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Guidelines for Selection and Use of Pressure-Treated Wood

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Abstract

Wood is a versatile and sustainable building material but may be vulnerable to fungal decay and insect damage when used outdoors or otherwise subjected to moisture. Pressure treatment with wood preservatives is the most common method of protecting wood from biological deterioration. This publication summarizes characteristics of pressure-treating preservatives and provides guidance for selection of pressure-treated wood for specific applications. It also discusses construction practices, service life expectations, and environmental considerations. The intended audience for this publication is users of pressure-treated wood such as homeowners, builders, contractors, engineers, and architects.

Keywords: Pressure treatment; wood preservatives; selection; specification; standards

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Contents

Conversion table

English unit	Conversion factor	SI unit
inch (in.)	2.54×10^1	millimeter (mm)
$T_{°F}$	$T_{°C} = (T_{°F} - 32)/1.8$	$T_{°C}$
Nominal lumber size (in.)		Standard lumber size (mm)
2 by 4 (actual 1.5 by 3.5)		38 by 89
2 by 8 (actual 1.5 by 7.5)		38 by 184
4 by 4 (actual 3.5 by 3.5)		89 by 89
6 by 6 (actual 5.5 by 5.5)		140 by 140

Guidelines for Selection and Use of Pressure-Treated Wood

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Introduction

Wood is one of the oldest and most versatile building materials. Today, wood is widely used for construction because of its unique combination of availability, high strength-to-weight ratio, and ease of machining. Wood is also being recognized for its value as a sustainable building material; the harvesting and production of structural wood products requires much less energy, and thus emits substantially less carbon dioxide, than does the harvesting and production of alternative building materials. It is estimated that the amount of carbon dioxide emitted to produce a ton of concrete or steel is 8 to 21 times greater than that to produce a ton of framing lumber (Falk 2010). Wood is also a renewable resource, and for more than 50 years, the volume of timber growing stock in U.S. forest lands has continued to increase. As of 2012, the volume of annual net growth was two times greater than the volume of annual removals (Oswalt 2014).

Wood is also a biodegradable material, and this plays an important and positive role in natural ecosystems. However, biodegradability can present challenges when a material is expected to provide many decades of service as a structural product. Fortunately, damage from most wood deterioration organisms is minimal, as long as wood is kept dry, and this continues to be the basis for use of wood in most structures. Although, protecting structural wood products from moisture is not always practical, and there are some situations in which even wood that is relatively dry may be attacked by fungi, termites, or wood-boring insects. In these situations, durable wood products must be used to ensure a satisfactory service life. Typically, this durability is imparted by pressure treatment with preservatives that protect the wood from a wide range of wood-degrading organisms. Both hardwoods (such as red oak) and softwoods (such as pine) are pressure-treated with preservatives for a range of applications. Pressure-treated softwood lumber is widely available at lumber yards, and softwoods are also commonly used for poles and pilings. Pressure-treated hardwoods are used extensively in railroad construction, as well as other applications in which the qualities of hardness and abrasion resistance are particularly useful.

Pressure-treating preservatives are often broadly grouped as either waterborne or oilborne. Although creosote is not actually oilborne, it has properties similar to oilborne preservatives and is often grouped with oilborne preservatives. The use of waterborne versus oilborne preservatives depends on the type of exposure and end-use requirements. Waterborne preservatives typically have little odor and leave the wood with a dry, paintable surface. They are used for a wide range of applications including treated lumber sold by lumber yards for construction of residential decks and fences. Oilborne treatments have the advantage of imparting some water repellency to the wood and can help protect metal fasteners from corrosion. They may have an odor and are most commonly used for heavy-duty industrial applications.

Selection of a type of pressure-treated wood depends on the species of wood being treated, the type of wood product, and the requirements of the specific application. To guide the selection process, the American Wood Protection Association (AWPA) publishes the Use Category System (UCS), which categorizes treated wood applications by the severity of the exposure, as well as the structural significance of the application. Ancillary properties of wood preservatives such as odor or compatibility with a wood species, should also be considered when selecting preservatives. Construction and design practices can extend durability by minimizing traps for moisture, minimizing field cuts, and applying supplemental preservatives to saw cuts and bolt holes that expose untreated wood during construction. The expected service life of pressure-treated structures depends on a number of factors, including type of structure and location. With proper selection of preservatives and construction detailing, wood structures often outperform durability estimates and outlast usefulness before succumbing to biological deterioration. Similar to many other construction materials, preservative-treated wood contains chemicals that could potentially harm the environment if released in sufficient quantities. However, research indicates that for most applications, the amount of chemical released from preservative-treated wood is too low to be a concern. An online screening assessment tool is available to evaluate the potential of environmental effect for projects that use large volumes of treated wood in sensitive aquatic habitats. The risk of environmental impacts can be further decreased by specifying treatment in accordance with best management practices for wood used in aquatic environments.

When is Pressure-Treated Wood Needed?

In general, some type of biological deterioration may occur in any untreated portion of a structure in which wood moisture content above 20% to 25% and oxygen are present for sustained periods. Moist wood is required or preferred for most degrading organisms. Decay fungi require a moisture content of at least 20% to sustain any growth, and higher moisture contents (greater than 29%) are required for initial spore germination (Clausen 2010, Zabel and Morrell 1992). Because decay fungi also require oxygen, wood that is continually immersed in water does not suffer damage from decay fungi, although this wood can very slowly degrade because of anaerobic bacteria. This accounts for the longevity of submerged wood in some types of nonseawater structures and the subsequent onset of decay when water levels decline. However, ample oxygen and moisture for decay are almost always present in wooden members placed in contact with the ground or above the waterline area of members placed in freshwater. Even in very dry climates, wood in contact with the ground has sufficient moisture for decay. In moist climates, there is also sufficient moisture for decay in members that are not in contact with soil or water if they are not protected from precipitation. Liquid water is rapidly absorbed in end-grain during rain events, and subsequent drying can be slowed if air movement is limited in that area. Wood that rests on concrete or masonry near the ground may absorb sufficient moisture for biodeterioration even if protected from other sources of wetting.

Although moisture is the most important risk factor for biodeterioration, in some situations, dry wood can be vulnerable to attack by termites and other insects. Native subterranean termites require moisture but can attack wood with moisture content well below the fiber saturation point (about 30% moisture content) by building shelter tubes from the soil and periodically returning to the soil to replenish water lost from their bodies. Native subterranean termites are widely distributed in the United States with heaviest populations in the Southeast. The introduced Formosan termite is an invasive species that has become established in Hawaii and along coastal regions of the southeastern United States, where it continues to slowly expand its range northward. Formosan subterranean termites also require a source of moisture to attack wood above ground but are less reliant on proximity to soil for survival. Formosan termites may establish colonies on upper floors of buildings if a consistent source of moisture is present. Drywood termites are so-named because they can survive in wood structures above ground, deriving moisture solely from the wood. Structural infestations of drywood termites occur in Hawaii and across the most southern states of the United States from coastal regions of southern California through Texas and Florida. In regions with a particularly severe termite hazard, using pressure-treated lumber for interior construction is at least advisable and in some cases may be required by building codes.

Wood immersed in seawater requires pressure treatment with preservative for protection against various types of marine borers. The three most destructive groups in the United States are shipworms, boring clams, and gribbles. Shipworms and the less commonly found boring clams are both bivalve mollusks, related to oysters and mussels, whereas gribbles are isopod crustaceans. Unlike the boring clams and gribbles, which attack wood near exterior surfaces producing visible damage that can be monitored, the damage from shipworms can go undetected until it becomes catastrophic. The reason for this is that shipworms eat away at the interior of wood members creating tunnels as they grow, but because they enter the wood as small larvae, the exterior appears undamaged. Unlike decay fungi and termites, marine borers can attack wood with low oxygen levels, and thus, constant immersion does not provide protection. The number of species of destructive borers increases in warmer waters, but at least one species of destructive borer is present in all U.S. coastal waters (Clausen 2010).

In structures complying with building codes, use of a preservative-treated or naturally durable wood is required for some members. Examples include joists within 18 in. of the soil beneath a structure, sill plates, and posts or columns resting on concrete. More specific information on code requirements for use of pressure-treated wood can be found in the International Building Code and International Residential Code (ICC 2018). This is a model code; therefore, states or local governments may have modifications. Depending on the use and custodianship of the structure, other standards such as those of the American Association of State Highway and Transportation Officials (AASHTO 2016) or federal or state agencies may govern specifications for pressure-treated wood.

What are Pressure-Treating Preservatives?

Because the term “wood preservative” is applied to a broad range of products, there is often confusion or misunderstanding about the types of products being described. The term preservative is sometimes applied to water-repellents, hardeners, or finishes whose purpose is to maintain the appearance or stability of a wood product. For additional information on surface-applied water-repellents and finishes, see Williams (2010). In this guide, we consider wood preservatives to be substances that extend the useful service life and structural integrity of wood products by protecting them from fungal and insect attack. Such wood preservatives are generally chemicals that are either toxic to wood-degrading organisms and/or cause some change

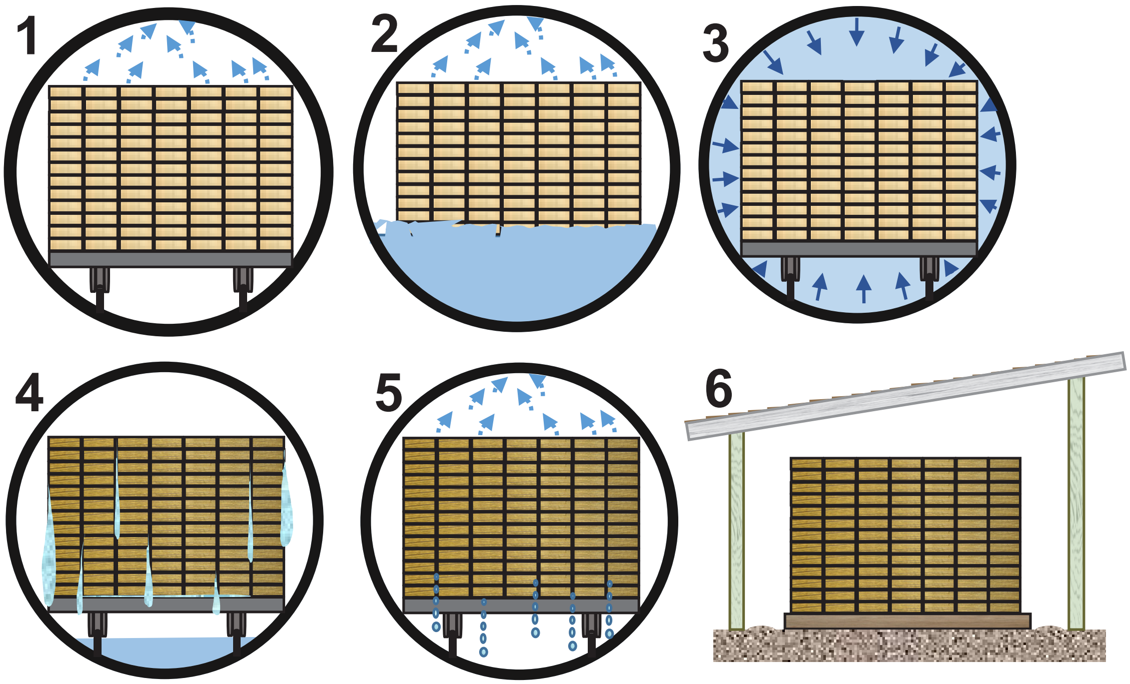

Figure 1. A typical pressure-treatment process with waterborne preservatives includes (1) pulling an initial vacuum to remove air from the wood cells, (2) filling the cylinder with preservative while maintaining the vacuum, (3) releasing the vacuum and applying pressure to force preservative into the wood, (4) releasing the pressure and emptying the cylinder, (5) pulling a final vacuum to remove excess preservative, and (6) storing on a covered drip pad.

in wood properties that renders the wood less vulnerable to biodegradation. Most contain biocide ingredients and meet the definition of a pesticide under federal law, and as such, must have registration with the U.S. Environmental Protection Agency (EPA) as well as state or territory lead agencies.

The greatest volume of wood preservatives is used in the pressure treatment of wood at specialized treatment facilities. In these treatment plants, bundles of wood products are placed into large pressure cylinders and combinations of vacuum, pressure, and sometimes heat are used to force the preservative deeply into the wood (Fig. 1). Pressure-treated wood typically has much deeper and more uniform preservative penetration than wood treated by other methods. Pressure-treating preservatives and pressure-treated wood also undergo review by standard-setting organizations to ensure that the resulting product will be sufficiently durable in the intended end-use. Standards also apply to treatment processes and require specific quality control and quality assurance procedures for the treated wood product (AWPA 2018). This level of oversight is needed because pressure-treated wood is often used in structural applications in which it is expected to provide service for decades and premature failure could result in injury or death.

Preservatives are not always applied by pressure treatment. In some cases, preservatives may be brushed on the surface of the wood or applied to holes drilled into large wooden members. A major limitation of these nonpressure treatments is that the preservative is not forced deeply into the wood under pressure, and thus, a much lower proportion of the wood volume is protected with preservative. This is not to suggest that nonpressure preservatives do not have a role in wood protection. They can be of great value when used as in-place treatments to supplement wood that was initially pressure-treated. Nonpressure treatments are beyond the scope of this guide, but a detailed discussion on their use can be found in Lebow and others (2012).

Characteristics of Pressure-Treating Preservatives

Pressure-treating preservatives are often broadly divided into two groups depending on whether they are waterborne or oilborne. Although creosote is not an oilborne preservative, it is often grouped with oilborne preservatives because of the similarity in properties. Typically, a concentrated formulation of active ingredient(s) is provided to the pressure-treatment facility, and that concentrate is then diluted with water or oil before treatment. An exception is creosote, which is often used without dilution. The distinction between waterborne and oilborne preservatives is sometimes blurred, however, because some can be formulated for use with either type of carrier.

Figure 2. Lumber pressure-treated with waterborne preservatives is an important component of residential construction.

Waterborne Preservatives

Waterborne preservatives typically have little odor and leave the wood with a dry, paintable surface. They are used for a wide range of applications, including the treated lumber sold by lumber yards for construction of residential decks (Fig. 2) and fences. Some waterborne preservatives are also used for more industrial-type applications, such as poles, piling, and bridge timbers. Most waterborne preservatives have some type of chemical mechanism, which makes the active ingredients resistant to leaching in rainfall or standing water.

Waterborne preservatives typically contain at least two active ingredients, which makes them effective against a range of decay fungi and insects. The ratio of these active ingredients in any particular preservative depends on efficacy determined in testing, formulation stability, cost, and other factors. Years of laboratory and field tests were conducted during the development of preservative formulations. Many waterborne preservatives contain copper as an active ingredient. Copper is effective against most types of decay fungi as well as major insect pests and has low toxicity for mammals. However, certain types of copper-tolerant decay fungi can sporadically cause severe and rapid damage in wood treated with copper. Thus, commercial copper-based preservatives typically include a co-biocide (e.g., quaternary ammonium compounds, triazoles, or naphthenic acids) to provide additional protection. In some situations, waterborne preservatives containing copper are less effective in protecting hardwoods than softwoods, leading to less common use in hardwoods. The color of wood treated with copper-based preservatives varies from light green to greenish brown, although in some cases, stains or colorants are used to create an appearance more similar to cedar or redwood. More recently, some waterborne preservatives have also been formulated without copper for use in above-ground applications in which the decay hazard is typically less severe. These treatments impart little color change to the wood.

Alkaline Copper Betaine (KDS and KDS-B)

Alkaline copper betaine is an example of a preservative formulation that utilizes copper solubilized with ethanolamine along with polymeric betaine and borate (KDS) or polymeric betaine (KDS-B). The active ingredient composition for KDS is 47% copper oxide, 23% polymeric betaine, and 30% borate as boric acid, whereas KDS-B has 68% copper oxide and 32% polymeric betaine. Both are standardized by AWPA for treatment of commodities used above ground and for posts in contact with soil. AWPA standards do not currently list KDS for critical structural components in ground contact.

