Biodeterioration of Wood

An Online Continuing Education Course for Engineers

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Under proper conditions, wood will give centuries of service. However, under conditions that permit the development of wood-degrading organisms, protection must be provided during processing, merchandising, and use.

The organisms that can degrade wood are principally fungi, insects, bacteria, and marine borers.

Molds, most sapwood stains, and decay are caused by fungi, which are microscopic, thread-like microorganisms that must have organic material to live. For some of them, wood offers the required food supply. The growth of fungi depends on suitably mild temperatures, moisture, and air (oxygen). Chemical stains, although they are not caused by organisms, are mentioned in this course because they resemble stains caused by fungi.

Insects also may damage wood and in many situations must be considered in protective measures. Termites are the major insect enemy of wood, but on a national scale, they are a less serious threat than fungi.

Bacteria in wood ordinarily are of little consequence, but some may make the wood excessively absorptive. In addition, some may cause strength losses over long periods of exposure, particularly in forest soils.

Marine borers can attack susceptible wood rapidly in salt water harbors, where they are the principal cause of damage to piles and other wood marine structures.

Wood degradation by organisms has been studied extensively, and many preventive measures are well known and widely practiced. By taking ordinary precautions with the finished product, the user can contribute substantially to ensuring a long service life.

Fungus Damage and Control

Fungus damage to wood may be traced to three general causes: (a) lack of suitable protective measures when storing logs or bolts; (b) improper seasoning, storing, or handling of the raw material produced from the log; and (c) failure to take ordinary simple precautions in using the final product. The incidence and development of molds, decay, and stains caused by fungi depend heavily on temperature and moisture conditions (Fig. 1).

Molds and Fungal Stains

Molds and fungal stains are confined to a great extent to sapwood and are of various colors. The principal fungal

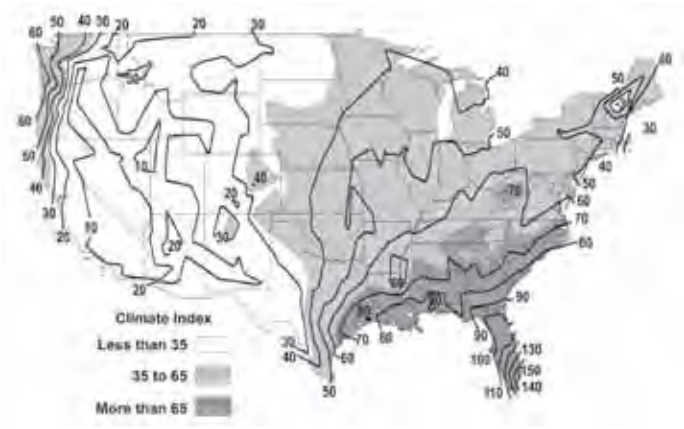

Figure 1. Climate index for decay hazard. Higher numbers indicate greater decay hazard.

Figure 2. Typical radial pen-etration of log by stain. The pattern is a result of more rapid penetration by the fungus radially (through the ray) than tangentially.

stains are usually referred to as sap stain or blue stain. The distinction between molding and staining is made primarily on the basis of the depth of discoloration. With some molds and the lesser fungal stains, there is no clear-cut differentiation. Typical sap stain or blue stain penetrates into the sapwood and cannot be removed by surfacing. Also, the discoloration as seen on a cross section of the wood often appears as pie-shaped wedges oriented radially, corresponding to the direction of the wood rays (Fig. 2). The discoloration may completely cover the sapwood or may occur as specks, spots, streaks, or patches of various intensities of color. The so-called blue stains, which vary from bluish to bluish black and gray to brown, are the most common, although various shades of yellow, orange, purple, and red are sometimes encountered. The exact color of the stain depends on the infecting organisms and the species and moisture condition of the wood. The fungal brown stain mentioned here should not be confused with chemical brown stain.

Mold discolorations usually become noticeable as fuzzy or powdery surface growths, with colors ranging from light shades to black. Among the brighter colors, green and yellowish hues are common. On softwoods, though the fungus may penetrate deeply, the discoloring surface growth often can easily be brushed or surfaced off. However, on large-pored hardwoods (for example, oaks), the wood beneath the surface growth is commonly stained too deeply to be surfaced off. The staining tends to occur in spots of various concentration and size, depending on the kind and pattern of the superficial growth.

Under favorable moisture and temperature conditions, staining and molding fungi may become established and develop rapidly in the sapwood of logs shortly after they are cut. In addition, lumber and such products as veneer, furniture stock, and millwork may become infected at any stage of manufacture or use if they become sufficiently moist. Freshly cut or unseasoned stock that is piled during warm, humid weather may be noticeably discolored within 5 or 6 days.

