Fungi in Forest Products

by CARL HARTLEY

ONE WAY in which wood can be made to give better service to the user is to increase its durability. As a matter of fact, wood is already more lasting than is needed for many uses—it remains unharmed in air that is moist enough to cause serious corrosion of steel, and most of the timber that comes out of buildings that have been in service for centuries is practically as good as when it went in. Nevertheless it is true that decay fungi destroy considerable quantities of wood in some situations, and the uncertainty they cause is sometimes more serious than the actual total damage. The labor cost of replacements is high. Because an increasing part of our lumber supply is from young stands with a large proportion of sapwood, losses from decay will increase unless more precaution is taken to prevent them.

One way to get reliable service at low cost is to select wood intelligently. During the war, species were put to exacting uses, particularly in production of training planes and gliders, where maximum strength with minimum weight were prime considerations. In yellow birch, sweetgum, and yellow poplar for plywood, and in the poplar that also went into aircraft frames when spruce was scarce, material of the best texture and grain was in great demand.

Discolorations not previously studied led to the rejection of much of the wood that otherwise would have been accepted, because of the suspicion that the discolorations indicated weakening by incipient decay. Microscopical and cultural studies were conducted on them; we learned that, for those species and also for beech, only the brownish tints indicated infection with decay fungi. Most of the conspicuously discolored wood, sometimes pink, purple, green, or even nearly black, was found to contain no decay organisms. Thousands of strength tests showed that most such discolorations indicated no highly important decrease in strength.

Studies were also made on Sitka spruce, western hemlock, noble fir, and mahogany. Hundreds of sets of specimens demonstrating the acceptable and objectionable discolorations were prepared for use by Government inspectors and men in the wood-working industries. With their help, it was possible to use safely much valuable material that was badly needed and would otherwise have been rejected. We estimated that the information on yellow poplar made possible a 20-percent increase in the aircraft grades accepted, at a time when the production of poplar veneer was far below the requirements.

The black streaks in wood that extend in both directions from nails are familiar to everyone who has worked with wood. Most of the darkening of wood at nail holes comes from the chemical interaction of the iron with the tannic acid of the wood; small quantities of iron tannate, a common component of black ink, are formed. Such darkening is generally harmless except where appearances are important. It is frequently observed, however, that decay by fungi is more common at nail holes, and decay at those places may be important because it weakens the joint. This localization of decay is probably due mostly to water that condenses on the nail or penetrates the wood by following the nail, but it may be that the iron in the nail sometimes has an additional effect.

In a study of the darkening and molding of mahogany-faced aircraft plywood near nails used during the gluing process, it was found that iron inactivated the toxic extractives on which the wood depends for its resistance to fungi, thus allowing the fungi to develop. A similar but less pronounced effect was found with white oak heartwood. In redwood and in nondurable woods, the iron had no consistent effect on decay by the test fungi used. Since the wood and the extracts tested were heat-sterilized after the iron was added, further tests in which there is no heating are needed before final conclusions can be drawn.

Another precaution that would avoid some failures of wood in service is to use only seasoned lumber for building. Since the beginning of the war, too much of the lumber intended for buildings has been shipped green, and some of it is still shipped without seasoning. Green lumber is physically less desirable and, besides, may contain the first stages of decay, developed during transit or storage. Decay is not always easy to recognize, but lumber that is reasonably free from sapstain or blue stain is usually free from decay, since the stain fungi develop under the same conditions that permit decay fungi to start. For uses in which great strength is required, wood that is heavily blue-stained should be avoided. In the substructure of a basementless building on a moist site, or in a wall assembly in which vapor barriers will hinder drying, lumber that has not been dried may further cause the spread of decay.

Even when mills consider it necessary to ship green lumber, it has been possible to reduce materially the danger that serious infection will develop in it before it has a chance to dry out. The chemical dips that were previously used before open piling have been shown to delay the establishment of heavy stain infections or of decay fungi in bulk-piled green lumber for weeks or months, and sometimes as long as a year. The concentrations found in wartime experiments to be most effective are somewhat stronger than those used on open-piled lumber, but it was found that lower concentrations, which are less likely to irritate the skin of men who handle the lumber, can be made effective by adding rather large quantities of borax to the solutions.

Much deterioration in service can be avoided by using decay-resistant wood in the places where it is needed. It has long been known that heartwood from certain species of trees, as, for example, black locust, osage orange, bald cypress, redwood, and some of the cedars, is highly resistant to decay, and that a number of other species furnish moderately durable wood. Laboratory studies on shipbuilding timbers have confirmed previous opinions as to the general superiority of white oak to the red and black oaks. They also indicated that among the white oaks, chestnut oak is more resistant than true white oak. Studies completed recently in cooperation with the Soil Conservation Service show that there are large differences between different strains of black locust. The shipmast and flowerfield varieties, both in field experience and in accelerated laboratory tests, were decidedly more resistant to decay than ordinary locust.

