CHAPTER 13

BRIDGE INSPECTION FOR DECAY AND OTHER DETERIORATION

13.1 INTRODUCTION

Wood is an amazing combination of polymers that exhibits both strength and durability as a structural material. Nevertheless, from the time it is formed in the tree, wood is subject to deterioration by a variety of agents. Damage ranges from relatively minor discolorations caused by fungi or chemicals to more serious decay and insect attack. Wood degradation is beneficial in the ecosystem, returning carbon and other elements to the soil and air, but it becomes detrimental when the deteriorating material is part of a bridge or other structure. Wood outperforms most other materials when used in a properly designed and maintained structure; however, when used in adverse environments, it must be protected to ensure adequate performance. Although the use of pressure-treated wood has significantly extended the life of timber, decay is still the primary cause of bridge deterioration.

The decision to establish a management program for timber bridges is a difficult one that often comes after the user has experienced losses because of previous poor management. Like any investment, a timber bridge must be inspected and maintained on a regular basis to maximize the investment. Yet, most users simply install the structure and walk away, hoping that all will be well. If it is not, they blame the material, when in fact, poor design, poor construction practices, and poor management were probably major factors in the decline. Over the life of a timber bridge, deterioration can be minimized by alert inspectors who identify and record information on structure condition and performance. With such information, timely maintenance operations can be undertaken to correct situations that could otherwise lead to extensive repair or even replacement.

Timber bridge inspectors have the difficult task of accurately assessing the condition of an existing structure. They must understand the biotic and physical factors associated with wood deterioration as well as the relative rate at which these processes occur in a given environment. Timber inspection is a learned process that requires some knowledge of wood pathology, wood technology, and timber engineering. This chapter covers the fundamentals of timber bridge inspection for decay and deterioration; it identifies the agents of deterioration and outlines inspection methods.

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Additional information on more general aspects of bridge inspection is available in references listed at the end of this chapter.[1,52,54]

13.2 AGENTS OF WOOD DETERIORATION

Wood deterioration is a process that adversely alters wood properties. In broad terms, it can be attributed to two primary causes: biotic (living) agents and physical (nonliving) agents. In most cases, wood deterioration is a continuum, whereon the degrading actions from one or more agents alter wood properties to the degree required for other agents to attack. The inspector's familiarity with the agents of deterioration is one of the most important aids in effective bridge inspection. With this knowledge, inspection can be approached with a thorough understanding of the processes involved in deterioration and the factors that favor or inhibit its development.

BIOTIC AGENTS OF DETERIORATION

Wood is remarkably resistant to biological deterioration but a number of organisms have evolved with the ability to utilize wood in a manner that alters its properties. Organisms that attack wood include bacteria, fungi, insects, and marine borers. Some of these organisms use the wood as a food source, while others use it for shelter.

Biotic Requirements

Biotic agents require certain conditions for survival. These requirements include moisture, available oxygen, suitable temperatures, and an adequate source of food, which is generally the wood. Although the degree of dependency on these requirements varies among different organisms, each must be present for deterioration to occur. When any one is removed, the wood is safe from biotic attack.

Moisture

Although many wood users speak of *dry rot*, the term is misleading since wood must contain water for most biological attacks to occur. Wood moisture content is a major determinant of the types of organisms present and the rate at which they degrade the wood. Generally, wood below the fiber saturation point will not decay, although some specialized fungi and insects can attack wood at much lower moisture levels. While keeping wood dry makes sense, it is sometimes difficult to implement, particularly in exposed timber bridges.

Moisture in wood serves several purposes in the deterioration process. For fungi and insects, it is required for many metabolic processes. For fungi, it also provides a diffusion medium for enzymes that degrade the wood structure. When water enters wood, the microstructure swells until the fiber saturation point is reached (about 30 percent wood moisture content). At this point, free water collects in the wood cell cavities, and many fungi can begin to degrade the wood. The swelling associated with water is believed to make the cellulose more accessible to fungal enzymes, enhancing the rate of decay. Additionally, repeated wetting and drying or continuous exposure to moisture can result in leaching of toxic heartwood extractives and some preservatives, reducing decay resistance.

Oxygen

With the exception of anaerobic bacteria, all organisms require oxygen for respiration. While depriving them of oxygen may seem a logical decay control strategy, it is generally impractical in bridge applications since most fungi can survive at very low oxygen levels. An exception is piling that is totally submerged or placed below the water table. In marine environments, piling may be wrapped in plastic or concrete so that marine borers are unable to exchange nutrients and oxygen with the surrounding seawater. In many cases, untreated piling in fresh water will decay to the water line, but remain sound underwater where oxygen is absent.

Temperature

Most organisms thrive in an optimum temperature range of 70 to 85 °F; however, they are capable of surviving over a considerably wider range. At temperatures below 32 °F, the metabolism of most organisms slows, or they produce resistant survival structures to carry them through the unfavorable period. As temperatures rise above freezing, they once again begin to attack wood, but activity slows rapidly as the temperature approaches 90 °F. At temperatures above 90 °F, the growth of most organisms declines, although some extremely tolerant species continue to thrive up to 104 °F. Most organisms succumb at prolonged exposure above this level, and it is generally accepted that 75 minutes of exposure to 150 °F will eliminate all decay fungi established in wood.[9]

In the context of timber bridges, temperature is not controllable, but the inspector should realize that decay will be much more serious in warm environments where the rate of biological activity is higher. This factor has been used, in combination with rainfall, to develop a climate index that expresses temperature and rainfall for an area to formulate a decay hazard index.[46] Although this index cannot account for small variations in regional weather patterns, it does provide a relative guide to decay hazard.

Food

Most biotic agents that attack wood use it as a food source. When wood is treated with preservatives, the food source is poisoned, and infestation can occur only where the preservative treatment envelope is inadequate, or has been broken. If the exposed wood is from a naturally durable species it will initially have some degree of resistance to attack, but this resistance will be reduced rapidly by weathering and leaching. Maintaining an effective preservative treatment is essential for preventing biotic attack.

Bacteria

Bacteria are small, single-cell protists that are among the most common organisms on earth. They recently have been shown to be important colonizers of untreated wood in very wet environments, causing increased permeability and softening of the wood surface. Bacterial decay is normally an extremely slow process, but can become serious in situations where untreated wood is submerged for long periods. Many bacteria are also capable of degrading preservatives and may modify treated wood in such a way that it becomes more susceptible to less chemically tolerant organisms.[13] Although significant strength loss may develop in untreated wood that remains saturated for very long periods, bacterial decay does not appear to be a significant hazard to the pressure-treated timber typically used for bridge construction.

Fungi

Fungi are simple, plantlike organisms that break down and utilize wood material as a food source. They move through the wood as a network of microscopic, threadlike hyphae that grows through the pits or directly penetrates the wood cell wall (Figure 13-1). As the hyphae elongate, they secrete enzymes that degrade cellulose, hemicellulose, or lignin and absorb the degraded material to complete the digestion process. Once the fungus obtains a sufficient amount of energy from the wood, it produces a sexual or asexual fruiting body to distribute reproductive spores that can invade other wood. Fruiting bodies vary from single-cell spores produced at the end of the hyphae to elaborate perennial fruiting bodies that produce millions of spores (Figure 13-2). These spores are so widely spread by wind, insects, and other means that they can be found on most exposed surfaces. As a result, all wood structures are subject to fungal attack when moisture and other requirements conducive to fungal growth are present.

Although wood decay has been noted throughout recorded history, it was not until 1878 that R. Hartig accurately described the relationship between fungal hyphae and wood decay.[20] Even today, we continue to discover new species and intriguing relationships among the organisms that colonize wood. Although there are hundreds of fungal species, the fungi that attack wood can be divided into three types: mold fungi, stain fungi, and decay fungi. These fungi are similar in many ways, but differ substantially in their effects on timber structures.

Mold and Stain Fungi

Mold and stain fungi colonize wood soon after it is cut and continue to grow as long as the moisture content remains high (above approximately 25 percent for softwoods). The primary effect of these fungi is to stain or discolor the wood (Figure 13-3). They are considered nondecay fungi and are of practical consequence primarily where wood is produced for its aesthetic qualities. Mold fungi infect the wood surface, causing blemishes that can generally be removed by brushing or planing, but stain fungi cause serious concerns because they penetrate deeper and discolor the

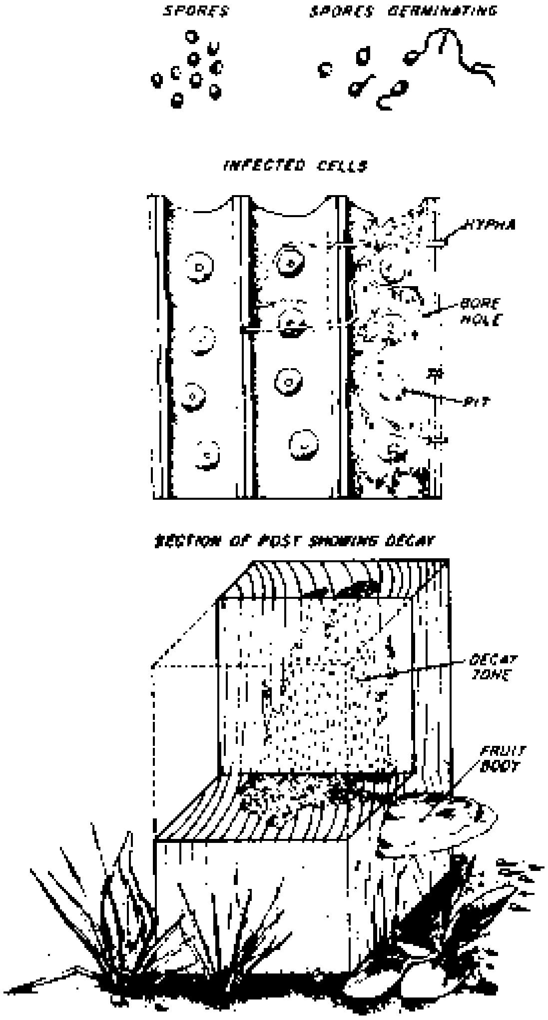


Figure 13-1. - The decay cycle (top to bottom). Fungi begin as minute spores that germinate and grow through the wood. Once enough energy has been obtained, the fungus produces a fruiting body and releases spores that spread and infect other wood.

wood. Under optimum conditions, some stain fungi may also continue to degrade wood, causing decreased toughness and increased permeability; consequently, stained wood is generally rejected during grading for structural uses.

Mold and stain fungi use the contents of the wood cell for food, and do not degrade the cell wall. They do not adversely affect strength, but their presence can indicate conditions favorable for more serious decay fungi. The continued growth of some mold and stain fungi may cause a slow detoxification of natural wood toxins or surface preservatives that can lead to accelerated attack by decay fungi. Since most species attack sapwood, they are more of a problem on thick-sapwood species such as Southern Pine.

Figure 13-2. - A typical fungal fruiting body. Such growths vary considerably in size, color, and shape among species of fungi.

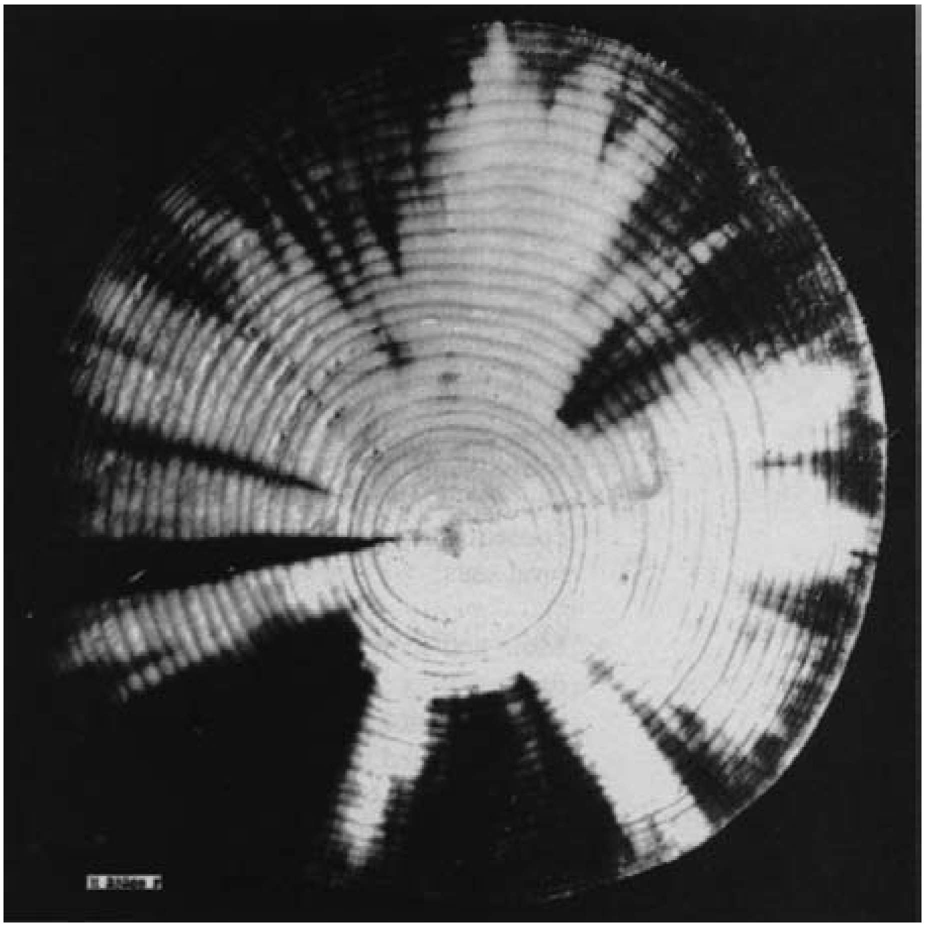


Figure 13-3. - Log cross section showing discoloration caused by stain fungi.

Decay Fungi

Decay in timber bridges is normally caused by decay fungi. These fungi are grouped into three broad classes based on the manner in which they attack wood and the appearance of the decayed material. The three types of decay fungi are brown rot fungi, white rot fungi, and soft rot fungi.

Brown rot fungi, as the name implies, give decayed wood a brownish color. In advanced stages, brown rotted wood is brittle and has numerous cross checks, similar in appearance to the face of a heavily charred timber (Figure 13-4). In the 1700's, scientists examining brown rotted wood stated that the wood had cornbusted, and it was not until the latter 1800's that fungi were associated with this damage. The brown rots primarily attack the cellulose and hemicellulose fractions of the wood cell wall and modify the residual lignin, causing weight losses of nearly 70 percent. Because cellulose provides the primary strength to the cell wall, the brown rot fungi cause substantial strength losses at the very early stages of decay. At this point, the wood appears sound and the fungus may have removed only 1 to 5 percent of the wood weight, but some strength properties may be reduced by as much as 60 percent.[56]

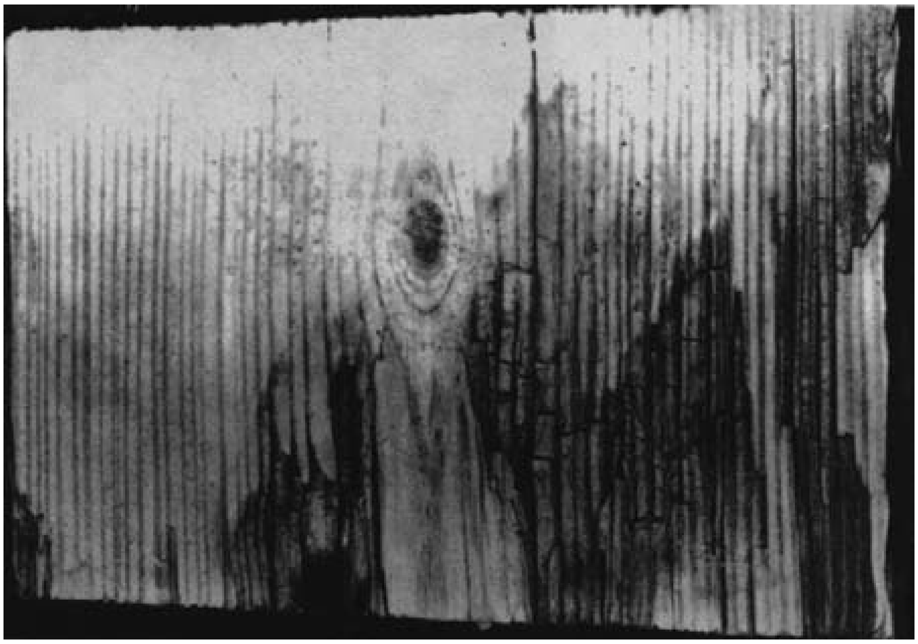


Figure 13-4. - Wood infected with brown rot fungi in an advanced stage. The decayed wood has a darkened color with a cracked, brittle surface that resembles charred wood.