Alkaline Copper Quat (ACQ-A, ACQ-B, ACQ-C, ACQ-D)

Alkaline copper quat (ACQ) contains copper and a quaternary ammonium compound (quat). Multiple variations of ACQ are standardized. ACQ-A differs in that it has 50% copper oxide and 50% quat, whereas the other formulations have 67% copper oxide and 33% quat. ACQ-B is an ammoniacal copper formulation, whereas ACQ-D is an ethanolamine and/or ammoniacal-copper formulation. ACQ-C is a combined ammoniacal-ethanolamine formulation with a slightly different quat compound. The multiple formulations of ACQ allow some flexibility in achieving intended treating results for specific wood species and applications. When ammonia is used as the carrier, ACQ has improved ability to penetrate difficult to treat wood species. However, if the wood species is readily treatable, such as pine sapwood, an amine carrier is typically used.

Ammoniacal Copper Zinc Arsenate (ACZA)

ACZA is a waterborne preservative that contains copper oxide (50%), zinc oxide (25%), and arsenic pentoxide (25%). It is a refinement of an earlier formulation, ammoniacal copper arsenate (ACA), which is no longer in use. The color of the treated wood varies from brown to bluish green. The wood may have a slight ammonia odor until it is thoroughly dried after treatment. The ammonia in the treating solution, in combination with processing techniques such as steaming and extended pressure periods, allows ACZA to obtain better penetration of difficult-to-treat wood species than many other waterborne wood preservatives. ACZA has been commonly used for treatment of Douglas-fir poles, piles, and large timbers. It can also be used for treated wood placed in seawater.

Chromated Copper Arsenate (CCA)

CCA composition in terms of active ingredients is 47.5% chromium oxide, 18.5% copper oxide, and 34% arsenic pentoxide. Wood treated with CCA (commonly called "green treated") dominated the treated wood market from the late 1970s until 2004. However, as the result of voluntary label changes submitted by the CCA registrants, the EPA labeling of CCA currently permits the product to be used for industrial and certain agricultural applications only, and CCA-treated lumber is not available at retail lumber yards for residential use. It is important to note that existing structures are not affected by this labeling change, and that the EPA has not recommended removing structures built with CCA-treated lumber. Examples of common uses for new installations include sawn crossarms, round poles, piles, agricultural fencing and posts, plywood, and wood used in seawater or in highway construction. Use for permanent wood foundations is also allowed. The chromium in CCA helps to mitigate metal fastener corrosion sometimes associated with the use of solubilized copper.

Copper Azole (CA-B, CA-C, MCA, and MCA-C)

Copper azole is a formulation composed of copper (96%) and 4% triazole compounds. The triazole is either tebuconazole or a 50:50 mixture of propiconazole and tebuconazole (C designation). Copper azole may be prepared with copper solubilized in ammonia and/or ethanolamine (CA-B and CA-C) or with the copper ground to very fine particles (micronized), which are then dispersed in the treatment solution with surfactants (MCA and MCA-C). Wood treated with the particulate formulations tends to have a lighter color than that treated with soluble copper formulations. Both types of copper azole formulations are commonly used to pressure-treat decking and dimension lumber commonly found at lumber yards but are also standardized for treatment of posts, poles, and timbers. Copper azole formulations using particulate copper may be less corrosive to metal fasteners than the soluble copper formulations.

Copper HDO (CX-A)

Copper HDO or CX-A is an ethanolamine copper waterborne preservative that has been used in Europe and is standardized in the United States. It is also referred to as copper xyligen. The active ingredients are copper oxide (61.5%), boric acid (24.5%), and HDO (N-cyclohexyldiazeniumdioxide) (14.0%). The appearance and handling characteristics of wood treated with CX-A are similar to the other amine copper-based treatments. Currently, CX-A is standardized by AWPA only for applications that are not in direct contact with soil or water. It has seen little commercial use in North America but is used to some extent in Europe.

EL2

EL2 is an emulsion form of waterborne preservative composed of the fungicide 4, 5-dichloro-2-N-octyl-4-isothiazolin-3-one (DCOI), the insecticide imidacloprid, and a moisture control stabilizer (MCS). The percentage active ingredient composition is 98% DCOI and 2% imidacloprid, but the MCS is also considered to be a necessary component to ensure preservative efficacy. EL2 is currently listed in AWPA standards for above-ground applications only and is most commonly used to treat decking and dimension lumber for residential applications. Moisture control stabilizers are incorporated into the treatment solution to lessen checking and splitting. The treatment is essentially colorless.

Inorganic Boron (Borate) (SBX)

Borates are unusual among waterborne preservatives because they remain water soluble in the wood after pressure treatment. They include formulations prepared from sodium tetraborate, sodium pentaborate, and boric acid, but the most common form is disodium octaborate tetrahydrate (DOT). DOT has greater water solubility than many other forms of borate, allowing the use of higher

Figure 3. Creosote is often used for pressure treatment of railroad ties.

solution concentrations and increasing the mobility of the borate through the wood. Borates are used for pressure treatment of framing lumber that will be used in areas with high termite hazard, such as Hawaii. With the use of heated solutions, extended pressure periods, and diffusion periods after treatment, DOT is able to penetrate relatively refractory species, such as spruce. Although boron has many potential applications in framing lumber, it is not suitable for applications in which it is exposed to frequent wetting unless the boron can be somehow protected from liquid water. An exception is recent developments in the use of boron formulations as a pretreatment for railroad crossties and switch ties prior to pressure treatment with creosote or copper naphthenate. In this case, the boron is intended to diffuse deeply in the wood and protect the interior of the tie while the subsequent creosote or oil treatment protects the exterior of the tie and helps to lessen boron depletion in service. Wood treated with borates is colorless. However, some borate treaters use a dye to color the wood for easier field identification.

Propiconazole-Tebuconazole-Imidacloprid (PTI)

PTI is a waterborne preservative solution composed of two fungicides (propiconazole and tebuconazole) and the insecticide imidacloprid. PTI is currently listed in AWPA standards for above-ground applications only. The efficacy of PTI is enhanced by the incorporation of a water-repellent stabilizer in the treatment solutions, and lower retentions are allowed if the stabilizer is used. The treatment is essentially colorless.

Oilborne Preservatives, Including Creosote

Oilborne preservatives are dissolved in either heavy or light oils. Heavy oil is similar to diesel, whereas light oil is similar to mineral spirits. The properties and applications of oilborne preservatives depend on the type of oil used. Heavy oil treatments are typically used for heavy-duty applications, such as utility poles, bridge timbers, and railroad ties (Fig. 3). Heavy oil treatments have the advantage of imparting some water-repellency to the wood and can help protect metal fasteners from corrosion. However, wood that has been pressure-treated with heavy oils may have a noticeable odor and should not be used in the interior of inhabited structures. Light oil treatments are sometimes used when it is desirable that the wood have a drier surface and less residual odor. Oilborne treatments are typically used to treat glue-laminated timbers (when treated after lamination) because they do not swell the wood as do waterborne preservatives. Oilborne preservatives are effective in protecting hardwoods at retentions similar to those used in softwoods. Creosote is grouped with the oilborne preservatives in this guide, although it is not always diluted with oil. Currently, there are fewer oilborne preservatives than waterborne preservatives.

Creosote (CR, CR-S, CR-PS)

Coal-tar creosote is the oldest wood preservative still in commercial use and remains the primary preservative used to protect wood used in railroad construction. It is made by distilling the coal tar that is obtained after high-temperature carbonization of coal. Unlike the other oil-type preservatives, creosote is not always dissolved in oil, but it does have properties that make it look and feel oily. In AWPA standards, creosote is further differentiated as either coal tar distillate (CR), a solution of coal tar in coal tar distillate (CR-S), or a 50:50 creosote–petroleum solution combination (CR-PS). Creosote-treated wood has a dark brown to black color and a noticeable odor and is often not the first choice for applications in which there is a high probability of human contact. Creosote is effective in protecting both hardwoods and softwoods and is thought to improve the dimensional stability of the treated wood. It is used in the pressure treatment of utility poles, bridge timbers, railroad ties, agricultural fences, guardrails for highway construction, and glue-laminated timbers. Creosote is also effective in protecting wood used in seawater environments (in northern latitudes) and is often used to treat marine piles. With the use of heated solutions and lengthy pressure periods, creosote can be fairly effective at penetrating even difficult-to-treat wood species. Creosote treatment does not accelerate, and may even inhibit, the rate of metal fastener corrosion compared with untreated wood.

Oxine Copper (Cu8)

Copper-8-quinolinolate or oxine copper is an organometallic compound that has been used for pressure treatment of wood exposed above ground or above water but not in contact with the ground or immersed in water. Copper-8-quinolinolate has a relatively low toxicity to mammals, and the light oil formulation has sometimes been used for parts of a structure in which human contact is expected, such as hand rails of pedestrian bridges. The treated wood has a greenish-brown color.

Pentachlorophenol (PCP-A, PCP-C)

Pentachlorophenol has been widely used as a pressure treatment since the 1940s. The active ingredients, chlorinated phenols, are crystalline solids that can be dissolved in different types of organic solvents. The performance of pentachlorophenol, and the properties of the treated wood, are influenced by the properties of the solvent. The heavy oil solvent (PCP-A) may be preferable when the treated wood is to be used in ground contact because wood treated with lighter solvents (PCP-C) may not be as durable in such exposures. Wood treated with pentachlorophenol in heavy oil typically has a brown color and may have a slightly oily surface that is difficult to paint. It also has some odor, which is associated with the solvent. As with creosote, pentachlorophenol in heavy oil is not the first choice for applications in which frequent contact with skin is likely (e.g., hand rails). Pentachlorophenol in heavy oil has long been a common choice for treatment of utility poles, bridge timbers, glue-laminated timbers, and foundation piling. As with creosote, pentachlorophenol is effective in protecting both hardwoods and softwoods and is often thought to improve the dimensional stability of the treated wood. Unlike creosote, pentachlorophenol is not used in marine–saltwater environments. With the use of heated solutions and extended pressure periods, pentachlorophenol is fairly effective at penetrating difficult-to-treat species. It does not accelerate corrosion of metal fasteners compared with untreated wood, and the heavy oil solvent helps to impart some water-repellency to the treated wood.

Copper Naphthenate (CuN, CuN-W)

The preservative efficacy of copper naphthenate has been known since the early 1900s, and various formulations have been used commercially since the 1940s. It is an organometallic compound formed as a reaction product of copper salts and petroleum-derived naphthenic acids or a blend of naphthenic acid and other carboxylic acids. It is also often recommended for field treatment of cut ends and holes drilled during construction with pressure-treated wood. Copper-naphthenate-treated wood initially has a green color that weathers to light brown. The treated wood also has an odor that dissipates somewhat with time. Depending on the solvent used and treatment procedures, it may be possible to paint copper-naphthenate-treated wood after it has been allowed to weather for a few weeks. As with pentachlorophenol, copper naphthenate can be dissolved in a variety of solvents but has greater efficacy when dissolved in heavy oil. Copper naphthenate is used in the pressure treatment of utility poles, bridge timbers, glue-laminated timbers, and railroad ties. It is not used for treatment of wood used in seawater. A waterborne formulation of copper naphthenate (CuN-W) is also standardized for some applications, but wood pressure-treated with waterborne copper naphthenate is currently less available than wood with the oilborne formulation.

DCOI

The oilborne formulation of DCOI uses the same active ingredient (4, 5-dichloro-2-N-octyl-4-isothiazolin-3-one) as the waterborne emulsion formulation EL2. DCOI is soluble in the types of oils used for wood preservation and is standardized for treatment of posts and pole cross-arms with heavy oil. In contrast to other oilborne preservatives, diluted DCOI is nearly colorless and the treated wood has little color change other than that imparted by the oil.

IPBC/PER

IPBC/PER has an active ingredient composition of 64% of the fungicide 3-iodo-2-propynyl butyl carbamate (IPBC) with 36% permethrin (PER) included to prevent insect attack. It has been standardized for light solvent for treatment of glue-laminated timbers that extend outside a structure but are partially protected by a roof overhang. The treatment is clear, allowing the wood to maintain its natural appearance. It is not currently standardized to treat wood that is fully exposed to the weather.

Figure 4. Ground-contact stake testing is conducted for years as part of evaluating a wood preservative.

Inorganic Boron (SBX-O)

A fairly recent development in use of boron for pressure treatment is the formulation of boric acid in a manner that allows it to be mixed directly into creosote and creosote solutions for one-step pressure treatment of cross-ties and switch-ties. The creosote acts as the primary preservative to protect the exterior of the tie, while the boron gradually diffuses more deeply into the tie to provide interior protection. Although currently this approach is primarily used for treatment of hardwoods in railroad construction, it may have potential for protection of large timbers used in other types of applications.

Quality Assurance for Pressure-Treated Wood

Before a wood preservative can be approved for pressure treatment of structural members, it must be evaluated to ensure that it provides the necessary durability without adversely compromising the strength properties of the wood. The EPA typically does not evaluate how well a wood preservative protects the wood. Traditionally, this evaluation has been conducted through the standardization process of AWPA, an ANSI-accredited standard setting body (AWPA 2018). The *AWPA Book of Standards* lists a series of laboratory and field exposure tests (Fig. 4) that must be conducted when evaluating new wood preservatives. The durability of test products are compared with those of established durable products and nondurable controls. The results of those tests are then presented to the appropriate AWPA committees for review. AWPA committees are composed of representatives from industry, academia, and government agencies who have familiarity with conducting and interpreting durability evaluations. Preservative standardization by AWPA is a two-step process. If the performance of a new preservative is considered appropriate, it is first listed as a potential preservative. Secondary committee action is needed to have the new preservative listed for specific commodities and to set the required treatment levels for each use category.

More recently, the International Code Council Evaluation Service (ICC-ES) has evolved as an additional route for gaining building code acceptance of new types of pressure-treated wood. In contrast to AWPA, the ICC-ES does not standardize preservatives. Instead, it issues evaluation reports that provide evidence that a building product complies with building codes (ICC-ES 2018). The data and other information needed to obtain an evaluation report are first established as acceptance criteria (AC). AC326, which sets the performance criteria used by ICC-ES to evaluate proprietary wood preservatives, requires submittal of documentation from accredited third-party agencies in accordance with AWPA, ASTM, and EN standard test methods. The results of those tests are then reviewed by ICC-ES to determine if the preservative has met the appropriate AC.

The American Association of State Highway and Transportation Officials (AASHTO) also has a standard specification for Preservatives and Pressure Treatment Processes for Timber, called M 133 (AASHTO 2016). This specification is under the oversight of AASHTO Technical Section 4c - Coatings, Paints, Preservatives,

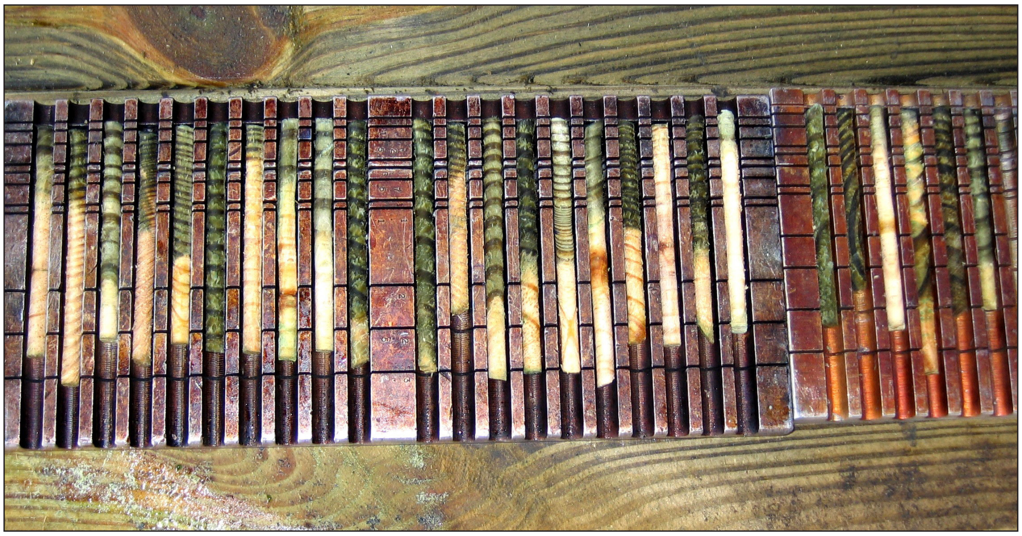

Figure 5. Each pressure-treated charge (cylinder load) of wood is inspected by removing increment cores from 20 or more pieces. Preservative penetration is measured on the cores, and then the portion corresponding to the assay zone is removed for chemical analysis of preservative retention.

