-cycle environmental assessment (LCA) approach was used to examine a 223 sq. meter single-family house built for the Toronto market (Trusty and Meil, 2000). The designs for the three homes were similar; the environmental analysis was limited to the structural and envelope components that differed across the three designs. Summary of the results, presented in Table 3, shows that the wood-framed homes have less embodied energy, lower global warming potential,

Table 1. Environmental performance

Category	Wood frame	Steel frame
Acidification – 17%	2	17
Eutrophication – 17%	4	17
Global Warming – 17%	2	17
Indoor Air – 16%	0	0
Natural Resources – 17%	2	17
Solid Waste – 16%	16	0
Sum	26	68

Table 2. Overall performance

Category	Wood frame	Steel frame
Economic performance – 50%	44	50
Environmental performance – 50%	13	34
Sum	57	84

Note: Lower values are better.

Table 3. Environmental measures results summary

Category	Wood design	Steel design	Concrete design
Embodied energy (GJ)	255	389	562
Global warming potential (kg CO ₂ equivalent)	62,183	76,453	93,573
Air toxicity (critical volume measure)	3,236	5,628	6,971
Water toxicity (critical volume measure)	407,787	1,413,784	876,189
Weighted resource use (kg)	121,804	138,501	234,996
Solid waste	10,746	8,897	14,056

and lower air and water toxicity, and that they require less use of resources than do the steel and concrete homes.

Subsequent analysis by ATHENA indicates that the steel design has a lower effective R-value than the wood design (R 12.7 vs. R17.2) (Trusty and Meil, 2000). Steel is 300-400 times more conductive than wood. For wall assemblies, a 20-gauge (0.04 inch thick) standard steel stud conducts roughly 10 times more heat than does a 3.8 cm thick wood stud. This conduction can cause thermal bridging, increasing the cost and environmental burden of heating and cooling buildings. Projecting the ATHENA findings onto the life cycle assessment by Puettmann on borate pressure-treated lumber would indicate that homes constructed with borate-treated structural systems would also have less embodied energy and lower global warming potential than would homes constructed of steel and concrete (Puettmann, 2000).

For most homes, wood structural systems, treated or untreated, are much less expensive than those made with steel or concrete. Demonstrated by the BEES model, this point has been validated by others. For example, in 1999 as part of its initiative to deal with the massive economic damage being caused by Formosan termites, the State of Louisiana formed the Formosan Termite Task Force. The Economic Impact Committee appointed by the Task Force determined that for a typical 188.6 sq. meters house in Louisiana, using pressure-treated lumber and plywood instead of untreated lumber and plywood for the structural system would result in a \$3,000 cost increase (Formosan Termite Task Force, 1999). Oriented strand board (OSB) is by far the dominant structural panel material in homes being built in the United States, and the cost would be less if treated OSB were substituted for treated plywood. On a material basis only, substituting steel would increase the cost of the home by about \$6,300 over untreated wood. Considering that the cost of construction is often higher with steel than with wood, the cost implications of switching to steel are likely to be even higher (Barta, 2000). An independent study sponsored by the Florida Wood Council compared the cost to build a 338 sq. meters, double-story house in Broward County, Florida, with concrete masonry units (CMU) versus framing lumber. The study found that in 1998 the labor and materials required to construct the concrete shell was \$52,675 versus \$45,008 for the wood shell (Florida Wood Council, 1998). In this case the wood structural system was \$7,600 less expensive, not including the cost penalties that the builder would expect to pay in the extra time that it takes to build with concrete and the difficulty in modifying concrete structures to satisfy finishing and detailing.

Current Approach of Protecting Wood Structures

The desire to protect buildings from WDO is well established and evident in mandates by building codes in many regions of the United States as well as in standards required by home mortgage lenders. Building codes recognize that the termite infestation potential is highest in

California, the southeast United States, Hawaii, and Puerto Rico, whereas the decay potential is highest in the southeast and along both coasts. Additionally, highly destructive species of non-native termites such as the Formosan subterranean termite (FST) are increasing in population and range (Woodson et al., 2001). As of January 2001, more than 90 counties and parishes have been infested with FST.

The predominant method of protecting homes requires establishing a barrier against subterranean termites by treating the soil under and around homes prior to construction and treating in and around existing homes when termites are detected. Additionally, treated wood is used for selected building elements such as sill plates. This approach provides some relief, but even perfect barriers don't protect structures against airborne termites (such as FST and drywood termites), carpenter ants, or wood decay. Also, chemical barriers degrade substantially over time and are often destroyed in the construction process or by simple homeowner activities such as landscaping.

