Focus

Material Selection and Preservative Treatments for Outdoor Wood Structures

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Abstract

The long-term performance of wood in exterior exposures depends on material quality and decay resistance, either natural or that imposed by chemical treatment. The information presented here is intended to aid those who design and construct wood decks or similar outdoor structures.

Introduction

Outdoor wood structures, such as decks, ramps, fences, piers. and patios, enhance outdoor living. For structures that are fully exposed to the weather, extra attention should be given to certain aspects of material specification. The special considerations will contribute to safety and long-term reliability. This paper will address frequent problem areas, particularly where there is conflicting or misleading information from other sources. It is written as an aid for those interested in detailed information on designing, constructing, and/or maintaining wood decks or similar outdoor structures. There are few absolute rules for constructing outdoor wood structures, along with many options in which the best solution must be tempered by factors including local weather conditions, labor, aesthetics, personal taste, and availability and cost of materials.

The information provided assumes the use of commonly available softwood species and preservative treatments intended for outdoor construction. Emphasis is placed on wood treated with inorganic waterborne preservatives. However, naturally decay-resistant wood species (redwood and western cedars) are also discussed.

Commercial Lumber for Outdoor Structures

Commercial lumber. in a broad sense, is any lumber that is bought or sold in the normal channels of commerce. For marketing purposes, many wood species are grouped. Those most likely used for deck construction are listed in Table 1. Lumber may be found in a variety of forms, species, and types, and in various commercial establishments, both wholesale and retail.

A log, when sawed, yields lumber of varying quality. To enable users to buy the quality that best suits the intended application. lumber is graded into *use categories.* Generally, the grade of a piece of lumber is based on the number, character, and location of features that may lower its strength, durability, or utility value. Among the more common visual features are knots, checks, pitch pockets, shake, and stain, some of which are natural parts of the tree. Some grades are free or practically free from these features. Other grades, comprising the great bulk of lumber, contain knots and other features. The grade assignment reflects how the growth features are expected to impact the utilization in applications. Factors likely to be impacted include orientation of loading, appearence, or even treatability.

Most commercial softwood lumber is graded by standardized rules that make purchasing more or less uniform throughout the country. However. establishment of grading procedures is largely the responsibility of manufacturers' associations. Because of the wide variety of wood species, industrial practices, and customer needs, different lumber grading practices coexist. The grading practices that are of most interest to designers and builders of outdoor wood structures are considered in the following sections.

Structural Grades. Most softwood lumber that is nominally 2 to 4 in. (50 to 100 mm) thick (dimension lumber), and some that is 5 in. (125 mm) or thicker (timber), is stress graded for use as structural lumber. Stress-graded lumber is assigned allowable properties under the National Grading Rule (NGR), a part of the American Softwood Lumber Standard (USDC, 1970). For stress-graded dimension lumber, there is a single set of grade names and descriptions used throughout the United States and Canada, although the assigned allowable properties may vary with species or species group. Table 2 provides a sampling of grade names and descriptions.

Visual stress grading is based on the premise that the strength of any piece of structural lumber depends on the strength-reducing defects visually discernible in that piece. Visual grading rules specifically detail the allowable size and location of knots, the allowable slope of the grain. and any other characteristics that affect strength. These characteristics include between-grade provisions for accepting larger knots in lower grades and within-grade provisions for accepting larger centerline knots than edge knots on the wide face. (Edge knots lower bending strength to a greater degree than equivalent-size centerline knots.) Other provisions, intended to assure strength, utility, and appearance, include specific limits for density, shake. checks, splits, wane, and pitch pockets. For various regions of the country, different grade rule-writing agencies apply the uniform criteria of the NGR to their particular species through published "grading rules;" for example, those promulgated by the Western

Table 1. Species groups used for outdoor construction.