Of the three types of decay fungi, brown rots are among the most serious because of their pattern of attack. Enzymes produced by these fungi migrate or diffuse far from the point where the fungal hyphae are growing. As a result, strength losses in wood may extend a substantial distance from locations where the decay can be visibly detected.

White rot fungi produce decay that resembles normal wood in appearance, but may be whitish or light tan in color with dark streaks. In the advanced stages of decay, infected wood has a distinctively soft texture, and individual fibers can be peeled from the wood (Figure 13-5). The white rots differ from brown rots in that they attack all three components of the wood cell wall, causing weight loss of up to 97 percent. In most cases, the associated strength loss is approximately comparable to weight loss. The enzymes produced by white rot fungi normally remain close to the growing hyphae, and the effects of infestation are not as noticeable at the early decay stages.

Figure 13-5. - Wood infected with white rot fungi. The decayed wood is abnormally light colored with dark streaks (arrows).

Soft rot fungi are a more recently recognized group that generally confine their attack to the outer wood shell (Figure 13-6). They typically attack wood subjected to continuous wetting or changing moisture conditions, and may occur in low-oxygen environments that inhibit conventional decay fungi. Most soft rot fungi require the addition of exogenous nutrients to cause substantial attack. These nutrients are often inadvertently provided by fertilizers in agricultural soils, pulp waste in cooling towers, and other miscellaneous nutrient sources. Although they may be encountered in some situations, soft rot fungi normally are not associated with significant strength loss in bridge components.

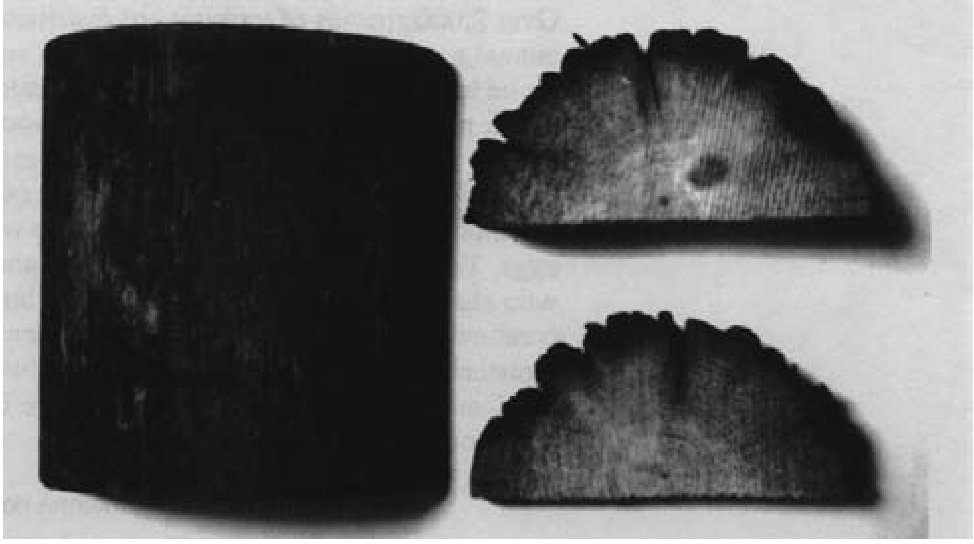


Figure 13-6. - Soft rot decay in a timber pole. Note the shallow depth of decay.

For descriptive purposes, the degree of decay in wood can be classified into three stages: incipient, intermediate, and advanced. Incipient decay occurs at the advancing margin or newest part of the infection, where the damage is difficult to detect because there are no visible signs of attack. Significant changes in wood properties can occur in the incipient stages. As decay enters the intermediate stage, the wood becomes softened, discolored, and retains little, if any, strength. In the advanced stages of decay, wood retains virtually no strength, decay pockets or voids are formed, or the wood is literally dissolved. Detecting decay in the initial or incipient stage is the most difficult, but also the most important, part of bridge inspection. At this point, decay can be most effectively controlled to prevent more severe damage to the structure.

Insects

Insects are among the most common organisms on earth, and it is not surprising that a number of species have developed the ability to use wood for shelter or food. Of the 26 insect orders, 6 cause wood damage. Termites (Isoptera), beetles (Coleoptera), and bees, wasps, and ants (Hymenoptera) are the primary causes of most insect-related deterioration. Insect attack is generally apparent from tunnels or cavities in the wood, which often contain wood powder or frass (insect feces). Powder posting, a pile of wood powder or frass on the outside of the wood, is another sign of attack. In addition to removing portions of the wood structure, insects may also carry stain and decay fungi that further deteriorate wood. One insect even carries a fungus that causes hard pines to wilt.

Termites

Over 2,000 species of termites are distributed in areas where the average annual temperature is 50 °F or higher. In some cases, termites extend their range into cooler climates by living in heated humanmade structures. They attack most wood species, but the heartwood of a few species, such as juniper and southern cypress, exhibits some resistance to attack. Termites are social insects, organized into a series of castes that perform specific functions. The colony's leader is a queen whose sole purpose is to lay eggs. The queen is protected by soldiers and nurtured and fed by workers, who also build the nest and cause wood damage (Figure 13-7). Like all creatures, termites have certain requirements, including wood at a high moisture content, a suitable food source (wood), a high carbon dioxide level, and oxygen. Termite colonies range in size from several hundred to a million or more members.

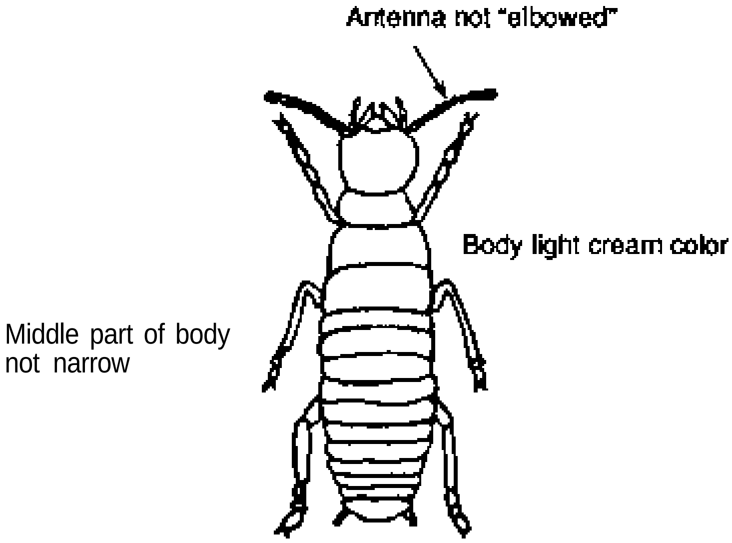


Figure 13-7. - Drawing of a termite worker showing general anatomical features.

Termites that attack wood are separated into five families, three of which are found within the continental United States. The species most associated with wood damage are the subterranean, dampwood, and drywood termites.

Subterranean Termites

Subterranean termites (Rhinotermitidae) attack virtually any available wood, but they need a moisture source and typically nest in the ground. They have developed the ability to attack wood aboveground by constructing earthen tubes that protect them from light and carry moisture to the wood. In the United States, subterranean termites are common throughout the southeast and extend northward into less temperate climates (Figure 13-8). Wood damaged by subterranean termites has numerous tunnels through the springwood, but there are no exit holes to the surface that indicate the termite's presence. Often, a sharp tap on the wood surface will reveal that only a thin veneer of wood remains. Subterranean termite

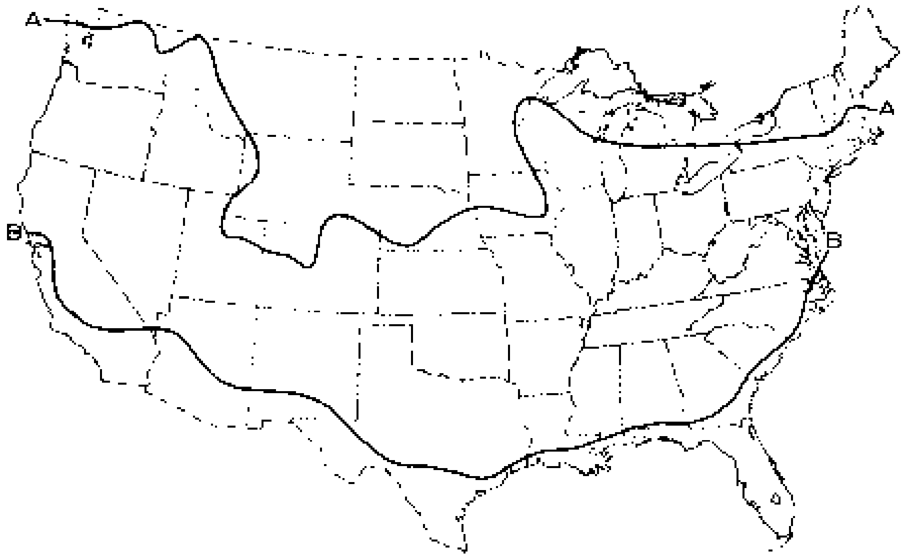


Figure 13-8. - (A) The northern limit of recorded damage done by subterranean termites in the United States. (B) The northern limit of damage done by drywood termites.

tunnels are filled with a mixture of frass and debris and have a dirty appearance (Figure 13-9). The economic impact of these insects in the United States has been conservatively estimated at $1.5 billion per year.[12]

A variety of subterranean termites known as Formosan termites *(Coptotermes formosanus)* recently has moved into several Southeastern States. The presence of this species is cause for concern because of its ability to attack preservative-treated wood, the large size of its colonies, and its habit of occasionally nesting in moist wood not in ground contact. Fortunately, the Formosan termite has been found only at some ports of entry along the southern portions of the United States; however, their capabilities are cause for concern throughout the warmer Southern States.

Dampwood Termites

Dampwood termites are common to the Pacific Northwest, although one group is found in the more arid Southwest. The most common dampwood species is found along the Pacific coast from northern California to British Columbia. Like the subterranean termites, dampwood species need wood that is very wet, and their attack is often associated with decay. These insects are a problem in freshly cut lumber, utility poles, and any untreated wood in ground contact. Tunnels made by dampwood termites are fairly large, but like the subterranean species, they tend to avoid the harder summerwood. The tunnels often contain small amounts of pelletlike frass, but the wood looks somewhat cleaner than that attacked by the subterranean species. Dampwood termite attack can be prevented or arrested by removing the moisture source or by using preservative-treated wood in situations requiring ground contact.

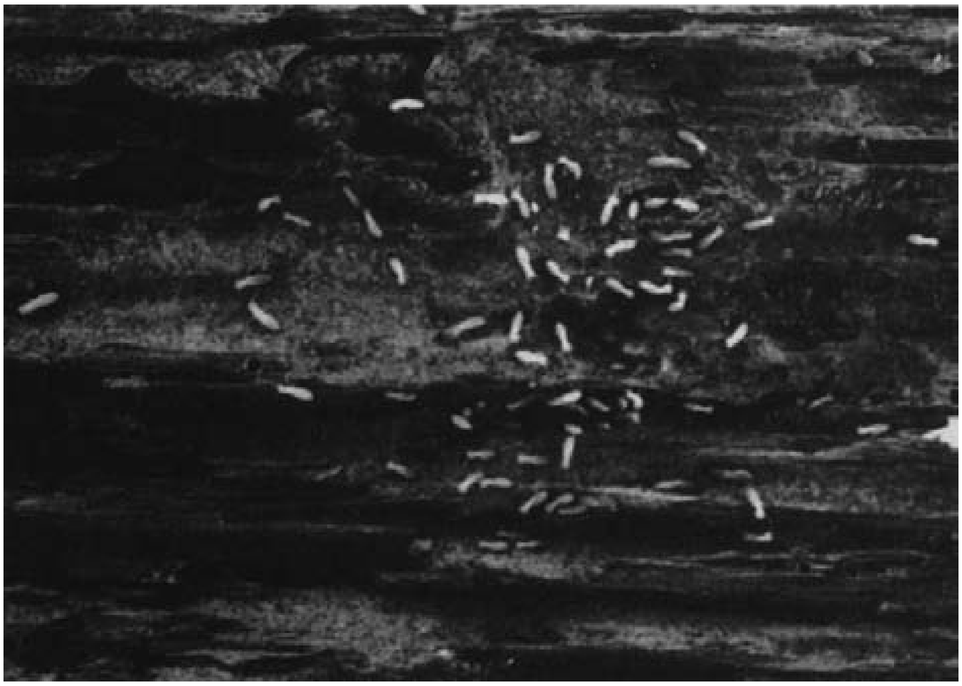


Figure 13-9. - Subterranean termites and the wood damage they cause. Note the frass and debris accumulations in the tunnels (photo courtesy of USDA Forest Service, Forest Sciences Laboratory, Gulfport, Mississippi).

Drywood Termites

Drywood termites (Kalotermitidae) differ from subterranean and dampwood termites in their ability to attack wood that is extremely dry (5 to 6-percent moisture content). As a result, drywood termites attack wood not in ground contact and away from visible moisture sources. Wood damaged by these insects has large, smooth tunnels that are free of either frass or debris. In addition, there is no variation in attack between springwood and summerwood. Drywood termites will frequently clean out their nests by chewing holes to the surface and kicking out debris, which collects below the infested wood. Although these holes are resealed, the presence of debris below a kick hole is a good sign of attack. In general, clusters of infestations are found in one geographic area, and prevention poses some difficulty. Should an infestation occur, the use of structural fumigation has been reported to be effective. Fortunately, the drywood termite is confined to a relatively small geographic region.

Beetles

Beetles (Coleoptera) represent the largest order of insects and contain nine families that cause substantial damage to wood (Table 13-1). Many beetles in these families attack only living trees or freshly cut timber, but they will be briefly discussed because their damage may be encountered during inspection and can be confused with active deterioration.

Table 13-1. - Families of wood-attacking beetles.