Ordinarily, stain and mold fungi affect the strength of the wood only slightly; their greatest effect is usually confined to strength properties that determine shock resistance or toughness. They increase the absorbency of wood, and this can cause over-absorption of glue, paint, or wood preservative during subsequent processing. Increased porosity also makes wood more wettable, which can lead to subsequent colonization by typical wood-decay fungi.

Stain- and mold-infected stock is practically unimpaired for many uses in which appearance is not a limiting factor, and a small amount of stain may be permitted by standard grading rules. Stock with stain and mold may not be entirely satisfactory for siding, trim, and other exterior millwork because of its greater water absorbency. Also, incipient decay may be present, though inconspicuous, in the discolored areas. Both of these factors increase the possibility of decay in wood that is rain-wetted unless the wood has been treated with a suitable preservative.

Chemical Stains

Nonmicrobial or chemical stains are difficult to control and represent substantial loss in wood quality. These stains, which should not be confused with fungal brown stain, include a variety of discolorations in wood that are often promoted by slow drying of lumber and warm to hot temperatures. Such conditions allow naturally occurring chemicals in wood to react with air (enzymatic oxidation) to form a new chemical that is typically dark in color. Common chemical stains include (a) interior sapwood graying, prevalent in oak, hackberry, ash, and maple, (b) brown stain in softwoods, and (c) pinking and browning in the interior of light-colored woods such as maple. Another common discoloration, iron stain, is caused by the interaction of iron with tannins in wood. Iron stain is more prevalent in hardwoods (for example, oak and many tropical hardwoods) and in some softwoods such as Douglas-fir. Control is achieved by eliminating the source of iron.

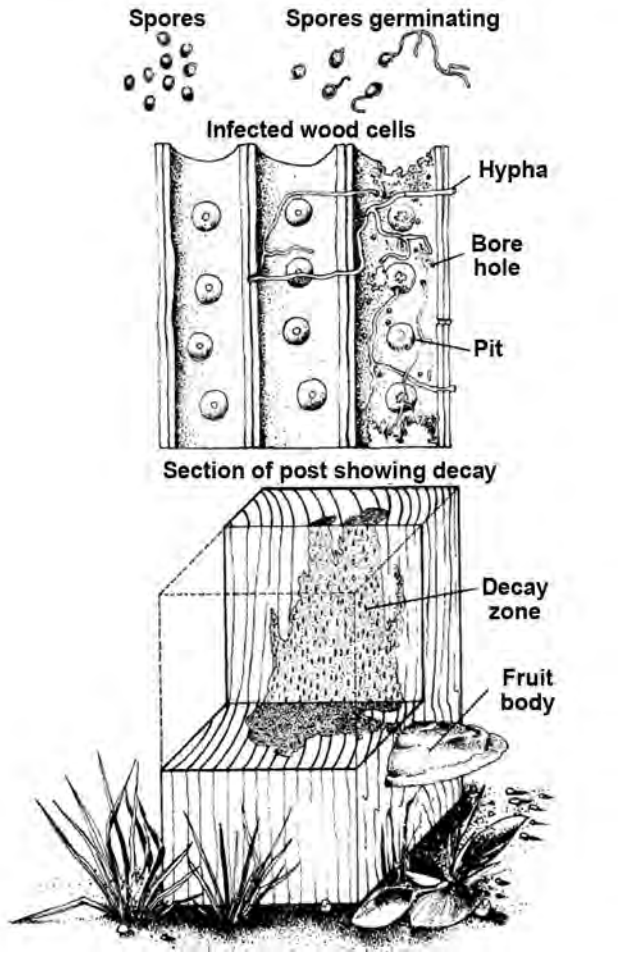

Figure 3. The decay cycle (top to bottom). Thousands of spores produced in a fungal fruiting body are distributed by wind or insects. On contacting moist, susceptible wood, spores germinate and fungal hypha create new infections in the wood cells. In time, serious decay develops that may be accompanied by formation of new fruiting bodies.

Decay

Decay-producing fungi may, under conditions that favor their growth, attack either heartwood or sapwood in most wood species (Fig. 3). The result is a condition designated as decay, rot, dote, or doze. Fresh surface growths of decay fungus may appear as fan-shaped patches (Fig. 4), strands, or root-like structures that are usually white or brown in color. Sometimes fruiting bodies are pro- duced that take the form of mushrooms, brackets, or crusts. The fungus, in the form of microscopic, threadlike strands called hyphae, permeates the wood and uses parts of it as food. Some fungi live largely on cellulose, whereas others use lignin and cellulose.