Species Group	Species included - in group	Grading Agency
Douglas-fir-Larch	Douglas-fir Western larch	WCLIB, WWPA
Hem-Fir	California red fir Grand fir Noble fir Pacific silver fir Western hemlock White fir	WCLIB, WWPA
Ponderosa pine		NLGA
Redwood		RIS
Southern Pine	Loblolly pine Longleaf pine Shortleaf pine Slash pine	SPIB
Spruce-Pine-Fir	Alpine fir Balsam fir Black spruce Engelmann spruce Jack pine Lodgepole pine Red spruce White spruce	NLGA
Spruce-Pine-Fir (South)	Balsam fir Black spruce Jack pine Norway (red) pine Red spruce White spruce	NELMA, NSLB
	Engelmann spruce Lodgepole pine Sitka spruce	WCLIB, WWPA
Western cedars	Alaska cedar Incense cedar Port-Orford cedar Western Red cedar	WCLIB, WWPA

NELMA, Northeastern Lumber Manufacturers Assoc., 272 Tuttle Rd., P.O. Box 87A, Cumberland Center, ME 04021.

NLGA, National Lumber Grades Authority, 260- 1055 W. Hastings St., Vancouver, B.C., Canada V6E 2E9.

NSLB, National Softwood Lumber Bureau, 272 Tuttle Rd., P.O. Box 87A, Cumberland Center, ME 04021.

RIS, Redwood Inspection Service, 405 Enfrente Dr., Suite 200, Novato, CA 94949.

SPIB, Southern Pine Inspection Bureau, 4709, Scenic Highway, Pensacola, FL 32504.

WCLIB, West Coast Lumber Inspection Bureau, 6980 S.W. Vames Road. P.O. Box 23145, Portland, OR 97223.

WWPA, Western Wood Products Association, 522 S.W. 5th Ave., Yeon Building, Portland, OR 97204.

Wood Products Association (WWPA, 1991) or the Southern Pine Inspection Bureau (SPIB, 1991).

Grade Stamps. A grade stamp is placed on dimension lumber to designate the official grade of the piece at the time it is graded. Grade stamps are used to inform the user of the grade, species or species group, producing mill, moisture content when surfaced, and grading agency. Any remanufacturing of graded lumber, such as ripping or crosscutting, negates the legitimacy of the grade stamp. Because building inspectors look for grade stamps when they inspect a structure, it is prudent for the builder to avoid removing the stamp when cutting lumber.

Lumber sizes. Nominal sizes, such as 2 × 4 in. (50 × 100 mm), 2 × 6 in. (50 × 150 mm), and 4 × 4in.(100 × 100 mm), have been used to refer to dimension lumber for more than 100 years, despite many changes in the lumber standards and sizes. The actual sizes of lumber are smaller than the commonly referred to nominal size: for example, 2 × 4 in. is l-1/2 × 3-l/2 in. (38 × 89 mm) dry. and 1-9/16 × 3-9/16 in. (40 × 90 mm) unseasoned. These dimensions may be found in agency grading rules.

Appearance Grades. Some species, such as Western cedars and redwood, are available in appearance grades as well as structural grades. Some factors that affect the appearance grades include the amount of heartwoodlsapwood, clear areas, the grain orientation, growth rate, and number and size of knots. The redwood appearance grade available on the market is Construction Heart (RIS, 1991).

Decking Lumber Grades. Decking lumber is the lumber used to construct the deck surface. Several types of lumber can be used for this surface, including dimension lumber and radius-edge decking. Radius-edge decking has well-rounded edges and is available in dressed widths of 3-l/2 in. (89 mm), 4-l/2 in. (114 mm), and 5-l/2 in. (140 mm). Radius-edge decking is available in nominal l-1/4 in. (32 mm) [dressed 1 in. (25 mm)] thickness. The Western species are available in Patio 1 and Patio 2 grades (WWPA, 199l), and Southern Pine species are available in Premium and Standard grades (SPIB, 1991).

Dimension lumber thickness used for decking is nominal 2 in. (50 mm) [actual 1-1/2 in. (38 mm)] and nominal widths are 4 or 6 in. (100 or 150 mm). Preservative-treated dimension material is available in structural grades of No. 1, No. 2, and No. 2 & Btr. The naturally decay-resistant species include redwood and western cedar. Redwood is graded Select Heart, Construction Heart, Select Structural, No. 1, No. 2, and No. 3. Two special purpose redwood decking grades, Deck Heart and Deck Common, are available. They have been graded for strength characteristics besides appearance. Western red cedar is graded into six deck-grade categories, three clear and three knotty. They are Architect Clear, Custom Clear, Contractor Clear, Architect Knotty, Custom Knotty, and Contractor Knotty.

