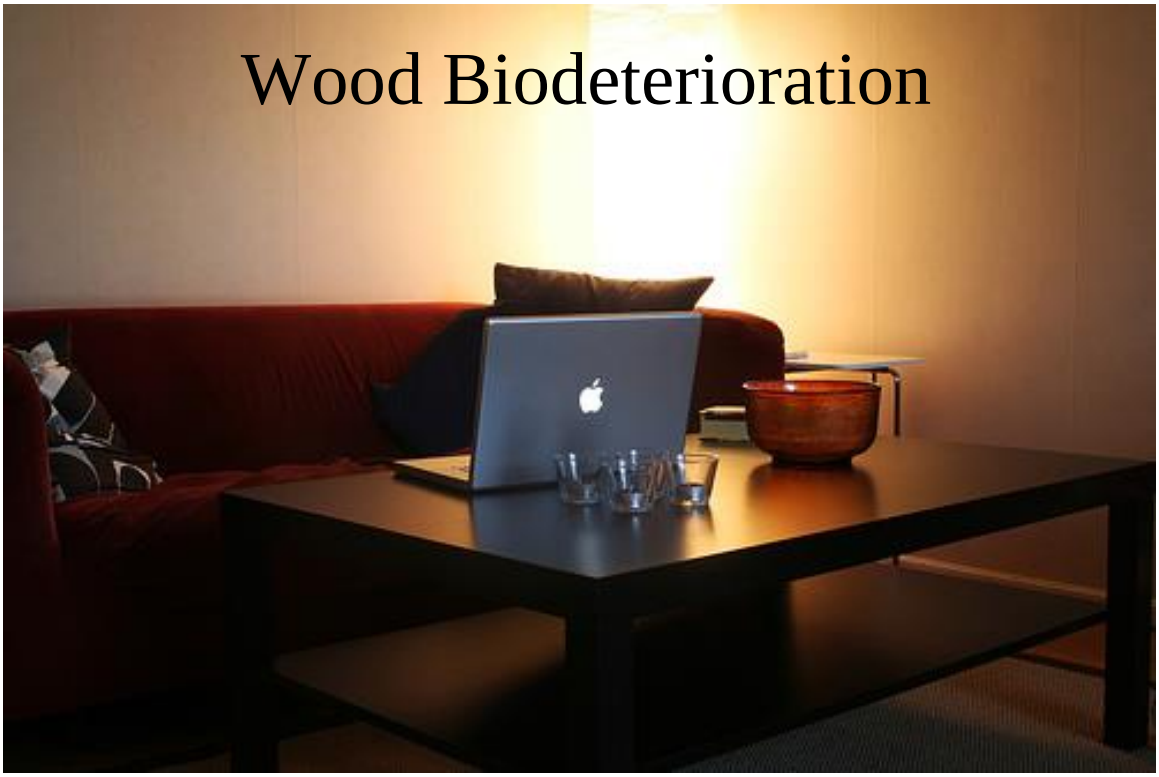


Wood Biodeterioration

By

D. Allen Hughes, P.E.

PDHLibrary Course No 2025023
1 PDH HOURS

Wood Biodeterioration

Carol A. Clausen, Supervisory Research Microbiologist

Contents

Fungus Damage and Control 14–1
- Molds and Fungal Stains 14–1
- Chemical Stains 14–2
- Decay 14–3
- Prevention of Mold, Stain, and Decay 14–6

Bacteria 14–9

Insect Damage and Control 14–9
- Beetles 14–9
- Termites 14–11
- Carpenter Ants 14–13
- Carpenter Bees 14–13

Marine Borer Damage and Control 14–13
- Shipworms 14–13
- Pholads 14–14
- *Limnoria* and *Sphaeroma* 14–14
- Protection from Marine Borers 14–14

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 chapter 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. 14–1).

Molds and Fungal Stains

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

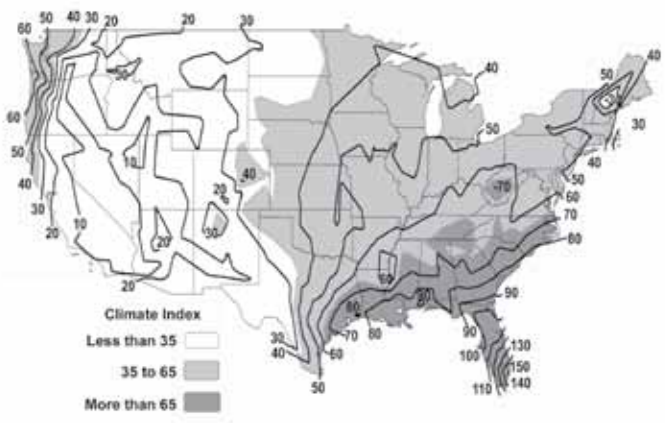


Figure 14–1. Climate index for decay hazard. Higher numbers indicate greater decay hazard.

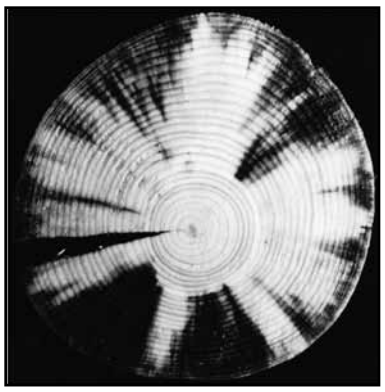


Figure 14–2. Typical radial penetration of log by stain. The pattern is a result of more rapid penetration by the fungus radially (through the ray) than tangentially.

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. 14–2). 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. Recommended moisture control measures are given in Chapter 13.

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 (Chap. 5). 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.

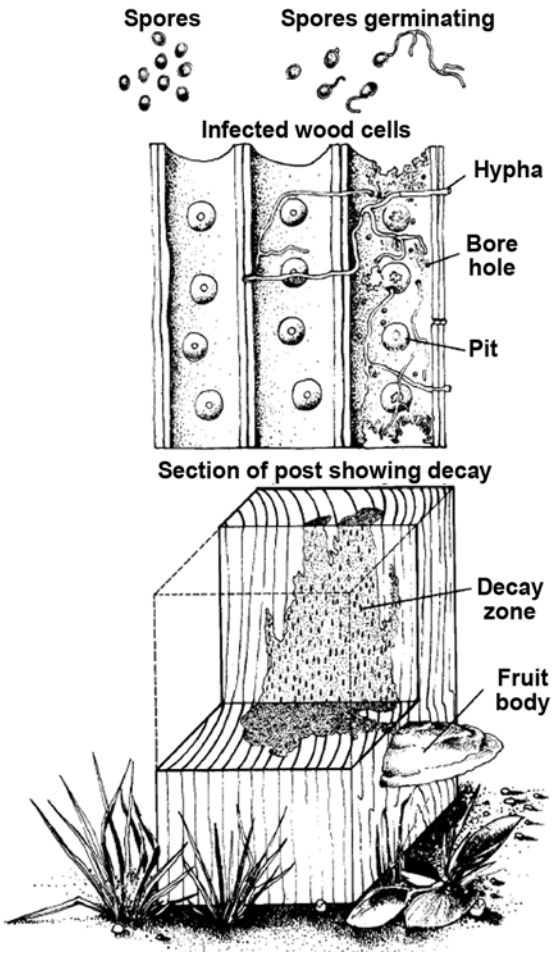


Figure 14–3. The decay cycle (top to bottom). Thousands of spores produced in a fungal fruiting body are distributed by wind or insects. On contacting moist, susceptible wood, spores germinate and fungal hypha create new infections in the wood cells. In time, serious decay develops that may be accompanied 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. 14–3). 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. 14–4), strands, or root-like structures that are usually white or brown in color. Sometimes fruiting bodies are produced 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 14–4. 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.