Bonding Agents, and Traffic Markings. Unlike AWPA and ICC-ES, AASHTO does not evaluate new preservatives for inclusion in AASHTO M 133. Instead, AASHTO lists some (but not necessarily all) preservatives that have been either standardized by AWPA or have an ICC-ES evaluation report. AASHTO M 133 also refers to AWPA standards or ICC-ES evaluation reports for specifications on treatment processes and limitations.

Specifications on the treatment of various wood products by pressure processes have been developed by AWPA. These specifications limit pressures, temperatures, and time of conditioning and treatment to avoid conditions that will cause damage to the wood. The specifications also contain minimum requirements for preservative penetration and retention levels and recommendations for handling wood after treatment to provide a quality product. However, specifications are broad in some respects, allowing the purchaser some latitude in specifying the details of their individual requirements. Regardless, the purchaser should recognize that their individual requirements cannot stray outside the tolerances that balance treating conditions with quality of the treatment and strength properties of the final product.

Penetration and retention requirements are equally important in determining the quality of preservative treatment. Penetration levels vary, even in pressure-treated material. Generally the outer portion of the tree stem adjacent to the bark (sapwood) is more readily treated with preservatives because sapwood cells function to move sap up and down the tree. In contrast, the darker inner heartwood portion of the stem is difficult to treat for many species. Complete penetration of the sapwood should be the goal in all pressure treatments. It can often be accomplished in small-size timbers of various commercial woods and is sometimes obtained in piles, ties, and structural timbers. Practically, however, the operator cannot always ensure complete penetration of sapwood in every piece when treating large pieces with thick sapwood (such as poles and piles). Accordingly, treatment requirements vary, depending on the preservative, wood species, size, class, and use category.

Preservative retentions are expressed on the basis of the mass of preservative per unit volume of wood within a prescribed assay zone, typically pounds per cubic foot or kilograms per cubic meter. The retention calculation is not based on the volume of the entire piece of wood. Retention is determined by assaying the amount of active ingredients retained in a predetermined assay zone predicated by wood species, size, and AWPA processing standards for the use category. For example, the assay zone for Southern Pine lumber (<2 in. thick) is 0 to 0.6 in. from the wood surface. To determine the retention, a boring is removed from the narrow face (edge) of at least 20 pieces in each charge and these borings are then combined and analyzed for preservative concentration (Fig. 5). Because the borings are combined for analysis, the retention value is similar to an average retention for the pieces in a charge. Individual pieces may have higher or lower retentions.

The preservatives and minimum charge retention levels are listed in the AWPA commodity standards and ICC-ES evaluation reports. The current issues of these specifications should be referenced for up-to-date recommendations and other details (AWPA 2018, ICC-ES 2018). Higher preservative retention levels are specified for products to be installed under severe climatic or exposure conditions. Heavy-duty transmission poles and items with a high replacement cost, such as structural timbers and house

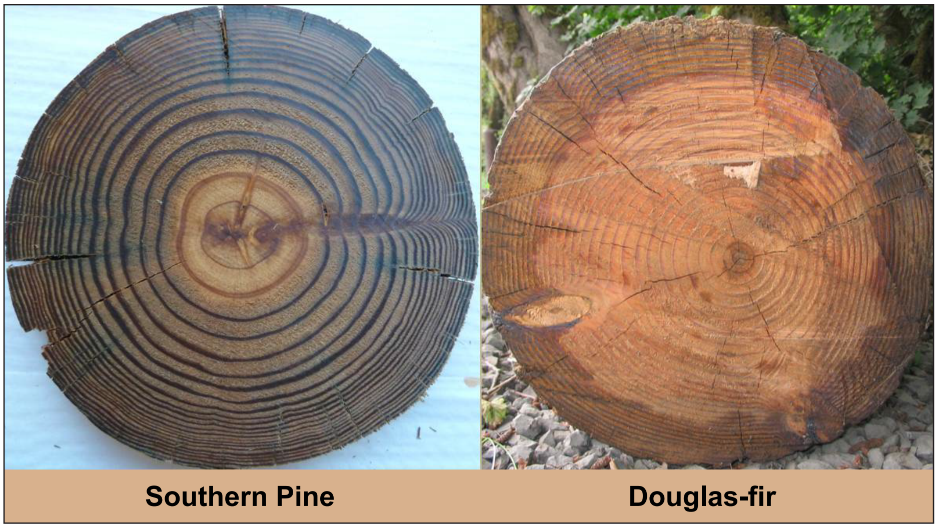

Figure 6. Example of the cross sections of pressure-treated poles showing the greater proportion of treatable sapwood in Southern Pine compared with Douglas-fir.

foundations, are also required to be treated to higher retention levels.

Fortunately, the end-user does not need to become an expert in treated wood specifications. The UCS standards developed by AWPA simplify the process of finding appropriate preservatives and preservative retentions for specific end-uses. To use the UCS standards, one needs only to know the intended end-use of the treated wood. An end-user would first refer to AWPA Standard U1, table 3-1, where most types of applications for treated wood are listed. They will then be shown the use category and directed to the appropriate commodity specification. The AWPA commodity specification lists all the preservatives that are standardized for each use category, as well as the appropriate preservative retention and penetration requirements. However, the user needs only to specify that the product be treated according to the appropriate use category.

As the treating industry adapts to the use of new types of wood preservatives, it is more important than ever to ensure that wood is being treated to standard specifications. In the United States, the U.S. Department of Commerce American Lumber Standard Committee (ALSC) accredits third-party inspection agencies for treated wood products. Quality control overview by ALSC-accredited agencies is preferable to simple treating plant certificates or other claims of conformance made by the producer without inspection by an independent agency. Updated lists of accredited agencies can be obtained from the ALSC website at http://www.alsc.org. The use of treated wood with such third-party certification may be mandated by applicable building code regulations. Wood that is treated in accordance with these quality assurance programs will have a stamp or end tag with the quality mark of an accredited inspection agency.

Detailed specifications on the different treatments can be found in the applicable standards of AWPA.

Selecting a Type of Treated Wood

The type of preservative that is most appropriate depends on the species of wood being treated, the type of wood product, and the requirements of the specific application. Ancillary properties of a preservative, such as odor, may also affect its suitability for an application. For example, lumber treated with creosote or oilborne preservatives is not standardized for interior residential applications. Also, not all standardized preservatives are readily available in all areas of the United States. Large retail home improvement stores typically only stock one or two types of waterborne preservatives used in residential construction, and wood treated with other types of preservatives may need to be ordered. The type of preservatives available varies geographically and in particular is influenced by the dominant tree species available in a region.

Southern Pine species are most commonly used for pressure treatment because these trees have a high proportion of readily treatable sapwood (Fig. 6). Southern Pine species are also the most widely used for conducting wood preservative research. In some geographic regions, other wood species such as western hemlock, true firs, Douglas-fir, red pine, or ponderosa pine are used. Some of these species are less readily treated with preservatives and may have incising requirements in order to meet penetration specifications. Incising is a process of cutting small slits into the wood before treatment to improve preservative penetration (Fig. 7). Incising can cause reductions in mechanical properties, and adjustments are provided in design specifications (NDS 2018). Douglas-fir, an important structural wood species in the western United States, is less treatable than pine and thus has been standardized with

Figure 7. Examples of the appearance of lumber that has been incised prior to pressure treatment to increase the depth and uniformity of preservative penetration.

slightly fewer preservatives. The treatability of Douglas-fir harvested from coastal regions (defined as west of the crest of the Cascade mountain range) tends to be greater than that from the interior west, and in some cases, the standards limit the source of Douglas-fir to coastal areas (AWPA 2018). There are also some traditional differences in preservatives used to treat hardwoods and softwoods. Hardwoods have generally been treated with oilborne preservatives, in part because of concerns that copper-containing waterborne preservatives may be less effective for hardwoods placed in contact with the ground. There are exceptions, however, such as the standardized use of ACZA to treat railroad ties.

Standardized preservatives may also vary by the type of wood product. Sawn lumber is commonly used for many applications and has the greatest number of standardized pressure-treating preservatives. Preservative compatibility may not have been evaluated for some types of wood products, whereas in other cases, there are known concerns with some types of preservatives. For example, waterborne preservatives are generally not standardized for pressure treatment of glue-laminated timbers after gluing (with the exception of ACZA treatment of Douglas-fir) because of concerns that the forces created by water swelling and shrinking the timber could impact its subsequent mechanical properties.

The severity of the deterioration exposure hazard and criticality of the member have the greatest impact on the choices of standardized preservatives and the retention required. For example, direct contact with soil or water is considered a severe deterioration hazard, and preservatives used in these applications must have a high degree of leach resistance and efficacy against a broad spectrum of organisms. These same preservatives may also be used at lower retentions to protect wood exposed in lower deterioration hazards, such as above the ground. The exposure is less severe for wood that is partially protected from the weather, and preservatives that lack the permanence or toxicity to withstand continued exposure to precipitation may be effective in such protected applications. Other formulations, such as borates when used alone, may be so readily leachable that they can only be used where protected from precipitation. The importance of the member also factors into the retention and, in some cases, the types of preservatives that are standardized. For example, because bridge timbers are structurally critical, they warrant a higher retention with fewer standardized preservatives than for more general applications.

To guide selection of the types of preservatives and loadings appropriate to a specific end-use, AWPA developed the UCS standards (Table 1). The UCS standards simplify the process of finding appropriate preservatives and preservative retentions for specific end-uses. They categorize treated wood applications by the severity of the deterioration hazard, as well as the structural significance of the application. The lowest category, Use Category 1 (UC1) is for wood that is used in interior construction and kept dry, whereas UC2 is for interior wood, completely protected from the weather but occasionally damp. UC3 is for exterior wood used above ground and is further subdivided into UC3A and UC3B. UC3A is for products that will be partially protected from the weather, such as siding, whereas UC3B is for products that are fully exposed to the weather, such as deck boards. However, members used above ground for structurally critical applications are sometimes considered to fall under UC4, especially if the conditions

Table 1—Summary of AWPA use categories for pressure-treated wood

Use category	Description[a]
UC1	Interior and dry (insect attack is primary concern)
UC2	Interior but occasionally damp
UC3A	Exterior but partially protected from weather
UC3B	Fully exposed exterior, not structurally critical, moderate decay hazard
UC4A	General ground contact, or above ground for critical members or high decay hazard
UC4B	Heavy duty ground contact or critical members used in any ground contact
UC4C	Severe ground contact and structurally critical
UC5A	Seawater use, northern waters
UC5B	Seawater use, southern waters
UC5C	Seawater use, southern to tropical waters

[a]This table provides only an abbreviated summary. Refer to AWPA standards for full description.

Figure 8. Pressure-treated lumber and sawn timbers are used in a wide range of structures.

at the site create a high decay hazard (e.g., less than 6 in. above ground, poor air circulation, tropical climate). UC4 is for wood used in ground contact or placed into standing water (not including seawater). UC4A is for general use, whereas UC4B and UC4C applications are more structurally critical and/or have a greater decay or termite threat. UC5 includes applications that place treated wood in contact with seawater and marine borers. UC5 is further divided into UC5A, B, and C because types of marine borers vary with water temperature. AWPA Commodity Specifications then list all the preservatives that are standardized for a specific use category and the appropriate preservative retentions.

Sawn Lumber, Sawn Timbers, and Sawn Posts

Sawn material includes a large volume and wide range of types of treated wood products. Most of the pressure-treated wood sold by retailers and used in residential construction falls within this category. Similar dimensions of sawn treated products may be used in applications ranging from decks (Fig. 8) to highway bridges. The types and retentions of wood preservatives used to treat sawn products vary somewhat with the application and, to some extent, wood species (Table 2). For example, the water-soluble borate preservatives are not standardized for exterior applications of sawn lumber, timbers, and posts, whereas some of the

Table 2—General sawn lumber, sawn timbers, and sawn posts (excluding seawater applications). Preservatives standardized by AWPA by use category and wood species. Standardized preservatives or retentions may change; refer to current AWPA standards.

Use categories by species	Preservatives standardized by AWPA
Southern Pine	
UC1 and UC2	Waterborne: SBX
UC1 through UC3B	Oilborne: Cu8 Waterborne: CX-A, EL2, PTI
UC1 through UC4A	Waterborne: ACQ-A, CuN-W, KDS
UC3B and UC4A	Oilborne: DCOI-A
UC1 through UC4C	Oilborne: CR[a], CR-S[a], CR-PS[a], CuNa, PCP-A, C[a] Waterborne: ACQ-B,C,D, ACZA[b], CA-B,C, CCA[b], MCA, MCA-C
Eastern white, ponderosa, and red pines	Same as Southern Pine except exclude DCOI-A and MCA-C
Douglas-fir	Same as Southern Pine except exclude Cu8, MCA, and MCA-C
Hem–Fir group	Same as Southern Pine except exclude DCOI-A
Other species	There are some other species listed for specific use category/preservative combinations. Refer to AWPA standards.

[a]Not for interior residential use.
[b]ACZA and CCA allowable uses are limited to specific applications by EPA labeling. Most allowable applications fall into UC3B and above.

Table 3—Specific sawn lumber and sawn timbers for highway bridges (UC4C, excluding seawater immersion). Preservatives standardized by AWPA by use category and wood species. Standardized preservatives or retentions may change; refer to current AWPA standards.

Use category by species	Preservatives standardized by AWPA
Southern Pine and western hemlock	Oilborne: CR, CR-S, CR-PS, CuN, PCP-A,C Waterborne: ACQ-B,C, ACZA, CA-B,C, CCA, MCA, MCA-C
Douglas-fir	Same as Southern Pine except add ACQ-D, exclude MCA and MCA-C
Hem–Fir group	Waterborne: ACQ-C, CA-B,C, MCA, MCA-C

oilborne preservatives are not standardized for interior residential use. A few applications, such as highway bridges, have specific standards within the sawn lumber category. Some of the preservatives standardized for the general sawn lumber applications are not standardized for use in highway bridges (Table 3), and the use category level is increased because of the critical nature of bridge components.

Round Posts and Building Poles

Roundwood posts are widely used for farm and highway fencing, but have a variety of other uses as well (Fig. 9). AWPA standards specify that fence posts be treated to UC4A and list a number of preservatives depending on the wood species (Table 4). Round posts to be used for more structurally critical purposes, such as guardrail posts, should be treated to UC4B. Because of their structural importance, a separate AWPA listing has been created for poles and posts used in buildings (Table 5), all of which fall under the UC4B category.

Utility Poles

Round pressure-treated poles have long been a mainstay of utilities for transmission and distribution of electricity (Fig. 10). Utilities often have their own preferences and specifications for these poles but generally still rely on the AWPA standardization process to define wood species and preservative options. AWPA standards classify utility poles under UC4A, UC4B, or UC4C depending on the deterioration hazard, difficulty of replacement, and criticality (Table 6). As with many other wood products, the largest number of preservatives have been standardized for treatment of Southern Pine poles. Glue-laminated utility poles are also used in some situations and can be designed and installed to maximize properties in a desired direction. Only oilborne preservatives are currently standardized for treatment of glue-laminated utility poles.

Figure 9. Round building poles and posts are structurally critical and pressure-treated to meet AWPA Use Category 4B.

Table 4—Round posts. Preservatives standardized by AWPA by use category and wood species. Standardized preservatives or retentions may change; refer to current AWPA standards.