It has also been found that there are large differences between trees of different ages and between parts of the same tree. In the white oaks, locust, western red cedar, and Douglas fir, and in most other resistant species on which tests have been made, higher resistance or a larger amount of the extractives on which resistance depends has been found in wood of older trees, and in the outer rather than inner heartwood. The central part of the heart at the base sometimes has very little decay resistance. These findings open the way for selecting more resistant wood when it is needed for situations that especially favor decay, such as tank staves, boat ribs, and wood that is placed in contact with the soil.

One of the advances toward making wood more useful has been the increase in the amount of wood treated with fire-retardant chemicals. These usually contain ammonium salts, which in weak solutions many fungi can use as a source of nitrogen, an element of which there is little in untreated wood. It was therefore feared that treated wood would be more susceptible to decay than untreated wood. Laboratory tests made with pure cultures of three common decay fungi on pine sapwood, however, showed that while the treatments did favor some of the mold fungi, they actually hindered or prevented decay in wood not subject to leaching. In contact with soil, deterioration of treated wood was no more rapid than of untreated.

Fiberboard containers are sometimes subjected to moist conditions. The weakening of the board due to the moisture is frequently aggravated by the attack of micro-organisms. The paper layers of which fiberboards are built up are bonded with glue. When urea-formaldehyde resin is used in the glue, it is extended with several parts of starch. This mixture is susceptible to attack by fungi, which sometimes cause the fiberboard to delaminate; the fiber itself is also affected by fungi. Tests showed that this could be much delayed by the use of 2 percent sodium pentachlorophenate in the fiber, or "furnish." Loss in tensile strength in moist exposure was reduced to less than one-third of that in untreated board, and a higher concentration should give still better results.

Preliminary tests indicated that the contents of moist packages might be protected against mildew by volatile fungicides incorporated in the packing material. Of 40 different chemicals tested, the familiar paradichlorobenzene used for moth control appeared most promising; it prevented mold both on wood and on other materials exposed with it.

Plywood and Modified Woods

Protein glues used in bonding plywood were found to be destroyed by either molds or bacteria; the latter were able to attack the glue in submerged specimens in which delamination had been previously attributed to direct effect of moisture, but require much more moisture than do the molds. This points to the possibility of better protection by adding preservatives that are bactericides as well as fungicides.

The synthetic resins coming into use for gluing generally resist fungi and bacteria, when not extended with other materials, although most of them give little or no evidence of any lasting toxicity to fungi. Hot-pressed phenol- and resorcinol-formaldehyde and melamine resin glues applied in liquid form have hindered effectively in laboratory tests the passage of decay fungi from one wood ply to the next.

Cold-pressed urea resins were less effective, and cold-pressed resorcinol resins still less so. When a hot-press phenolic resin was used in the sheet form in which it is often applied, fungi spread through the glue lines with little hindrance, though two sheets used together proved very effective. The number of representatives tested in each type of glue was small, and additional tests may alter these findings. Phenolic resin used as a varnish had value in preventing the surface molding of wood, if enough coats were applied to give a continuous cover. Resin glue lines materially delayed the decay of the wood under experimental conditions in special types of plywood in which the veneers used were only 1/50 inch thick, but not in specimens made of 1/16-inch veneers.

Woods that have been modified by impregnation with resins or otherwise are of interest for use as face plywood and for other purposes. Both compressed wood and pulp impregnated with phenol-formaldehyde resin (compreg and papreg) have shown a high degree of resistance to decay fungi in laboratory tests. Acetylated wood has also been highly resistant in preliminary trials of Forest Service material.

Paint and Surface Application of Fungicides

A somewhat controversial question was the effect of paint on the decay hazard. A coating may influence decay by acting as a barrier to the entrance of fungi, by hindering the entrance of the water the fungi need, or by hindering its evaporation. These last two effects tend to balance each other, and paint can not ordinarily be regarded as an important preventive of decay. Painting wood that is still green should increase the chance of decay; that should also be true for paint on the inside of ship planking, or on any surface through which water would normally be escaping rather than entering. On the other hand, unpainted wood that is exposed to intermittent wetting by rain may become moist enough for decay during periods of wet weather, when painted wood with the same exposure might not reach the moisture content of 25–30 percent, which the decay fungi require. The effect of cracks and unpainted ends exposed in joints complicates the situation and makes it difficult to predict for a particular structure or weather cycle what effect paint may have. There has been similar doubt as to the usefulness of brush or dip treatments with fungicides, despite the strong claims of some dealers.