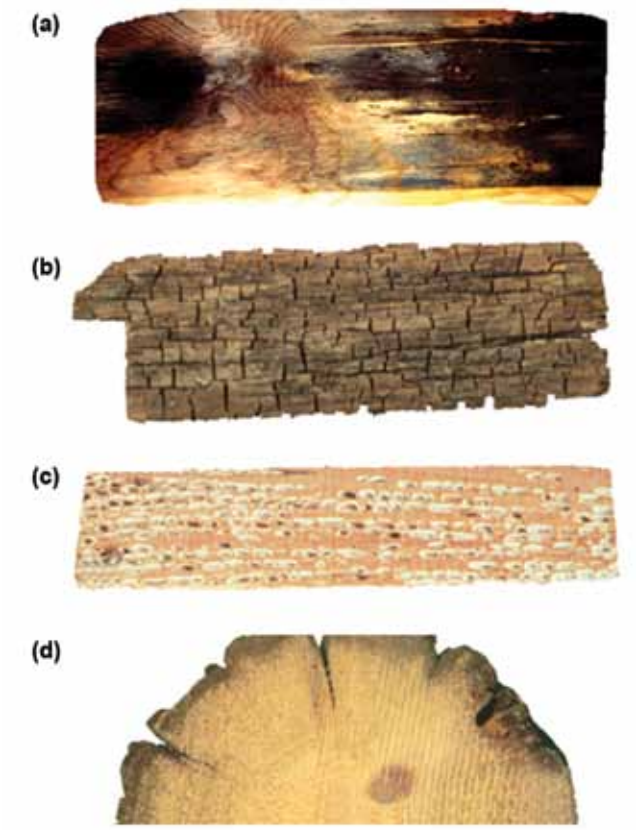


Figure 14–5. Representative samples of four common types of fungal growth on wood: (a) mold discoloration; (b) brown rotted pine (note the dark color and cubical checking in the wood); (c) white rot in maple (note the bleached appearance); (d) soft-rotted preservative-treated pine utility pole (note 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. 14–5). 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. 14–5). 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. 14–5). 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 14–1, which ranks the heartwood of a grouping of species according to decay resistance. The

Table 14–1. 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
	Cypress, Arizona		Hackberry
	Junipers		Hemlocks
	Mesquite		Hickories
	Oaks, white[b]		Magnolia
	Redwood, old growth		Maples
	Sassafras		Pines (other than those listed)[b]
	Walnut, black		Spruces
			Sweetgum
			Sycamore
			Tanoak
			Willows
			Yellow-poplar
Imported			
Angelique	Aftotmosia (Kokrodua)	Andiroba	Balsa
Azobe	Apamate (Roble)	Avodire	Banak
Balata	Balau[b]	Benge	Cativo
Goncalo alves	Courbaril	Bubinga	Ceiba
Greenheart	Determa	Ehie	Hura
Ipe (lapacho)	Iroko	Ekop	Jelutong
Jarrah	Kapur	Keruing[b]	Limba
Lignumvitae	Karri	Mahogany, African	Meranti, light red[b]
Purpleheart	Kempas	Meranti, dark red[b]	Meranti, yellow[b]
Teak, old growth	Mahogany, American	Mersawa[b]	Meranti, white[b]
	Manni	Sapele	Obeche
	Spanish-cedar	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

endanger life or require expensive repairs. When selecting naturally decay-resistant wood species for applications where conditions are conducive to decay, it is important to utilize heartwood. Marketable sizes of some species are primarily second growth and contain a high percentage of sapwood. Consequently, substantial quantities of heartwood lumber of these species are not available. If wood is subjected to severe decay conditions, pressure-treated wood, rather than resistant heartwood, is generally recommended. Preservative treatments and methods are discussed in Chapter 15.

Effect of Decay on Strength of Wood

Decay initially affects toughness, or the ability of wood to withstand impacts. This is generally followed by reductions in strength values related to static bending. Eventually, all strength properties are seriously reduced.

Strength losses during early stages of decay can be considerable, depending to a great extent upon the fungi involved and, to a lesser extent, upon the type of wood undergoing decay. In laboratory tests, losses in toughness ranged from 6% to >50% by the time 1% weight loss had occurred in the wood as a result of fungal attack. By the time weight losses resulting from decay have reached 10%, most strength losses may be expected to exceed 50%. At such weight losses (10% or less), decay is detectable only microscopically. It may be assumed that wood with visually discernible decay has been greatly reduced in all strength values.

Prevention of Mold, Stain, and Decay

Logs, Poles, Piles, and Ties

The wood species, geographic region, and time of year determine what precautions must be taken to avoid serious damage from fungi in logs, poles, piles, ties, and similar thick products during seasoning or storage. In dry climates, rapid surface seasoning of poles and piles will retard development of mold, stain, and decay. The bark is peeled from the pole and the peeled product is decked on high skids or piled on high, well-drained ground in the open to air-dry. In humid regions, such as the Gulf States, these products often do not air-dry fast enough to avoid losses from fungi. Preseasoning treatments with approved preservative solutions can be helpful in these circumstances.

For logs, rapid conversion into lumber or storage in water or under a water spray (Fig. 14–6) is the surest way to avoid fungal damage. Preservative sprays promptly applied to the wood will protect most timber species during storage for 2 to 3 months, except in severe decay hazard climates, such as in Mississippi (Fig. 14–1). For longer storage, an end coating is needed to prevent seasoning checks, through which infection can enter the log.

Lumber

Growth of decay fungi can be prevented in lumber and other wood products by rapidly drying them to a moisture content of 20% or less and keeping them dry. Standard air-drying practices will usually dry the wood fast enough to protect it, particularly if the protection afforded by drying is supplemented by dip or spray treatment of the stock with an EPA-approved fungicidal solution. Successful control by this method depends not only upon immediate and adequate treatment but also upon proper handling of the lumber after treatment. However, kiln drying is the most reliable method of rapidly reducing moisture content.



Figure 14–6. Spraying logs with water protects them against fungal stain and decay.

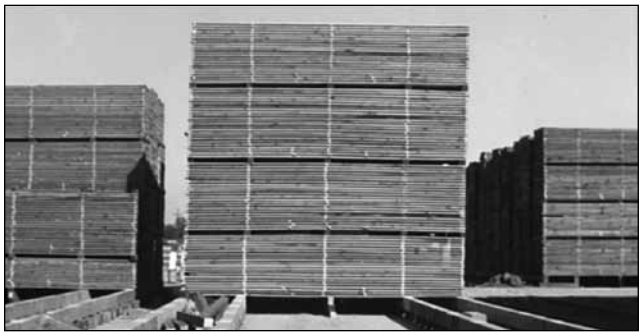


Figure 14–7. A sanitary, well-drained air-drying yard.