Use categories by species	Preservatives standardized by AWPA
Southern Pine	
UC4A	CuN-W, KDS, MCA-C
UC4A and UC4B	Oilborne: CR, CR-S, CR-PS, CuN, DCOI-A, PCP-A,C Waterborne: ACQ-B,C,D, ACZA, CA-B,C, CCA, MCA
Ponderosa pine	
UC4A and UC4B	Oilborne: CR, CR-S, CR-PS, CuN, PCP-A,C Waterborne: ACQ-B, ACZA, CCA
Lodgepole pine	
UC4A and UC4B	Oilborne: CR, CR-S, CR-PS, PCP-A,C Waterborne: ACQ-C, ACZA, CA-B,C CCA
Red pine	
UC4A and UC4B	Oilborne: CR, CR-S, CR-PS, CuN, DCOI-A, PCP-A,C Waterborne: ACQ-C, ACZA, CA-B,C, CCA
Douglas-fir	
UC4A	Oilborne: CR, CR-PS, CuN, PCP-A,C Waterborne: ACQ-B, ACZA, CCA, KDS
UC4B	Oilborne: CR, CR-S, CR-PS, CuN, DCOI-A, PCP-A,C Waterborne: ACQ-B, ACZA, CCA
Other species	There are some other species listed for specific use category/ preservative combinations. Refer to AWPA standards.

Table 5—Round building posts and poles (UC4B). Preservatives standardized by AWPA by wood species. Standardized preservatives or retentions may change; refer to current AWPA standards.

Wood species	Preservatives standardized by AWPA
Southern Pine	Oilborne: CR, DCOI-A, PCP-A,C Waterborne: ACZA, CA-B,C, CCA, MCA
Ponderosa pine	Oilborne: CR, PCP-A,C, Waterborne: ACZA, CCA
Red pine	Oilborne: CR, DCOI-A, PCP-A,C Waterborne: ACZA, CA-B,C, CCA
Douglas-fir	Oilborne: CR, PCP-A,C Waterborne: ACZA, CCA

Figure 10. Pressure-treated poles are widely used to support transmission and distribution of electricity.

Table 6—Utility poles. Preservatives standardized by AWPA by wood species. In each case, the preservatives listed are standardized for UC4A, UC4B, and UC4C, although retentions may differ by use category. Standardized preservatives or retentions may change; refer to current AWPA standards.

Wood species	Preservatives standardized by AWPA
Round utility poles	
Southern Pine	Oilborne: CR, CR-S, CuN, DCOI-A, PCP-A,C Waterborne: ACQ-B, ACZA, CA-B,C, CCA, MCA
Douglas-fir and red pine	Oilborne: CR, CR-S, CuN, DCOI-A, PCP-A,C Waterborne: ACQ-B, ACZA, CCA
Ponderosa, lodgepole, and jack pine	Oilborne: CR, CR-S, CuN, PCP-A,C Waterborne: ACQ-B, ACZA, CCA
Western redcedar	Oilborne: CR, CR-S, CuN, PCP-A,C Waterborne: ACQ-B, ACZA, CA-B, C, CCA
Western larch	Oilborne: CR, CR-S, PCP-A,C Waterborne: ACQ-B, ACZA, CCA
Other species	There are some other species listed for specific use category/ preservative combinations. Refer to AWPA standards.
Glue-laminated utility poles	
Southern Pine and Douglas-fir	Oilborne: CR, PCP-A,C, CuN

Figure 11. Pressure-treated round support piles used in applications such as this highway bridge are structurally critical and have a high decay hazard. They are treated to meet AWPA Use Category 4C.

Table 7—Round piles (UC4C). Preservatives standardized by AWPA by wood species. Standardized preservatives or retentions may change; refer to current AWPA standards.

Wood species	Preservatives standardized by AWPA
Southern Pine	Oilborne: CR, CR-S, CR-PS, CuN, PCP-A,C Waterborne: ACQ-C, ACZA, CA-B,C, CCA, MCA
Douglas-fir	Oilborne: CR, CR-S, CR-PS, CuN, PCP-A,C Waterborne: ACZA, CCA
Ponderosa, red, lodgepole, and jack pines, western larch	Oilborne: CR, CR-S, CR-PS, PCP-A,C Waterborne: ACZA, CCA

Round Piles (Foundation, Land, and Freshwater)

Round timber piles are almost always used in structurally critical applications and in many cases are difficult to replace (Fig. 11). As such, they are expected to be highly durable, and AWPA standards place them into UC4C (Table 7).

Plywood

Softwood plywood glued with exterior adhesive is routinely pressure-treated with wood preservatives and has been standardized with numerous preservatives. AWPA standards do not currently cover treatment of hardwood plywood. Although softwood species used in the plywood are not specified in AWPA standards, most softwood plywood is either Southern Pine or Douglas-fir (FPL 2010, Chapter 11). Good preservative penetration into plywood is usually possible because plywood is relatively thin and because the lathe checks formed during peeling create pathways for preservative flow. AWPA has categorized plywood applications from UC1 through UC4B (no UC4C category is listed for plywood) (Table 8).

Table 8—Plywood. Preservatives standardized by AWPA by use category. Standardized preservatives or retentions may change; refer to current AWPA standards.

Use category	Preservatives standardized by AWPA
UC1 and UC2	SBX
UC1 through UC3B	Oilborne: Cu8[a], CuN[a] Waterborne: CX-A, EL2, KDS, KDS-B, PTI
UC1 through UC4A	Waterborne: ACQ-A, ACQ-C
UC1 through UC4B	Oilborne: CR[a], CR-S[a], CR-PS[a], PCP-A,C[a] Waterborne: ACQ-B,D, ACZA[b], CA-B,C, CCA[b], MCA, MCA-C

[a]Not for interior residential use.
[b]Applications for plywood ACZA and CCA may be limited by EPA labeling.

Figure 12. Pressure-treated glue-laminated timbers are frequently used to support bridges and in other applications with long spans and/or high strength requirements

Laminated Timbers and Columns

Pressure-treated laminated timbers or columns are frequently used in applications with long spans and/or high strength requirements (Fig. 12). They are commonly used to support trail or road bridges but may also be used in building construction when a portion of the timber or column is exposed to the weather. Oilborne preservatives are typically used for treatment of timbers after gluing because the swelling and subsequent shrinkage associated with a waterborne treatment can stress glue bonds. One exception is that ACZA has been standardized for treatment of Douglas-fir laminated members (Table 9). Laminated timbers and columns can also be constructed from lumber that was previously pressure-treated (Table 1). Typically lumber used to assemble glue-laminated members is treated with waterborne preservatives because oilborne treatments (and particularly creosote or heavy oil solvents) can interfere with gluing. Mechanically laminated (nail- or screw-laminated) timbers can be constructed with lumber that was pressure-treated with either oil or waterborne preservatives (Table 10). It is important to note that AWPA standardization procedures do not require submission of data to demonstrate that a type of pressure-treated lumber can successfully be glued. Instead, AWPA standards state that it is the responsibility of the laminator to comply with bonding quality standards.

Table 9—Laminated timbers and columns treated after gluing. Preservatives standardized by AWPA by use category and wood species. Standardized preservatives or retentions may change; refer to current AWPA standards.

Use categories by species	Preservatives standardized by AWPA
Southern Pine	
UC1 through UC3A	Oilborne: IPBC/PER
UC1 through UC3B	Oilborne: Cu8[a]
UC1 through UC4A	Oilborne: CR-PS[a]
UC1 through UC4C	Oilborne: CR[a], CR-S[a], PCP-A,C[a], CuN[a]
Douglas-fir	
UC1 through UC3A	Oilborne: IPBC/PER
UC1 through UC4C	Oilborne: CR[a], CR-S[a], CR-PS[a], PCP-A,C[a], CuN[a] Waterborne: ACZA[b]
Western hemlock, Hem-Fir	
UC1 through UC3A	Oilborne: IPBC/PER
UC1 through UC3B	Oilborne: Cu8[a]
UC1 through UC4A	Oilborne: CR[a], CR-S[a], CR-PS[a], PCP-A,C[a], CuN[a]
Red oak, red maple, yellow-poplar	
UC1 through UC4A	Oilborne: CR[a], CR-S[a], CR-PS[a]

[a]Not for interior residential use.
[b]ACZA allowable uses are limited to specific applications by EPA labeling. Most allowable applications fall into UC3B and above.

Table 10—Laminated timbers and columns, treated before assembly. Preservatives standardized by AWPA by use category and wood species. Standardized preservatives or retentions may change; refer to current AWPA standards.

Use categories by species	Preservatives standardized by AWPA
Southern Pine	
UC1 through UC3A	Waterborne: PTI, KDS-B
UC1 through UC3B	Oilborne: Cu8 Waterborne: KDS
UC1 through UC4A	Oilborne: CR[a,b], CR-S[a,b], CuN[a,b], PCP-A,C[a,b] Waterborne: ACQ-A,C, ACZA[c], CA-C, CCA[c], MCA-C
UC4B, UC4C	None
Douglas-fir, western hemlock, Hem-Fir	Same as Southern Pine except exclude CR-S and MCA-C, add CR-PS

[a]Not for interior residential use.
[b]Oilborne preservatives are typically used for mechanically fastened members rather than glue-lamination.
[c]ACZA and CCA allowable uses are limited to specific applications by EPA labeling. Most allowable applications fall into UC3B and above.

Structural Composites

Parallel strand lumber (PSL) (Fig. 13) and laminated veneer lumber (LVL) have become increasingly used in high-capacity load-bearing applications, some of which require pressure treatment. PSL and LVL have substantially different compositions, and their standardized preservative options differ as well. Numerous preservatives, including both oilborne and waterborne, have been standardized for treatment of PSL (Table 11). In contrast, the only preservatives standardized for treatment of LVL are two creosote formulations (Table 12).

Figure 13. Pressure-treated parallel strand lumber (PSL) beams were used as supports for this trail bridge.

Table 11—Parallel strand lumber. Preservatives standardized by AWPA by use category and wood species. Standardized preservatives or retentions may change; refer to current AWPA standards.

Use categories by species	Preservatives standardized by AWPA
Southern Pine and Douglas-fir	
UC1 through UC4A	Oilborne: CR[a], CR-S[a], CR-PS[a], CuN[a], PCP-A,C[a] Waterborne: ACZA[b], CA-B,C, CCA[b], MCA
Southern Pine and Douglas-fir	
UC4B and UC4C	Same as U/C1 through UC4A except exclude CR-PS for Southern Pine
Yellow-poplar	
UC1 through UC4A	Oilborne: CR[a], CR-S[a], CR-PS[a]

[a]Not for interior residential use.
[b]ACZA and CCA allowable uses are limited to specific applications by EPA labeling. Most allowable applications fall into UC3B and above.

Table 12—Laminated veneer lumber. Preservatives standardized by AWPA by use category and wood species. Standardized preservatives or retentions may change; refer to current AWPA standards.

Use categories by species	Preservatives standardized by AWPA
Southern Pine, red maple, yellow-poplar	
UC1 through UC4C	Oilborne: CR[a], CR-S[a]

[a]Not for interior residential use.

Figure 14. Lumber and plywood used for permanent wood foundations is structurally critical and is treated to meet AWPA Use Category 4B.

Table 13—Permanent wood foundations (UC4B). Preservatives standardized by AWPA for plywood or by wood species for lumber. Standardized preservatives or retentions may change; refer to current AWPA standards.

Wood species	Preservatives standardized by AWPA
Softwood plywood	Waterborne: ACQ-B, ACQ-C, ACQ-D, ACZA, CA-B,C, CCA, MCA, MCA-C
Southern Pine, western hemlock, Hem-Fir	Waterborne: ACQ-B, ACQ-C, ACQ-D, ACZA, CA-B,C, CCA, MCA, MCA-C
Douglas-fir	Waterborne: ACQ-B, ACQ-C, ACQ-D, ACZA, CA-B,C
Ponderosa and red pine	Waterborne: ACQ-B, ACQ-C, ACQ-D, ACZA, CA-B,C, CCA, MCA, MCA-C
Other species	There are other lesser-used species listed for this application. Refer to AWPA standards.

Permanent Wood Foundations

Permanent wood foundations are engineered systems used to support primarily residential and other light-frame structures. They are constructed from pressure-treated plywood and lumber (Fig. 14), but an exterior membrane and gravel drainage system are also considered to be integral parts of the foundation (AWC 2015a) and stainless steel fasteners are recommended. Because of their structural criticality and difficulty of replacement, permanent wood foundations are considered UC4B applications. Currently, only waterborne preservatives are standardized for use in permanent wood foundations (Table 13). EPA labeling currently allows treatment with ACZA and CCA preservatives for this application.

Shakes and Shingles

Wood shakes and shingles are widely used as roofing and siding materials. Often, they are obtained from naturally durable species such as western redcedar, Alaska yellow-cedar, or redwood (Bonura and others 2011) and may be installed without preservative treatment. However, western redcedar shakes and shingles may also be pressure-treated before installation to enhance their durability. In addition, pressure treatment allows use of nondurable Southern Pine species for shakes and shingles. AWPA standards contain a section specific to pressure treatment of shakes and shingles and designate this application as falling within UC3B (Table 14). Currently, only waterborne preservatives are standardized for treatment of shakes and shingles (AWPA 2018).

Table 14—Shakes and shingles (UC3B). Preservatives standardized by AWPA for treatment of shakes and shingles. Standardized preservatives or retentions may change; refer to current AWPA standards.

Wood species	Preservatives standardized by AWPA
Wester redcedar	ACQ-A, ACQ-C, ACQ-D, CA-B, CA-C, CCA, CuN-W, CX-A
Southern Pine	ACQ-A, ACQ-C, ACQ-D, CA-B, CA-C, CCA, CuN-W, CX-A, MCA, MCA-C

Figure 15. Wood immersed or partially immersed in seawater, such as these marine piles, is pressure-treated with increased retentions of chromated copper arsenate, ammoniacal copper zinc arsenate, or creosote to prevent attack by marine borers.

Marine (Seawater) Applications

Seawater presents a unique challenge because of several types of marine borers that either consume wood or attempt to tunnel into it for shelter. These marine borers tend to be more tolerant of wood preservatives than decay fungi or termites, and currently only ACZA, CCA, and creosote are standardized for use in seawater (Fig. 15). Even for those preservatives, higher retentions are needed than for terrestrial or freshwater applications. Because of the unusual hazard, treated wood placed into seawater is placed into a separate use category, UC5. UC5 is further divided into UC5A, B, or C depending on latitude, and the retentions required vary accordingly. Warmer southern waters have a wider variety of marine borers, some of which are more preservative-tolerant. UC5A is for waters approximately north of San Francisco Bay on the west coast and from Long Island northward on the east coast (Fig. 16). UC5B extends south through the remainder of California on the west coast and down to the northern border of Florida on the east coast. Waters off Florida and further south (including Hawaii and Puerto Rico) fall into UC5C. Under severe UC5C conditions, dual treatment (treatment first with CCA or ACZA and then with creosote) may be needed to provide long-term protection. It is important to note that these boundaries are approximate and that marine borer distribution can vary with time. Persons knowledgeable about local marine borer populations should be consulted prior to selecting pressure-treated wood for a project. Preservative retentions for wood used in seawater also vary slightly depending on whether the product is round piles, sawn lumber, or plywood (Tables 15 and 16). Also, members of a structure that are above the typical high tide and subjected to only occasional seawater splash do not require UC5 preservatives or retentions. These elements of the structure can be treated with UC4B if above water or UC4C if in ground contact.

