

DURABILITY OF WOOD IN CONSTRUCTION

by Stan Lebow and Robert White

Biological Challenge

In the natural ecosystem, wood residues are recycled into the nutrient web through the action of wood-degrading fungi, insects, and other organisms. In some circumstances, these same natural recyclers have the potential to degrade wood used in construction. Termites and decay fungi are the most destructive, but other organisms, such as wood

boring beetles and carpenter ants, can be important in some regions. Several types of marine organisms can attack wood used in brackish water and saltwater. If conditions are favorable for the survival of one or more of these wood-destroying organisms, wood that has natural durability or that has been treated with preservatives should be employed to ensure the integrity of the structure.

Conditions Favorable for Biodeterioration

Three environmental components govern the development of wood-degrading organisms within terrestrial wood construction: moisture, oxygen supply, and temperature. Of these, moisture seems most directly influenced by design and construction practices. The oxygen supply is usually adequate except for materials submerged below water or deep within the soil, and wood-degrading organisms have evolved to survive in a wide range of temperatures. For these reasons, most of the following discussion will focus on relationships between wood moisture and potential for wood deterioration.

Decay fungi require free water within the wood cells (above 20 to 25 percent moisture content) to survive. Soil provides a continuing source of moisture. Nondurable wood in contact with the ground will decay most rapidly at the ground line where moisture from soil and the supply of oxygen within the wood support growth of decay fungi. Deep within the soil, a limited supply of oxygen prevents growth of most decay fungi. As the distance above ground increases, the decreasing moisture content limits fungal growth unless the wood is wetted through exposure to rain or from water entrapped as a consequence of design or construction practices. Wood absorbs water through cut ends about 11 times faster than through lateral surfaces. Consequently, decay develops first at the joints in aboveground construction.

Extremely low oxygen content in wood submerged below water will prevent growth of decay fungi, but other microorganisms can slowly colonize submerged wood over decades or centuries of exposure. Thus, properties of such woods need to be reconfirmed when old, submerged structures are retrofitted.

Most wood-degrading insects also prefer moist wood, but their moisture requirements vary somewhat by species. Subterranean termites native to the U.S. mainland establish a continuous connection with soil to maintain adequate moisture in wood that is being attacked above ground. Formosan termites have the capacity to use sources of above-ground moisture without establishing a direct connection with the soil. Dry-wood termites survive only in tropical or neotropical areas with sufficiently high relative humidity to elevate the wood moisture content to levels high enough to provide moisture for insect metabolism. Some types of wood-boring beetles, such as powder post beetles, can colonize wood with low moisture contents. Carpenter ants initially invade wood that is moist or decayed, but may then expand into adjacent dry wood.

Methods for Protecting Wood

Protection with Good Design The most important aspect of protecting wood in construction is use of designs that minimize moisture accumulation. Many wood structures have endured for several hundred years because of sound design and construction practices. In nearly all those old buildings the wood has been kept dry by a barrier over the structure (roof plus overhang), by maintaining a separation between the ground and the wood elements (foundation), and by preventing accumulation of moisture in the structure (ventilation). Where Formosan subterranean termites occur, good designs and construction practices that eliminate sources of aboveground moisture are particularly important. Channeling of water from roof drains, collection of condensate from air conditioners, and proper installation of flashing are examples of important considerations. Other design and construction practices also help to protect wood from insect attack. Chemical or physical barriers are often used to prevent subterranean termites from moving from the soil into a building. Many beetles attack only certain species or groups of woods that may be used in speciality items such as joinery. When these species are used, it is important to use wood that is not pre-inferred at the time of construction. Today's engineered wood products will last for centuries if good design practices are used. However, there

are many structures where it is impractical to prevent decay and insect attack simply through design. In these situations part or all the structure may need to be constructed with naturally durable wood species or with wood that has been treated with preservatives.

Naturally Durable Wood The heartwood of old-growth trees of certain species, such as bald cypress, redwood, cedars, and several white oaks, is naturally resistant or very resistant to decay fungi. Heartwood of several other species, such as Douglas-fir, longleaf pine, eastern white pine, and western larch, is moderately resistant to wood decay fungi. Some tropical species, such as ipe, are also imported because of their natural durability. Although decay resistance and resistance to termite attack are correlated, not all species that are decay-resistant are also resistant to termite attack. A more complete listing of naturally durable woods is given in "Wood Handbook." One limitation on the use of these species is that the durability is variable between trees and even between pieces cut from a single tree. In addition, the supply of naturally durable species is limited relative to the demand for durable wood products. Consequently, other forms of protection, such as preservative treatment, are more frequently used in current construction. Naturally durable species are not effective in preventing marine borer attack, and pressure treatment with wood preservatives is required to protect wood used in marine or brackish waters.

Preservative Treatments Wood preservatives have been used for over a hundred years. They are broadly classified as either water type or oil type based on the chemical composition of the preservative and the solvent used during the treating process. Each type of preservative has advantages and disadvantages, depending on the application. The most common oil-type preservatives are creosote, pentachlorophenol, and copper naphthenate. Because wood treated with oil-type preservatives may be oily to the touch or have a noticeable odor, it is not usually used for applications involving frequent human contact or for inhabited structures. Oil-type preservatives may offer improved water repellency and typically do not promote corrosion of fasteners. Water-based preservatives leave a dry, paintable surface and are commonly used to treat wood for residential applications such as decks and fences. They are primarily used to treat softwoods because hardwoods treated with these preservatives may not be well protected from soft-rot attack. Until recently, the most widely used water-type preservative was chromated copper arsenate (CCA). However, CCA has now been voluntarily phased out for most applications around residential areas and where human contact is expected. More recent water-based preservatives, such as alkaline copper quat or copper azole, rely primarily on copper to protect the wood. Water-based wood preservatives can increase susceptibility to corrosion, and metal fasteners used with the treated wood should be hot-dipped galvanized or stainless steel.