Air-drying yards should be kept as sanitary and as open as possible to air circulation (Fig. 14–7). Recommended practices include locating yards and sheds on well-drained ground; removing debris (which serves as a source of infection) and weeds (which reduce air circulation); and employing piling methods that permit rapid drying of the lumber and protect against wetting. Storage sheds should be constructed and maintained to prevent significant wetting of the stock. Ample roof overhang on open sheds is desirable. In areas where termites or water-conducting fungi may be troublesome, stock to be held for long periods should be set on foundations high enough so that the wood can be inspected from beneath.

The user's best assurance of receiving lumber free from decay other than light stain is to buy stock marked by a lumber association in a grade that eliminates or limits such

quality-reducing features. Surface treatment for protection at the drying yard is only temporarily effective. Except for temporary structures, lumber to be used under conditions conducive to decay should be all heartwood of a naturally durable wood species or should be adequately treated with a wood preservative (Chap. 15).

Buildings

The lasting qualities of properly constructed wood buildings are apparent in all parts of the country. Serious decay problems are almost always a sign of faulty design or construction, lack of reasonable care in the handling the wood, or improper maintenance of the structure.

Construction principles that ensure long service and avoid decay in buildings include (a) building with dry lumber, free of incipient decay and not exceeding the amounts of mold and blue stain permitted by standard grading rules; (b) using construction details and building designs that will keep exterior wood and wood-based building components dry and that will promote their drying if they become wet; (c) using wood treated with a preservative or heartwood of a decay-resistant species for parts exposed to aboveground decay hazards; and (d) using pressure-treated wood for the high hazard situation associated with ground contact.

A building site that is dry or for which drainage is provided will reduce the possibility of decay. Grading around the building is an important consideration, as is adequate planning for management of roof runoff (Chap. 17). Stumps, wood debris, stakes, or wood concrete forms are frequently subject to decay if left under or near a building and may become a source for decay infestation for the building.

Wet or infected wood should not be enclosed until it is thoroughly dried. Wet wood includes green (unseasoned) lumber, lumber that has been inadequately dried, or dried lumber that has been rewetted as a result of careless storage and handling. Wood can become infected because of improper handling at the sawmill or retail yard or after delivery to the job site.

Untreated wood parts of substructures should not be permitted to contact the soil. Minimums of 200 mm (8 in.) clearance between soil and framing and 150 mm (6 in.) between soil and siding are recommended. Where frequent hard rains occur, a foundation height above grade of 300 to 460 mm (12 to 18 in.) is advocated. An exception may be made for certain temporary constructions. If contact with soil is unavoidable, the wood should be pressure treated (Chap. 15).

Sill plates and other wood resting on a concrete slab foundation generally should be pressure treated and protected by installing a moisture-resistant membrane, such as polyethylene, beneath the slab. Girder and joist openings in masonry walls should be big enough to ensure an air space around the ends of these wood members. If the members are below the outside soil level, moisture proofing the outer face of the wall is essential.

In buildings without basements but with crawl spaces, wetting of the floor framing and sheathing by condensation may result in serious decay damage. The primary source of condensation is soil moisture. Isolating the crawl space from soil moisture can be achieved by laying a barrier such as polyethylene on the soil. To facilitate inspection of the crawl space, a minimum 460-mm (18-in.) clearance should be left under wood joists.

Wood and wood-based building components should also be protected from rain during construction. Continuous protection from rainwater or condensation in walls and roofs will prevent the development of decay. Thus, design, work quality, and maintenance of wall and roofing systems are critical, particularly at roof edges and points where roofs interface with walls. A fairly wide roof overhang (0.6 m (2 ft)) with gutters and downspouts that are kept free of debris is desirable.

The use of sound, dry lumber is equally important for the interior of buildings. Primary sources for interior moisture are humidity and plumbing leaks. Interior humidity control is discussed in Chapter 17. Plumbing leaks can result in serious decay problems within buildings, particularly if they are undetected for long periods.

Where service conditions in a building are such that the wood cannot be kept dry, the use of preservative-treated wood (Chap. 15) or heartwood of a durable species is advised. Examples include porches, exterior steps, and decking platforms and such places as textile mills, pulp and paper mills, and cold storage plants.

In making repairs necessitated by decay, every effort should be made to correct the moisture condition that led to the damage. If the condition cannot be corrected, all infected parts should be replaced with preservative-treated wood or with all-heartwood lumber of a naturally decay-resistant wood species. If the sources of moisture that caused the decay are entirely eliminated, it is necessary only to replace the weakened wood with dry lumber.

Other Structures and Products

In general, the principles underlying the prevention of mold, stain, or decay damage to veneer, plywood containers, boats, and other wood products and structures are similar to those described for buildings—dry the wood rapidly and keep it dry, or treat it with approved protective and preservative solutions. Interior grades of plywood should not be used where the plywood will be exposed to moisture; the adhesives, as well as the wood, may be damaged by fungi and bacteria and degraded by moisture. With exterior-type panels, joint construction should be carefully designed to prevent the entrance and entrapment of rainwater.

In treated bridge or wharf timbers, checking may occur and may expose untreated wood to fungal attack. Annual in-place treatment of these checks will provide protection from