Family	Common name	Wood damage
Anobiidae	Powder post beetle	Powder posting
Bostricidae	Powder post beetle	Powder posting
Brentidae	Timber worm	Pin holes
Buprestidae	Flat-headed borer	Grub holes
Cerambycidae	Round headed borer	Grub holes
Lyctidae	Powder post beetle	Powder posting
Lymexylidae	Timber worm	Pin holes
Platypodidae	Ambrosia beetles	Pin holes & stain
Scolytidae	Ambrosia and bark beetles	Pin holes & stain

Powder Post Beetles

The powder post beetles are insects whose larvae attack wood, leaving behind a series of small tunnels packed with powderlike frass (Figure 13-10). The three families of powder post beetles are the Anobiidae, the Bostrichidae, and the Lyctidae. These insects cause serious damage to seasoned wood and are a particular problem in museums, where wooden artifacts may go unobserved for long periods. In the field, the Anobiidae and Bostrichidae attack moist wood in dead branches but will also attack untreated construction timbers. The damage is worsened by emerging adults reinfesting the same piece of wood. The Lyctidae, or true powder post beetles, are found on hardwoods throughout the world and attack wood at moisture contents above 8 percent. As the larvae of these beetles tunnel, they push frass out of the wood. This frass collects beneath

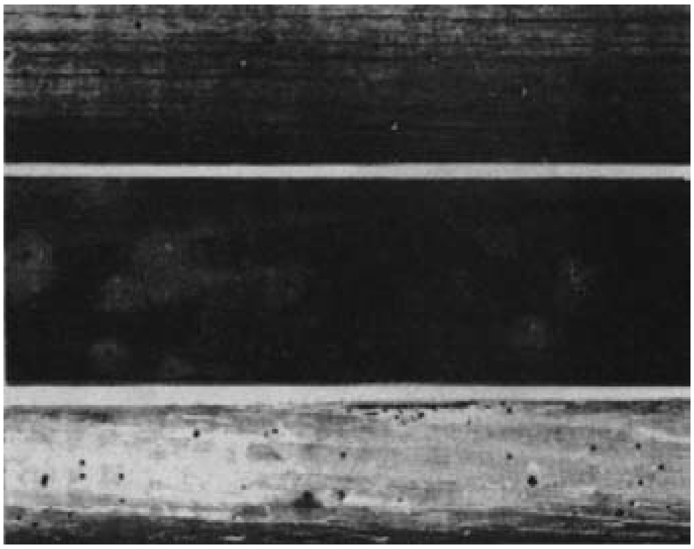


Figure 13-10. - Emergence holes in wood damaged by powder post beetles. The beetle larvae tunnel through the wood, without discoloring it, and leave behind a flourlike frass.

the affected wood and is a good sign of powder post infestation. The use of preservative treatments or sealing of the wood surface will prevent Lyctidae infestation. However, powder post beetle attack can become a problem where untreated wood is used in older existing bridges.

Brentidae and Lymexylidae

The Brentidae, or primitive weevils, and the Lymexylidae, or ship timber beetles, attack freshly cut hardwood logs. The larvae of these beetles make extensive galleries in the wood and cause considerable reduction in lumber quality. The effects of the Brentidae and Lymexylidae can be minimized by removing woody debris that may serve as breeding areas, by ponding logs before processing, or by debarking logs as soon as possible. Neither species is capable of surviving in the seasoned wood once the bark has been removed, although the damage cannot be eliminated. In general, damage caused by these beetles is mainly cosmetic and should not adversely affect strength.

Scolytidae

Scolytidae attack freshly cut timber while the bark remains intact, producing pinholes and providing an avenue of entry for stain fungi. As a result, the wood is aesthetically ruined, and its value decreases. Most Scolytids are confined to the wood cambial layer, and damage is relatively minor; however, some species, such as the Ambrosia beetle, penetrate to greater depths and carry stain fungi deep into the wood interior (Figure 13-11). Adult beetles bore into the wood to lay their eggs and deposit a small amount of fungal material with each egg. The fungus grows into the wood

Figure 13-11. - Damage by Ambrosia beetles in green wood. The galleries are free of residue and the surrounding wood is darkly stained.

structure and the larvae consume the wood to obtain the fungal nutrition. Ambrosia beetles are found throughout the United States and their control is difficult. Although log ponding is an effective preventive measure, surfaces exposed to the air can be reinfested. Prompt bark removal appears to be the most practical solution for limiting damage by this beetle, but this removal permits more rapid entry by stain and decay fungi unless the wood is rapidly processed and dried.

Buprestidae

The Buprestidae, also called flat-headed or metallic wood borers, are almost entirely dependent on trees to complete their life cycle. They cause significant damage by attacking living trees, leaving damage that may be evident in lumber or other wood products. Buprestids lay their eggs on the surface of bark or in tree wounds, and hatching larvae burrow into the wood to varying depths. Over the course of their 1- to 3-year life cycles, the larvae tunnel extensively in the wood, leaving galleries tightly packed with frass. The mature larvae pupates, and the adult chews its way out through a D-shaped exit hole. In addition to the species that attack living trees, one species, the Golden Buprestid *(Buprestis aurulenta)*, is capable of attacking Douglas-fir in service. The Golden Buprestid causes serious damage to utility poles, where its attack is often associated with extensive decay (Figure 13-12). The Golden Buprestid larvae are extremely resistant to dry conditions and have been reported to live in seasoned wood for over 50 years.

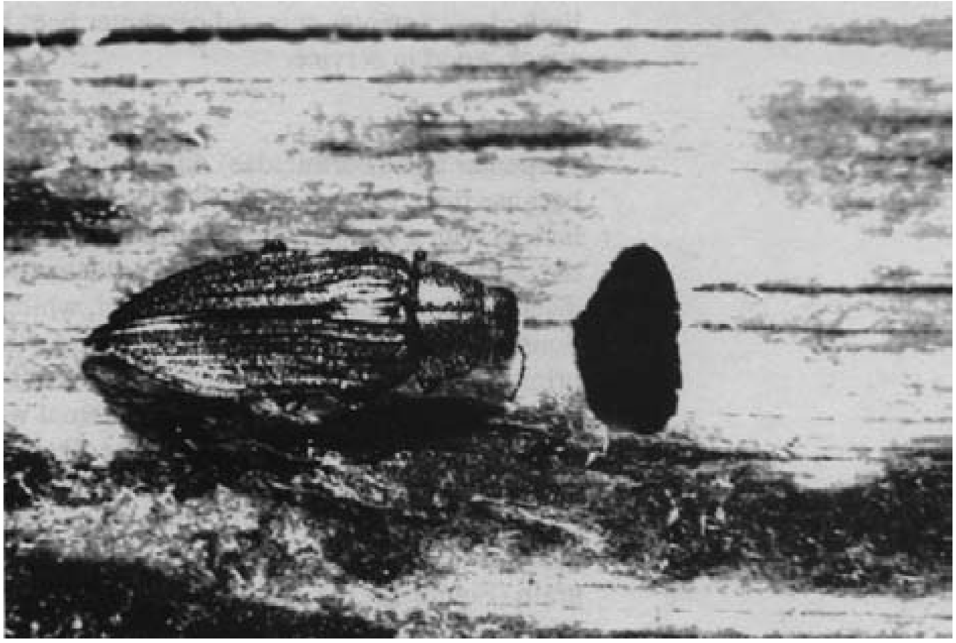


Figure 13-12. - Golden Buprestid next to a surface entrance hole. These insects tunnel through the wood of western species and are often associated with internal decay.

Long Horned Beetles

Long homed beetles (Cerambycidae) include a number of wood degraders that generally have antennae longer than their bodies. They attack wood in all conditions, depending on the species, and cause substantial damage. Some, like the sugar maple borer and poplar borer, attack only living trees, eventually killing them and reducing the value of the wood. Other species attack freshly cut pine, rapidly degrading the wood. One interesting attacker of green wood is the ponderous borer, whose larvae attack Douglas-fir and ponderosa pine, producing tunnels nearly 1 inch in diameter. Although this larva can complete its development in the sawn timber, it will not reinfest the seasoned wood.

In addition to the long homed beetles that attack living or freshly harvested trees, several species cause damage to wood in service. The telephone pole borer was once a common inhabitant of untreated utility poles and was associated with extensive internal decay; however, the use of preservative treated wood has decreased the incidence of this species. Another species, the old house borer, is one of the most destructive wood borers and prefers dry coniferous wood. The old house borer has been reported to cause extensive damage to structural timber along the coastal southeastern United States, but does not cause serious problems elsewhere. Generally, infestations by these beetles can be prevented by using preservative-treated wood.

Ants, Bees, and Wasps

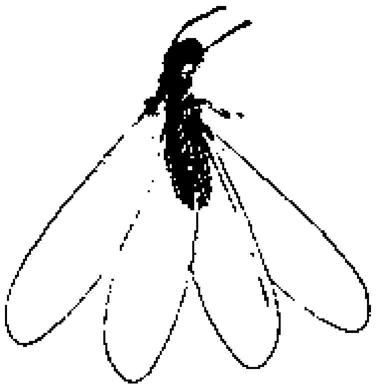
Ants, bees, and wasps are collectively included in the order Hymenoptera. Several members of this order can attack wood, but discussions here are limited to carpenter ants and carpenter bees because these two groups attack wood in service.

Carpenter Ants

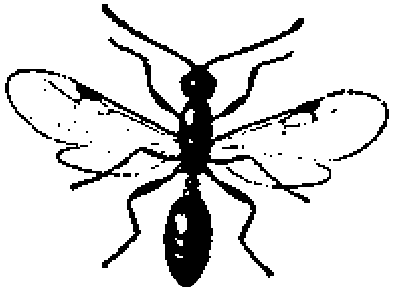
Carpenter ants (Formicidae) differ from the insects previously discussed because they use wood for shelter rather than for food. They are social insects with a complex organization revolving around a queen. To sustain the colony and rear their young, carpenter ant workers must forage great distances from the nest to obtain food, which can consist of insect secretions, insects, and sugary food sources. As the colony grows from the original queen to its eventual 100,000 members, the workers gradually enlarge their nest, causing serious internal wood damage. Many colonies seem to prefer wood that is above the fiber saturation point and are often associated with internal decay. Wood damaged by carpenter ants is characterized by the presence of clean, frass-free tunnels that are largely confined to the softer earlywood, and extend parallel to and across the grain (Figure 13-13). As the workers attack the wood, they remove large amounts of fibrous frass that collect at the base of the piece under attack and provide a readily identifiable sign of infestation. Carpenter ants are often confused with termites but there are several easy methods for distinguishing attack by these two species (Table 13-2).

Figure 13-13. - Wood damaged by carpenter ants. The tunnels are generally clear of debris and extend parallel to, and across, the grain.

Table 13-2. - Differences between termites and carpenter ants.



Termite



Carpenter ant

Characteristic	Termites	Carpenter ants
Body segments	Equal size, no constrictions	Variable size, with constrictions
Mature workers	Cream color, rarely seen outside nest	Dark colored, often seen outside nest
Wings	2 pairs of equal sized wings	2 pairs of unequal sized wings
Wood damage	Tunnels contain frass	Tunnels free of frass
Food source	Digested wood	Sugar, other insects

Carpenter Bees

Like carpenter ants, carpenter bees (*Xylocopa* sp.) use wood only for shelter and for rearing their young. In this process, they tunnel along the grain of coniferous wood, creating 5- to 18-inch long by 0.3- to 0.5-inch wide galleries (Figure 13-14). Carpenter bees look remarkably similar to bumble bees but differ slightly in coloration. They are not common, but when infestation does occur, damage can be serious. The adults of this species tunnel into the wood and lay their eggs in individual cells that are provisioned with food for the growing larvae. The adults emerge and can reinfest the wood. These insects have also been found attacking wood treated with inorganic arsenicals at aboveground retentions.

Marine Borers

When timber substructures are located in salt or brackish waters, severe damage may occur from attack by marine borers. The marine borers that cause wood damage in the United States are classified into three groups based upon their morphology and pattern of wood attack (Figure 13-15): pholads, shipworms, and *Limnoria.* Collectively, these organisms cause over $250 million in damage each year,[53] but their damage is often overlooked because it usually occurs in isolated areas over relatively long time periods. More spectacular short-term losses, such as the $25 million loss in San Francisco Bay during the 1920's, have highlighted the importance of these organisms in marine environments and stimulated interest in their control.[27]

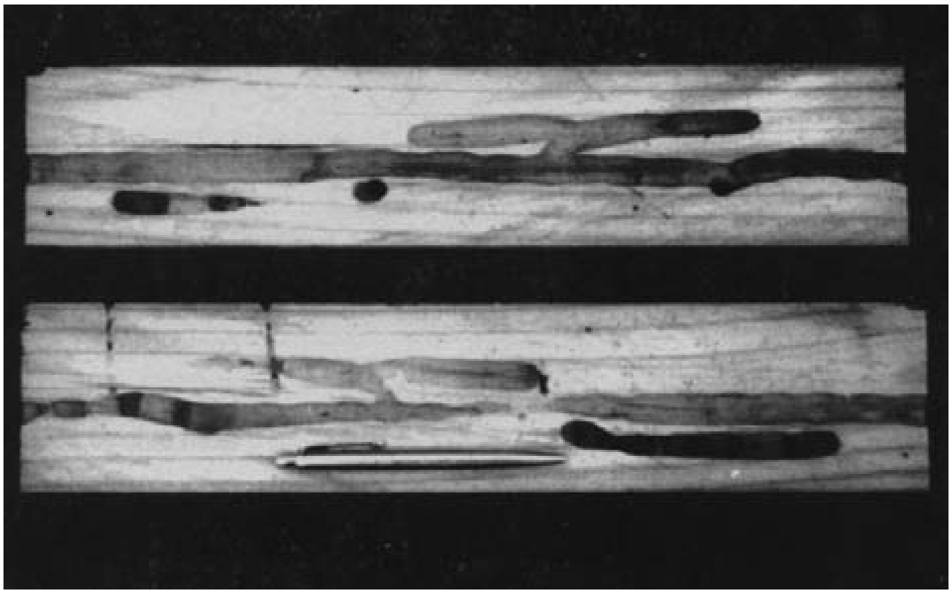


Figure 13-14 - Carpenter bee damage in wood. The bees bore long tunnels along the grain to lay their eggs (photo courtesy of USDA Forest Service, Forest Sciences Laboratory, Gulfport, Mississippi).

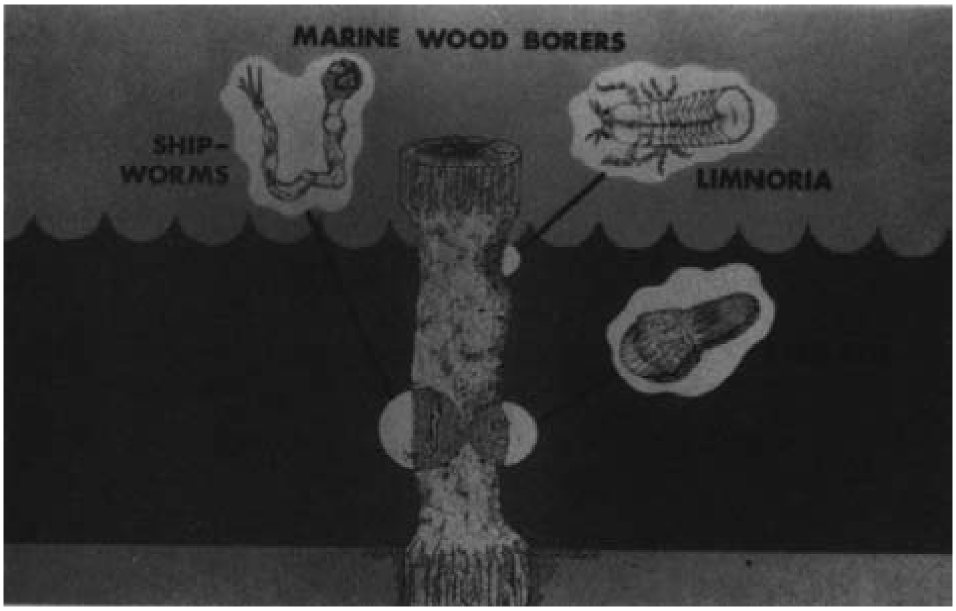


Figure 13-15. - Marine borers that cause wood damage in U.S. waters.

Pholads

Pholads are clamlike mollusks that burrow into wood and filter food from the surrounding water. They begin life as tiny free-swimming larvae that eventually settle onto a suitable wood surface and become permanently established in the wood. Pholads grow to be approximately 2.5 inches long and leave an entry hole in the wood surface about 0.25 inches in diameter. As pholads burrow into wood, the surface eventually weakens and tends to break away under wave action. Internal damage is generally identifiable by characteristic pear-shaped borings (Figure 13-16). Eventually, the wood area decreases to the point where it fails. Although pholads do not pose a problem along the continental United States, one species, *Martesia striata*, causes extensive damage to wood in more tropical marine environments. Attack can be prevented by the use of creosoted wood; however, other wood-degrading organisms in the tropical environment are resistant to creosote so dual treatment with both creosote and a waterborne inorganic arsenical is required. In temperate waters rock burrowing pholads also cause damage to concrete structures.