Historically, organochlorine pesticides such as chlordane, aldrin, and heptachlor were used to place a chemical barrier at the soil level. These materials were long lasting (30 years or more), and the vapor pressure from these materials would "fill in" any missed or disturbed areas to provide a continuous layer of protection. These properties, while functionally desirable in a termiticide, were environmentally unacceptable. As a result, chlordane and other organochlorine pesticides were removed from the market in the late-1980s. Many of the current termiticides are less persistent, with effective working lives of about 5 years, and much less forgiving of applicator error and disturbances.

The inadequacy of the current mitigation method for WDO has become apparent in many areas of the continental United States. The findings of a Florida commission consisting of entomologists, builders, architects, pest control operators, and government officials is reported in a 1994 publication (Florida Department of Agriculture and Consumer Services, 1994). The commission found that in 1993, 72% of pest control operators (PCOs) had pre-construction treatment failures within 5 years of treatment and that the failure rate was 92% for post-construction treatment. In Louisiana, PCOs are enduring significantly more liability claims from ineffective termite treatments (Ring, 1999). The consequences to the homeowner are increased risk of property damage, increased maintenance expenses, and the constant stress of worrying about what's happening behind the walls.

Integrated Approach

It is generally acknowledged that total eradication of WDO is not a realistic goal and that pest-control efforts should be focused on limiting the risk to buildings through an integrated pest management (IPM) approach involving proper design, construction, building materials, and the judicious use of pesticides (Griffith, 2001). An often discussed IPM approach for WDO is the Six "S" strategy, involving suppression, site management, soil barriers, slab and foundation details, structural protection, and surveillance and remediation (Morris, 2000).

Suppression involves programs to reduce termite populations over large areas. This typically involves government-sponsored initiatives such as Operation Full Stop to reduce Formosan termites in the French Quarter in Louisiana. In most locales, however, there are no area-wide suppression programs. Site management is essential to good design and construction practices. It involves grading the site to ensure that water drains away from the structure and clearing the site to ensure that there are no wood debris or tree stumps buried on-site to attract termites. It also involves ensuring that there is no wood-to-soil contact for untreated wood. Soil barriers involve placing a chemical or physical layer at the foot of the structure. With the current soil termiticides, chemical barriers must be reapplied over and over. Physical barriers are a new approach; they can include such items as a 10-cm thick layer of precisely sized sand or crushed stone or stainless-

steel termite mesh. Slab foundation details involve using the physical structure of the slab as a physical barrier. Subterranean termites can pass through cracks that are as narrow as 0.6 cm; subterranean termites build earthen, shelter tubes to pass from the soil into a building. Hence, slabs and foundations should include details so that shrinkage cracks and other openings are less than 0.6 cm, metal termite shields are placed between the foundation and the sill plate, and exterior wall coverings such as stucco, brick veneer, or siding do not extend below grade to provide a hidden passageway for termites. Structural protection requires building wall, roof, and floor assemblies with materials that are resistant to WDO and designed to properly manage moisture. Even with these mitigation methods working, regular inspections should be performed to identify any problems and to take corrective actions while the problems are manageable (Canadian Wood Council, 2001).

Structural Protection

Structural protection for WDO involves two basic elements: managing moisture within the building assemblies and choosing materials that are protected against WDO. In building assemblies, the four moisture transport mechanisms of bulk water movement (rain, snow, or groundwater), capillary action (water wicking up through the concrete foundation), air-transportation (pressure differences), and diffusion (vapor pressure differences) can result in a build-up of water in the building envelope (Tooley, 2000). This build-up can cause conditions that are favorable to termites, decay, and mold activity. Hence, thoughtful attention must be paid to design and construction features such as drainage planes, vapor barriers, and building materials in the building assemblies.

Sometimes, non-wood building materials are chosen solely because they are resistant to decay and insect attack, when wood products would otherwise be the material of choice. However, common building materials such as steel and concrete can increase the water loading in the building envelopes, providing a more favorable environment for wood-destroying organisms. Water can condense on the steel frame members, creating problems of corrosion, decay, and insects. It can also result in mold growth in surrounding building materials (Snell and Pettit, 2001). Concrete is a porous material that allows moisture to migrate and accumulate on the cool side of the block wall, creating a condition for WDO to prosper.

Borate-Treated Wood

Wood industrially pretreated with borates has been successfully used for structural systems in various parts of the world where termites, decay, and other wood-destroying organisms pose significant problems. This use has resulted from the realization that it is far more cost effective and environmentally responsible to provide lasting, built-in protection to the very building components and systems that are susceptible to degradation than to provide remedial protection year after year.