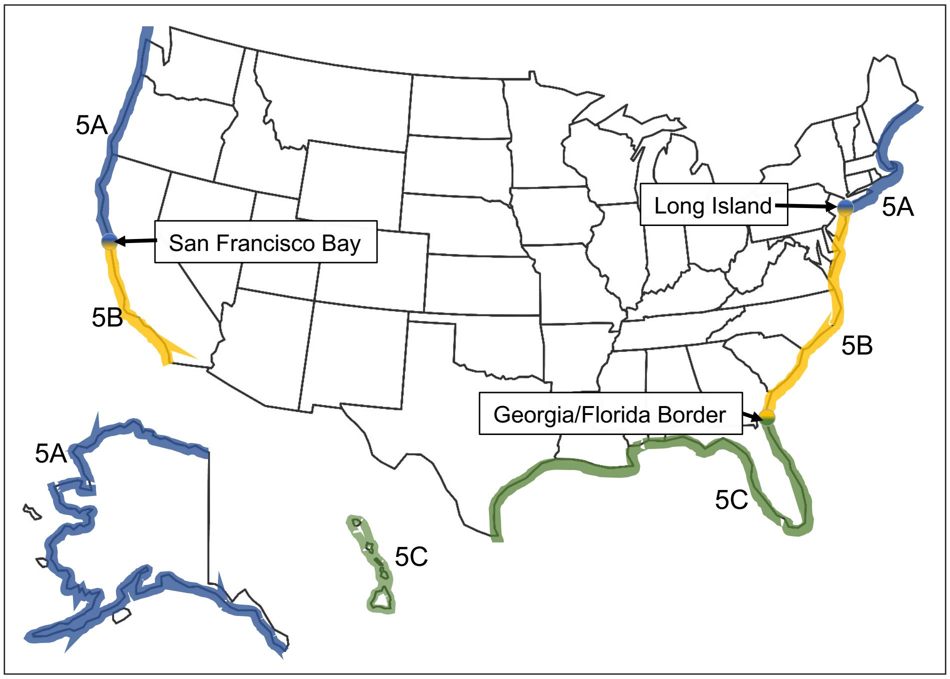

Figure 16. AWPA-designated locations of Use Categories 5A, 5B, and 5C for pressure-treated wood placed into seawater. The designations are based on the type of marine borers present and should be considered approximate because of potential changes in marine borer populations.

Table 15—Sawn lumber, sawn timbers, or plywood used in seawater. Preservatives standardized by AWPA for plywood or by wood species for lumber. Listings are for UC5A, B, and C, but retentions vary by product and use category. Standardized preservatives or retentions may change; refer to current AWPA standards.

Wood species	Preservatives standardized by AWPA
Plywood	Oilborne: CR, CR-S Waterborne: ACZA, CCA
Southern Pine, red pine, ponderosa pine, Douglas-fir	Oilborne: CR, CR-S Waterborne: ACZA, CCA
Western hemlock, Hem-Fir	Oilborne: CR, CR-S Waterborne: ACZA
Oak, black and red gum	Oilborne: CR, CR-S
Dual treatment (lumber or timbers)	
Southern Pine, Douglas-fir, Hem-Fir	ACZA or CCA then CR or CR-S

Table 16—Round piles in seawater. Preservatives standardized by AWPA by wood species. Listings are for UC5A, B, and C, but retentions vary by species and use category. Standardized preservatives or retentions may change; refer to current AWPA standards.

Wood species	Preservatives standardized by AWPA
Southern Pine, red pine, Douglas-fir	Oilborne: CR, CR-S Waterborne: ACZA, CCA
Dual treatment	
Southern Pine, Douglas-fir	ACZA or CCA then CR or CR-S

Table 17—Railway ties. Preservatives standardized by AWPA by wood species grouping. In each case, the preservatives listed are standardized for UC4A, UC4B, and UC4C. Standardized preservatives or retentions may change; refer to current AWPA standards.

Wood species	Preservatives standardized by AWPA
Oak, hickory, and mixed hardwood, Southern Pine, ponderosa pine	Oilborne: CR, CR-S, CR-PS, CuN, PCP-A,C,G, SBX-O Waterborne: ACZA, SBX pretreatment[a]
Douglas-fir (coastal), western hemlock, western larch	Oilborne: CR, CR-S, CR-PS, CuN, PCP-A,C,G Waterborne: ACZA
Douglas-fir (interior)	Oilborne: CR, CR-S, CR-PS, PCP-A,C,G
Jack, red, and lodgepole pine	Oilborne: CR, CR-S, CR-PS Waterborne: ACZA

[a]Must be subsequently pressure-treated with CR, CR-S, CR-PS, or CuN.

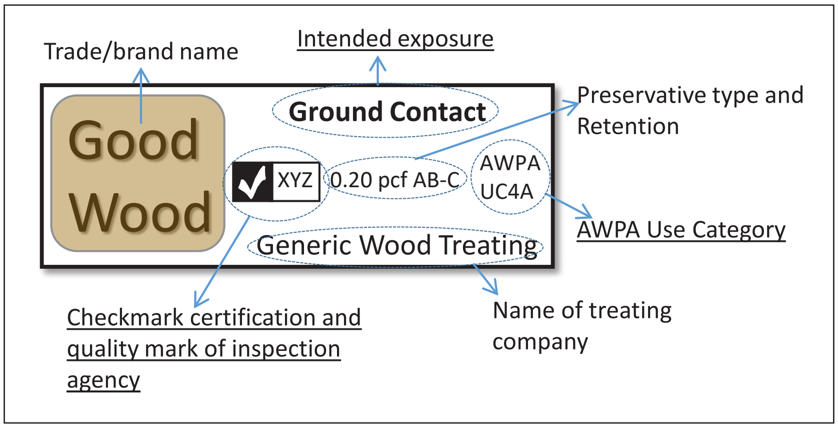

Figure 17. The end tags on pieces of treated wood provide valuable information about the intended end-use, preservative type and retention, and conformance to treatment standards.

Railway Ties

Railway ties were among the earliest wood components to be pressure-treated with wood preservatives. They are different from other pressure-treated commodities because hardwoods are more commonly used than softwoods. Creosote formulations have been the primary preservatives used to treat railway ties for more than a century (Webb and Webb 2016), but other preservatives have been standardized and are now used for these applications (Table 17). Recent developments have been the pretreatment of ties with borate solution prior to pressure treatment with creosote or copper naphthenate or incorporation of boric acid into the creosote formulation. Ties are considered UC4A, B, or C applications, but although retentions vary slightly by species grouping, they do not currently vary by use category.

Interpreting the End Tag

Most pressure-treated wood products sold at retail outlets have an end tag stapled to one end of each piece. The end tag provides valuable information about the intended end-use, type of preservative, and if the wood was treated in accordance with an ALSC-accredited quality assurance program (Fig. 17). The tag will indicate the exposure conditions in which the wood is intended to be used. "Above-ground" or "ground contact" are the most common examples. The checkmark and third-party inspection agency logo is also of great importance because it indicates that the wood was treated in accordance with AWPA standards and an ALSC-accredited third-party inspection program. If the end tag does not include these marks, it is likely that the wood was not produced in full accordance with AWPA standards. The end tag also indicates the type of preservative, use category, and retention of the preservative in the wood. The use category designation is of further value in determining if the wood will be sufficiently durable for the intended end-use. For example, wood treated to both UC4A and UC4B is intended to provide protection for wood placed in contact with the ground, but UC4B provides additional protection for critical ground contact members in locations with a high decay hazard. In many cases, the type of preservative and retention are of lesser importance to the user than the use category, but they are necessary to confirm that the treatment complies with a specification. Although the content on the tag that is required to claim treatment to AWPA standards is standardized, the arrangement of that information on the tag is not (Fig. 17). The layout of the tag varies by producer, and in some cases, content is on the back of the tag.

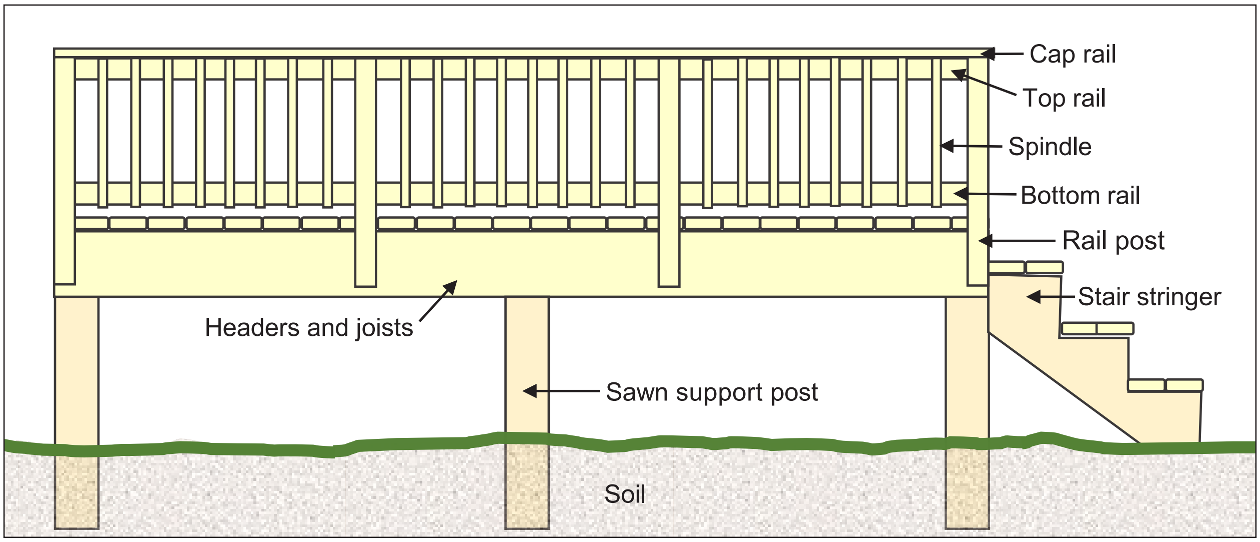

Figure 18. Residential decks are one of the most common applications for pressure-treated sawn lumber and posts. Decking and rail components are often treated to Use Category 3B, whereas headers, joists, and stair stringers may be treated to Use Category 3B or 4A, depending on the situation. Sawn support posts are treated to either Use Category 4A or 4B.

Examples of Selecting Types of Pressure-Treated Wood

This publication provides guidance on selection and use of pressure-treated wood in relation to resistance to biological degradation. It is not intended as a guide for engineering or design of structures. Diagrams are illustrative only.

Residential Decks

One of the most common uses of pressure-treated wood is for construction of residential decks. Although decks vary greatly in construction, typical deck members include support posts, headers, joists, deck boards, rail posts, rails, balusters or spindles, and stairs (Fig. 18). Because low odor and a dry wood surface are important for residential decks, the members are typically treated with waterborne preservatives rather than oilborne preservatives. EPA labeling does not allow use of ACZA- or CCA-treated wood in construction of new residential decks.

Support posts: Deck support posts are structurally critical and typically in direct contact with either the ground or some type of footing. Soil contact creates a high deterioration hazard, and many post footing configurations create conditions that trap moisture, promoting fungal decay and termite attack. Because of these factors, deck support posts fall into UC4A or UC4B, depending on the climate and type of structure. In warm humid climates and for elevated decks, UC4B should be considered. Deck support posts typically are either the 4 by 4 or 6 by 6 dimension with the larger dimension now recommended by the American Wood Council (AWC 2015b). Because these dimensions are primarily used for posts rather than for above-ground supports, they are usually treated for ground-contact use. One possible area of confusion is the 4 by 4 deck railing posts sold at many lumber yards. Deck railing posts are intended for above-ground use and are often only treated to UC3B. However, railing posts are sold in shorter lengths than support posts and typically have some type of notching or decorative detailing. In either case, the end tag will indicate if the post is intended for above-ground or ground-contact applications. Depending on the wood species, standardized preservatives for residential deck support posts are the waterborne preservatives ACQ-B,C,D; CA-B,C; MCA; and MCA-C for UC4A or UC4B applications and ACQ-A, CuN-W, and KDS for UC4A applications (Table 2).

Joists and headers: Deck joists and headers are important structural elements that are typically not in contact with the ground. AWPA standards call for them to be treated to either UC3B or UC4A depending on the situation. The UC4A designation applies when the members are difficult to replace and critical to the performance of the structure. One example is cantilevered joists that extend out from inside the building envelope. UC4A also applies if the specific application involves decay hazard conditions more similar to ground contact. This may occur if the joists or headers are within 6 in. of the ground, airflow is limited, or if accumulation of leaf litter or other organic debris is likely. The UC4A treatment should also be used for all joists and headers for construction in tropical climates. Availability of UC3B versus UC4A joists and headers vary by retailer. Some retailers have transitioned to stocking primarily UC4A treatments for all dimension lumber 1.5 in. thick or larger, whereas others carry both UC3B and UC4A material. It is important with products of these dimensions to check the end tag to confirm that the members are treated to the desired use category. Depending on the wood species, standardized preservatives for residential deck joists and headers are the waterborne preservatives CX-A, EL2, and PTI for UC3B applications and ACQ-A,B,C,D; CA-B,C; CuN-W; KDS; MCA; and MCA-C for UC3b or UC4A applications (Table 2).

Deck boards: Because deck boards are easily replaced and failure of a single member does not compromise the overall structure, they are considered UC3B for most applications, although UC4A may be warranted. Many retailers stock decking products that are uniquely dimensioned (for example, the 5/4 radius edge deck boards) and not easily confused with dimension lumber for structural applications. These specialized decking products are often available as UC3B, although some retailers also stock UC4A deck boards. Conventional "2 by" dimension lumber is also used for decking, and these members may be available as either UC3B, UC4A, or both, depending on the vendor. Use of UC4A deck boards is necessary in tropical climates and is a consideration for any deck built close to the ground (<6 in.) or in situations where accumulation and contact with organic debris is likely. Deck boards are often marketed with colorants and/or an incorporated water-repellent. The colorant does not affect the durability or use category designation, but in some cases, the water-repellent may increase durability and lessen cracking. The benefit of the water-repellent, if any, has been considered in standardization of preservative and the use category designation; therefore, no further increase in decay resistance should be expected when a retailer advertises a product as having an incorporated water-repellent. However, the water-repellent may provide benefit in maintaining the appearance of the deck boards. Depending on the wood species, standardized preservatives for residential deck boards are the waterborne preservatives CX-A, EL2, and PTI for UC3B applications and ACQ-A,B,C,D; CA-B,C; CuN-W; KDS; MCA; and MCA-C for UC3B or UC4A applications (Table 2).

Deck rail posts: Deck rail posts can be purchased from retailers or cut from longer 4 by 4 or 6 by 6 support posts. Deck rail posts sold are often designated as UC3B although some vendors carry rail posts treated to UC4A. In contrast, sawn support posts are UC4A or higher. AWPA standards allow the UC3B designation for deck railing posts, but UC4A rail posts may be warranted for elevated decks or for conditions of high decay hazard, such as tropical climates or applications with limited airflow and where accumulation of leaf litter or other organic material is likely. Depending on the wood species, standardized preservatives for residential deck railing posts are the waterborne preservatives CX-A, EL2, and PTI for UC3B applications and ACQ-A,B,C,D; CA-B,C; CuN-W; KDS; MCA; and MCA-C for UC3B or UC4A applications (Table 2).

Deck rails: Deck rails are considered an above-ground UC3B application, and the machined hand rails that can be purchased from some retailers are typically treated to UC3B. Use of UC4A material may be warranted for elevated decks and for construction in tropical climates. In addition, some retailers only carry UC4A treatments in sawn dimension lumber, and thus UC4A may be the only choice for rails constructed from stock dimension lumber. Depending on the wood species, standardized preservatives for residential deck railing posts are the waterborne preservatives CX-A, EL2, and PTI for UC3B applications and ACQ-A,B,C,D; CA-B,C; CuN-W; KDS; MCA; and MCA-C for UC3B or UC4A applications (Table 2).

Balusters and spindles: Deck railing balusters and spindles are of unique dimensions that serve a specialized purpose. They are easily replaced, their small dimensions lessen moisture retention, and failure of single member is unlikely to affect the integrity of the structure. Because of these factors and the low risk of confusion with other members, they are typically designated UC3B and may not be readily available as UC4A. If a UC4A treatment is warranted (such as in tropical climates), it may be necessary to special order or use 2 by 4 material for the spindles or balusters. Depending on the wood species, standardized preservatives for balusters and spindles are the waterborne preservatives ACQ-A,B,C,D; CA-B,C; CuN-W; CX-A; EL2; KDS; MCA; MCA-C; and PTI. (Table 2).

Residential Fences

Backyard fences, such as those built for privacy or pet containment, are another very common use for pressure-treated wood. Unlike many other uses of treated wood, residential fences are not structurally critical and are also not especially difficult to replace. Still, they are important to the homeowner, who expects some level of durability.