Shipworms

Shipworms are long, wormlike mollusks that cause interior damage to wood while leaving only a small hole on the surface as evidence of their attack. Like pholads, shipworms begin life as small, free-swimming larvae, then settle down to begin their sedentary, wood-inhabiting life. In the 1700’s, ship captains exploited this portion of the life cycle by sailing their infested wooden ships upriver into fresh water where the trapped shipworms would succumb to the lack of salinity.

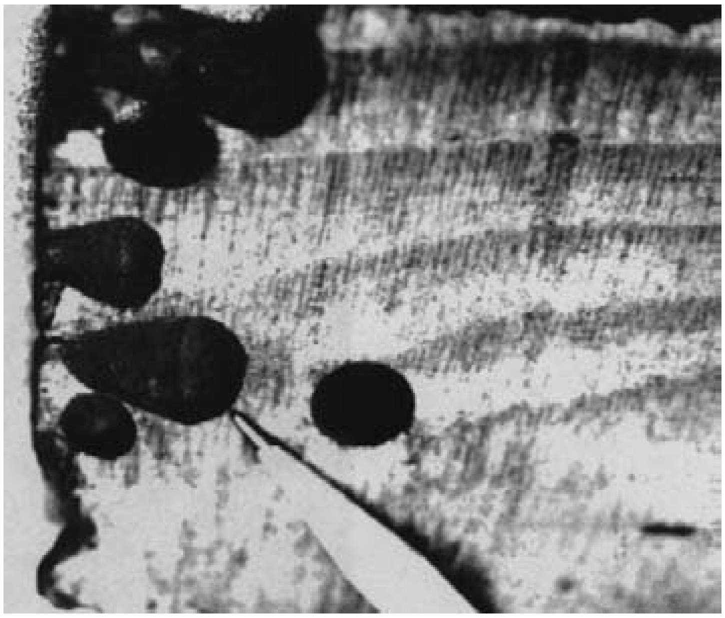


Figure 13-16. - Internal wood damage caused by pholads. These borers generally burrow near the wood surface and are characterized by pear-shaped borings.

Two shipworm species, *Teredo navalis* and *Bankia setacea,* are commonly encountered along the United States continental coasts. These species differ in their morphology, with the former growing to be 3.5 to 7 inches long and 0.5 inch in diameter, and the latter growing to be 59 to 71 inches long and 0.8 inch in diameter. Generally, *T. navalis* has a greater tolerance to low salinity and can survive far upstream in many estuaries, while *B. setacea* is more temperature resistant and is found in more northerly harbors.

As shipworms become established in wood, two hard, clamlike shells near the tops of their heads begin to rasp away at the wood, leaving tunnels with a characteristic white coating (Figure 13-17). The shipworm gradually enlarges the tunnel within the wood, but the initial hole it entered rarely enlarges beyond 0.06 inch in diameter. From the safety of their wood burrow, shipworms extend a pair of feathery siphons into surrounding water. These siphons function in the exchange of nutrients, oxygen, and waste products. At any sign of danger, the siphons are retracted and the surface hole is covered by a hardened pallet that protects the organism from attack. The protection of the pallet also allows the shipworm to survive in wood out of water for 7 to 10 days. The small size of the surface hole and the presence of the pallet make visual detection of internal shipworm attack unreliable, but recent advances in acoustic detection have improved the prospects for detecting infestations before substantial damage occurs.

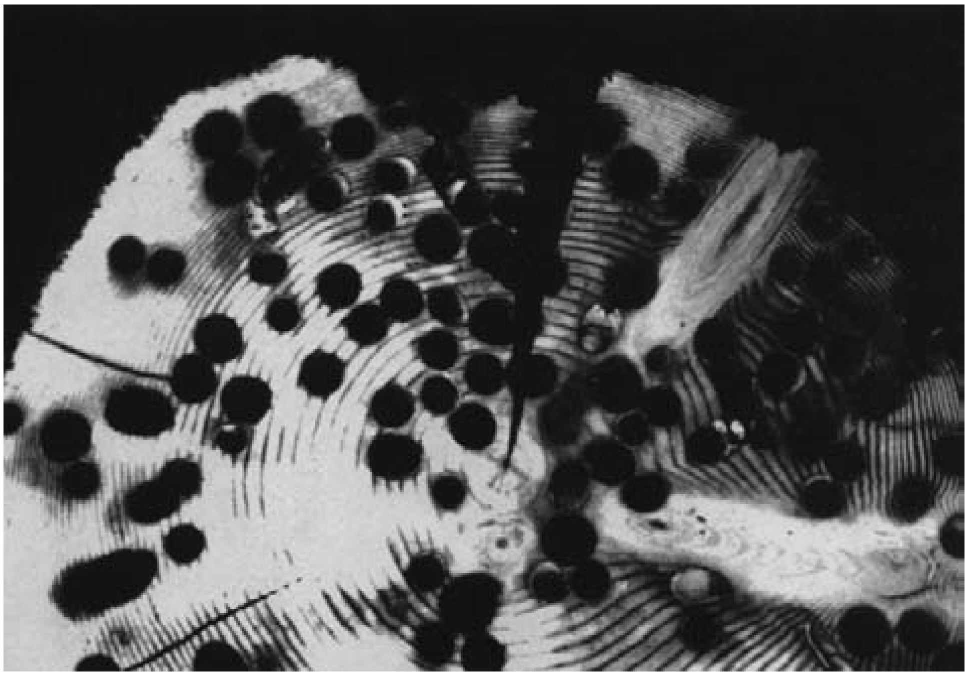


Figure 13-17 - Internal wood damage caused by ship worms. Tunnels extend throughout the cross section and are usually covered with white calcium deposits.

Limnoria

Limnoria or gribbles are mobile crustaceans that differ from shipworms and pholads in their ability to move from one piece of wood to another during their life cycle. There are 20 species of *Limnoria* that attack wood in marine waters, but only 3 cause major damage in the United States. Two of these species are capable of attacking only untreated wood, but the other species, *L. tripunctata,* attacks creosote-treated wood in waters south of San Francisco Bay on the west coast and all along the east coast of the United States. Specimens of this species have been removed from creosoted wood and the preservative could literally be squeezed from their bodies, yet they continued to attack the wood. This remarkable resistance has both fascinated and stymied scientists, who have yet to develop a plausible explanation for this phenomenon.

Limnoria damage wood by burrowing small-diameter (0.12 inch) tunnels near the wood surface. Although the damage is minimal, continued removal of the weakened wood by wave action exposes new wood to attack. Eventually, the member area is reduced to the point where the structure fails or must be replaced. A classic sign of *Limnoria* attack is the hourglass shape that severely attacked piling take about the tidal zone (Figure 13-18); however, attack can and does extend to the mudline if oxygen and salinity conditions are suitable.

Other Marine Borers

A relatively new concern for wood users in semitropical waters is *Sphaeroma terebrans,* a mobile crustacean native to the Florida mangrove

Figure 13-18. - Limnoria damage to a timber pile, evidenced by the characteristic hour-glass shape in the tidalzone.

swamps. This species exhibits greater tolerance to copper-containing wood preservatives and may become an important factor in Florida and other warm-water regions.

PHYSICAL AGENTS OF DETERIORATION

Although wood deterioration is traditionally viewed as a biological process, wood can also be degraded by physical agents. These agents are generally slow acting, but can become quite serious in specific locations. Physical agents include mechanical abrasion or impact, ultraviolet light, metal corrosion by-products, and strong acids or bases. Damage by physical agents can be mistaken for biotic attack, but the lack of visible signs of fungi, insects, or marine borers, plus the general appearance of the wood, can alert the inspector to the nature of the damage. Although destructive in their own right, physical agents can also damage the preservative treatment, exposing untreated wood to attack by biotic agents.

Mechanical Damage

Mechanical damage is probably the most significant physical agent of timber bridge deterioration. It is caused by a number of factors and varies considerably in its effects on the structure. Most commonly, mechanical damage is from vehicle abrasion, which produces worn or marred surfaces and reduces the effective wood section. Obvious examples of this damage occur in the bridge deck area where abrasion produces degradation of wearing surfaces and wheel guards. More severe mechanical damage may be caused by long-term exposure to vehicle overloads, foundation settlements, and debris or ice floes in the stream channel (Figure 13-19).

Ultraviolet Light Degradation

Some of the most visible wood deterioration results from the action of the ultraviolet portion of sunlight, which chemically degrades the lignin near the wood surface (Figure 13-20). Ultraviolet degradation typically causes light woods to darken and dark woods to lighten, but this damage penetrates only a short distance below the surface.[17] The damaged wood is slightly weaker, but the shallow depth of the damage has little influence on strength except where continued removal of damaged wood eventually reduces the member dimensions.

Corrosion

Wood degradation from metal corrosion is frequently overlooked as a cause of bridge deterioration. This type of degradation can be significant in some situations, particularly in marine environments where saltwater galvanic cells form and accelerate degradation.[31] Corrosion begins when

Figure 13-19. - Severe mechanical damage to a glulam bridge caused by debris flow during high stream levels.

Figure 13-20. - Ultraviolet light degradation of the end grain of a guardrail post. Note the minor surface erosion of earlywood between the latewood (growth rings).

moisture in the wood reacts with iron in a fastener to release ferric ions that in turn deteriorate the wood cell wall. As corrosion progresses, the fastener becomes an electrolytic cell with an acidic end (anode) and an alkaline end (cathode). Although the conditions at the cathode are not severe, the acidity at the anode causes cellulose hydrolysis and severely reduces wood strength in the affected zone. Wood attacked in this fashion is often dark and appears soft (Figure 13-21). In many wood species, discoloration also occurs where iron contacts the heartwood.

In addition to the deterioration caused by corrosion, the high moisture conditions associated with this damage can initially favor the development of fungal decay. As corrosion progresses, the toxicity of the metal ions and the low pH in the wood eventually eliminate fungi from the affected zone, although decay may continue at some distance away from the fastener. The effect of wood metal corrosion can be limited by using galvanized or noniron fasteners.

Chemical Degradation

In isolated cases, the presence of strong acids or bases can cause substantial damage to wood. Strong bases attack the hemicellulose and lignin, leaving the wood a bleached white color. Strong acids attack the cellulose and hemicellulose, causing weight and strength losses. Wood damaged by acid is dark in color and its appearance is similar to that of wood damaged by fire. Strong chemicals will normally not contact a timber bridge unless accidental spills occur.

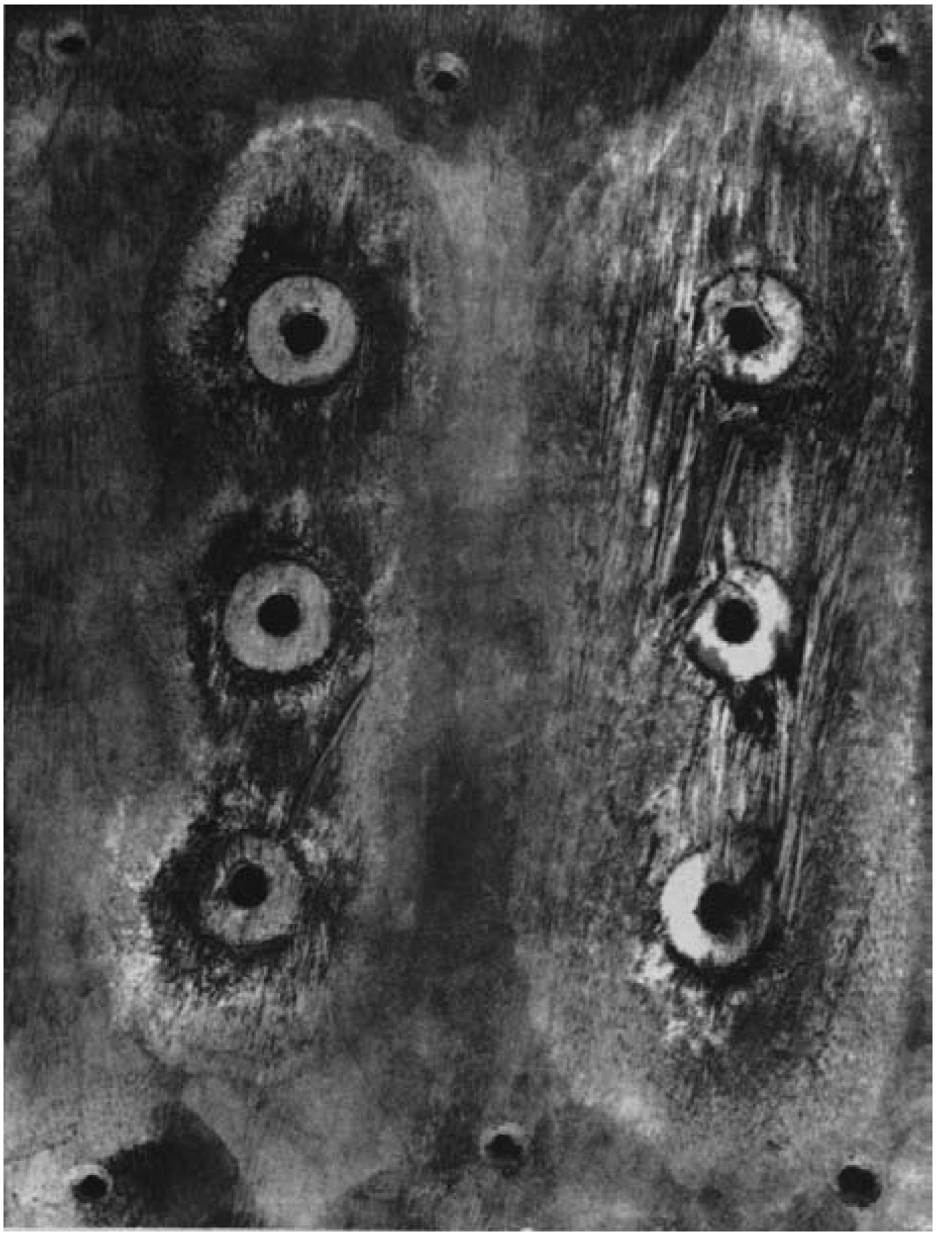


Figure 13-21. - Wood damage around bolt holes caused by corrosion of the metal fasteners.

13.3 METHODS FOR DETECTING DETERIORATION

Until this point, discussions have been fairly specific about the effects that various organisms have on wood. Unfortunately, our ability to detect wood deterioration has lagged far behind our knowledge of deterioration mechanisms. As a result, the inspection process varies widely among regions, although the tools of the trade are fairly standard. There is no magic box that will accurately determine the condition of a given structure, but a number of tools used in combination can give a reasonable estimate of the amount and degree of wood deterioration present.

Methods for detecting deterioration in bridges are divided into two categories: those for exterior deterioration and those for interior deterioration. In both cases, specific methods or tools are appropriate for certain types of damage, and their usefulness varies depending on the type of structure. Although a variety of inspection methods may be employed, in practice the inspector uses only a few tools. The methods or tools are often dictated by budget, previous experience, and the types of problems that are encountered. No equipment can replace a well-trained inspector who has a broad knowledge of wood systems.

METHODS FOR DETECTING EXTERIOR DETERIORATION

Exterior deterioration is the easiest to detect because it is often readily accessible to the inspector. The ease of detection depends on the severity of damage and the method of inspection. The four methods or tools most commonly used include visual inspection, probing, the pick test, and the Pilodyn. When areas of exterior deterioration are located by these methods, further investigation by other methods is required in order to confirm and define the extent of damage.

Visual Inspection

The simplest method for locating deterioration is visual inspection. The inspector observes the structure for signs of actual or potential deterioration, noting areas for further investigation. Visual inspection requires strong light and is suitable for detecting intermediate or advanced surface decay. It will not detect decay in the early stages, when control is most effective, and should never be the sole method employed. Some of the more common visual signs of deterioration include the following (Figure 13-22):

Fruiting bodies provide positive indication of fungal attack, but do not indicate the amount or extent of decay. Some fungi produce fruiting bodies after small amounts of decay have occurred, while others develop only after decay is extensive. Because fruiting bodies are not common on bridges, they almost certainly indicate serious decay problems when they are present.