Species with Natural Decay Resistance. The three most common native species or species groups that produce lum-

ber with natural decay resistance are redwood, cedars, and bald cypress. The decay resistance of these species is based on the performance of heartwood cut from the center of slow-grown trees. The decay resistance of lumber derived from smaller, moderately to quickly grown trees may not be as great as that from the slow-grown wood, particularly if that lumber contains any sapwood. If untreated lumber from these decay-resistant species is used for decking, it should be specified as "all-heartwood" if a high level of decay resistance is needed.

Preservative-Treated Wood: Treatment and Quality Assurance

Wood will not decay if temperature, oxygen, and moisture are controlled. The simplest way to prevent biological deterioration is to keep wood dry. However, this is not practical for outdoor structures. Where temperature, oxygen, and moisture cannot be entirely controlled, use of decay-resistant wood species and/or woods treated with preservatives is the only option to prevent wood deterioration.

Outdoor structures require decay-resistant wood or preservative-treated wood using U.S. Environmental Protection Agency (EPA) approved preservatives that are commercially applied to lumber by pressurized treatment. The most common preservative treatments are chromated copper arsenate (CCA), ammoniacal copper quaternary ammonium compound (ACQ), and ammoniacal copper zinc arsenate (ACZA) waterborne preservatives (Zabel and Morrell, 1992). The copper gives the wood a green color. Sometimes a dye is added to change the color to brown.

These preservative chemicals are registered by the EPA as pesticides and can be applied to wood only by a treater with a Certified Pesticide Applicators License. These chemicals are broad-spectrum pesticides that are introduced into wood under pressure to eliminate wood as a potential food source for decay fungi and insects. They have also been rigorously studied by the EPA and found to have many benefits, with only minimal risks, when used properly.

Preservative Treatments

Pressure-Applied Treatments. Proper preservative treatment needs to meet specific use requirements as detailed in American Wood Preservers' Association (AWPA) standards (AWPA, 1992). These standards require specific penetration limits, which, when achieved, still allow an untreated core surrounded by a treated shell of wood. In some species or species groups, such as ponderosa pine and Southern Pine, which have thick sapwood, preservative under pressure can easily move through the decay-prone sapwood. With waterborne preservative treatments, sufficient chemical can be added to the sapwood to protect it in high-decay-hazard areas, such as in ground contact. Both CCA and ACQ are commonly used to treat easily treated woods, such as ponderosa pine and those in the Southern Pine group. and moderately difficult-to-treat woods, such as those in the

Table 2. Grade names and physical characteristics of nominal 2- × 4-in. dimension lumber produced under the American Softwood Lumber Standard (USDC, 1970).

Grade Category	Strength Ratio*	Maximum Edge Knot[2]	Wane	Warp[3]	
				Crook	Twist
		(inches)		----- (inches) -----	
Structural Light Framing					
Select Structural	0.67[4]	0.75	¼ thickness, ¼ width	0.50	0.56
No. 1	0.55	1.00	¼ thickness, ¼ width	0.50	0.56
No. 2	0.45	1.25	1/3 thickness, 1/3 width	0.69	0.75
No. 3	0.26	1.75	½ thickness, ½ width	1.00	1.12
Light Framing					
Construction	0.34	1.00	¼ thickness, ¼ width	0.50	0.56
Standard	0.19	2.00	1/3 thickness, 1/3 width	0.69	0.75
Utility	0.09	2.50	½ thickness, ½ width	1.00	1.12
Stud					
Stud	0.26	1.75	1/3 thickness, ½ width	0.38	0.44

[1] Ratio of expected strength of that grade of lumber to clearwood, ASTM D245 (ASTM, 1993).
[2] Larger sizes would have proportionally larger permissible edge knots.
[3] Assuming a 12-ft length, various sizes would have progressively higher or lower maximums. Stud grade assumes a 10-ft length.
[4] 0.65 for all larger sizes.