Fence posts: Residential fences typically use sawn posts of the 4 by 4 dimension, although the 6 by 6 dimension is also sometimes used, especially for gate or corner posts. Because fence posts are in contact with the ground but not structurally critical, it is considered acceptable to use posts meeting UC4A in most situations (Fig. 19). This is true regardless of whether they are set in concrete, soil, or gravel. However, UC4B should be considered for tropical climates or in other locations with a high deterioration hazard. Retailers commonly stock sawn posts treated to either UC4A or UC4B, which will be shown on the end tag. Depending on the wood species, standardized preservatives for sawn residential fence posts are the waterborne preservatives ACQ-B,C,D; CA-B,C; CuN-W; MCA; and MCA-C for UC4A or UC4B applications and ACQ-A and KDS for UC4A applications (Table 2). Preservatives standardized for treatment of round fence posts can be found in Table 4.

Fence rails: The selection of the use category for fence rails depends on how the fence is constructed. Durability of the fence will be greater if space is left between the

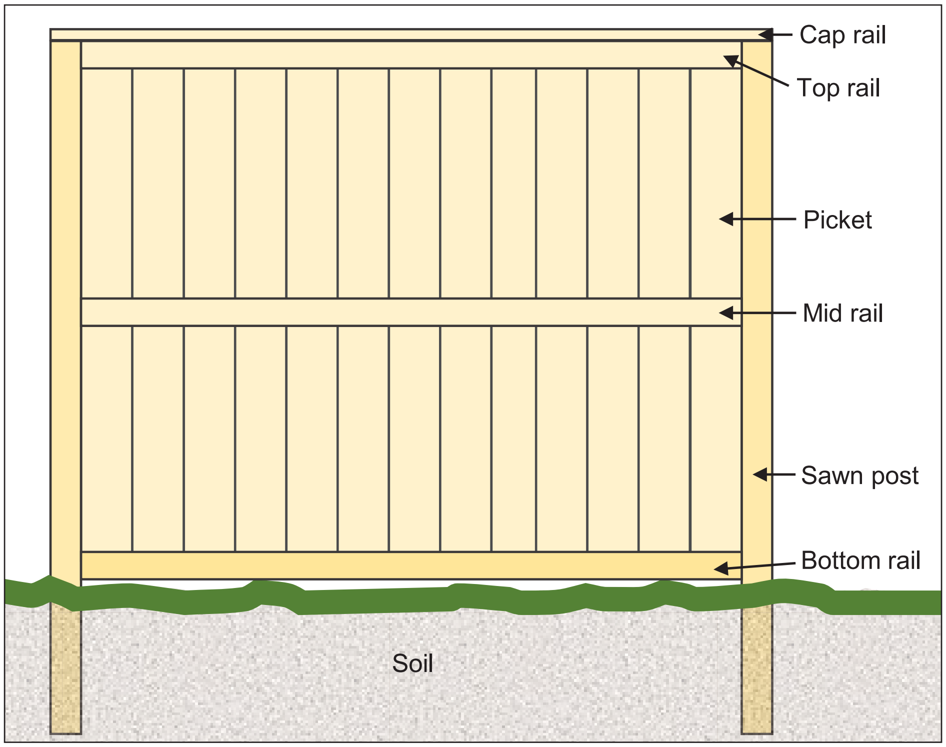

Figure 19. Posts used to construct a privacy fence should be treated to AWPA Use Category 4A or 4B, whereas other components can be treated to Use Category 3B or 4A.

bottom rail and the ground. If the bottom rail is in contact with the ground or very close to the ground, it is likely that soil or build-up of organic debris will create a decay hazard similar to soil contact. In this case, the bottom rail should be treated to UC4A, whereas UC3B is sufficient for the other rails. The exception is tropical climates where UC4A may be necessary for all of the rails. If pre-assembled rail and picket panels are purchased, it may be difficult to determine the use category of the bottom rail. In this case, it is especially important to leave clearance between the bottom rail and the ground. Depending on the wood species, standardized preservatives for residential deck railing posts are the waterborne preservatives CX-A, EL2, and PTI for UC3B applications and ACQ-A,B,C,D; CA-B,C; CuN-W; KDS; MCA; and MCA-C for UC3B or UC4A applications (Table 2).

Fence pickets: The fence picket boards are the least structurally important and most easily replaced members of the fence and are typically not exposed to ground contact. As such, they are considered a UC3B application and may only be available as UC3B from many retailers. UC3A may also be considered acceptable if sold with a durable protective coating. In some cases, retailers stock pickets that are not treated to AWPA standards because they are so readily replaced. The above-ground treatment typically used for pickets can create an area of vulnerability if the bottom rail is placed close to the ground or if the bottoms of the pickets are extended below the bottom rail to near the ground level. In addition to the increased risk of decay, moisture wicking up into the bottom of the pickets can shorten the longevity of finishes applied to the wood. Depending on the wood species, standardized preservatives for pickets are the waterborne preservatives ACQ-A,B,C,D; CA-B,C; CuN-W; CX-A; EL2; KDS; MCA; MCA-C; and PTI (Table 2).

Highway Bridges

A wide range of pressure-treated wood products are used in highway construction, but perhaps one of the most important applications is timber bridges. It is estimated that more than 50,000 timber highway bridges are currently in use across the United States (Wacker and Brashaw 2017). Because highway bridges are structurally critical, most components are treated to UC4C. This includes both round and sawn support piles, stringers, abutment materials, and deck components. An exception is the rail posts and rails, which are typically treated to UC4A or even UC3B. Unless constructed with separate walkways or fishing areas, most timber bridges are expected to have relatively little pedestrian use, and preservatives carried in heavy oil can be used. EPA labeling also allows CCA and ACZA to be used for round timber piles and for other highway bridge components. If frequent pedestrian use or fishing activities are anticipated, waterborne preservatives should be considered for bridge rail components. Figure 20 provides an example of a timber highway bridge with a

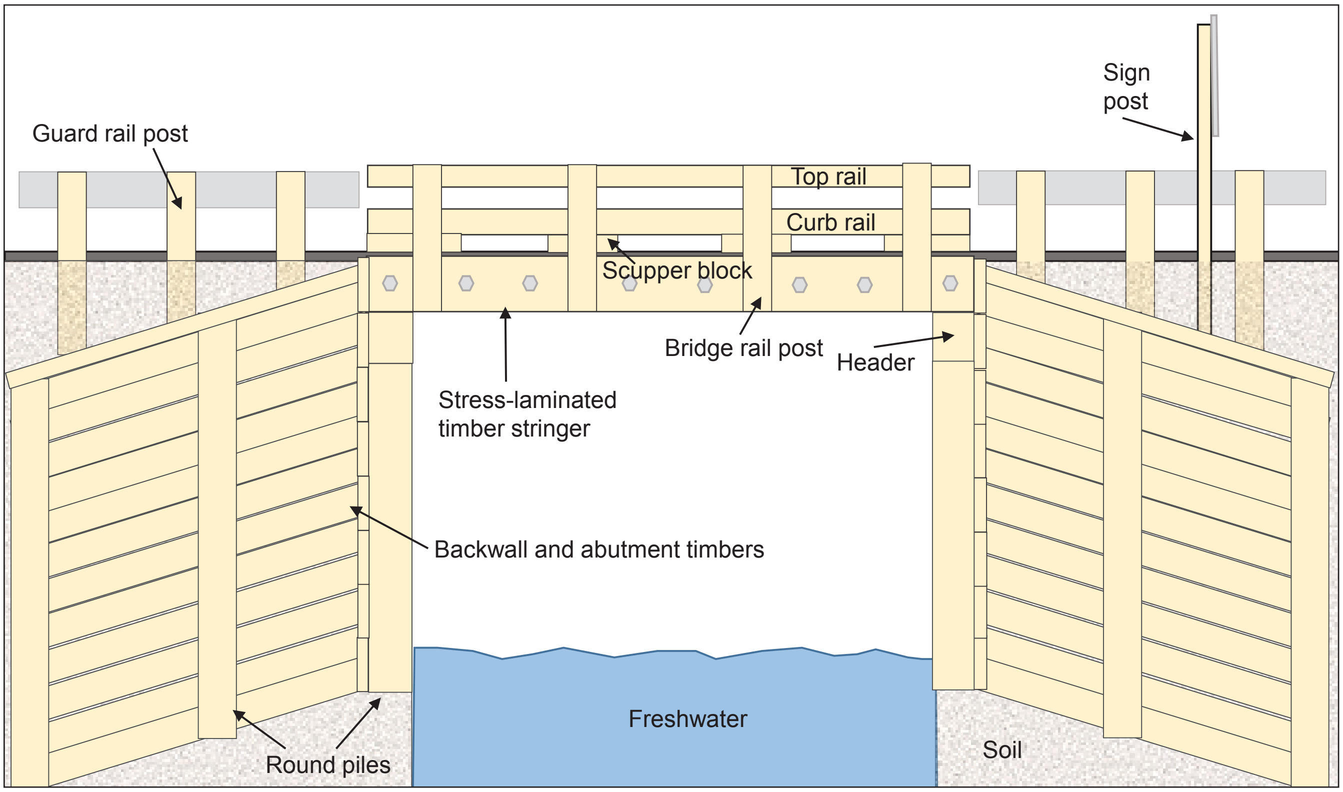

Figure 20. Pressure-treated wood components supporting a highway bridge are considered to be structurally critical and most are pressure-treated to meet AWPA Use Category 4C.

stress-laminated timber deck supported by round piles. Depending on the wood species, the standardized UC4C preservative options for round timber piles are the oilborne preservatives CR, CR-S, CR-PS, CuN, and PCP-A,C and the waterborne preservatives ACQ-C, ACZA, CCA, MCA, and CA-B,C (Table 7). The headers, abutment timbers, and bulkhead timbers are also specified as UC4C and the standardized preservatives (depending on the wood species) are the oilborne preservatives CR, CR-S, CR-PS, CuN, and PCP-A,C and the waterborne preservatives ACQ-B,C; ACZA; CA-B,C; CCA; MCA; and MCA-C (Table 3). If an engineer or specifier does not have a preservative preference, it is sufficient to specify that the piles be treated in accordance with AWPA Standard U1 Commodity Specification E and that lumber and timbers be treated to AWPA Standard U1 Commodity Specification A Section 4.3 (AWPA 2018).

Standards do not require the rail components of a highway bridge to be treated to UC4C. Although treatment of highway bridge rail posts is not separately specified in AWPA standards, the application would appear to warrant treatment to at least UC4B given the structural importance. Although the rail posts are above ground, their critical nature and the tendency for gravel and soil to accumulate at the edges of the bridge increases risk. Similar logic would apply to the curb rail and blocks. The top rail would be considered a UC3B application in terms of decay hazard, but at least UC4A is warranted because of the structural importance.

Trail Bridge with Glue-Laminated Stringers

Pressure-treated wood is a commonly used construction material for trail bridges, elevated walkways, and boardwalks. Wood's relatively light weight and ease of construction make it especially well-suited for difficult-to-access trail locations. In many cases, the use categories and preservative option for trail structures are similar to those of residential structures. However, trail bridges in remote areas may be difficult to access and replace, and this may warrant consideration of higher use category levels. There are also some differences in the types of wood products used, especially for the longer stringers sometimes used in trail bridges. In the example shown in Figure 21, the bridge deck is supported by glue-laminated stringers, which in some cases can allow for longer spans than solid sawn timbers. Although a glue-laminated stringer used in a trail bridge is primarily above the ground or water, conditions that favor moisture retention often occur when the stringer rests on the sills and makes contact with the back wall planks. The stringer is also structurally critical and, because of these factors, should be considered as UC4A or 4B, depending on the climate, risks associated with failure, and difficulty of replacement.

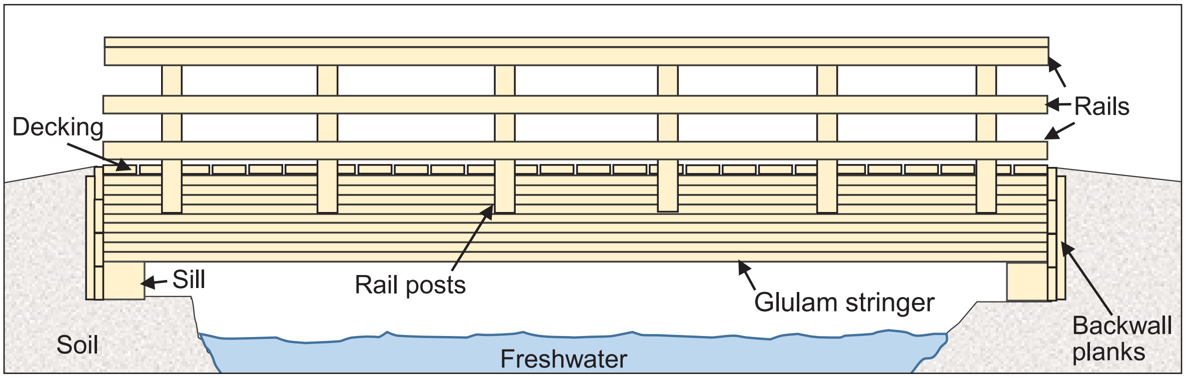

Figure 21. Pressure-treatment options for glulam beams, such as those used to support a trail bridge, differ somewhat from solid-sawn members.

Glue-laminated timbers can be constructed from lumber that was previously pressure-treated with a waterborne preservative or pressure-treated after gluing, typically with an oilborne preservative. When treated before gluing, the highest AWPA use category is currently UC4A, whereas timbers treated after gluing can also meet UC4B and UC4C. The UC4A waterborne preservatives standardized for treatment before gluing are ACQ-A,C; ACZA; CA-C; CCA; and MCA-C, depending on the wood species. Note that ACZA and CCA are allowed for the laminated timber portion of a trail bridge but not for the rail components. The glue-laminated stringer of a trail bridge is unlikely to have frequent human hand contact, and thus oilborne preservatives are an option. The oilborne preservatives standardized for UC4B treatment of glue-laminated timbers (after gluing) are CR; CR-S; PCP-A,C; and CuN, depending on the species. This list expands to CR-PS for UC4A applications (Table 9). The waterborne preservative ACZA is also standardized for UC4A and UC4B treatment after gluing but only with Douglas-fir.

The sill and back wall components of the example trail bridge shown in Figure 21 are in direct contact with the ground and therefore should be considered UC4A or UC4B, depending on the severity of the decay hazard at the location. As with the glue-laminated stringer, the sill and back wall components are not likely to have frequent hand contact and thus can be treated with either waterborne or oilborne preservatives. There is no AWPA standard specific to trail bridges. Therefore, the applicable standards are those that cover general sawn products (Table 2). Depending on the wood species, the AWPA standardized UC4B preservatives for this application are the oilborne preservatives CR, CR-S, CR-PS, CuN, and PCP-A,C and the waterborne preservatives ACQ-B,C,D; CA-B,C; MCA; and MCA-C. For UC4A applications, the standardized preservatives also include oilborne DCOI-A and waterborne ACQ-A, CuN-W, and KDS. CCA and ACZA (depending on the species) can also be used for sill treatment (both UC4A and UC4B) if that member is greater than 5 in. thick.

Decking for a trail bridge presents slightly different conditions than that used in residential decking. Trail bridge decking is susceptible to repeated wear within a confined path and often 2 by lumber or thicker is used rather than the 5/4 radius edge decking that is often used in residential decks. In addition, the approaches on each end of a trail bridge are more vulnerable to accumulation of gravel or soil from the adjacent trail, thus creating more severe decay conditions. Because of these considerations, trail bridge decking is often considered a UC4A application, although UC3B is an option in situations with low decay hazard and low safety risk associated with failure. In some cases, dimension lumber may only be available treated for UC4A or higher. Depending on the wood species, standardized preservatives for trail bridge decking are the waterborne preservatives CX-A, EL2, and PTI for UC3B applications and ACQ-A,B,C,D; CA-B,C; CuN-W; KDS; MCA; and MCA-C for UC3B or UC4A applications (Table 2). Oilborne preservatives can also be used. Heavy oil treatments with CuN or PCP may result in some odor and some oil visible on the surface during initial rainfall events but may also lessen checking. Light solvent treatments are also sometimes used for trail bridge decking.