Sunken faces or localized surface depressions can indicate underlying decay. Decay voids or pockets may develop close to the surface of the member, leaving a thin, depressed layer of intact, or partially intact, wood at the surface.

Staining or discoloration indicates that members have been subjected to water and potentially high moisture contents suitable for decay. Rust stains from connection hardware are also a good indication of wetting.

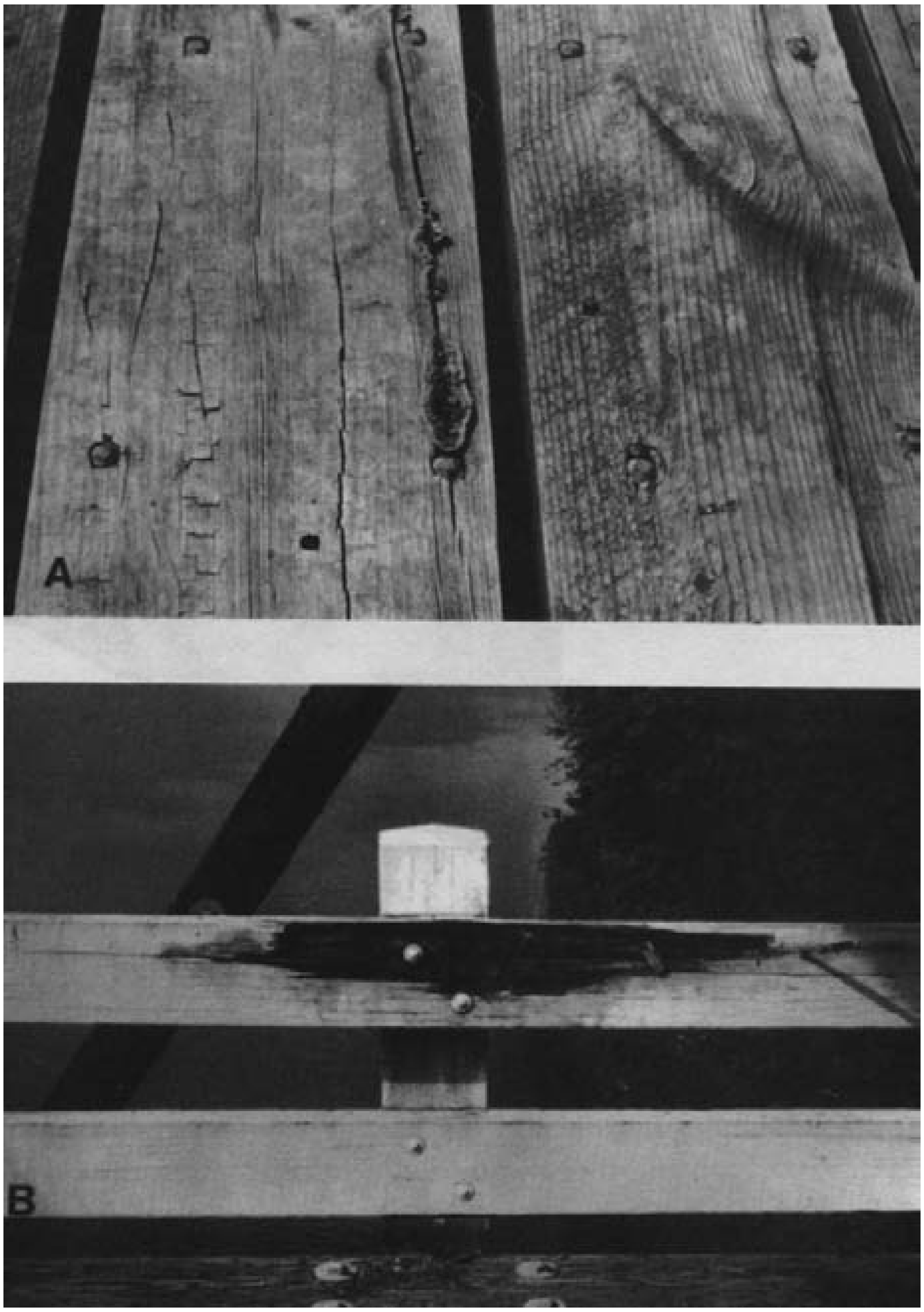


Figure 13-22. - Visual signs of potential deterioration. (A) Fruiting bodies. (B) Sunken faces (shown with the thin surface layer removed).

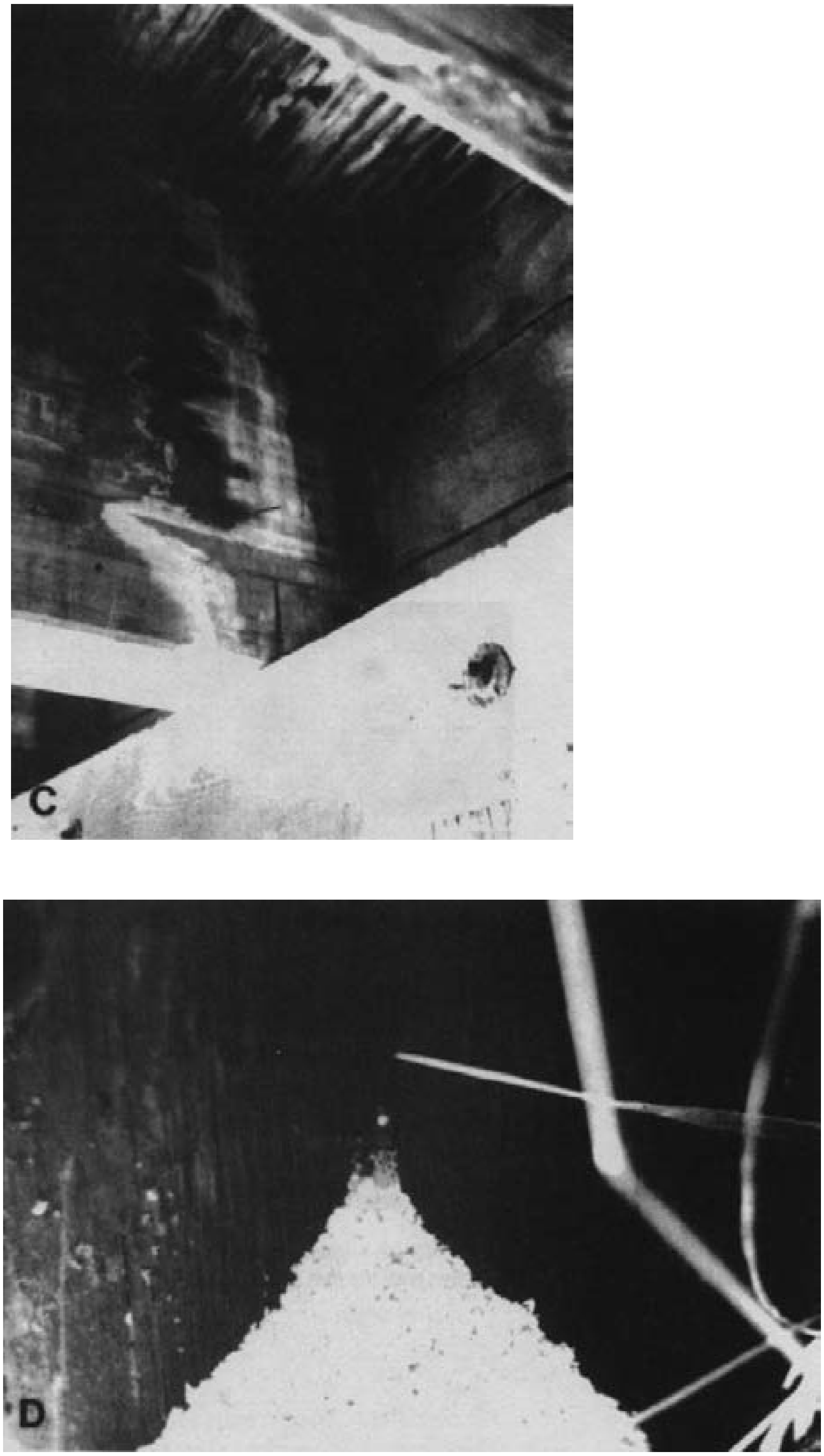


Figure 13-22. - Visual signs of potential deterioration (continued). (C) Water staining. (D) Insect activity (powder posting).

Figure 13-22. - Visual signs of potential deterioration (continued). (E) Plant growth.

Insect activity is visually characterized by holes, frass, powder posting, or other signs previously discussed. The presence of insect activity may also indicate the presence of decay.

Plant or **moss growth** in splits, cracks, or soil accumulations on the structure indicate that adjacent wood has been at a relatively high moisture content suitable for decay for a sustained period of time.

Probing

Probing with a moderately pointed tool, such as an awl or knife, locates decay near the wood surface by revealing excessive softness or a lack of resistance to probe penetration. Although probing is a simple inspection method, experience is required to interpret results. Care must be taken to differentiate between decay and water-softened wood that may be sound but somewhat softer than dry wood. It is also sometimes difficult to assess damage in soft-textured woods such as western redcedar.

Pick Test

The pick test is one of the simplest, yet most widely used, methods for detecting surface decay. A pointed pick, awl, or screwdriver is driven a short distance into the wood and used to pry out a sliver (Figure 13-23). The wood break is examined to determine if the break is brash (decayed) or splintered (sound). Sound wood has a fibrous structure and splinters when broken across the grain. Decayed wood breaks abruptly across the grain or crumbles into small pieces. Several studies indicate that the pick test is reasonably reliable for detecting surface decay. The only drawback to this method is having to remove a large sliver of wood for each test.

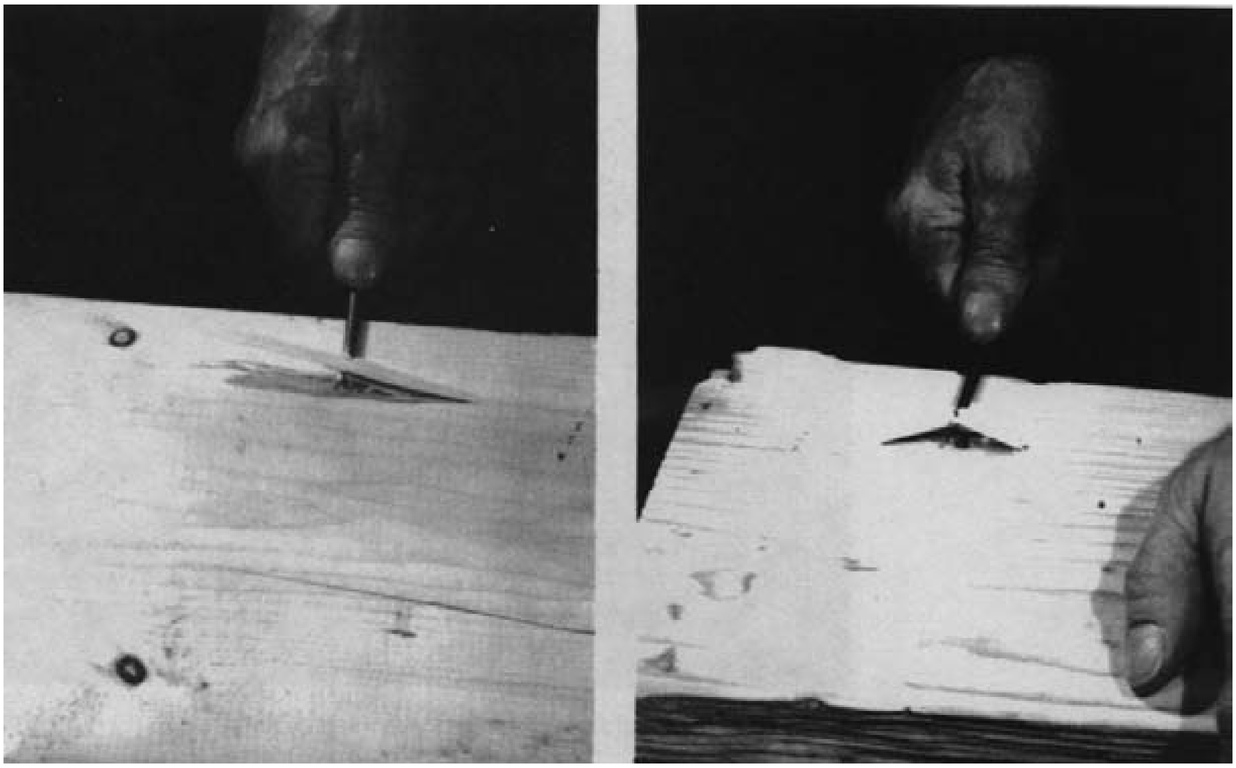


Figure 13-23. - The pick test for detecting earlywood decay. (Left) Sound wood pries out as long slivers. (Right) Decayed wood breaks abruptly across the grain without splintering.

Pilodyn

Like the pick test, the Pilodyn is also used to detect surface damage. The Pilodyn is a spring-loaded pin device that drives a hardened steel pin into the wood (Figure 13-24). The depth of pin penetration is used as a measure of the degree of decay. The Pilodyn is used extensively in Europe, where soft rot attack is more prevalent. It is also used to measure the specific gravity of wood for tree improvement programs. Where surface damage is suspected, the Pilodyn can produce an accurate assessment, provided corrections are incorporated for moisture content and the wood species tested.[48]

METHODS FOR DETECTING INTERIOR DETERIORATION

Unlike exterior deterioration, interior deterioration is difficult to locate because there may be no visible signs of its presence. Numerous methods and tools have been developed to evaluate internal damage that range in complexity from sounding the surface with a hammer to sophisticated sonic or radiographic evaluation. In addition, such tools as moisture meters are used to help the inspector identify areas where conditions are suitable for development of internal decay.

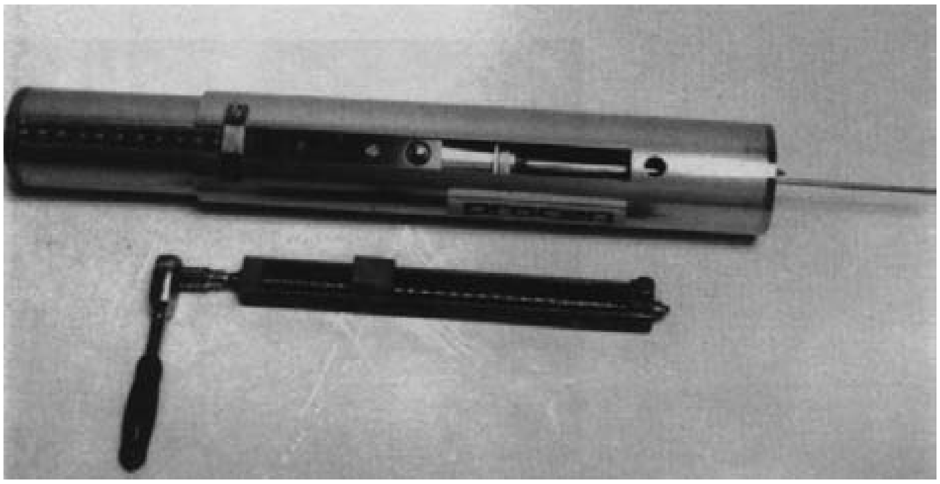


Figure 13-24. - The Pilodyn uses a spring-loaded pin that is forced into the wood surface. The depth of pin penetration provides a measure of wood condition.

Sounding

Sounding the wood surface by striking it with a hammer or other object is one of the oldest and most commonly used inspection methods for detecting interior deterioration (Figure 13-25). Based on the tonal quality of the ensuing sounds, a trained inspector can interpret dull or hollow sounds that may indicate the presence of large interior voids or decay. Although sounding is widely used, it is often difficult to interpret because factors other than decay can contribute to variations in sound quality. In addition, sounding provides only a partial picture of the extent of decay present and will not detect wood in the incipient or intermediate stages of decay. Nevertheless, sounding still has its place in inspection and can quickly identify seriously decayed structures. When suspected decay is encountered, it must be verified by other methods such as boring or coring.