Hem-Fir group. ACQ and ACZA are used on woods that are more difficult to treat because the ammonia in the formulation swells the wood to enhance penetration of the preservative. These species include Douglas-fir, which is difficult to treat with CCA.

Other factory-applied preservative treatments include the organic preservatives, creosote and oil-borne pentachlorophenol (penta), and copper naphthenate. Organic preservative chemicals are often used on railroad ties and utility poles. These products are not recommended for residential deck construction because of their odor, sometimes tarry surface, and the greater chemical volatility.

Field Treatments. Field treatments refer to field-applied treatments to saw cuts and drilled holes in pressure-treated lumber during construction. The simplest chemical treatment for wood in a non-factory or field situation is by brush, soak, or dip application. However, it is difficult to achieve adequate preservative penetration by these field-applied methods, and the risk of toxic exposure is greatly increased both to the individuals treating the wood and to the environment. Copper napthenate is the only preservative that does not require a certified applicator's license, and is currently approved in AWPA Standard M-4 (AWPA, 1992) as a field treatment for materials intended for ground contact. Water-repellent preservatives (WRP), while not approved in AWPA M-4, can be used as field treatments to cuts and drilled holes, but only on materials intended for aboveground use. As the name "water-repellent" implies. treatment with WRP of end-cuts and drill holes in wood enhances both water repellency and resistance of exposed. untreated end-grain to decay when used in aboveground applications. Water-repellent preservatives alone do not provide sufficient decay resistance when used in ground-contact applications.

Liquid water is absorbed more easily through the end grain than across the grain (FPL, 1987). Because application of WRP helps retard absorption of liquid water by wood. especially at the end-grain. the wood stays drier during rainy periods. Yet. while WRP retards liquid-water absorption by wood, it does little to restrict water-vapor movement. Thus. the wood remains dryer most of the time. which minimizes dimensional change. Less dimensional change means less cracking and splitting, less raised grain, and better-looking. longer-lasting. outdoor structures.

Use and Handling of Preservative-Treated Wood

Wood treated with EPA-registered preservatives should be used only where protection from insect attack and decay is important. Waterborne preservatives penetrate deeply into, and remain within, the treated wood for a long time. Use or exposure to waterborne-treated wood may present certain hazards (Brooks, 1993; USDA, 1981). Therefore, the following precautions should be taken both when handling, and when deciding where to use or dispose of the treated wood. Consumer information sheets that outline these precautions are available from retailers when purchasing preservative-treated wood.

Waterborne-preservative-treated wood may be used inside residential and commercial structures if all sawdust and construction debris are removed after construction. Treated wood should not be used where the preservative may become a component of food or animal feed, or in applications such as beehives. Only treated wood that is visibly clean and free of surface residue should be used for patios, decks, and walkways. Treated wood should not be used where it may come into direct or indirect contact with public drinking water, except those uses involving incidental contact such as docks and bridges.

Dispose of treated wood through ordinary trash collection or burial. Do not bum treated wood in open fires, stoves, fireplaces, or residential boilers because toxic chemicals may be produced as part of the smoke and ashes. Alternative disposal methods are discussed by Kempton (1992).

Avoid frequent or prolonged inhalation of sawdust from treated wood. When sawing and machining, wear goggles to protect eyes from flying particles. After working with treated wood (and before eating, drinking, or using tobacco products) wash exposed skin thoroughly. If preservatives or sawdust accumulate on clothes, launder before reuse. Wash work clothes separately from other household clothing.

Treatment Standards

Wood preservative treatments should be performed according to the American Wood-Preservers' Association Standards (AWPA, 1992), a series of voluntary standards that describe chemicals, processing, quality control, and inspection.

At the consumer level. the most important information on preservative-treated wood used for outdoor structures is the use category of the preservative. The use category defines the amount of preservative chemical and how deeply it penetrates into the wood. This directly affects the longevity of the treated wood in exposed environments (Preston *et al.,* 1992). The commonly used waterborne-preservative use-categories are: above-ground use, which has a specified preservative retention of 0.25 lb/ft^3 (4.0 kg/m^3); ground-contact use at 0.30 lb/ft^3 (6.4 kg/m^3); and wood foundation and freshwater use at 0.60 lb/ft^3 (9.6 kg/m^3). When treated according to the AWPA Standards, treated wood should provide many decades of service.