Table 14–2. Types of damage caused by wood-attacking insects

Type of damage	Description	Causal agent	Damage	
			Begins	Ends
Pin holes	0.25 to 6.4 mm (1/100 to 1/4 in.) in diameter, usually circular			
	Tunnels open**:**			
	Holes 0.5 to 3 mm (1/50 to 1/8 in.) in diameter, usually centered in dark streak or ring in surrounding wood	Ambrosia beetles	In living trees and unseasoned logs and lumber	During seasoning
	Holes variable sizes; surrounding wood rarely dark stained; tunnels lined with wood-colored substance	Timber worms	In living trees and unseasoned logs and lumber	Before seasoning
	Tunnels usually packed with fine sawdust:			
	Exit holes 0.8 to 1.6 mm (1/32 to 1/16 in.) in diameter; in sapwood of large-pored hardwoods; loose floury sawdust in tunnels	Lyctid powder-post beetles	During or after seasoning	Reinfestation continues until sapwood destroyed
	Exit holes 1.6 to 3 mm (1/16 to 1/8 in.) in diameter; primarily in sapwood, rarely in heartwood; tunnels loosely packed with fine sawdust and elongate pellets	Anobiid powder-post beetles	Usually after wood in use (in buildings)	Reinfestation continues; progress of damage very slow
	Exit holes 2.5 to 7 mm (3/32 to 9/32 in.) in diameter; primarily sapwood of hardwoods, minor in softwoods; sawdust in tunnels fine to coarse and tightly packed	Bostrichid powder-post beetles	Before seasoning or if wood is rewetted	During seasoning or redrying
	Exit holes 1.6 to 2 mm (1/16 to 1/12 in.) in diameter; in slightly damp or decayed wood; very fine sawdust or pellets tightly packed in tunnels	Wood-boring weevils	In slightly damp wood in use	Reinfestation continues while wood is damp
Grub holes	3 to 13 mm (1/8 to 1/2 in.) in diameter, circular or oval			
	Exit holes 3 to 13 mm (1/8 to 1/2 in.) in diameter; circular; mostly in sapwood; tunnels with coarse to fibrous sawdust or it may be absent	Roundheaded borers (beetles)	In living trees and unseasoned logs and lumber	When adults emerge from seasoned wood or when wood is dried
	Exit holes 3 to 13 mm (1/8 to 1/2 in.) in diameter; mostly oval; in sapwood and heartwood; sawdust tightly packed in tunnels	Flatheaded borers (beetles)	In living trees and unseasoned logs and lumber	When adults emerge from seasoned wood or when wood is dried
	Exit holes ~6 mm (~1/4 in.) in diameter; circular; in sapwood of softwoods, primarily pine; tunnels packed with very fine sawdust	Old house borers (a roundheaded borer)	During or after seasoning	Reinfestation continues in seasoned wood in use
	Exit holes perfectly circular, 4 to 6 mm (1/6 to 1/4 in.) in diameter; primarily in softwoods; tunnels tightly packed with coarse sawdust, often in decay softened wood	Woodwasps	In dying trees or fresh logs	When adults emerge from seasoned wood, usually in use, or when kiln-dried
	Nest entry hole and tunnel perfectly circular ~13 mm (~1/2 in.) in diameter; in soft softwoods in structures	Carpenter bees	In structural timbers, siding	Nesting reoccurs annually in spring at same and nearby locations
Network of galleries	Systems of interconnected tunnels and chambers	Social insects with colonies		
	Walls look polished; spaces completely clean of debris	Carpenter ants	Usually in damp partly decayed, or soft-textured wood in use	Colony persists unless prolonged drying of wood occurs
	Walls usually speckled with mud spots; some chambers may be filled with “clay”	Subterranean termites	In wood structures	Colony persists
	Chambers contain pellets; areas may be walled off by dark membrane	Dry-wood termites (occasionally damp wood termites)	In wood structures	Colony persists
Pitch pocket	Openings between growth rings containing pitch	Various insects	In living trees	In tree
Black check	Small packets in outer layer of wood	Grubs of various insects	In living trees	In tree
Pith fleck	Narrow, brownish streaks	Fly maggots or adult weevils	In living trees	In tree
Gum spot	Small patches or streaks of gum-like substances	Grubs of various insects	In living trees	In tree
Ring distortion	Double growth rings or incomplete annual layers of growth	Larvae of defoliating insects or flatheaded cambium borers	In living trees	In tree
	Stained area more than 25.4 mm (1 in.) long introduced by insects in trees or recently felled logs	Staining fungi	With insect wounds	With seasoning

decay. Similarly, pile tops may be protected by treatment with a wood preservative followed by application of a suitable capping compound or shield.

Wood boats present certain problems that are not encountered in other uses of wood. The parts especially subject to decay are the stem, knighthead, transom, and frameheads, which can be reached by rainwater from above or condensation from below. Frayed surfaces are more likely to decay than are exposed surfaces, and in salt water service, hull members just below the weather deck are more vulnerable than those below the waterline. Recommendations for avoiding decay include (a) using only heartwood of durable species, free of infection, and preferably below 20% moisture content; (b) providing and maintaining ventilation in the hull and all compartments; (c) keeping water out as much as is practicable, especially fresh water; and (d) where it is necessary to use sapwood or nondurable heartwood, impregnating the wood with an approved preservative and treating the fully cut, shaped, and bored wood before installation by soaking it for a short time in preservative solution. Where such mild soaking treatment is used, the wood most subject to decay should also be flooded with an approved preservative at intervals of 2 or 3 years. During subsequent treatment, the wood should be dry so that joints are relatively loose.

Bacteria

Most wood that has been wet for a considerable length of time probably will contain bacteria. The sour smell of logs that have been held under water for several months, or of lumber cut from them, manifests bacterial action. Usually, bacteria have little effect on wood properties, except over long periods, but some may make the wood excessively absorptive. This can result in excessive absorption of moisture, adhesive, paint, or preservative during treatment or use. This effect has been a problem in the sapwood of millwork cut from pine logs that have been stored in ponds. There also is evidence that bacteria developing in pine veneer bolts held under water or sprayed with water may cause noticeable changes in the physical character of the veneer, including some strength loss. Additionally, a mixture of different bacteria and fungi was found capable of accelerating decay of treated cooling tower slats and mine timbers.

Insect Damage and Control

The more common types of damage caused by wood-attacking insects are shown in Table 14–2 and Figure 14–8. Methods of controlling and preventing insect attack of wood are described in the following paragraphs.

Beetles

Bark beetles may damage the surface of the components of logs and other rustic structures from which the bark has not been removed. These beetles are reddish brown to black and

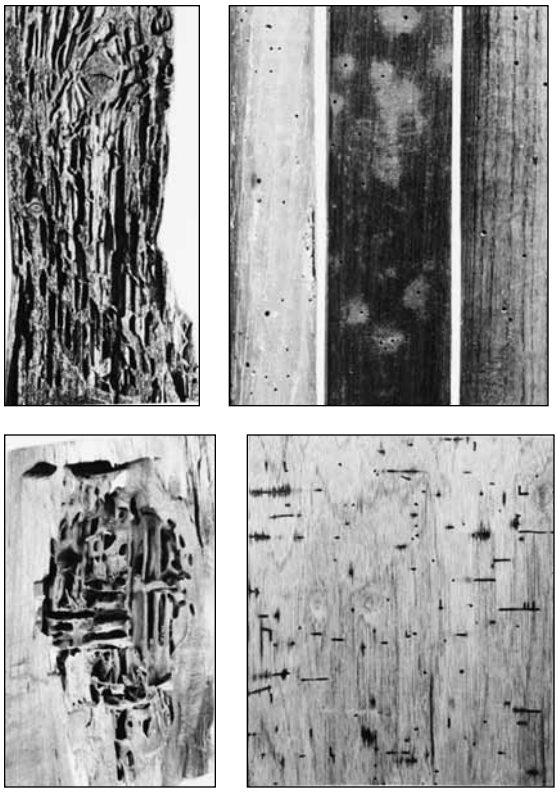


Figure 14–8. Types of insect damage most likely to occur in a building. Upper left—Termite attack; feeding galleries (often parallel to the grain) contain excrement and soil. Upper right—Powder-post beetle attack; exit holes usually filled with wood flour and not associated with discolored wood. Lower left—Carpenter ant attack; nesting galleries usually cut across grain and are free of residue. Lower right—Beetle attack; feeding galleries (made in the wood while green) free of residue and surrounding wood darkly stained.

vary in length from approximately 1.5 to 6.5 mm (1/16 to 1/4 in.) They bore through the outer bark to the soft inner part, where they make tunnels in which they lay their eggs. In making tunnels, bark beetles push out fine brownish-white sawdust-like particles. If many beetles are present, their extensive tunneling will loosen the bark and permit it to fall off in large patches, making the structure unsightly.