Moisture Meters

As wood decays, certain electrolytes are released from the wood structure and electrical properties of the material are altered. Based on this phenomenon, several tools can be used for detecting decay hazard by changes in electrical properties. One of the simpler tools is the resistance type moisture meter. This unit uses two metal probes (pins) driven into the wood to measure electrical resistance, and thus, moisture content (Figure 13-26). Moisture meters must be corrected for temperature and are most accurate at wood moisture contents between 12 and 22 percent. Pins are available in various lengths for determining moisture content at depths up to 3 inches.

Although it does not detect decay, the moisture meter will help identify wood at high moisture content and is recommended to initially check suspected areas of potential decay. Moisture contents higher than 30 percent indicate conditions suitable for decay development unless the wood in the immediate area is treated with preservatives and no breaks

Figure 13-25. - A decay pocket near the wood surface is detected by sounding with a hammer.

are occurring in the treatment envelope. If inspection is conducted after an unusually long period of dry weather, lower moisture levels in the range of 20 to 25 percent should be used as an indication of potentially hazardous conditions. Information on the use and limitations of moisture meters is more thoroughly discussed elsewhere.[29]

Shigometer

The Shigometer, a device that has been compared to the moisture meter, uses a pulsed current to measure changes in electrical conductivity associated with decay (Figure 13-27). A small hole is drilled into the wood, and a twisted wire probe connected to a meter is inserted into the hole. As the probe encounters zones of decreased resistance, the meter reading drops. Zones of large meter declines (50 to 75 percent of that indicated for sound wood) are then bored or drilled to determine the nature of the defect. The Shigometer has performed very well in detecting decay in living trees, but wood in service is normally too dry to permit the use of this instrument. Nevertheless, several studies show that the Shigometer is a reasonable method for detecting decay if it is used under proper conditions by trained operators who understand its operation and interpretation.[58]

Drilling and Coring

Drilling and coring are the most common methods for detecting internal deterioration in bridges.[34] Both techniques are used to detect the presence of voids and to determine the thickness of the residual shell when voids are present. Drilling and coring are similar in many respects and will be discussed together.

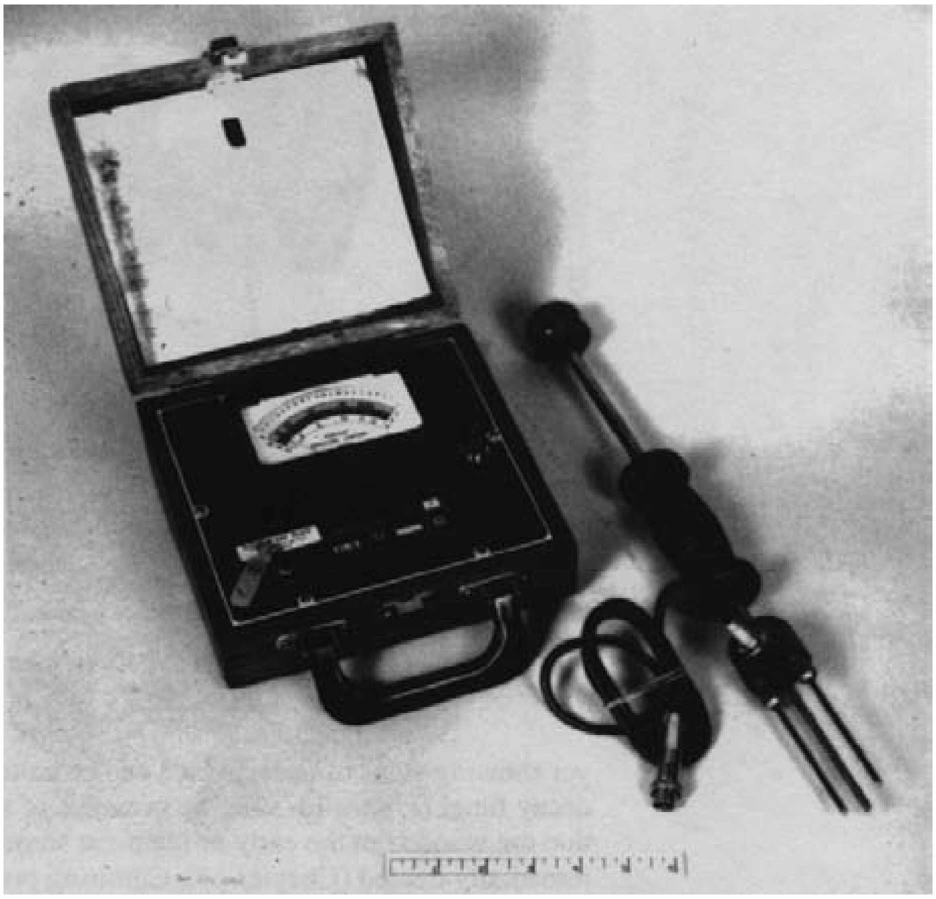


Figure 13-26. - The resistance-type moisture meter uses two steel pins that are driven into the wood to measure moisture content (the middle probe between the pins is a depth indicator). This device can help determine whether the wood moisture content is suitable for decay organisms.

Drilling is usually done with an electric power drill or hand-crank drill equipped with a 3/8- to 3/4-inch-diameter bit. Power drilling is faster, but hand drilling allows the inspector a better feel and may be more beneficial in detecting pockets of deterioration. Generally, the inspector drills into the structure, noting zones where the drilling becomes easier (torque releases), and observes the drill shavings for evidence of decay (Figure 13-28). The presence of common wood defects such as knots, resin pockets, and abnormal grain must be anticipated while drilling and. must not be confused with decay. If decay is detected, the inspection hole can also be used to add remedial treatments to the wood.

Coring with increment borers also provides information on the presence of decay pockets and other voids, and coring produces a solid wood core that can be carefully examined for evidence of decay (Figure 13-29). Where appropriate, the core also can be used to obtain an accurate measure of the depth of preservative penetration and retention. Where structures are not

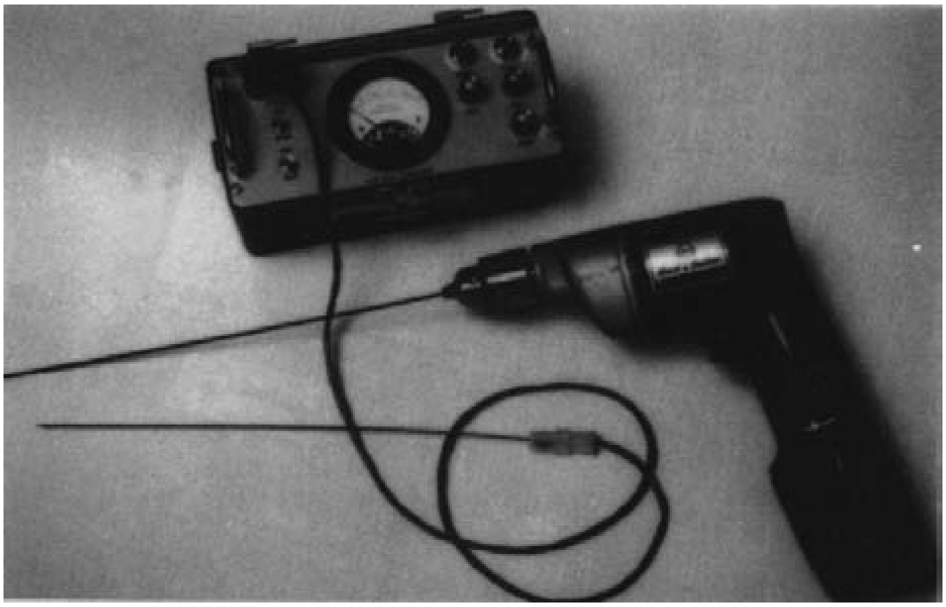


Figure 13-27. - A Shigometer and the drill and bit used to bore holes for insertion of the wire probe.

yet showing signs of decay, cores can be cultured to detect the presence of decay fungi (Figure 13-30). The presence of such fungi usually indicates that the wood is in the early or incipient stage of decay and should be remedially treated (Chapter 14). Culturing provides a simple method for assessing the potential decay hazard and many laboratories provide routine culturing services.[39] Because of the wide variety of fungi near the surface, culturing is not practical for assessing the hazard of external decay.

Drilling and coring are generally used to confirm suspected areas of decay identified by the use of moisture meters or other methods. When decay is detected, drilling and coring are also used to further define the decay's extent and limits. Inspectors may find drilling best for initial inspection until some evidence of decay is found. When decay is detected, coring may be preferred for defining the limits of the infection and extracting samples for further examination and analysis. It is important to use sharp tools for both drilling and coring and the inspector should always carry extra bits or increment borers. Dull tools tend to crush or break wood fibers and cause excessive core or shaving breakage that may be confused with decay.

Shell-Depth Indicator

A tool that is useful when drilling or coring is the shell-depth indicator. This tool is a metal bar, notched at the end and inscribed in inches, that is inserted into the inspection hole and pulled back along the hole sides (Figure 13-31). As it moves along the wood, the hook will catch on the edges of voids. In this way the inspector can note the depth of the solid shell, which can be used to estimate residual wood strength.

Figure 13-28. - Drilling the underside of a timber bridge beam to detect internal voids. The inspector feels and listens for torque release as the drill bit enters the wood, and examines shavings for evidence of decay.

Figure 13-29. - Solid wood core removed with an increment borer. Such cores can be examined to determine the location and extent of decay.

Figure 13-30. - Culturing increment cores to determine the presence of decay fungi. This process can detect decay before visible damage occurs and provides a method of assessing future risk.

Figure 13-31. - Use of a shell depth indicator, illustrated with a portion of the member removed. The tool is inserted into an inspection hole and moved along the hole sides to feel for decay voids.

Sonic Evaluation

Sophisticated sonic tests for evaluating wood condition have been developed in recent years. Several of these methods, including sonic wave velocity, acoustic emission, and stress wave analysis have been investigated. The simplest of the sonic techniques uses an instrument to measure the velocity changes of a sound wave moving across the wood (Figure 13-32). The earliest versions of these tools were used with mixed results on utility poles. More recent efforts have concentrated on measuring how the sonic wave is altered by wood defects. The altered sonic wave or fingerprint can be used to determine the exact size and nature of a defect. Several sonic methods are nearing commercialization and offer a significant advancement in decay detection capabilities; however, where defects are detected, other methods must still be used to determine the cause.

X Rays and Tomography Scanners

X rays were once commonly used for detecting internal voids in wood? As the x rays pass through the wood, the presence of knots or other defects alters the density of the resulting radiograph (Figure 13-33). X-ray technology has advanced considerably since the first field units were developed; however, the high cost of equipment, along with the safety factors associated with the use of ionizing radiation and the need for expert interpretation of results, have largely eliminated its use in wood. Despite these problems, x rays are particularly useful for detecting insect and marine borer infestations in wood.

Figure 13-32. - A sonic inspection device for detecting internal defects in wood.

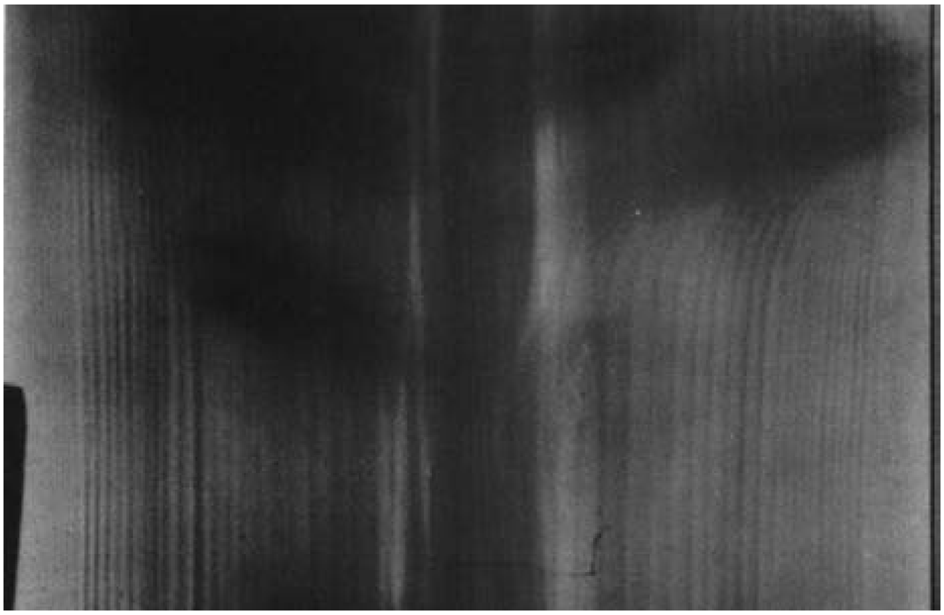


Figure 13-33. - X-ray radiograph of a timber member. X rays can be used to detect internal wood defects, but are particularly useful for locating insect or marine borer damage.

Recently, several European universities have developed computer-aided tomography scanners for wood poles. The scanners move up or down a pole and provide an image of internal wood conditions. Prototypes of these devices are in the early stages of development, and further refinements are necessary to speed up the process of data evaluation.

POSTINSPECTION TREATMENT

Several inspection methods involve techniques that destroy or remove a portion of the wood. Splinters, probe holes, and borings may become avenues for decay entry if not properly treated at the conclusion of the inspection. All surface damage should be treated with liquid or paste wood preservative (Chapter 14). For bore holes, liquid wood preservative should be squirted into the hole, which then should be plugged with a preservative-treated dowel slightly larger in diameter than the inspection hole (Figure 13-34). Treatment with creosote or copper naphthenate is generally sufficient for most bridge inspections, but other treatments should be used for additional protection in areas of marine borer hazard. When wood is subject to attack by *Limnoria*, surfaces and plugs should be treated with waterborne salts. In areas where pholads may attack, treatment with both creosote and waterborne salts is advisable. Failure to follow these procedures may result in accelerated decay development or deterioration in the structure.

Figure 13-34.- After treating an inspection hole in a bridge deck with liquid wood preservative it is plugged with a treated wood dowel (photo courtesy of Frank Muchmore, USDA Forest Service).

13.4 INSPECTION PROCEDURES

Inspection procedures for timber bridges depend on such variables as the age and type of bridge and the environment in which the bridge is located. Therefore, detailed recommendations for specific procedures are somewhat impractical. In general, the inspector must thoroughly examine the bridge for decay and other deterioration and record findings in sufficient detail for an engineering appraisal. The specific procedures and methods, however, will vary substantially from bridge to bridge.

Bridge inspection can be divided into three major steps: preinspection evaluation, field inspection, and preparation of reports and records. Although the specific procedures in each step vary among bridges, the basic process is the same. Discussions in this section are intended to provide the inspector with an understanding of the general characteristics of deterioration and the concepts related to inspection procedures. With this understanding, specific inspection procedures can be developed that are best suited to a particular structure.

PREINSPECTION EVALUATION

The potential for deterioration in a timber bridge depends on its environment. A preliminary assessment of hazard potential will reduce the need to speculate on potential causes and effects and better prepare the inspector to formulate methods of inspection. From an environmental viewpoint, decay potential varies considerably among localities, and local experience is the best information source.

Preinspection evaluation involves an office review of information before field inspection. The purpose of the evaluation is to learn as much as possible about the history of the bridge to better prepare the inspector for the field work. During the evaluation, the inspector should make a thorough study of historical records, reports, and other available information. It is also beneficial to discuss factors related to the bridge with people who are familiar with its location and history. A little effort spent on preinspection evaluation will help the inspector anticipate potential problems and make field inspection more effective.

The previous inspection reports are one of the best sources of bridge information. These reports provide the most current information on bridge condition and familiarize the inspector with the types and locations of previous damage. In addition, the original bridge construction drawings and documents are good sources of information. As-built drawings are most informative, but when they are not available design drawings may be used. The drawings provide information about the dimensions, species, and grade of material used as well as the type and retentions of preservative treatments. Other construction documents such as contract specifications, inspection records, material certifications, and shipping invoices are also good sources of information.