Certain decay fungi colonize the heartwood (causing heart rot) and rarely the sapwood of living trees, whereas others confine their activities to logs or manufactured products,

Figure 4. Mycelial fans on a wood door.

such as sawn lumber, structural timbers, poles, and ties. Most fungi that attack trees cease their activities after the trees have been cut, as do the fungi causing brown pocket (peck) in baldcypress or white pocket in Douglas-fir and other conifers. Relatively few fungi continue their destruction after the trees have been cut and worked into products and then only if conditions remain favorable for their growth. Although heartwood is more susceptible to decay than is sapwood in living trees, for many species, the sapwood of wood products is more susceptible to decay than is the heartwood.

Most decay can progress rapidly at temperatures that favor growth of plant life in general. For the most part, decay is relatively slow at temperatures below 10 °C (50 °F) and above 35 °C (95 °F). Decay essentially ceases when the temperature drops as low as 2 °C (35 °F) or rises as high as 38 °C (100 °F).

Serious decay occurs only when the moisture content of the wood is above the fiber saturation point (average 30%). Only when previously dried wood is contacted by water in the form of rain or condensation or is in contact with wet ground will the fiber saturation point be reached. By itself, the water vapor in humid air will not wet wood sufficiently to support significant decay, but it will permit development of some mold fungi. Fully air-dried wood usually will have a moisture content not exceeding 20% and should provide a reasonable margin of safety against fungal damage. Thus, wood will not decay if it is kept air dry, and decay already present from prior infection will not progress.

Wood can be too wet for decay as well as too dry. If the wood is water-soaked, the supply of air to the interior of a piece may not be adequate to support development of typical decay fungi. For this reason, foundation piles buried beneath the water table and logs stored in a pond or under a suitable system of water sprays are not subject to decay by typical wood-decay fungi.

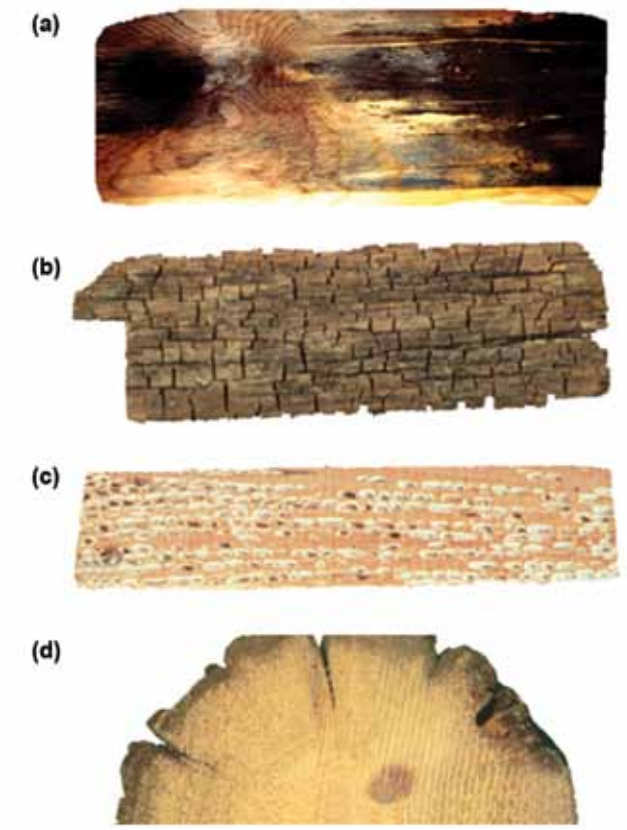

Figure 15. Representative samples of four com-mon types of fungal growth on wood: (a) mold discoloration; (b) brown rotted pine (note the dark color and cubical checking in the wood); (c) white rot in maple (note the bleached appearance); (d) soft-rotted preservative-treated pine utility pole (note the shallow depth of decay).

The early or incipient stages of decay are often accompanied by a discoloration of the wood, which can be difficult to recognize but is more evident on freshly exposed surfaces of unseasoned wood than on dry wood. Abnormal mottling of the wood color, with either unnatural brown or bleached areas, is often evidence of decay infection. Many fungi that cause heart rot in the standing tree produce incipient decay that differs only slightly from the normal color of the wood or gives a somewhat water-soaked appearance to the wood.

Typical or late stages of decay are easily recognized, because the wood has undergone definite changes in color and properties, the character of the changes depending on the organism and the substances it removes.

Two kinds of major decay fungi are recognized: brown rot and white rot. With brown-rot fungi, only the cellulose is extensively removed, the wood takes on a browner color, and it can crack across the grain, shrink, collapse, and be crushed into powder (Fig. 5). With white-rot fungi, both lignin and cellulose usually are removed, the wood may lose color and appear "whiter" than normal, it does not crack across the grain, and until severely degraded, it retains its outward dimensions, does not shrink or collapse, and often feels spongy (Fig. 5). Brown-rot fungi commonly colonize softwoods, and white-rot fungi commonly occur on hardwoods, but both brown- and white-rot fungi occasionally colonize both types of wood.