To avoid bark beetle damage, logs may be debarked rapidly, sprayed with an approved insecticidal solution, stored in water or under a water spray, or cut during the dormant season (October or November, for instance). If cut during this period, logs should immediately be piled off the ground and arranged for good air movement to promote rapid drying of the inner bark. This should occur before the beetles begin to fly in the spring. Drying the bark will almost always prevent damage by insects that prefer freshly cut wood.

Ambrosia beetles, roundheaded and flatheaded borers, and some powder-post beetles that get into freshly cut timber

can cause considerable damage to wood in rustic structures and some manufactured products. Certain beetles may complete development and emerge several years after the wood is dry, often raising a question as to the origin of the infestation.

Proper cutting practices, rapid debarking, storing under water, and spraying with an approved chemical solution, as recommended for bark beetles, will control these insects. Damage by ambrosia beetles can be prevented in freshly sawn lumber by dipping the product in a chemical solution. The addition of one of the sap-stain preventives approved for controlling molds, stains, and decay will keep the lumber bright. Powder-post beetles attack both hardwoods and softwoods and both freshly cut and seasoned lumber and timber. Powder-post damage is indicated by holes made in the surface of the wood by the winged adults as they emerge and by the fine powder that may fall from the wood. The powder-post beetles that cause most of the damage to dry hardwood lumber belong to the genus *Lyctus*. They attack the sapwood of ash, hickory, oak, and other large-pored hardwoods as it begins to season. Eggs are laid in pores of the wood, and the larvae burrow through the wood, making tunnels from 1.5 to 2 mm (1/16 to 1/12 in.) in diameter, which they leave packed with a fine powder. Species of anobiid beetles colonize coniferous materials.

Susceptible hardwood lumber used for manufacturing purposes should be protected from powder-post beetle attack as soon as it is sawn and when it arrives at the plant. An approved insecticide applied in water emulsion to the green lumber will provide protection. Such treatment may be effective even after the lumber is kiln dried, until it is surfaced. Heat sterilization is another way to kill insects in green lumber. To effectively kill insects in lumber or timbers, heat sterilization requires that the center of the wood be held at 56 °C (133 °F) for 30 min. The time required to reach that temperature is highly variable and depends on thickness of boards, dimension of timbers, and moisture content of the wood (Chap. 20). For example, heating time increases with increasing board thickness or increasing cross-sectional dimension.

Good plant sanitation is extremely important in alleviating the problem of infestation. Proper sanitation measures can often eliminate the necessity for other preventative steps. Damage to manufactured items frequently is traceable to infestation that occurred before the products were placed on the market, particularly if a finish is not applied to the surface of the items until they are sold. Once wood is infested, the larvae will continue to develop, even though the surface is subsequently painted, oiled, waxed, or varnished.

When selecting hardwood lumber for building or manufacturing purposes, any evidence of powder-post infestation should not be overlooked, because the beetles may continue to be active long after the wood is put to use. Heat sterilization under conditions that ensure the center of the wood will be held at 56 °C (133 °F) for 30 min will effectively kill insects in infested lumber. Those conditions vary with moisture content, size, and dimension of wood—see Chapter 20 for further information on heat sterilization. A 3-min soaking in a petroleum oil solution containing an insecticide is also effective for checking infestation or preventing attack on lumber up to standard 19 mm (nominal 1 in.) thick. Small dimension stock also can be protected by brushing or spraying with approved chemicals. For infested furniture or finished woodwork in a building, the same insecticides may be used, but they should be dissolved in refined petroleum oil, such as mineral spirits. Because *Lyctus* beetles lay their eggs in the open pores of wood, infestation can be prevented by covering the entire surface of each piece of wood with a suitable finish.

Powder-post beetles in the family Anobiidae, depending on the species, infest hardwoods and softwoods. Their life cycle takes 2 to 3 years, and they require wood moisture content around 15% or greater for viable infestation. Therefore, in most modern buildings, the wood moisture content is generally too low for anobiids. When ventilation is inadequate or in more humid regions of the United States, wood components of a building can reach the favorable moisture conditions for anobiids. This is especially a problem in air-conditioned buildings where water condenses on cooled exterior surfaces. Susceptibility to anobiid infestation can be alleviated by lowering the moisture content of wood through improved ventilation and the judicious use of insulation and vapor barriers. Insecticides registered for use against these beetles are generally restricted for exterior applications to avoid potential safety hazards indoors. Wood being reused or recycled from older structures often has lyctid or anobiid larvae in it. Such wood should be fumigated or kiln dried before use in another structure.

Beetles in the family Bostrichidae and weevils in the family Curculionidae are associated with wood moisture contents favorable for wood-infesting fungi because they may benefit nutritionally from the fungi. Thus, protection against these insects consists of the same procedures as for protection against wood-decay fungi.

A roundheaded beetle, commonly known as the old house borer, causes damage to seasoned, coniferous building materials. The larvae reduce the sapwood to a powdery or granular consistency and make a ticking sound while at work. When mature, the beetles make an oval hole approximately 6.5 mm (1/4 in.) in diameter in the surface of the wood and emerge. Anobiid powder-post beetles, which make holes 1.6 to 3.2 mm (1/16 to 1/8 in.) in diameter, also cause damage to pine joists. Infested wood should be drenched with a solution of one of the currently recommended insecticides in a highly penetrating solvent. Beetles nesting in wood behind plastered or paneled walls can be eliminated through fumigation of the building by a licensed operator.



Figure 14–9. A, the northern limit of recorded damage done by subterranean termites in the United States; B, the northern limit of damage done by dry-wood termites.

Termites

Termites superficially resemble ants in size, general appearance, and habit of living in colonies. About 56 species are known in the United States. From the standpoint of their methods of attack on wood, termites can be grouped into two main classes: (a) ground-inhabiting or subterranean termites and (b) wood-inhabiting or nonsubterranean termites.

Subterranean Termites

Subterranean termites are responsible for most of the termite damage to wood structures in the United States. This damage can be prevented. Subterranean termites are more prevalent in the southern than in the northern states, where low temperatures do not favor their development (Fig. 14–9). The hazard of infestation is greatest (a) beneath buildings without basements that were erected on a concrete slab foundation or were built over a crawl space that is poorly drained and lacks a moisture barrier (see Chap. 17) and (b) in any substructure wood component close to the ground or an earth fill (for example, an earth-filled porch).

Subterranean termites develop their colonies and maintain their headquarters in the ground. They build their tunnels through earth and around obstructions to reach the wood they need for food. They also must have a constant source of moisture, whether from the wood on which they are feeding or the soil where they nest. The worker members of the colony cause destruction of wood. At certain seasons of the year, usually spring, male and female winged forms swarm from the colony, fly a short time, lose their wings, mate, and if successful in locating a suitable home, start new colonies. The appearance of "flying ants" or their shed wings is an indication that a termite colony may be near and causing serious damage. Not all "flying ants" are termites; therefore, suspicious insects should be identified before investing in eradication (Fig. 14–10).