When local information is not available, the general potential for fungal attack can be correlated geographically based on variations in average rainfall and temperature. The Southeastern region of the United States, with abundant rainfall and moderate temperatures, represents an area with high decay potential. The Northwest Pacific coast area is also in this category because of the unusually high annual rainfall. Bridges in areas having less than approximately 25 inches per year of rainfall or abnormally short growing seasons have reduced potential for decay. Maps are available that depict insect and decay hazards based on climatic conditions in broad regions (Figure 13-35); however, local conditions within these regions may vary considerably.

FIELD INSPECTION

Field inspection is the physical examination of a bridge for evidence of deterioration. Variations in bridge configurations and exposure conditions make this a complex task. It is therefore necessary for the inspector to be well acquainted with the agents of deterioration, the areas conducive to decay, and the fundamentals of component inspection. With this knowledge as a guide, the inspector is better prepared to identify and locate deterioration and accurately define its extent.

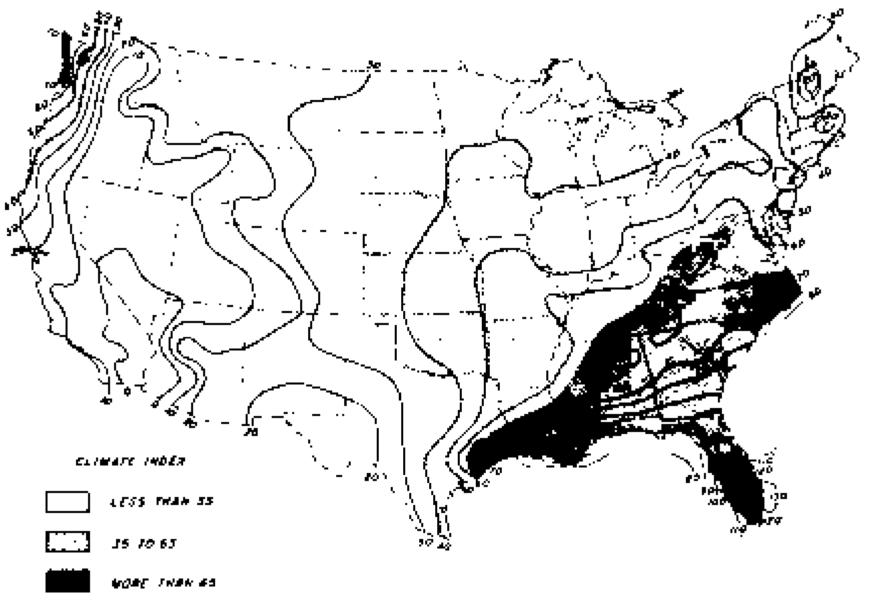


Figure 13-35. - Climate index map for decay hazard. The higher numbers indicate a higher decay hazard.

Areas Susceptible to Decay

Wood decay can occur only when proper conditions prevail for fungal growth. Although timber bridges differ in many respects, there are several common areas where decay is most likely to occur. These areas involve situations where the wood moisture is high and where breaks in the preservative envelope (or insufficient preservative penetration) provide an entry point for decay organisms. Signs of high moisture content and sites around fasteners, checks, or mechanical damage should be considered areas of high decay potential (Figure 13-36).

The moisture content of bridge components is not uniform, and substantial variations occur within and between members. End-grain surfaces absorb water much quicker than do side-grain surfaces (Figure 13-37). With other conditions equal, permeability in the longitudinal direction (parallel to grain) is 50 to 100 times greater than in the transverse direction (perpendicular to grain). Decay development is most affected by the moisture content of the wood in the immediate vicinity of the infection. Therefore, a member may remain generally dry and uninfected along most of its length but be severely decayed in localized areas where untreated wood is exposed and water is continuously or intermittently trapped. Bridge moisture conditions are also subject to seasonal variations and may be altered by maintenance operations or changes in drainage patterns. Wood that appears thoroughly dry may have been exposed to high moisture contents in the past and could be seriously decayed. The inspector must be alert for any visual or intuitive indications of wetting. Visual signs may appear as

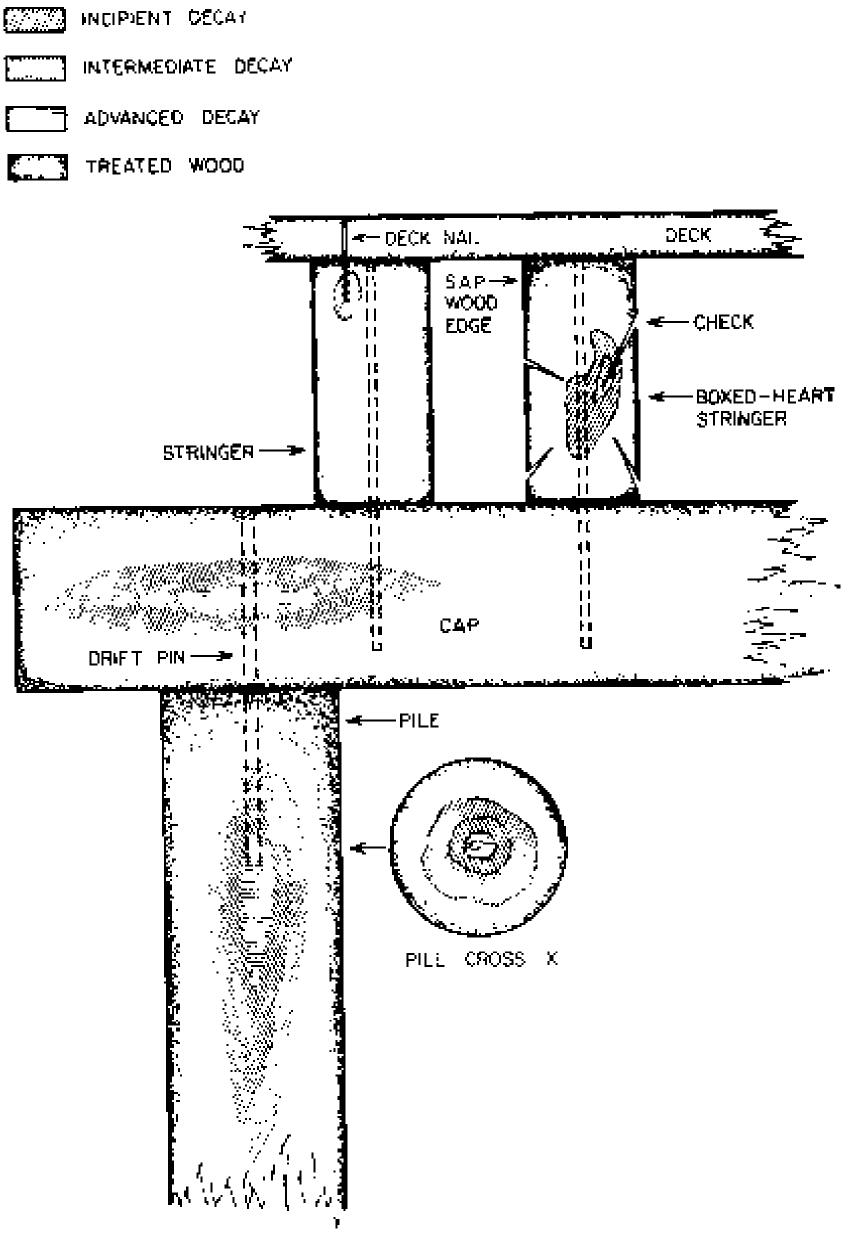


Figure 13-36. - Diagram depicting potential decay locations in a timber bridge.

watermarks, staining, or light mud stains. Intuitive signs include any horizontal surfaces, contact areas, depressions, or other features that may trap water and therefore indicate potentially high moisture exposures.

As discussed, the potential for bridge decay is highest where untreated wood is exposed. This condition occurs most often in the vicinity of seasoning checks, fasteners, and areas of mechanical damage. Conditions for deterioration are enhanced at these locations because moisture enters cracks or other crevices where air circulation and drying are inhibited. Seasoning checks commonly develop in large lumber members, and, to a

Figure 13-37. - Decay in the end grain of a timber rail post (photo courtesy of Duane Yager, USDA Forest Service).

lesser extent, in glulam. Although the size of the check influences the area of exposed untreated material, very small openings are still sufficient to allow entry of decay organisms (Figure 13-38). Holes for bolts, nails, or other hardware can trap water, which will be absorbed deep into the wood end grain by capillary action. Decay susceptibility at connections is higher because fasteners may be placed in field-bored holes that are not adequately treated with preservatives (Figure 13-39). Mechanical damage from improper handling, overloads, vehicle abrasion, and support settlements also breaks the preservative barrier and provides an entry point for decay organisms. In addition to increasing the decay hazard, mechanical damage may also affect structural capacity, depending on the decay's nature, location, and extent (Figure 13-40).

Component Inspection

Component inspection involves the systematic examination of individual bridge members. When deterioration is found, its location and extent must be defined and noted so that the load-carrying capacity of the structure can be determined by engineering analysis. At some locations, deterioration may have no significant effect on member strength. In other locations, any deterioration will reduce capacity. In both cases, the inspector must accurately locate, define, and record all deterioration, notwithstanding its perceived effects on structural capacity.

Because of the large number of structural components and the variety of locations where conditions for decay development exist in a bridge, the degree of accuracy for assessing the extent of deterioration depends on the judgment of the inspector. Regardless of bridge size, no inspection can

Figure 13-38. - Cross section of a timber curb, exposed by sawing, reveals interior decay resulting from seasoning checks in the upper surface.

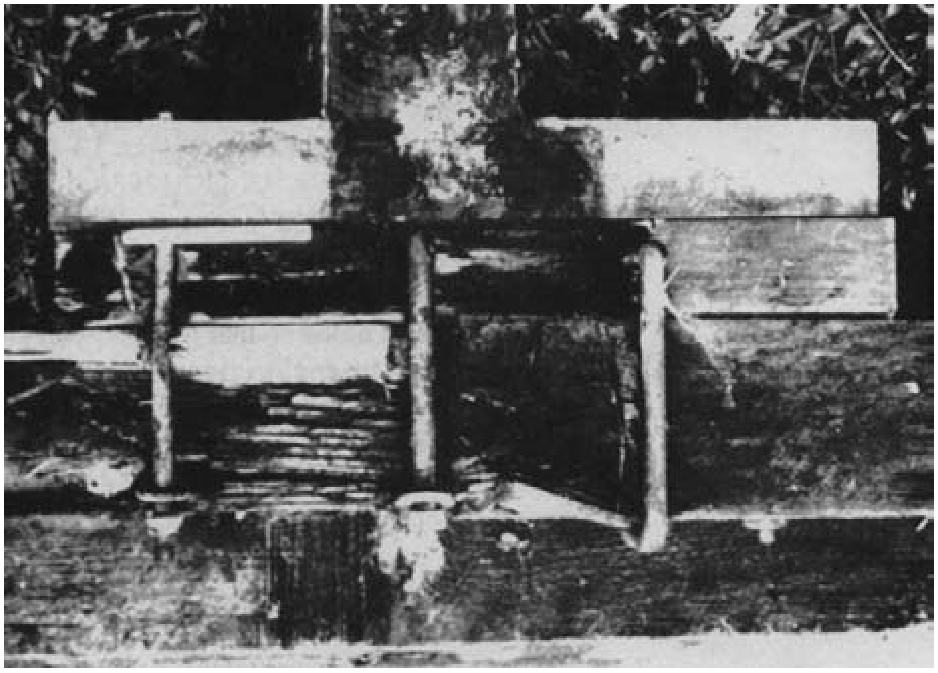


Figure 13-39. - Decay in timber members around field-bored fastener holes.

Figure 13-40. - Large crack in a sawn lumber bridge beam caused by vehicle overloads (photo courtesy of Duane Yager, USDA Forest Service).

reasonably or economically examine every bridge component. Rather, the inspector must base the degree of inspection on information from the preinspection evaluation and knowledge of bridge deterioration and its causes, signs, and probable locations. For example, it may not be practical to examine the area around each fastener when deck members are attached with penetrating fasteners in each beam. Instead, the inspector should select the most probable areas of deterioration for evaluation. If deterioration is found, its extent is determined and additional inspections are made at other locations. If no deterioration is found in high-hazard zones, it is unlikely that other areas are affected.

One of the most important aspects of component inspection is the sequence and coordination of inspection efforts. To ensure that all critical areas are covered, a systematic, well-defined plan must be developed. When more than one inspector is involved, the responsibilities of each must be clearly defined to avoid either missing areas or excessive duplication. The preferred inspection sequence generally follows the sequence of construction. After initially surveying the structure, the inspector begins with the lower substructure members and progresses upward to the top of the superstructure. Following this sequence, the inspector can observe the behavior of members under load before their actual inspection.

Initial Survey

The best way to begin a bridge inspection is to take a brief walk across and around the structure, observing general features and looking for obvious signs of deterioration or distress. Particular attention should be given to changes in the longitudinal or transverse deck elevation that may indicate foundation movement, deck swelling, or other adverse conditions. The rail and curb elements should also be checked for position and alignment. Slanted posts or separated rails may indicate deck swelling or superstructure movement. This is also a good time to observe drainage patterns on approach roadways and obstructions to deck drains, as well as the effectiveness of the deck and wearing surface in protecting underlying components. General observations of this type can alert the inspector to potentially adverse situations requiring more detailed examination later in the inspection. This inspection also can provide an opportunity to prepare initial sketches of the structure and to define the directions and other features used in recording inspection findings.

Substructure Inspection

The substructure is the portion of a bridge that is probably most susceptible to deterioration. Soil-contacting members such as posts, piling, abutments, and wing walls are exposed in varying degrees to nearly constant wetting, resulting in wood moisture contents suitable for decay. Surrounding soil frequently contains large numbers of fungal spores and woody plant material in which decay fungi can live and spread to infect bridge members. Substructure decay potential is also greater because of the high incidence of field fabrication (cutting and drilling) and the large number of penetrating fasteners.

Initial inspection of the substructure should begin with a visual examination of abutments for signs of deterioration, mechanical damage, and settlement. The most probable locations for decay are in the vicinity of the ground line, at connections between the cap and column, and at framing connections for bracing, tie rods, and backwall or wingwall planks. Starting at the base of the abutment, soil should be removed around a representative number of members in order to inspect for indications of decay or insect attack. When soil is very wet or covered by water, decay is generally limited to areas close to ground level because the lack of oxygen below the surface limits the growth of most fungi. As soil moisture content decreases, conditions below ground become more favorable, and decay may occur at depths of 2 feet or more in moderately dry soils. Surface decay and insect damage can be revealed by visual observation and probing. When evidence of decay is found, its extent is further defined by drilling or coring (Figure 13-41). Detecting internal decay is generally accomplished by using a combination of sounding and drilling or coring. Because sounding will reveal only serious internal defects, it should never be the only method used.

Figure 13-41. - Hand drilling at the base of a timber pile.

From below the ground line, inspection should proceed upward, with particular attention given to connections, seasoning checks, and mechanical damage. Timber backwalls, wingwalls, and incidental bracing should also be examined for breakage or bulging from earth pressure. Exposed end grain on pile or post tops should also be inspected for decay. Many tops are intentionally cut at an angle in the belief that water will run off. Instead, angled cuts expose more untreated end grain, increasing the decay potential. When tops are provided with protective sheet-metal caps, the condition of the cap should be checked for holes or tears in the surface. Damaged caps allow water to enter through the break and penetrate end grain, creating ideal conditions for internal decay (Figure 13-42).

Above the supporting piles or posts, the cap supporting the superstructure provides a horizontal surface that traps debris and water runoff from the deck. Connections into the cap and horizontal checks that trap water and debris are critical zones. The connection between the cap and column is especially important because many connections are made with drift pins or bolts that extend deep into the column end grain. Water from the cap flows into these connections and can result in substantial internal decay with little evidence of exterior damage (Figure 13-43). The inspector should also check for crushed zones at bearing points along the cap that trap water and damage the treated wood shell. Crushing can also indicate overloads or load redistribution from settlement and should be further investigated in other components of the structure.