In laboratory tests with southern pine sapwood, brief dip treatments in oil solutions of pentachlorophenol were quite effective in preventing the entrance of the important decay fungus, *Poria xantha,* despite heavy inoculation with it. The treatment was particularly effective in protecting exposed ends. This agrees with expectation since penetration of solutions through end grain is much deeper than through side surfaces. The futility of drawing general conclusions from tests made under only one set of conditions was shown by the results obtained when some of this same treated wood was buried in soil in two widely separated localities. In both places, the pentachlorophenol gave little protection, while copper compounds that had been decidedly inferior in the inoculation test proved much better than the pentachlorophenol in the soil. In general, for non-durable wood in contact with soil no mere surface treatment is adequate, and thorough impregnation is needed.

Experiments were conducted in warm moist surroundings in southern Mississippi in which pieces of 2 × 4-inch pine sapwood were joined in pairs, the end of a diagonal piece being fastened against the side of a vertical one. Part of these assemblies were given 30-minute soak treatment with the oil-soluble preservatives, copper naphthenate, pentachlorophenol, and phenyl mercury oleate. All of the treated and part of the untreated were then painted. The preservatives were allowed to reach all faces of the pieces, but assembling was done before painting, so the end of the diagonal piece that was in the joint was not painted. All were exposed outdoors on racks for 3½ or 4 years; at the end of that time decay had made marked progress in most of the untreated assemblies. There was still very little decay in those with the preservative.

Painted assemblies without preservatives, in which the painting had been done very carefully so as to seal the joint, were in nearly as good condition as those with the preservative. A rather high proportion of the painted assemblies in which the joint was not sealed, and which were thus more like the ordinary paint job, showed decay, but it was mainly limited to the wood near the joint, with total damage slightly less than in the unpainted, a result that needs confirmation by further experiments.

Many additional tests are needed before positive statements can be made as to how much brush or dip treatments with preservatives decrease the decay hazard, and in what situations the increase in safety justifies the cost of the treatment. Pending further evidence it would seem advisable to give such treatments to lumber used in porches and outside steps, for houses in moist climates. For houses built over moist soil, such treatments might well be used on sills and outer ends of joists, unless preservative-impregnated wood is readily available. The lower siding boards might also profitably be treated, at least to the extent of dipping their ends. Treatment to be most effective should be on unpainted wood, but paint applied afterward and properly maintained should prolong the effectiveness of the preservative.

An experiment was set up in southern Mississippi with modifications of construction such as might be applied in rails of porches, stairs, and fences. A rail that passes over the top of a post without a break should lower the absorption of rain water by the post; in the experiment, such assemblies actually remained nearly free from decay after 3 years. Where the end of the rail met the end of another rail on top of the post or where the end of a rail was fastened against the side of the post, decay has started in most of the assemblies that have so far been opened. Builders have gone far in the development of metal flashing and overlapping joints to keep water out of the roofs and walls of frame buildings, but there is still room for improvement in this respect in some details of buildings, and still more in fences, platforms, bridges, tank supports, and similar outdoor structures.

Houses Without Basements

In the defense housing projects started since 1940, the chief concern as to decay hazard was the fact that the houses and barracks were mostly built close to the ground and without basements. The error of putting decay-susceptible wood members in direct contact with the ground or imbedding them in moist concrete was less frequent than in the emergency construction of the First World War. The principal concern was for the lack of ventilation under many of the houses set on moist sites. Particularly in the winter in the colder parts of the country, moisture condenses on the inner faces of the sills of some of the houses, and in a smaller number on the joists near the outside foundation, or throughout the substructure if the building above is unheated. Occupants of the houses usually are unwilling to keep ventilators open during the colder parts of the year.

Evidence was obtained indicating that vapor from soil was an important source of this condensation moisture, and a simple method was devised for shutting it off. Asphalt roll roofing was laid on the soil under buildings that were too moist. There was a surprising decline in the moisture content of the wood; no more moisture condensation has been observed during the 3½ years since the cover was put on, although nearby houses that had the same moisture content before the beginning of the test continued to show high moisture and in some cases condensation. Many houses, even on moist sites and with mineral-board skirting completely closed around the base during the winter, do not reach the moisture danger point. The houses that do become moist enough for decay can apparently be safeguarded sufficiently by the use of roofing of the grade weighing 55 pounds per 108 square feet and costing at retail about 3 cents a square foot. Ordinary asphalt-impregnated roofers' felt, the 15-pound grade costing about a fourth as much as the asphalt roofing, also appeared to be a sufficient vapor barrier in the places where it has been tested, but it will deteriorate when lying on moist soil, so its use under buildings should be limited to those that will be needed for only a very few years. Tests have been extended to buildings with ordinary types of foundations in addition to the houses with mineral-board skirting but conclusions are not yet final.

THE AUTHOR

Carl Hartley is a pathologist in the Division of Forest Pathology, Bureau of Plant Industry, Soils, and Agricultural Engineering. Except for 3 years of general plant-disease investigations for the Instituut voor Plantenziekten, Netherlands East Indies, Dr. Hartley has been continuously with the Department since 1909. His principal contributions have been on diseases of forest nursery stock and deterioration of forest products.