Subterranean termites normally do not establish themselves in buildings by being carried there in lumber; they primarily

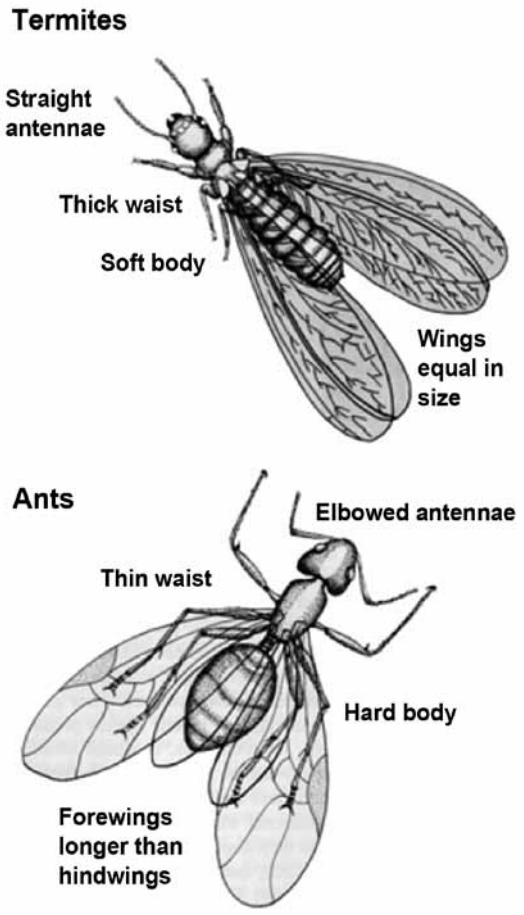


Figure 14–10. A, winged termite; B, winged ant (both greatly enlarged). The wasp waist of the ant and the long wings of the termite are distinguishing characteristics.

enter from ground nests after the building has been constructed. An introduced species, the Formosan termite, is adept at initiating aboveground infestations and nests in structures where wood remains wet for prolonged periods, such as from roof leaks. Telltale signs of subterranean termite presence are the earthen tubes or runways built by these insects over the surfaces of the foundation or other exposed areas to reach the wood above. Another sign is the swarming of winged adults early in the spring or fall. In the wood itself, the termites make galleries that generally follow the grain, leaving a shell of sound wood to conceal their activities. Because the galleries seldom show on the wood surfaces, probing with a pick or knife is advisable if the presence of termites is suspected.

The best protection for wood in areas where subterranean termites are prevalent is to prevent the termites from gaining hidden access to a building. The foundations should be of concrete, pressure-treated wood, or other material through which the termites cannot penetrate. With brick, stone, or concrete block, cement mortar should be used because termites can work through some other kinds of mortar. Also,

it is a good precaution to cap the foundation with 100 mm (4 in.) of reinforced concrete. Posts supporting floor girders should, if they bear directly on the ground, be of concrete. If there is a basement, it should be floored with concrete. Untreated posts in such a basement should rest on concrete piers extending a few inches above the basement floor. However, pressure-treated posts can rest directly on the basement floor. With the crawl-space type of foundation, wood floor joists should be kept at least 460 mm (18 in.) and girders 300 mm (12 in.) from the earth with a polyethylene vapor barrier covering exposed soil and extending partially up the foundation wall. Moisture condensation on the floor joists and subflooring, which may cause conditions favorable to decay and contribute to infestation by termites, can be avoided by covering the soil below with a moisture barrier and assuming proper drainage of rainwater away from all sides of a structure by managing rain and roof runoff with gutters, downspouts, and proper grading around the foundation. All concrete forms, stakes, stumps, and wastewood should be removed from the building site because they are possible sources of infestation. Generally, the precautions effective against subterranean termites are also helpful against decay.

The principal method of protecting buildings in high termite areas is to thoroughly treat the soil adjacent to the foundation walls and piers beneath the building with a soil insecticide. When concrete slab floors are laid directly on the ground, all soil under the slab should be treated with an approved insecticide before the concrete is poured. Furthermore, insulation containing cellulose that is used as a filler in expansion joints should be impregnated with an approved chemical toxic to termites. Sealing the top 13 mm (1/2 in.) of the expansion joint with roofing-grade coal-tar pitch also provides effective protection from ground-nesting termites. Several soil treatments and insecticidal bait control methods are currently available. Information on current control methods is available from national pest control operator associations. These organizations should be consulted to take advantage of the latest technology in termite control.

To control termites already in a building, contact between the termite colony in the soil and the woodwork must be broken. This can be done by blocking the runways from soil to wood, treating the soil, repairing leaks that keep wood within the structure wet (for example, plumbing leaks), or some combination of these techniques. Possible reinfestation can be guarded against by frequent inspections for signs of termites.

Nonsubterranean Termites

In the United States, nonsubterranean termites have been found only in a narrow strip of territory extending from central California around the southern edge of the continental United States to Virginia (Fig. 14–9) and in the West Indies and Hawaii. Their principal damage is confined to an area in southern California, to parts of southern Florida, notably Key West, and to the islands of Hawaii. They also are a localized problem in Arizona and New Mexico.

The nonsubterranean termites, especially the dry-wood type, do not multiply as rapidly as the subterranean termites and have a somewhat different colony life and habits. The total amount of destruction they cause in the United States is much less than that caused by the subterranean termites. The ability of dry-wood termites to live in dry wood without outside moisture or contact with the ground, however, makes them a definite menace in the regions where they occur. Their destruction is not rapid, but they can thoroughly riddle timbers with their tunneling if allowed to work undisturbed for many years. Nonsubterranean termites are often moved from structure to structure in infested items such as furniture.

In constructing a building in localities where the dry-wood type of nonsubterranean termite is prevalent, it is good practice to inspect the lumber carefully to see that it was not infested before arrival at the building site. If the building is constructed during the swarming season, the lumber should be watched during the course of construction, because infestation by colonizing pairs can easily take place. Because paint is a good protection against the entrance of dry-wood termites, exposed wood (except that which is preservative treated) should be kept covered with a paint film. Fine screen should be placed over any openings to the interior unpainted parts of the building. As in the case of ground-nesting termites, dead trees, old stumps, posts, or wood debris of any kind that could serve as sources of infestation should be removed from the premises.

If a building is infested with dry-wood termites, badly damaged wood should be replaced. If the wood is only slightly damaged or is difficult to replace, further termite activity can be arrested by injecting a small amount of an approved pesticidal dust or liquid formulation into each nest. Current recommendations for such formulations can be found from state pest control associations. Buildings heavily infested with nonsubterranean termites can be successfully fumigated. This method is quicker than the use of poisonous liquids and dusts and does not require finding all of the colonies. However, it does not prevent the termites from returning because no poisonous residue is left in the tunnels. Fumigation is very dangerous and should be conducted only by licensed professional fumigators. Infested pieces of furniture, picture frames, and other small pieces can be individually fumigated, heated, or placed in a freezer for a short time. In localities where dry-wood termites do serious damage to posts and poles, the best protection for these and similar forms of outdoor timbers is full-length pressure treatment with a preservative.