The trail bridge rail components would be considered UC3B or UC4A, depending on the circumstances. For the rail posts, UC4A should be considered because of their structural importance and because dirt and organic debris often accumulate on the edges of the bridge, especially near the bridge ends. The rail components would typically be considered UC3B except in areas of high decay hazard. Hand contact is likely to occur with rail components, and treatment with preservatives in heavy oil is less common. However, light solvent treatments with CuN or PCP are sometimes used for UC3B or UC4A rail components, and light solvent Cu8 treatment is also standardized for UC3B rail members. Depending on the wood species, waterborne preservatives standardized for UC4A trail bridge rail components are CX-A, EL2, and PTI for UC3B applications and ACQ-A,B,C,D; CA-B,C; CuN-W; KDS; MCA; and MCA-C for UC3B or UC4A applications (Table 2).

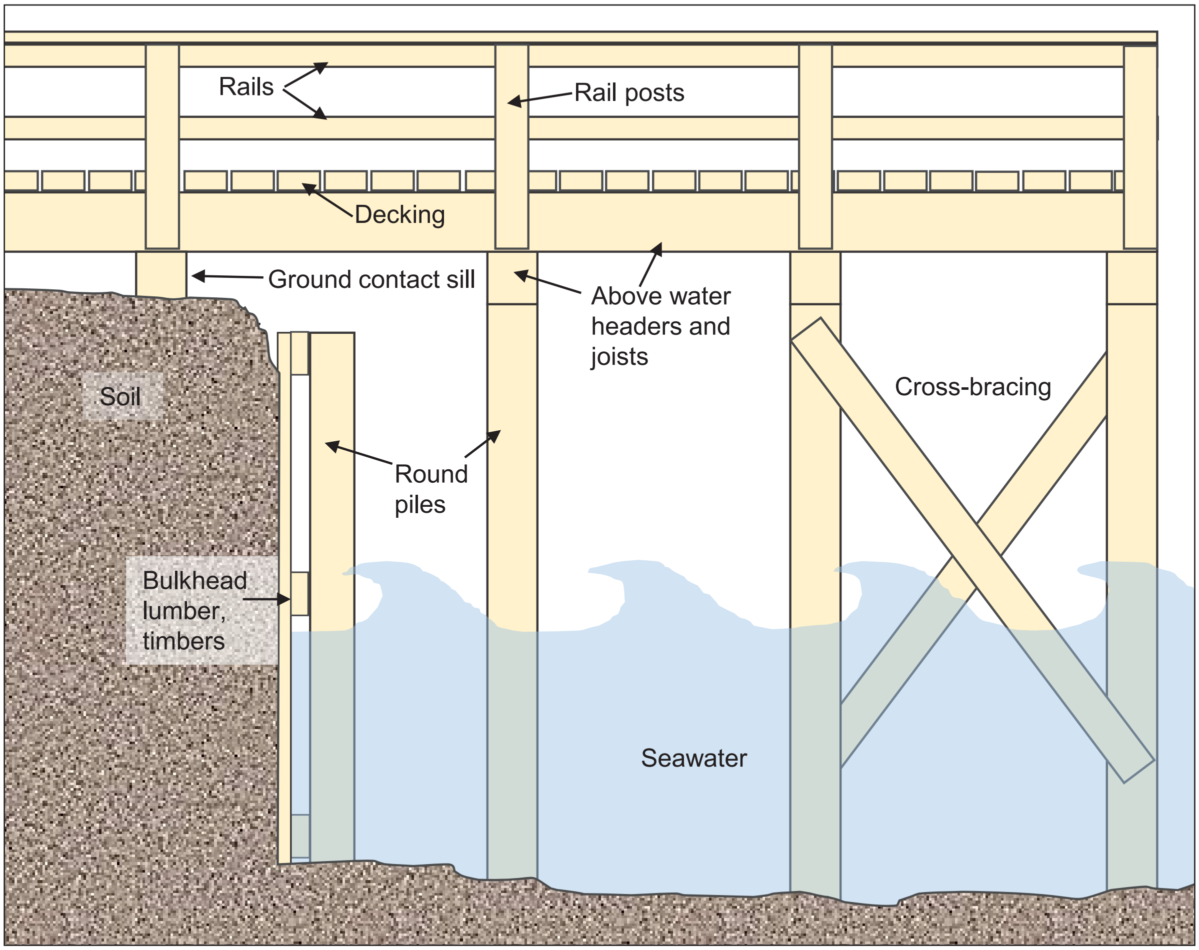

Figure 22. Pressure-treated wood partially or fully immersed in seawater requires different treatment compared with the treated wood used above the water.

Marine Dock, Pier, or Wharf

Structures placed into seawater require special consideration for treatment. Portions of the structure that are routinely immersed are susceptible to marine borer activity and thus are considered UC5. This includes not only the piles but also any lumber, timbers, or wood composites that are partially immersed. In the example shown in Figure 22, all round piles and sawn lumber or timbers used in the cross-bracing and bulkhead would be considered UC5. Currently, only creosote, CCA, and ACZA are standardized for treatment of wood immersed in seawater (Tables 14 and 15), and the required retentions of those preservatives vary depending on geographic location. Portions of the structure that are not routinely immersed but are subject to saltwater splash are considered either UC4B or UC4C. The UC4B designation applies to members above the water and not in contact with the ground, such as the joists and headers, decking, and rail components shown in Figure 22. If a member is both in contact with the ground and subject to salt water splash, as is the case for the sill shown in Figure 22, it is designated as UC4C. The preservatives standardized for lumber and timbers treated for UC4B and UC4C (depending on the wood species) are the oilborne preservatives CR, CR-S, CR-PS, CuN, and PCP-A,C and the waterborne preservatives ACQ-B,C,D; ACZA; CA-B,C; CCA; MCA; and MCA-C (Table 2). However, above-water use of CCA- and ACZA-treated lumber and timbers in marine structures is limited by EPA labeling to dimensions that are 2 by 8 and larger or greater than 3 in. thick. Use of waterborne preservatives for decking and rail components may be advisable if the structure is intended for public use, whereas both waterborne and oilborne preservatives are options for industrial-use structures.

Construction Practices that Influence Longevity

Decay and Insect Resistance

There are at least three primary areas where construction practices can influence durability of a structure constructed from pressure-treated wood. The first is ensuring that the end-use matches the use category (more specifically, avoiding use of material treated for UC3B applications

Figure 23. Gradual accumulation of dirt and other organic debris can create a ground contact decay hazard in portions of a structure that were originally above ground.

in conditions that create a decay hazard similar to ground contact). This can happen simply by mistake if material of similar dimensions but different use categories is present at a job site. But perhaps a more common occurrence is underestimation of the decay hazard or assuming that UC3B is sufficient if most of a member is used above ground. Construction that places members treated to UC3B close to the ground (less than 6 in.) or in areas where organic debris will accumulate can also expose those members to a greater deterioration hazard than anticipated (Fig. 23).

Another concern is the extent to which the structure design affects moisture trapping and organic debris accumulation, particularly in the above-ground portion of the structure. Fungal decay above ground is dependent on the presence of sufficient moisture, and the risk of decay is greater when construction details cause portions of the structure to decrease air circulation and hold moisture. Moisture trapping can occur with many types of wood on wood connections and is difficult to avoid. However, some moisture trapping scenarios occur because wood is added primarily for aesthetic purposes. One example in residential deck construction is covering the ends of deck boards with a decorative skirt or fascia board (Fig. 24). This construction method allows leaf litter to accumulate against the ends of the deck boards where moisture is readily wicked into the end-grain. The problem can be exacerbated because the outer ends of deck boards are often trimmed to uniform length after installation, potentially exposing inadequately treated wood in the center of the deck boards. Installation of an under-deck roof (or ceiling) on an elevated deck can also contribute to decay by preventing drying and allowing leaf litter to accumulate against the deck joists.

Figure 24. A deck construction design that covers the cut ends of the deck boards with a decorative skirt or fascia board. This practice allows organic debris to accumulate and trap moisture, which can increase the decay hazard and shorten the life of the structure.

A third construction consideration than can affect durability is the exposure of untreated wood during on-site fabrication. Pressure treatment forces preservative deeply into the wood, but often the center of a member has poorly treated wood. This is particularly the case for larger dimensions, for members that include heartwood, and for thin sapwood species, such as Douglas-fir. When these members are cut to length or bored, untreated wood can be exposed (Fig. 25). For designed and custom pressure-treatment orders, such as timber bridges, this potential problem should be minimized by completing as much of the necessary cutting as possible

Figure 25. Sawn posts may contain poorly treated heartwood that is exposed if the post is cut to height after installation. If cutting to height is necessary, the exposed top should be coated with a field treatment preservative such as copper naphthenate.

prior to pressure treatment. However, when structures are built with stock pressure-treated material available from retail vendors, it is much more difficult to avoid cutting, which might result in exposure of untreated wood. To lessen the risk of decay development, all cuts, holes, or injuries that may have penetrated through the treated zone should be brushed or sprayed with field treatment preservative. Preservatives currently listed for this use by AWPA are copper naphthenate containing 1% or 2% elemental copper or an oilborne solution containing at least 0.675% oxine copper (copper-8-quinolinolate). Borate solutions can also be used for field treatment of wood used in indoor (UC1 or UC2) applications. Manufacturers may have recommendations on field treatments most suitable for specific pressure-treating preservatives.

Fastener Selection

Corrosion of metal fasteners is a concern for any type of structure exposed to moisture, and pressure-treated wood structures are no exception. In addition, some waterborne preservatives containing copper have the potential to increase the rate of fastener corrosion compared with that of fastener corrosion in untreated wood. In contrast, treatments with creosote or oilborne preservative have the potential to lessen fastener corrosion. However, protection is required because corrosion is always possible when moisture is present. Building codes require use of stainless steel, hot dip galvanized, bronze, or copper fasteners in most instances (ICC 2018). Preservative suppliers may have additional recommendations specific to the preservative formulation. Fastener protection is especially important for joist hangers, bolts, lag screws, and other components used in structurally critical supports. Zelinka (2013a, 2013b) provides a more detailed discussion of fastener protection in pressure-treated wood.

Environmental Considerations

All common outdoor construction materials, including concrete, steel, pressure-treated wood, and even some species of untreated wood, contain compounds that are potentially toxic to aquatic organisms (Lalonde and others 2011). However, impact is not expected unless the environmental concentrations of the compounds reach levels of concern for the organisms(s) present. In the case of pressure-treated wood, concerns sometimes arise that preservative may leach from the wood and impact sensitive organisms, particularly when used in aquatic environments. This type of concern is initially evaluated by the EPA before a wood preservative can be marketed. As part of the registration process, the EPA develops risk assessments that evaluate the potential for harm to humans, wildlife, fish, and plants, including endangered species and nontarget organisms (EPA 2018). Potential environmental impact has also been the subject of extensive research over the past two decades, including several studies conducted or funded by the U.S. Forest Service (Brooks 2000, 2011a, 2011b, 2011c, 2011d; Lebow and others 2000, 2004; Lebow and Foster 2010; Morrell and others 2003, 2011; Townsend and Solo-Gabriele 2006). These studies of the environmental impact of treated wood reveal several key points. All types of treated wood evaluated release small amounts of preservative components into the environment. These components can be detected in soil or sediment samples. Shortly after construction, elevated levels of preservative components sometimes can be detected in the water column. Detectable increases in soil and sediment concentrations of preservative components generally are limited to areas close to the structure. The leached preservative components either have low water solubility or react with components of the soil or sediment, limiting their mobility and limiting the range of environmental contamination. The levels of these components in the soil immediately adjacent to treated structures can increase gradually over the years, whereas levels in sediments tend to decline with time (Fig. 26). Research on existing structures indicates that environmental releases from treated wood rarely cause measurable impacts on the abundance or diversity of aquatic invertebrates adjacent to the structures (Brooks 2000). In most cases, levels of preservative components were below concentrations that might be expected to affect aquatic life. Samples with elevated levels of preservative components tended to be limited to fine sediments beneath stagnant or slow-moving water in which the invertebrate community is somewhat tolerant of pollutants (Brooks 2000, 2011b).

Figure 26. This wetland boardwalk in Oregon was part of a study to evaluate the leaching and aquatic impacts of treated wood used in sensitive environments.

Minimizing the potential for environmental impacts of future treated-wood structures has also been the subject of research. The expected environmental concentration of preservative associated with use of pressure-treated wood has been found to be dependent on factors such as type of preservative, volume of wood used, amount of precipitation, and volume and flow rate of the receiving water body (Brooks 2011d). Toxicity at a given environmental concentration varies depending on the form or biological availability of the pesticide component. For carbon-based preservative components, environmental concentrations are also dependent on rate of pesticide decomposition in the environment. Comprehensive reviews of preservative-treated wood impacts have indicated that environmental pesticide concentrations from most treated-wood structures are unlikely to reach levels of concern (NOAA Fisheries 2009, Stratus Consulting 2006, Brooks 2011b) but that risks may be greater with large structures constructed in stagnant water.

Environmental Assessment Modeling Tool

A large research effort was undertaken to characterize the extent of pesticide release from most types of preservative-treated wood and to develop models for assessment of potential environmental impacts (Brooks 2011c, 2011d). The model uses site-specific inputs for physical, biological, and chemical conditions, as well as project design characteristics. Potential effects are then calculated based on pesticide leaching rates, biological effects, and environmental fate, as well as water quality standards and benchmarks for the chemicals of concern. Subsequently, Oregon State University and the Western Wood Preservers Institute (WWPI) cooperated to produce a web-based version of the model that project designers and regulators can use to evaluate potential impacts of projects (WWPI 2018a). Use of this tool is suggested for proposed projects involving large volumes of preservative-treated wood placed in or above slow-moving water.

Best Management Practices for Aquatic Environments

The potential for wood preservative components to leach or move out of pressure-treated wood and into the environment can be influenced to some extent by processing conditions and construction practices. Industry associations, the AWPA, and government agencies have developed best management practices (BMPs) and/or guidance documents to minimize environmental releases (AWPA 2018, Pilon 2002, Lebow and Tippie 2001, WWPI 2011).

Best Management Practices during Production

The WWPI and other industry groups have cooperated to produce the most comprehensive BMPs for production of treated wood (WWPI 2011). These BMPs prescribe treating procedures and, in some cases, testing that can be used to minimize potential environmental releases for treated wood intended for aquatic environments. Following the BMP treatment procedures is the responsibility of the producer, and it is not necessary that the specifier understand these procedures in detail. However, it is important that the specifier request these BMP procedures when pressure-treated wood is intended for use in sensitive environments. The WWPI has produced a supplemental specifier's guide to the BMPs to assist in its implementation (WWPI 2018b). The specifier's guide stresses three main points for specification:

- That the wood be treated in accordance with AWPA standards (the BMPs do not replace AWPA standards, they are additional requirements).
- That the wood be produced in accordance with the most recent version of the BMPs.
- That BMP compliance be subject to third-party inspection.

The specifier and contractor can also have a role in the production process beyond specifying BMPs. Although treatment processes may seem to be solely the responsibility of the treater, they are also influenced by the specifications and demands of the specifier and contractor. Specifying prefabrication prior to pressure treatment may help to lessen environmental releases and does increase the long-term durability of a structure. Whenever possible, it is desirable to cut wooden members to length and perform boring and other machining processes prior to treatment. Durability is enhanced because fewer field cuts, which often break the treated shell and expose untreated wood, are required. Decreasing the amount of field fabrication also helps to prevent the discharge of treated sawdust, drill shavings, and other construction debris into the environment at the construction site. It also minimizes the need for treatment of these field cuts with a topical wood preservative at the construction site. Admittedly, the exact dimensions of members and location of connectors is not always known, but in many cases, it is possible to perform prefabrication. Decking and rail posts are examples of members that can often be cut and/or bored prior to treatment.

One pitfall to avoid is specifying excessive treatment retentions. Asking the treater to increase the retention based on the "more is better" theory needlessly increases the amount of leachable chemical in the wood without providing a durability benefit. It is rarely good practice to ask for a retention higher than those specified in wood treatment standards. Typically, increasing the retention by one use category level is sufficient to account for any uncertainty in the severity of the exposure hazard.

It is also important to allow time for the producer to implement BMPs. If the contractor demands the treated product on very short notice, the treater may be forced to rush or delete processing steps that improve the final product. This includes adequate drying or otherwise conditioning the nonseasoned wood prior to pressure treatment. These conditioning steps (air seasoning, kiln-drying, and steam conditioning) prior to treatment are important because they help maximize preservative penetration, ensure specified retention levels are achievable, and kill any resident fungi and termites that might already be present in the wood.