In New Zealand, for example, the use of borate-treated lumber and structural panels for the entire structure has been standard practice for more than 50 years (Vinden, 1990). New Zealand's weather is often wet and cold, and the homes are commonly wood-framed. As a result buildings are at risk from decay fungi, as well as wood-boring beetles. Borate-treated wood has shown excellent performance as a building material in the wet environment encountered by builders in New Zealand. There is virtually no remedial treatment industry in New Zealand, and dry rot and borer attack have not been recorded in borate-treated wood since the mid-1950s (Vinden, 1990). This result contrasts pointedly with the United States, where society spends a lot of money every year to treat and repair WDO damage.

Hawaii is believed to have the highest Formosan termite pressure in the United States; Formosan termites were present in Hawaii many decades before they were introduced into the

continental United States. Formosan termites are the most voracious, destructive, and difficult to control among all economically important WDO found in the United States. The use of treated wood for structural systems has been standard construction practice in Hawaii for decades. The practice was embodied into the building codes in the mid-1980s, and all wood framing was required to be constructed with pressure-treated wood. When borate-treated wood was introduced into the Hawaiian market in 1992, it quickly became the most widely used structural material for building homes. In this very tough environment, borate-treated wood has performed very well in field tests, and structural systems built with borate-treated wood have an exemplary record in real world use.

The success of borate wood preservatives for treating structural materials is due to boron's many performance attributes. Borates have a well-established record of performance against a broad spectrum of wood-destroying organisms. The wood-protection properties of borates have been known for centuries, and since the last half of the 20th century the use of borate wood preservatives has been growing significantly. Borates are cost effective and easy to use for industrially pretreating lumber, plywood, and wood composites such as oriented strand board (OSB). Lumber and plywood is pressure treated with waterborne borates, whereas in wood composites such as OSB the borates are added to the engineered wood product during the manufacturing process. The advantage with industrial pretreatment is that deep penetration of borates is achieved and the treatment quality is verified, either as part of industry standards and 3rd party quality control mechanisms or as operating practices of the companies making the products. For example, industrially pretreated lumber in North America is produced by pressure treating the wood according to AWWA standard C31, which requires a minimum 0.6-inch penetration from the face and a loading of 0.28 pounds B₂O₃ per cubic foot (AWWA, 2001). The AWWA standards also define minimum in-plant as well 3rd party sampling and analytical procedures as part of the quality control mechanisms of the treatment standards.

In treated wood, borates are colorless (although a dye is often added); non-volatile, and robust so they don't evaporate, degrade, or produce an odor during service; and are non-corrosive, requiring no special fasteners. The implication to builders, designers, and entomologists is that a meaningful additional measure of protection against termites and decay can be easily added to the structure.

Borate Environmental and Safety Profiles

Important aspects of borates are their strong environmental and safety profiles and the fact that their use can increase the sustainability of buildings. Borates are generally known to be safe materials, as evidenced by their use in many common products such as laundry detergents, eye drops, cosmetics, and plant food. Borate wood preservatives, materials that are no more acutely toxic than table salt, are excellent replacements for conventional wood preservatives for wood products that are used in covered and above ground applications (Wilson and Yost, 2000). Further, the use of borate-treated wood for the structural systems in buildings can reduce or eliminate pesticide treatments (Wilson, 2001). This effect may in fact extend beyond WDO control and into general pest control. Recent scientific work sponsored by U.S. Borax supports the anecdotal evidence that homes built entirely of borate pressure-treated lumber can have fewer pests such as cockroaches in addition to the wood-destroying organisms the treatment is designed to prevent.

The safety and efficacy of borates is a consequence of boron's functionality in living forms. Borates are essential micronutrients for plants, and there is evidence to suggest that borates are also nutritionally important to humans. Boron's functionality is based on its ability to form complexes with various sugar alcohol compounds such as vitamins and co-enzymes. Scientists suggest that this feature could be one important role of boron in regulating metabolic processes. If the borate levels are massively increased, however, regulation will turn to inhibition and stop

cells from growing. This characteristic makes borates a biostat rather than a biocide. It also explains why, although the mild biostatic effect make borates non-harmful to humans, borates can control many different pests and why acquired resistance to borates, a common problem with other substances in pest control, is unlikely (Lloyd, 1999).

SUMMARY

Wood is a cost effective and environmentally desirable material for construction. However, wood-destroying organisms such as termites, carpenter ants, and decay fungi can challenge the durability and sustainability of wood-framed structures. Borates are used to provide protection against wood-destroying organisms. Borate wood preservatives have an excellent reputation for safety and performance, and this reputation has been built over many years of safe and effective use in various wood products. Borate-treated wood is an excellent fit with integrated pest management (IPM) approaches for controlling wood destroying organisms. The use of lumber and structural panels that have been industrially pretreated with borates provides a means to build homes that are cost effective, durable, and sustainable.

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