Naturally Termite-Resistant Woods

Only a limited number of woods grown in the United States offer any marked degree of natural resistance to termite

attack. The close-grained heartwood of California redwood has some resistance, especially when used above ground. Very resinous heartwood of Southern Pine is practically immune to attack, but it is not available in large quantities and is seldom used.

Carpenter Ants

Carpenter ants are black or brown. They usually occur in stumps, trees, or logs but sometimes damage poles, structural timbers, or buildings. One form is easily recognized by its giant size relative to other ants. Carpenter ants use wood for shelter rather than for food, usually preferring wood that is naturally soft or has been made soft by decay. They may enter a building directly by crawling or may be carried there in firewood. If left undisturbed, they can, in a few years, enlarge their tunnels to the point where replacement or extensive repairs are necessary. The parts of dwellings they frequent most often are porch columns, porch roofs, window sills, and sometimes the wood plates in foundation walls. They often nest in hollow-core doors. The logs of rustic cabins are also attacked.

Precautions that prevent attack by decay and termites are usually effective against carpenter ants. Decaying or infested wood, such as logs, stumps, or retaining walls, should be removed from the premises, and crevices present in the foundation or woodwork of the building should be sealed. Particularly, leaks in porch roofs should be repaired because the decay that may result makes the wood more desirable to the ants.

When carpenter ants are found in a structure, any badly damaged timbers should be replaced. Because the carpenter ant needs high humidity in its immature stages, alterations in the construction may also be required to eliminate moisture from rain or condensation. In wood not sufficiently damaged to require replacement, the ants can be killed by injection of approved insecticide into the nest galleries. Carpenter ant nests are relatively easy to find because they keep their internal nest sites very clean and free of debris. As particles of wood are removed to create galleries or as pieces of insects that have been fed upon accumulate, the debris is removed from the nest and then accumulates below the nest opening.

Carpenter Bees

Carpenter bees resemble large bumblebees, but the top of their abdomen is hairless, causing their abdomens to shine, unlike bumblebees. The females make large (13-mm- (1/2-in.-) diameter) tunnels into unfinished soft wood for nests. They partition the hole into cells; each cell is provided with pollen and nectar for a single egg. Because carpenter bees reuse nesting sites for many years, a nesting tunnel into a structural timber may be extended several feet and have multiple branches. In thin wood, such as siding, the holes may extend the full thickness of the wood. They nest in wood that has been finished with a stain or thin paint film, or light preservative salt treatments, as well as in bare wood. A favorite nesting site is in unfinished exterior wood not directly exposed to sunlight (for example, the undersides of porch roofs, and grape arbors).

Control is aimed at discouraging the use of nesting sites in and near buildings. The tunnel may be injected with an insecticide labeled for bee control and plugged with caulk. Treating the surface around the entry hole will discourage reuse of the tunnel during the spring nesting period. A good paint film or pressure preservative treatment protects exterior wood surfaces from nesting damage. Bare interior wood surfaces, such as in garages, can be protected by screens and tight-fitting doors.

Marine Borer Damage and Control

Damage by marine-boring organisms to wood structures in salt or brackish waters is practically a worldwide problem. Evidence of attack is sometimes found in rivers even above the region of brackishness. The rapidity of attack depends upon local conditions and the kinds of borers present. Along the Pacific, Gulf, and South Atlantic Coasts of the United States, attack is rapid, and untreated pilings may be completely destroyed in a year or less. Along the coast of the New England States, the rate of attack is slower because of cold water temperatures but is still sufficiently rapid to require protection of wood where long life is desired. The principal marine borers from the standpoint of wood damage in the United States are described in this section. Control measures discussed in this section are those in use at the time this handbook was revised. Regulations should be reviewed at the time control treatments are being considered so that approved practices will be followed.

Shipworms

Shipworms are the most destructive of the marine borers. They are mollusks of various species that superficially are worm-like in form. The group includes several species of *Teredo* and several species of *Bankia*, which are especially damaging. These mollusks are readily distinguishable on close observation but are all very similar in several respects. In the early stages of their life, they are minute, free-swimming organisms. Upon finding suitable lodgment on wood, they quickly develop into a new form and bury themselves in the wood. A pair of boring shells on the head grows rapidly in size as the boring progresses, while the tail part or siphon remains at the original entrance. Thus, the animal grows in length and diameter within the wood but remains a prisoner in its burrow, which it lines with a shell-like deposit. It lives on the wood borings and the organic matter extracted from the sea water that is continuously being pumped through its system. The entrance holes never grow large, and the interior of wood may be completely honeycombed and ruined while the surface shows only slight perforations. When present in great numbers, shipworms grow only a few centimeters before the wood is so completely occupied that growth is stopped. However, when not



Figure 14–11. *Limnoria* damage to piling.

crowded, they can grow to lengths of 0.3 to 1.2 m (1 to 4 ft) depending on the species.

Pholads

Another group of wood-boring mollusks is the pholads, which clearly resemble clams and therefore are not included with the shipworms. They are entirely encased in their double shells. The *Martesia* are the best-known species, but another well-known group is the *Xylophaga*. Like the shipworms, the *Martesia* enter the wood when they are very small, leaving a small entrance hole, and grow larger as they burrow into the wood. They generally do not exceed 64 mm (2-1/2 in.) long and 25 mm (1 in.) in diameter but are capable of doing considerable damage. Their activities in the United States appear to be confined to the Gulf Coast, San Diego, and Hawaii.

Limnoria and *Sphaeroma*

Another distinct group of marine borers are crustaceans, which are related to lobsters and shrimp. The principal borers in this group are species of *Limnoria* and *Sphaeroma*. Their attack differs from that of the shipworms and the *Martesia* in that the bore hole is quite shallow; the result is that the wood gradually is thinned from the surface inward through erosion by the combined action of the borers and water erosion. Also, the *Limnoria* and *Sphaeroma* do not become imprisoned in the wood but may move freely from place to place.

Limnoria are small, 3 to 4 mm (1/8 to 1/6 in.) long, and bore small burrows in the surface of wood. Although they can change their location, they usually continue to bore in one place. When great numbers of *Limnoria* are present, their burrows are separated by very thin walls of wood that are easily eroded by the motion of the water or damaged by objects floating upon it. This erosion causes the *Limnoria* to burrow continually deeper; otherwise, the burrows would probably not become greater than 51 mm (2 in.) long or 13 mm (1/2 in.) deep. Because erosion is greatest between tide levels, piles heavily attacked by *Limnoria* characteristically wear within this zone to an hourglass shape (Fig. 14–11). In heavily infested harbors, untreated piling can be destroyed by *Limnoria* within a year.

Sphaeroma are somewhat larger, sometimes reaching a length of 13 mm (1/2 in.) and a width of 6 mm (1/4 in.). In general appearance and size, they resemble the common sow bug or pill bug that inhabits damp places. *Sphaeroma* are widely distributed but are not as plentiful as *Limnoria* and cause much less damage, although damage caused by *Sphaeroma* action resembles that of *Limnoria*. Nevertheless, piles in some structures have been ruined by them. It has been reported that *Sphaeroma* attack salt-treated wood in Florida. Occasionally, they have been found in fresh water.