Brown, crumbly rot, in the dry condition, is sometimes called dry rot, but the term is incorrect because wood must be damp to decay, although it may become dry later. A few fungi, however, have water-conducting strands; such fungi are capable of carrying water (usually from the soil) into buildings or lumber piles, where they moisten and rot wood that would otherwise be dry. They are sometimes referred to technically as dry-rot fungi or water-conducting fungi. The latter term better describes the true situation because these fungi, like the others, must have water.

A third and generally less important kind of decay is known as soft rot. Soft rot is caused by fungi related to the molds rather than those responsible for brown and white rot. Soft rot typically is relatively shallow, primarily affecting the outer surface of wood; the affected wood is greatly degraded and often soft when wet, but immediately beneath the zone of rot, the wood may be firm (Fig. 5). Because soft rot usually is rather shallow, it is most damaging to relatively thin pieces of wood such as slats in cooling towers. It is favored by wet situations but is also prevalent on surfaces that have been alternately wet and dry over a substantial period. Heavily fissured surfaces, familiar to many as weathered wood, generally have been quite degraded by soft-rot fungi.

Decay Resistance of Wood

The heartwood of common native species of wood has various degrees of natural decay resistance. Untreated sapwood of essentially all species has low resistance to decay and usually has a short service life under conditions favoring decay. The natural decay resistance of heartwood is greatly affected by differences in preservative qualities of the wood extractives, the attacking fungus, and the conditions of exposure. Considerable differences in service life can be obtained from pieces of wood cut from the same species, even the same tree, and used under apparently similar conditions. There are further complications because, in a few species, such as the spruces and the true firs (not Douglas-fir), heartwood and sapwood are so similar in color that they cannot be easily distinguished.

Precise ratings of decay resistance of heartwood of different species are not possible because of differences within species and the variety of service conditions to which wood is exposed. However, broad groupings of many native species, based on service records, laboratory tests, and general expertise, are helpful in choosing heartwood for use under conditions favorable to decay. Groupings by natural resistance of some domestic and imported wood species to decay fungi are shown in Table 1, which ranks the heartwood of a grouping of species according to decay resistance. The

Table 1. Grouping of some domestic and imported woods according to average heartwood decay resistance[a]

Very resistant	Resistant	Moderately resistant	Slightly or nonresistant
Domestic			
Black locust	Baldcypress, old growth	Baldcypress, young growth	Alder, red
Mulberry, red	Catalpa	Cherry, black	Ashes
Osage-orange	Cedar	Douglas-fir	Aspens
Yew, Pacific	Atlantic white	Honey locust	Beech
	Eastern redcedar	Larch, western	Birches
	Incense	Pine, eastern white, old growth	Buckeye
	Northern white	Pine, longleaf, old growth	Butternut
	Port-Orford	Pine, slash, old growth	Cottonwood
	Western redcedar	Redwood, young growth	Elms
	Yellow	Tamarack	Basswood
	Chestnut		Firs, true
			Hackberry
			Hemlocks
			Hickories
			Magnolia
			Maples
			Pines (other than those listed)[b]
			Spruces
			Sweetgum
			Sycamore
			White oak
			Willows
			Yellow-poplar
Imported			
Angelique			
Azobe			
Balata			
Goncalo alves			
Greenheart			
Ipe (lapacho)			
Jarrah			
Lignumvitae			Mahogany, light red[b]
Purpleheart			Mahogany, yellow[b]
Teak, old growth			Meranti, white[b]
			Obeche
		Teak, young growth	Okoume
	Sucupira	Tornillo	Parana pine
	Wallaba		Ramin
			Sande
			Sepitir
			Seraya, white

[a]Decay resistance may be less for members placed in contact with the ground and/or used in warm, humid climates. Substantial variability in decay resistance is encountered with most species, and limited durability data were available for some species listed. Use caution when using naturally durable woods in structurally critical or ground-contact applications.
[b]More than one species included, some of which may vary in resistance from that indicated.

extent of variations in decay resistance of individual trees or wood samples of a particular species is much greater for most of the more resistant species than for the slightly or nonresistant species.

Natural resistance of wood to fungi is important only where conditions conducive to decay exist or may develop. Where decay hazard exists, heartwood of a species in the resistant category generally gives satisfactory service for wood used above-ground, while those in the very resistant category generally give satisfactory performance in contact with the ground. Heartwood of species in the other two categories will usually require some form of preservative treatment. For mild decay conditions, a simple preservative treatment—such as a short soak in preservative after all cutting and boring operations are complete—may be adequate for wood low in decay resistance. For more severe decay hazards, pressure treatment is often required. Even the very decay-resistant species may require preservative treatment for important structural uses or other uses where failure would