Best Management Practices during Construction

Construction site practices that can influence environmental releases include rejection of improperly treated material, on-site storage considerations, collection of construction debris, and application of in-place preservative treatments. Pressure-treated wood that arrives on the job site oozing preservative or with excessive surface residue should be rejected. It is not normal or typical for preservative to be dripping from the treated wood, and this is an indication that the BMPs were not properly implemented. However, moisture alone is not necessarily a concern for wood pressure-treated with waterborne preservatives because the chemical reactions that bind the preservative components in the wood do not require drying.

Treated material that is shipped to the job site should be stored in an area free from standing water or wet soil. Ideally, it should be covered but with adequate ventilation until used. Difficulties are sometimes encountered in construction of wetland boardwalks; therefore, it may be most convenient to divide the material and store smaller quantities at intervals along the intended path of construction. In this case, it is desirable to place untreated bunks into the wetland and then place the treated material on these bunks. Again, the stacks of treated wood should be covered to protect them from precipitation.

As previously discussed, the amount of field cutting and drilling of treated wood should be minimized by careful prefabrication before treatment. Unfortunately, this is not always practical for some members, and some degree of fabrication is usually necessary during construction. However, if sawdust and shavings generated during construction are allowed to enter a sensitive environment below a treated wood structure, they make a disproportionately large contribution to the overall releases from that structure. Because of their greater surface area to volume ratio, the proportional release from small wood particles such as sawdust is greater than that from the treated wood itself.

There are many approaches to ensuring the debris from field fabrication is not discharged into the environment. Tarps are commonly used to contain construction debris in a variety of ways. The large surface area of tarps makes them ideal for collecting sawdust from circular saws and chainsaws. Often, a single cutting station is set up over a large tarp, and pieces to be cut or drilled are carried to the tarp for fabrication. Ideally, this cutting station should be placed over soil, not water. If the member to be cut is already incorporated into the structure, tarps may be spread under that part of the structure before cutting. The use of tarps to contain sawdust becomes more difficult in windy or rainy conditions. Shavings from drilling holes are generally easier to contain in a small area than sawdust. Plastic tubs are useful collection devices when drilling holes on site. Regardless of the method used, it is inevitable that collection and disposal of construction debris will add some time and expense to a construction project. The importance of collection should be stressed in planning and budgeting for the project so that the construction crew is clear that debris collection is an integral part of the project.

It is important that any untreated wood that is exposed during field fabrication be treated to prevent decay. However, as with the treated wood itself, these field treatment preservatives contain ingredients that could be toxic to aquatic organisms if they are released into the environment in sufficiently high concentrations. Accordingly, field treatment preservatives should be applied sparingly and with care to avoid spillage. The use of field treatment preservatives is best limited through prefabrication of the treated wood, which decreases the need for field cutting and drilling. When field treatment preservative is needed, care in application should be stressed. Whenever possible, the field treatment should be applied to the member before it is placed in a structure over water. Excess preservative should be wiped from the wood. If the preservative must be applied to wood above water, a tray, bucket, pan, or other collection device should be used to contain spills and drips. Field treatments should not be applied in the rain to wood that is above water. Materials treated with field preservatives should not be placed directly into water unless the treated surface has dried and is free of excess preservative. AWPA Standard M4, Standard for the Care of Preservative-Treated Wood Products (AWPA 2018) gives requirements for field treatment and should be specified for construction projects in or over aquatic environments.

Service Life Expectations

"How long will it last?" is a common question about pressure-treated wood. There is not one answer to this question because durability of treated wood depends on several factors, some of which are specific to a particular application and location. It appears that in many cases specifiers or engineers may underestimate the longevity of pressure-treated wood. In the case of utility poles, analysis of replacement rate data indicates that the average service life of poles is much greater than perceived by utility personnel. One survey found that utility personnel reported an average perceived pole service life of only 33 years, whereas the replacement rate data indicated a service life of more than 75 years (Stewart 1996). Another researcher noted that, based on reported replacement rates, pole service life would easily reach 80 years in many parts of the United States (Morrell 2008). Australian researchers conducted a statistical analysis of utility pole service life data and concluded that the expected service life of the poles would be in the range of 80 to 95 years (Mackisack and Stillman 1996). A similar tendency to underestimate the durability of treated wood structures has been reported for timber bridges, for which the perceived longevity is 25 to 35 years despite numerous examples of bridges with 60- or 70-year service records (Wacker and Brashaw 2017).

A report on the durability of pressure-treated round posts exposed for 50 years in southern Mississippi also supports the long-term durability of pressure-treated wood (Lebow and others 2015). No failures occurred in any of the 125 posts treated with CCA or in any of the 75 posts treated with pentachlorophenol. Three of 25 posts treated with ACA (a precursor to ACZA) and five of 25 creosote-treated posts failed during the 50 years. Estimated times to 50% failure in the ACA and creosote-treated posts were calculated as 96 and 78 years, respectively. The estimated years to failure for the CCA- and pentachlorophenol-treated posts could not be calculated but would be greater than that calculated for ACA and creosote because of the current lack of failures. The long-term durability of the posts is notable considering that the exposure site presents a severe biodeterioration hazard.

There is relatively little data on the service life of pressure-treated wood used in residential construction, such as back yard decks. This is due to the lack of a centralized mechanism for collecting this type of data and because residential decks are often replaced for cosmetic reasons rather than failure from decay or insect attack (Smith and others 2006, McQueen and Stevens 1998). One study reported that the average age of a deck at its removal is 9 years (McQueen and Stevens 1998). In contrast, tests conducted with 2 by 4 sections placed into the ground indicate that pressure-treated lumber can potentially last in excess of 60 years (Fig. 27).

The longevity of pressure-treated structures can be increased by

- purchasing lumber that has been treated in accordance with AWPA standards,
- selecting the appropriate use category for the application (e.g., do not use wood treated for above-ground use if it will be in contact with the ground),
- using designs that minimize water trapping, and
- treating cut ends and bolt holes that expose untreated wood with preservative.

Figure 27. This pressure-treated 2 by 4 lumber specimen has remained in good condition for more than 60 years of exposure at the USDA Forest Service, Forest Products Laboratory test site in southern Mississippi.

Reuse and Disposal

Although preservative-treated wood is a durable construction material, it is eventually removed from service. The fate of treated wood removed from service varies depending on the original application and the type of preservative used. As with many materials, reuse of treated wood in a manner similar to that originally intended may be a viable alternative to disposal. In many situations, treated wood removed from its original application retains sufficient durability and structural integrity to be reused in a similar application (Clausen and Lebow 2011). Numerous other methods of recycling used treated wood have been proposed, and some have been shown to be technically feasible (Clausen and Lebow 2011, Smith and others 2006). However, most have economic or other barriers that have prevented widespread use. One alternative option to recycling is a current commercial practice that involves combustion of creosote- or copper-naphthenate-treated railroad ties for energy production.

Treated wood is not listed as hazardous waste under federal law, and it can be disposed of in any waste management facility authorized under state and local law to manage such material. The most common disposal method for treated wood waste in the United States is landfilling in a construction and demolition (C&D) facility (Clausen and Lebow 2011). However, C&D debris disposal is regulated by state agencies; therefore, requirements can and do vary from state to state. Older landfills were typically unlined, and some states, including Minnesota, have banned treated wood waste from unlined landfills, but other states currently allow disposal of CCA-treated wood waste in Class I, II, or III landfills and C&D debris disposal facilities (Clausen and Lebow 2011).

Used treated wood and treated construction scraps must not be burned in open fires because burning may release toxic gasses and/or may concentrate preservative elements in the ash. In some cases, wood treated with oilborne preservatives can be burned for production of energy but only in specialized facilities and in accordance with state and federal regulations.

State and local jurisdictions may regulate the use, reuse, and disposal of treated wood and treated wood construction waste. Users should check with state and local authorities for any special regulations relating to treated wood.

Alternatives to Pressure-Treated Wood

Naturally Durable Species

Naturally durable species produce chemicals that are toxic to wood decay fungi. These chemicals, or extractives, are produced as the wood cells transition from sapwood cells to heartwood cells. Extractives are found only in heartwood and serve to protect the tree from fungal and, in some cases, insect attack. Naturally durable tree species native to North America include old growth bald cypress, catalpa, cedars, chestnut, junipers, black locust, mesquite, redwood, red mulberry, several species of oak, osage orange, sassafras, black walnut, pacific yew, and heartwood of old growth southern yellow pine. A number of imported tropical hardwoods are also known for their natural durability. Some naturally durable wood species have other properties that are desirable in some applications. Cedar and redwood have less tendency to warp than commonly treated pine species, and the hardness of white oak makes it well suited for use as a wearing surface.

One widely recognized limitation of naturally durable species is that only the heartwood is durable. Untreated sapwood of naturally durable wood species has low resistance to decay and usually has a short service life under decay-producing conditions. Therefore, it is important to specify 100% heartwood for repair or replacement material. Although the vulnerability of sapwood is understood, it can be difficult and expensive to find sufficient material in which all pieces are completely free of sapwood. The presence of sapwood can be both an aesthetic and a structural concern for large timbers in moisture-prone areas.

A less-recognized characteristic of many naturally durable species is the high degree of variability in durability. The properties that make a wood naturally resistant to decay and insects can vary considerably from tree to tree and even within the same tree (Daniels and Russell 2007, DeBell and others 1999, Pollet and others 2008). Therefore, predicting performance based on durability can be difficult. The decay resistance of heartwood is greatly affected by differences in the preservative qualities of the wood extractives, the attacking fungus and/or insect, and the conditions of exposure. Considerable difference in service life can be obtained from pieces of wood cut from the same species, even from the same tree, and used under apparently similar conditions.

Some naturally durable species also appear to be more affected by the severity of the decay environment than wood treated with preservatives. Woods that provide adequate performance above ground may sometimes decay nearly as rapidly as nondurable species when placed into ground contact. These differences appear to be a function of wood permeability. Less permeable woods used above ground, such as cedar, absorb less moisture during wetting events and thus are less likely to be sufficiently moist long enough to sustain growth of decay. This advantage is lost for wood placed in contact with the ground because moisture from the soil eventually diffuses into wood with low permeability.

Thermal Modification

Thermal modification is a carefully controlled process in which wood is exposed to high temperatures for sufficient time to modify the wood's chemical structure. Thermal modification is sometimes confused with surface charring or with the heat treatment used to sterilize wood products for import or export. Neither of those processes imparts significant durability, but heating wood at high temperatures for extended periods can cause chemical changes that affect a range of wood properties, including decay resistance. Several thermal treatment processes are in commercial use in Europe and to a lesser extent in North America. In these processes, the wood is heated to temperatures ranging from 320 to 500 °F in specially constructed kilns under controlled conditions. The processes may use steam, nitrogen, or vacuum to minimize oxygen and chemical degradation by oxidative reactions. One process heats the wood in oil. Thermally treated wood has only moderate decay resistance and little termite resistance; therefore, most applications are confined to above-ground use. Decay resistance increases at higher processing temperatures, but losses in mechanical properties, especially impact bending, also increase. An advantage of heat treatment is that it can be used with wood species that are difficult to penetrate with preservatives. It can also lessen the tendency of wood to absorb moisture and thus decrease problems associated with shrinking and swelling. It also retains a natural appearance, and although the color is initially darkened somewhat, the wood does weather to grey when exposed to sunlight. Because of its qualities, thermally treated wood is sometimes used in noncritical above-ground applications, such as siding or decking. Thermally modified wood currently has limited availability in the United States.

Chemically Modified Wood

Chemical modification is a general term applied for treatments that attempt to modify the wood into a less attractive nutrient source for decay fungi and insects. Currently, the two most prevalent processes are acetylation and furfurylation. In the acetylation process, wood is treated with acetic anhydride, which replaces hydroscopic hydroxyl groups (OH-) with less hygroscopic acetyl groups in the wood cell walls. This process causes the wood to absorb less moisture. In the furfurylation process, the wood is treated with furfuryl alcohol, which is then catalyzed to form polymers in the wood. Furfuryl alcohol is also thought to react with chemical groups such as lignin that make up the wood cell structure. Furfurylation also causes the wood to absorb less water than untreated wood. Both processes require the use of much more chemical than is used in conventional wood preservatives to achieve significant durability. Weight gains of at least 15% to 20% are needed for acetylation, and even greater weight gains are needed in the furfurylation process. As a result, chemically modified wood tends to be more costly than wood pressure-treated with preservatives. In addition to decay resistance, the treated wood is harder, heavier, and more dimensionally stable. Protection against attack by mold fungi and termites has not been as thoroughly evaluated as decay resistance. Chemically modified wood currently has limited availability in the United States.

Summary

Most wood species need to be protected from decay fungi and insect attack when used for construction outdoors or otherwise exposed to frequent wetting. Typically, this protection is achieved by pressure treatment with preservatives that protect the wood from a wide range of wood-degrading organisms. Pressure treatment provides deeper and more uniform preservative penetration compared with wood treated by other methods. Pressure-treatment preservatives are liquids that are classed as either waterborne or oilborne. Although creosote can be used without oil dilution, it has properties similar to oilborne preservatives and is often grouped with these. Waterborne preservatives tend to have little odor and leave the wood with a dry, paintable surface. They are used for a wide range of applications, including the treated lumber sold by lumber yards for construction of residential decks and fences. Some waterborne preservatives are also used for more industrial-type applications such as round poles, piling, and bridge timbers. Oilborne preservatives are dissolved in either heavy or light oil. Heavy oil is similar to diesel, whereas light oil is similar to mineral spirits. The properties and applications of oilborne preservatives depend on the type of oil used. Heavy oil treatments are typically used for heavy-duty applications, such as utility poles, bridge timbers, and railroad ties. Heavy oil treatments have the advantage of imparting some water-repellency to the wood and can help protect metal fasteners from corrosion. However, wood pressure-treated with heavy oils may have a noticeable odor and should not be used for the interior of inhabited structures. Light oil treatments are sometimes used when it is desirable to have wood with a drier surface and less residual odor.

Before a wood preservative can be approved for pressure treatment of structural members, it must be evaluated to ensure that it provides the necessary durability. Traditionally, this evaluation has been conducted through the standardization process of the AWPA. Part of the AWPA evaluation process includes specifications for minimum preservative penetration and retention levels. To guide selection of the types of preservatives and retentions appropriate to a specific end-use, the AWPA developed UCS standards. The UCS standards categorize treated-wood applications by the severity of the deterioration hazard, as well as the structural significance of the application. There are separate UCS standards for sawn products (lumber, timbers, and posts), round poles, piles, and structural wood composites. They list the preservatives that are standardized for each type of end-use by wood species. AWPA also considers other factors such as odor and surface cleanliness when making recommendations for specific applications.

Design and construction practices also play an important role in the durability of pressure-treated wood. One potential pitfall is the use of wood treated for UC3B (above-ground) applications under conditions that immediately or over time create a decay hazard similar to ground contact. Similarly, construction designs that create moisture traps or facilitate accumulation of leaf litter can create increased decay hazards. Field cuts or bolt holes can expose untreated wood, especially in larger members. These areas should be field-treated in accordance with AWPA Standard M4 (AWPA 2018).

Most wood preservatives contain pesticides, and concerns sometimes arise that pressure-treated wood may negatively affect sensitive aquatic environments. However, potential environmental effects are evaluated by the EPA before a wood preservative can be registered, and studies by university and government researchers have indicated that environmental risks associated with pressure-treated wood are low in most situations. A web-based environmental assessment tool has been developed to assist users in evaluating potential pesticide released from proposed projects involving large volumes of preservative-treated wood placed in or above slow moving water. Best management practices for production and use of pressure-treated wood in sensitive aquatic environments have also been developed to further decrease the potential for environmental impacts.

Alternatives to preservative treatment include naturally durable species, thermally modified wood, and chemically modified wood. Resistance to warping and cracking can be an advantage of these alternatives, although this is not the case for all naturally durable woods. Naturally durable species may vary greatly in durability from piece to piece, and they may not be sufficiently durable for some applications. Chemically and thermally modified wood is typically substantially more costly than pressure-treated wood, and thermal modification can negatively impact strength properties.

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