Borates are another type of waterborne preservative that may be used to treat interior building components for protection against insect attack. Borates should not be used where they are exposed to soil or rainfall because they are readily leached from the wood. In non-load-bearing applications such as exterior millwork around windows and doors, wood is usually protected with water-repellent preservative treatments that are applied by nonpressure processes. Standards for preservative treatment are published by the American Wood-Preservers' Association, and detailed information on wood preservation is given in "Wood Handbook." It is important to ensure that wood is being treated to standard specifications. The U.S. Department of Commerce American Lumber Standard Committee (ALSC) accredits third-party inspection agencies for treated wood products. Updated lists of accredited agencies can be found on the ALSC Website (www.alsc.org). If the wood has been treated to these specifications, it will have the quality mark or symbol of an ALSC-accredited inspection agency.

Protection from Weathering The combination of sunlight and other weathering agents will slowly remove the surface fibers of wood products. Removal of fibers can be greatly reduced by providing a wood finish; if the finish is properly maintained, the removal of fibers can be nearly eliminated. Information on wood finisher is available in Cassens and Feist, "Exterior Wood in the South."

Protection from Fire In general, proper design for fire safety allows the use of treated wood. When there is a need to reduce the potential for heat contribution or flame spread, fire-retardant treatments are available. Although fire-retardant coatings or dip treatments are available, effective treatment often requires that the wood be pressure-impregnated with the fire-retardant chemicals. These chemicals include inorganic salts such as monoammonium and diammonium phosphate, ammonium sulfate, zinc chlorate, sodium tetraborate, and boric acid. Resin polymerized after impregnation into wood is used to obtain a leach-resistant treatment. Such amino resin systems are based on urea, melamine, dicyandiamide, and related compounds. An effective treatment can reduce the ASTM E 84 flame spread to less than 25 and show an evidence of significant progressive combustion when the ASTM E 84 test is continued for an additional 20-min period. When the external source of heat is removed, the flames from fire-retardant-treated wood will generally self-extinguish. Many fire-retardant treatments reduce the generation of combustible gases by lowering the thermal degradation temperature. ASTM standards have been developed to address other performance requirements such as initial strength loss due to treatment and kiln drying, strength loss when exposed to elevated temperatures in use, excessive hygroscopicity in areas of high humidity, and loss of fire performance due to outdoor exposure to rainfall.

Effect of Aging

Long exposure of wood to the atmosphere also causes changes in the cellulose. A study by Kohara and Okamoto of sound old timbers of a softwood and hardwood of known ages from temple roof beams shows that the percentage of cellulose decreases steadily over a period up to 1,400 years while the lignin remains almost constant. These changes are reflected in strength losses (Fig. 6.7.5). Impact properties approximate a loss that is nearly linear with the logarithm of time.

Allowable Working Stresses for Preservative-Treated Lumber

Allowable working stresses for preservative-treated lumber usually need not be reduced to account for the effect of the treating process. Tests made by the USDA Forest Service, Forest Products Laboratory, of preservative-treated lumber when undergoing bending, tension, and compression perpendicular to grain show reductions in mean extreme fiber stress from a few percent up to 25 percent, but few reductions in working stresses. Compression parallel to the grain is affected less and modulus of elasticity very little. The effect on horizontal shear can be estimated by inspection for an increase in shakes and checks

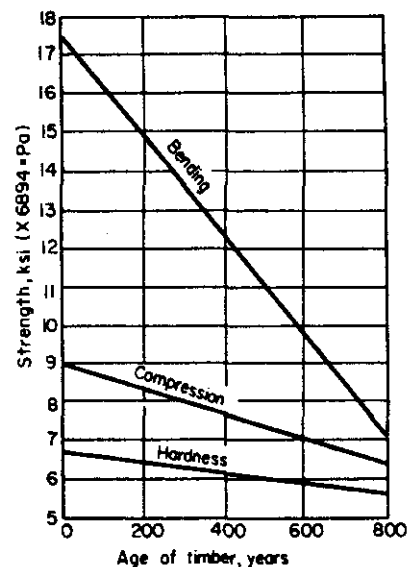


Fig. 6.7.5 Strength loss with age in a hardwood (*Zelkova serrata*). (Adapted from information in Kohara and Okamoto, 1955.)

after treatment. AWP Standards keep temperatures, heating periods, and pressures to a minimum for required penetration and retention, which precludes the need for adjustment in working stresses.

COMMERCIAL LUMBER STANDARDS

Standard abbreviations for lumber description and size standards for yard lumber are given in "Wood Handbook."

Cross-sectional dimensions and section properties for beams, stringers, joists, and planks are given in the "National Design Specification."

Standard patterns for finish lumber are shown in publications of the grading rules for the various lumber associations.

Information and specifications for construction and industrial plywood are given in Product Standard PS 1-95 and in ANSI/HPVA HP-1-2004 for hardwood and decorative plywood. Information and specifications for structural flakeboard are given in PS 2-95.

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