The average life of well-creosoted structures in areas susceptible to marine borer attack is many times the average life obtained from untreated structures. However, even thorough creosote treatment will not always stop *Martesia, Sphaeroma*, and especially *Limnoria*; shallow or erratic creosote penetration affords only slight protection. The spots with poor protection are attacked first, and from there, the borers spread inward and destroy the untreated interior of the pile.

When wood is to be used in salt water, avoidance of cutting or injuring the surface after treatment is even more important than when wood is to be used on land. No cutting or injury of any kind for any purpose should be permitted in the underwater part of the pile. Where piles are cut to grade above the waterline, the exposed surfaces should be protected from decay. This may be accomplished by in-place application of a wood preservative followed by a suitable capping compound.

Protection from Marine Borers

No wood is immune to marine-borer attack, and no commercially important wood of the United States has sufficient marine-borer resistance to justify its use untreated in any important structure in areas where borers are active. The heartwood of several foreign species, such as greenheart, jarrah, azobe, and manbarklak, has shown resistance to marine-borer attack. Service records on these woods, however, do not always show uniform results and are affected by local conditions. Borer damage to wooden marine structures can be prevented, but knowing the type of borer present in the geographic location is important for selection of proper preservative and treatment retention to protect the structure from surface erosion.

Protection of Permanent Structures

The best practical protection for piles in sea water with shipworms and moderate *Limnoria* hazard is heavy treatment with coal-tar creosote or creosote coal-tar solution. Where severe *Limnoria* hazard exists, dual treatment (copper-arsenate-containing waterborne preservatives followed by coal-tar creosote) is recommended. The treatment must be

thorough, the penetration as deep as possible, and the retention high to give satisfactory results in heavily infested waters. It is best to treat such piles by the full-cell process to refusal; that is, to force in all the preservative the piles can hold without using treatments that cause serious damage to the wood. For highest retentions, it is necessary to air- or kiln-dry the piling before treatment. Details of treatments are discussed in Chapter 15.

The life of treated piles is influenced by the thoroughness of the treatment, the care and diligence used in avoiding damage to the treated shell during handling and installation, and the severity of borer attack. Differences in exposure conditions, such as water temperature, salinity, dissolved oxygen, water depth, and currents, tend to cause wide variations in the severity of borer attack even within limited areas. Service records show average-life figures of 22 to 48 years on well-treated Douglas-fir piles in San Francisco Bay waters. In South Atlantic and Gulf of Mexico waters, creosoted piles are estimated to last 10 to 12 years and frequently much longer. On the North Atlantic Coast, where exposure conditions are less severe, piles can last even longer than the 22- to 48-year life recorded in the San Francisco Bay.

Metal armor and concrete or plastic jacketing have been used with various degrees of success for the protection of marine piles. The metal armor may be in the form of sheets, wire, or nails. Sheathing of piles with copper or muntz metal has been only partially successful, owing to difficulty in maintaining a continuous armor. Theft, mechanical damage from driving, damage by storm or driftwood, and corrosion of sheathing have sooner or later let in the borers, and in only a few cases has long pile life been reported. Attempts during World War II to electroplate wood piles with copper were not successful. Concrete casings are now in greater use than is metal armor, and they appear to provide better protection when high-quality materials are used and carefully applied. Unfortunately, they are readily damaged by ship impact. For this reason, concrete casings are less practical for fender piles than for foundation piles that are protected from mechanical damage.

Jacketing piles by wrapping them with heavy polyvinyl plastic is one form of supplementary protection. If properly applied, the jacketing will kill any borers that may have already become established by creating stagnant water, thereby decreasing oxygen levels in the water that is in contact with the piles. Like other materials, the plastic jacket is subject to mechanical damage.

Protection of Boats

Wood barges have been constructed with planking or sheathing pressure-treated with creosote to protect the hull from marine borers, and the results have been favorable. Although coal-tar creosote is an effective preservative for protecting wood against marine borers in areas of moderate borer hazard, it has disadvantages in many types of boats. Creosote adds considerably to the weight of the boat hull, and its odor is objectionable to boat crews. In addition, antifouling paints are difficult to apply over creosoted wood.

Antifouling paints that contain copper protect boat hulls against marine-borer attack, but the protection continues only while the coating remains unbroken. Because it is difficult to maintain an unbroken coating of antifouling paint, the U.S. Navy has found it desirable to impregnate the hull planking of some wood boats with certain copper-containing preservatives. Such preservatives, when applied with high retentions (40 kg m^{-3} (2.5 lb ft^{-3})), have some effectiveness against marine borers and should help to protect the hull of a boat during intervals between renewals of the antifouling coating. These copper preservatives do not provide protection equivalent to that furnished by coal-tar creosote; their effectiveness in protecting boats is therefore best assured if the boats are dry docked at regular and frequent intervals and the antifouling coating maintained. The leach-resistant wood preservatives containing copper arsenates have shown superior performance (at a retention of 40 kg m^{-3} (2.5 lb ft^{-3})) to creosote in tests conducted in areas of severe borer hazard.

Plywood as well as plank hulls can be protected against marine borers by preservative treatment. The plywood hull presents a surface that can be covered successfully with a protective membrane of reinforced plastic laminate. Such coverings should not be attempted on wood that has been treated with a preservative carried in oil, because the bond will be unsatisfactory.

To find similar courses based on other chapters of this same document search for "wood" in the course listing.

Wood Biodeterioration - Quiz

Updated: 02/11/2025

1. **Which of the following are organisms that can degrade wood?**
   a. Fungi
   b. Insects
   c. Marine borers
   d. All of the above

2. **Molds and fungal stains are confined to a great extent to what part of the tree?**
   a. Bark
   b. Cambium
   c. Sapwood
   d. Heartwood

3. **Fresh surface growths of decay may appear in which of the following shapes?**
   a. Fan-shaped patches
   b. Strands
   c. Root-like structures
   d. All of the above

4. **Which of the following methods can be used to eliminate beetles nesting in wood behind plastered or paneled walls?**
   a. Normal application of pesticides by a licensed exterminator
   b. Fumigation of the building by a licensed operator
   c. Use of and approved ultrasonic repellent device
   d. None of the above

5. **Termites can be grouped into which two main classes?**
   a. Nesting and swarming termites
   b. Flying and grounded termites
   c. Ground-inhabiting (subterranean) and wood-inhabiting (nonsubterranean) termites
   d. Hardwood eating and softwood eating

6. **Which of the following are the most destructive of the marine borers?**
   a. Shipworms
   b. Pholads
   c. Aquatic termites
   d. Sphaeroma

7. **When wood is to be used in salt water, _____ is even more important than when wood is used on land.**
   a. Application of a second or third surface coat
   b. Avoidance of cutting or injuring the surface after treatment
   c. Managing the moisture content of the lumber during construction
   d. All of the above

8. **What is the best practical protection for piles in seawater with shipworms?**
   a. Pressure treatment with high retentions of coal-tar creosote
   b. Installation of decoy piles
   c. Plastic jacketing
   d. Apply a low voltage electric current to the piles to repel the shipworms