Some species are difficult to treat and must be incised. Incising is a process that involves using closely spaced knives to cut perforations or slits in the faces and edges of lumber. This process greatly increases the penetration of preservatives into refractory wood species. Incising lumber before treatment makes it possible to treat wood species that normally could not be treated to acceptable penetration and retention levels. Incising is required by AWPA standards (AWPA, 1992) for treatment of thin-sapwood species such as Douglas-fir, spruce, hemlock, and true fir. Although in-

cising somewhat reduces strength of the lumber, it is generally agreed that the minimal strength loss is acceptable because of the substantial improvement in durability in service. Incised and treated refractory woods perform well in service, whereas unincised refractory woods may not perform as well.

Treatment Quality Assurance. It is not possible to assure proper penetration and retention of preservative by visual inspection. Thus, to ensure proper treatment (and long service life), insist that the treated material have American Lumber Standard Committee (ALSC)-approved, preservative-treatment-quality marks. Treatment-quality marks are ink-stamped or stapled tags on treated wood (Figure I). They are your assurance that the wood treater is qualified, and that the treated wood was inspected and chemically analyzed by an ALSC-accredited, independent, third-party inspection agency. The treatment-quality mark designates who treated the wood, the applicable standard to which it was treated, the preservative used, the preservative retention level, and the inspector. The use category of the preservative treatment is designated and its quality is assured by the treatment-quality mark. If a treater fails to maintain the level of quality designated in the standards, use of the stamp is revoked.

Preservative-treated lumber that has only a treater's guarantee is also available. This lumber usually has a plastic tag stapled to the end of each piece. Be aware that some tagged lumber may not have been inspected by an independent inspection agency.

In spite of these quality-control efforts, "treated lumber" that does not have preservative-treatment-quality marks is available. Landscape ties are often such a product. This non-standard material often carries no guarantee and might not be treated. although it appears identical in color to the quality-marked lumber.

Post-Treatment Drying

Kiln-drying. After wood is properly treated with any waterborne-preservative-treatment process, it is soaking wet. Occasionally, wood is re-dried after it is treated. Unless the treatment-quality mark indicates that the wood was kiln dried or air dried after treatment. treated lumber is usually only drip dried before banding for shipment. When it arrives at the retail lumberyard, it sometimes appears dry on the surface, but inside it can be very wet (moisture content > 50%).

As wet preservative-treated wood dries without restraint. it may warp. Lumber that is properly fastened in place will dry and still shrink. but twisting and warping are usually minimized. The handling hazard, weight, and shrinkage are considerably decreased after the treated lumber dries. It is best to buy treated lumber kiln dried or air dried after treatment. or to air dry the wet, treated lumber before use.

Drying Treated Wood. If lumber is air dried after treatment. those members that are prone to warp, check, or split

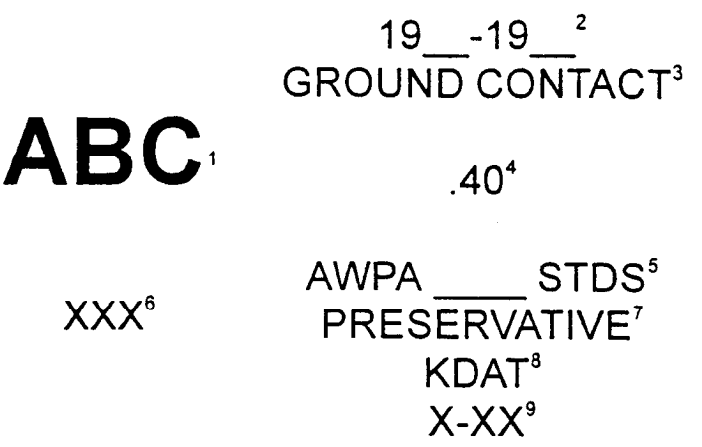

Figure 1. Hypothetical example of the treatment-quality mark of an inspection agency accredited by the U.S. Department of Commerce American Lumber Standards Committee for inspection of waterborne preservative-treated lumber: The footnote numbers are defined as:

1 = identifying symbol, logo, or name of accredited agency
2 = year of treatment, if required by AWPA standard
3 = exposure category (above ground, ground contact, etc.)
4 = level of preservative retention (lb/ft^3)
5 = applicable AWPA commodity standard
6 = treating plant name and location or plant number
7 = preservative used
8 = moisture content after treatment (if applicable)
9 = length and/or class of treated material (if applicable)

due to drying can be removed before construction. It is worth the extra time and effort to air dry the lumber if a quality outdoor structure is important. It is best if the lumber can be stickered and stored under cover on a solid base several inches above ground. with the sides kept open for good air movement. Application of an end-grain treatment. such as oil-based primer paint, varnish, or melted paraffin wax, will decrease splitting, with only slight increases in drying time.

The time it takes to dry lumber depends on the species, thickness, and weather conditions (temperature and relative humidity). It takes about two months of summer weather for 1-½ in. (38 mm) thick lumber to air dry (FPL, 1987). Increasing air movement through the stack of lumber by using a fan can cut this time to about one month. The weight of the wood should decrease by 25 to 35%. You can check this by pre-weighing several pieces at the start and checking them after a couple of weeks. A bathroom scale is adequate to determine the weight loss of the wood as it dries.

Selecting Treated Lumber

The lumber grades selected for outdoor structures depend on design, cost. and local building codes. Graded lumber contains a variety of features; the most obvious is knots. Other features include wane on edges, slope of grain, splits,

and warp. Check the quality mark to determine whether the treated wood was kiln dried after treatment. Kiln-dried lumber should be stored inside or at least under cover. Check for water stains or other indications of exposure to water. Many retail lumberyards offer help to the buyer. Many even provide deck design services.

In addition to changes in moisture content. the dimensional stability of wood is affected by the width and density difference between earlywood and latewood growth-ring bands. For example, in species that have wide, dense, latewood bands and low-density earlywood bands, the differential shrinking and swelling of these bands with changes in moisture content cause large stresses in the wood that can result in raised grain and shelling. Raised grain occurs from the different dimensional changes between the earlywood and latewood growth-ring bands, and is most severe on flat-grained lumber. Shelling is an extreme case of raised grain in which the latewood bands separate from the earlywood bands to form a knife- or spear-like edge. This is one reason why it is often recommended that decking lumber be placed bark-side up if both sides of the same board are of equal quality. Otherwise, the best side should be placed up.

The decay-resistant species include redwood and western cedars. Redwood is graded as Select Heart. Construction Heart, Select Structural. No. 1, No. 2, and No. 3. This material is untreated, and the latter four grades allow sapwood, which is not decay resistant. We recommend preselecting pieces with only heartwood. or simply using Construction Heart lumber for the outdoor structure.

Structural lumber grades for non-decay-resistant species do not limit the amount of sapwood; thus, only pressure-treated wood from these species should be used for the structural portions of an outdoor structure. Also, all structural dimension lumber used in an outdoor structure should be at least No. 2 grade. Finally, because the appearance of the outdoor structure will be enhanced. all decking lumber should be Construction Heart if redwood. If cedar, we recommend Architect Clear or Custom Clear deck grade. Patio 1, Select Dex, or Premium if radius-edge decking, or No. 1 & Btr. if dimension lumber is used.

Summary

Wood in exterior exposures can have long service lives if material quality and decay resistance are carefully selected and specified. The appropriate material/decay resistance combination is a function of several factors such as service, weather conditions. and appearance requirements. Lumber grades play a crucial role in the material specification and. ultimately, in serviceability of the structure. Designers are urged to carefully consider the various aspects of service prior to specifying the lumber grade. Because moisture. temperature, and oxygen cannot easily be controlled in exposed structures, the material must have some natural or imposed decay resistance. Pressure-applied treatments are preferred, while field-applied treatments are often inadequate.

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