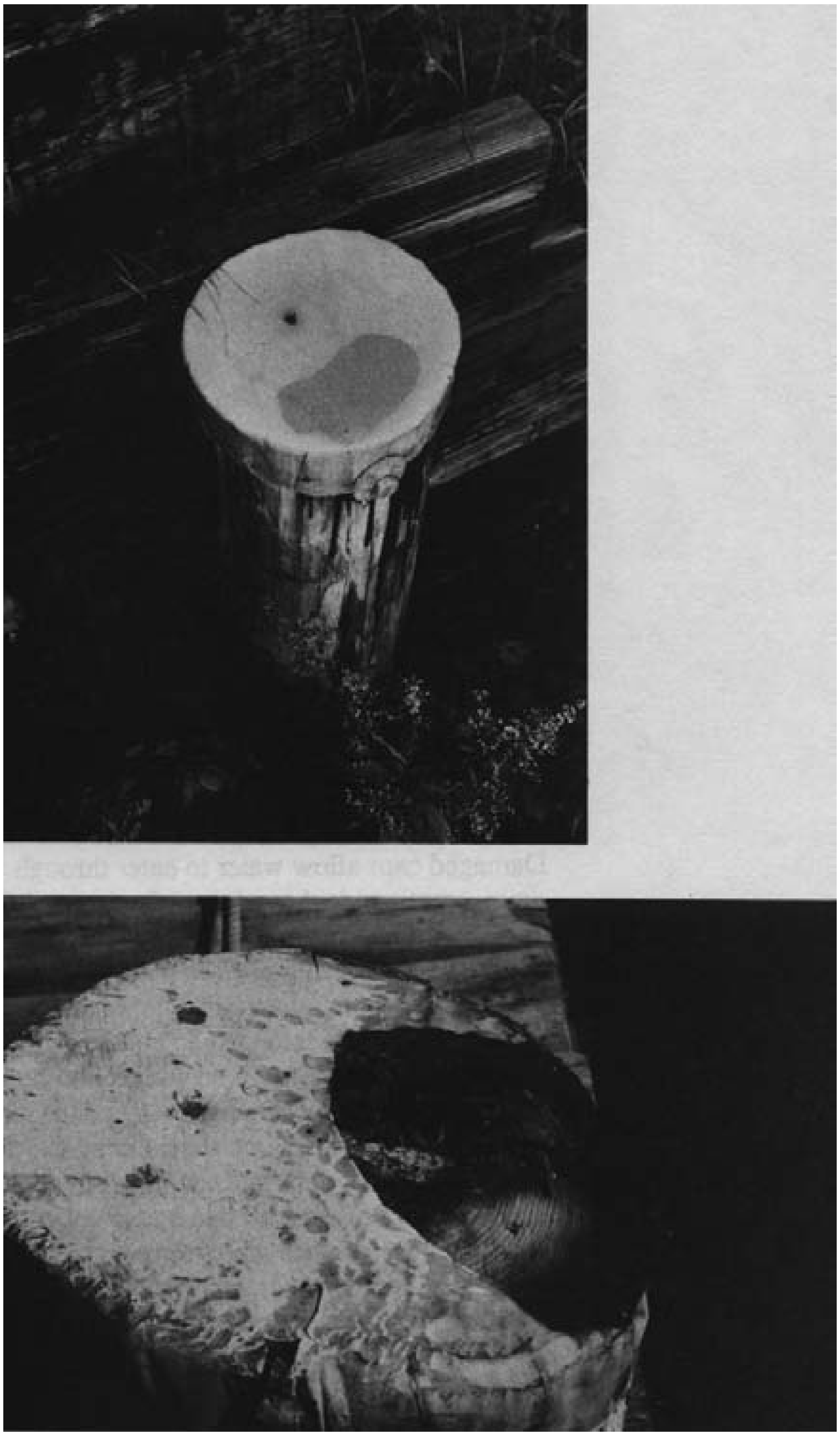


Figure 13-42. - (Top) Damaged metal pile caps allow water to enter, but restrict air circulation and drying. (Bottom) Pile decay is exposed when the damaged cap is removed.

Figure 13-43. - Internal decay in a timber pile where it was drift-pinned to the cap. Before the breakage of the outside shell, caused by cap removal, the pile showed little exterior sign of the interior decay.

Portions of the substructure containing piers or bents use the same basic inspection criteria for the same potential problem areas as abutments. If these structures are in water, however, inspection is much more difficult because access is limited. In water locations, members are also more susceptible to mechanical damage from floating debris and ice. In shallow water, inspectors can wear hip-waders to examine exposed members, whereas in deeper water a small boat or float is required. When inspection below the water level is necessary, the service of a diver is required. Underwater inspections require a high degree of skill and must be well coordinated to accurately identify and record deficiencies.[7,8]

For substructures located in seawater, low tides present the best opportunity to inspect for marine borer damage. Low-tide inspection is best suited for detecting *Limnoria,* which attack the external faces of members. A scraper and probe can be used to remove fouling organisms from the pile surface and thus permit better examination around bolt holes and adjoining wood members. Damage signs include an hourglass shape of piles in the tidal zone, bore holes; a general softening of wood in the attack areas; and loose bolts and bracing. Intertidal inspection is less effective for detecting damage by shipworms because they leave only a very small entrance hole on the wood surface, making visual detection difficult. Inspection methods using sonic instruments represent the best method for evaluating shipworm damage.

In areas where marine borer attack is suspected, an assessment of the hazard potential can be made by immersing sacrificial blocks of untreated wood at various depths around the substructure. These blocks are then removed periodically and examined for evidence of borer attack. Do not depend on the collection of driftwood to evaluate marine borer hazard because there is no way of knowing whether the wood came from sites outside the immediate area. Exposing wood samples can accurately assess marine borer hazard while providing a means for continually monitoring the long-term hazard.

Superstructure Inspection

After completing the substructure inspection, the inspector moves to the underside of the superstructure. It is best to thoroughly inspect all components from the bridge underside before moving to the roadway, since critical components are obscured by the wearing surface and deck. Superstructure inspection is generally hindered because access to the center portions of the underside is difficult or impossible without specialized equipment. When areas cannot be reached with ladders, a vehicle equipped with a mechanical arm or snooper may be required in order to adequately inspect the structure. Because ladders and other inspection equipment must be moved frequently to provide access to elevated areas, it is advisable that the inspection be performed by zones rather than by components. For the purposes of clarity, the following discussions are ordered by component.

Although most elements of the superstructure are out of ground contact, decay potential can be high in areas where water passes from the deck and collects at member interfaces, connections, checks, and crevices where air circulation and drying are inhibited. In many cases, this decay occurs with little or no surface evidence, although the member may be severely decayed inside. As a result, the inspector must be alert for conditions conducive to decay and must investigate areas where these conditions are likely to occur. As previously discussed, a moisture meter is a good tool for locating moisture conditions favorable to decay development (Figure 13-44). At least one boring should be made in areas of high moisture content where decay potential is considered highest. If decay is detected, additional borings should be taken to define its area, degree, and extent. If no decay is detected, but preservative penetration is shallow or moisture content is above 30 percent, it is desirable to remove a core for culturing to determine whether decay fungi are present.

The highest potential for decay in beams occurs at the deck-beam interface and attachment points, framing connections to other members, bearings, and seasoning checks. The deck-beam interface is one of the most frequent decay areas because water passing through the deck is trapped and enters fastener holes at the beam top. The hazard is highest when decks are attached with nails or lag screws that penetrate the top surface of the beam

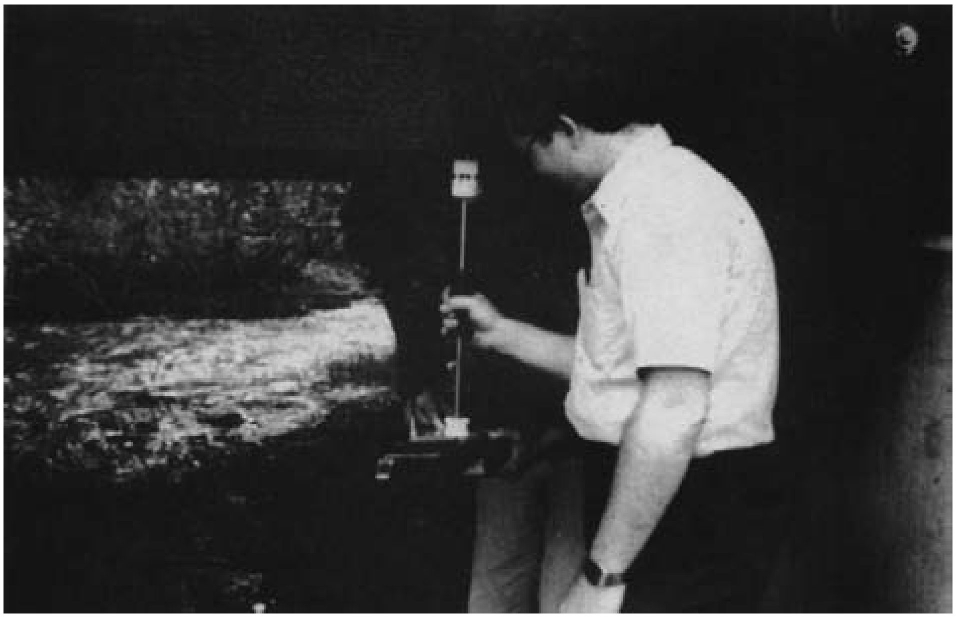


Figure 13-44. - The moisture content of a timber beam is measured with a resistance-type moisture meter.

(Figure 13-45). Glulam deck panels with bolted brackets do not involve attachments that penetrate the beam; thus, there is no significant increase in decay potential. On the deck underside, the inspector should be alert for signs of water movement and the presence of moisture at joint interfaces. Although stains are generally visible when water has passed through the deck, asphalt wearing surfaces tend to filter runoff, and visible signs are more difficult to detect. If significant decay is found along beam tops, it is advisable to remove deck sections to further examine beam condition.

In addition to the deck-beam interface and attachments, beam decay may develop in checks or delaminations, especially in the areas where end grain is exposed. Large checks or delaminations are not common in glulam and may be an indication of more severe structural problems. Bearings that trap water or show signs of beam crushing, and fasteners for transverse bracing or diaphragms are other potential decay locations. Sagging, splintering, or excessive deflections under load may also indicate mechanical damage or possible advanced decay. In some situations, surface decay may be present on a beam side or bottom that does not appear to be in an environment conducive to decay (Figure 13-46). Decay in such locations can occur in sawn lumber beams because of incomplete preservative penetration of heartwood.

Concurrent with beam inspection, the deck underside should be examined for signs of deterioration and conditions conducive to decay. Signs to observe include abnormal deflections and loose joints or fasteners, both of which may result from decay. Nail-laminated decks are frequently

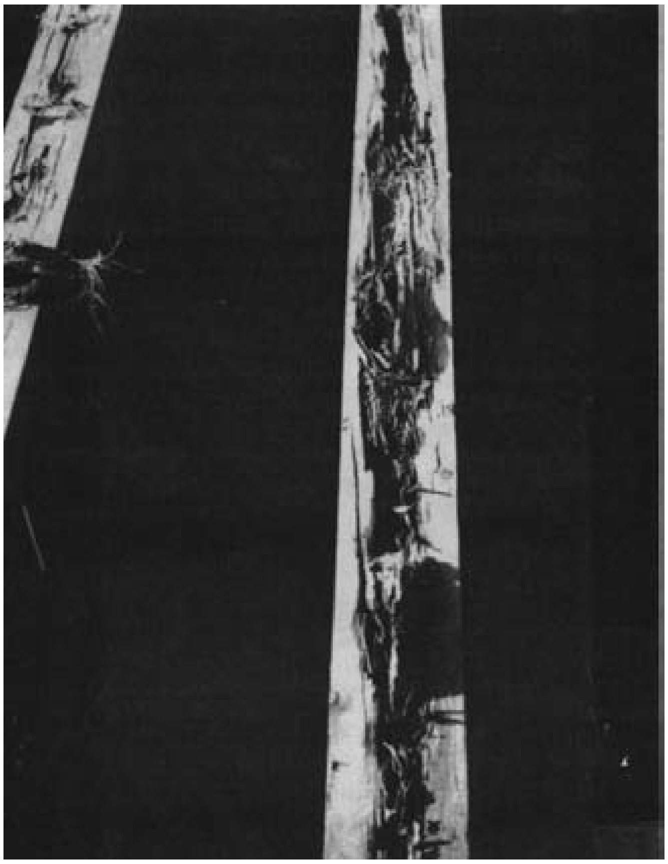


Figure 13-45. - Severe decay in the tops of sawn lumber beams where the deck was attached to the beams with spikes.

Figure 13-46. - Surface decay on the side of a sawn lumber beam (arrow). Decay in such locations is usually the result of poor preservative penetration of the heartwood.

delaminated by dynamic loading. Although delamination may not adversely affect strength, it does create voids between laminations, allowing water to flow on supporting beams and other components. Susceptibility to internal deck decay is highest with nail-laminated lumber or plank decks because they are interconnected and/or attached with nails or spikes (Figure 13-47). All fabrication for glulam panels is generally done before preservative treatment and the decay potential is lower unless panels are attached with spikes, lag screws, or other fasteners placed after the deck is treated.

Figure 13-47. - Decay on the underside of a spike-attached lumber plank deck at the deck-beam interface (arrow).

When inspection of the bridge underside is complete, efforts are next directed to the roadway portion of the deck. The upper deck is subject to wear and abrasion from traffic, and the horizontal surface facilitates water and debris accumulation. The highest decay potential occurs at fasteners or zones of mechanical damage and is influenced by the degree of protection provided by the wearing surface. A partial wearing surface affords the least deck protection because the gap between the running surfaces traps debris and moisture. On watertight glulam or stress-laminated timber decks, standing water may accumulate between running planks and remain for long periods. Moisture is also trapped under steel plate or full-plank surfaces where penetrating fasteners are normally placed after deck treatment. Asphalt wearing surfaces do not use mechanical fasteners, but moisture can accumulate at the deck interface when the surface is cracked or otherwise broken from excessive deflection.

The moisture content of timber decks generally averages 20 percent, but may frequently be much higher.[35] The inspector should carefully check exposed deck surfaces for moisture content and other conditions conducive to decay. When deck moisture contents are high, it is advisable to remove a number of cores from sites near the fasteners and other high-hazard locations. If necessary, portions of the wearing surface should be removed to assess deck condition. If evidence of substantial deterioration is found, the entire wearing surface should be removed to thoroughly inspect the deck.

Timber rails and curbs (wheel guards) are some of the most exposed elements of the bridge superstructure, yet are often ignored in bridge inspection. Although they are not critical for support of the structure, they are important for user safety and should be thoroughly inspected. Rails and curbs are susceptible to weathering, seasoning checks, and vehicle impact or abrasion. Rails and curbs are commonly the last components installed during the construction process and their installation presents an increased potential for field cutting and boring to meet alignment requirements. The inspector should pay particular attention to fasteners and areas that trap water and debris. One very probable decay situation occurs when approach railposts are embedded in concrete (Figure 13-48).

Figure 13-48. - Decay in a timber railpost embedded in concrete at the abutment. Concrete spalling was caused when water trapped in the post cavity was subjected to freeze-thaw cycles.

REPORTS AND RECORDS

While detecting decay or other wood damage is the major goal of bridge inspections, it is important to ensure that all pertinent inspection information is accurately recorded. The report prepared by the inspector provides the only means of communicating information about the structure and serves to

1. identify conditions that may limit the capacity of the structure or otherwise make it unsafe for public travel,
2. develop a chronological record of structural condition and provide the information necessary to complete a structural analysis when conditions change,
3. provide a basis for identifying current and future maintenance needs through the detection of early structural defects or deficiencies, and
4. provide a reference source for future inspections and comparative analysis.

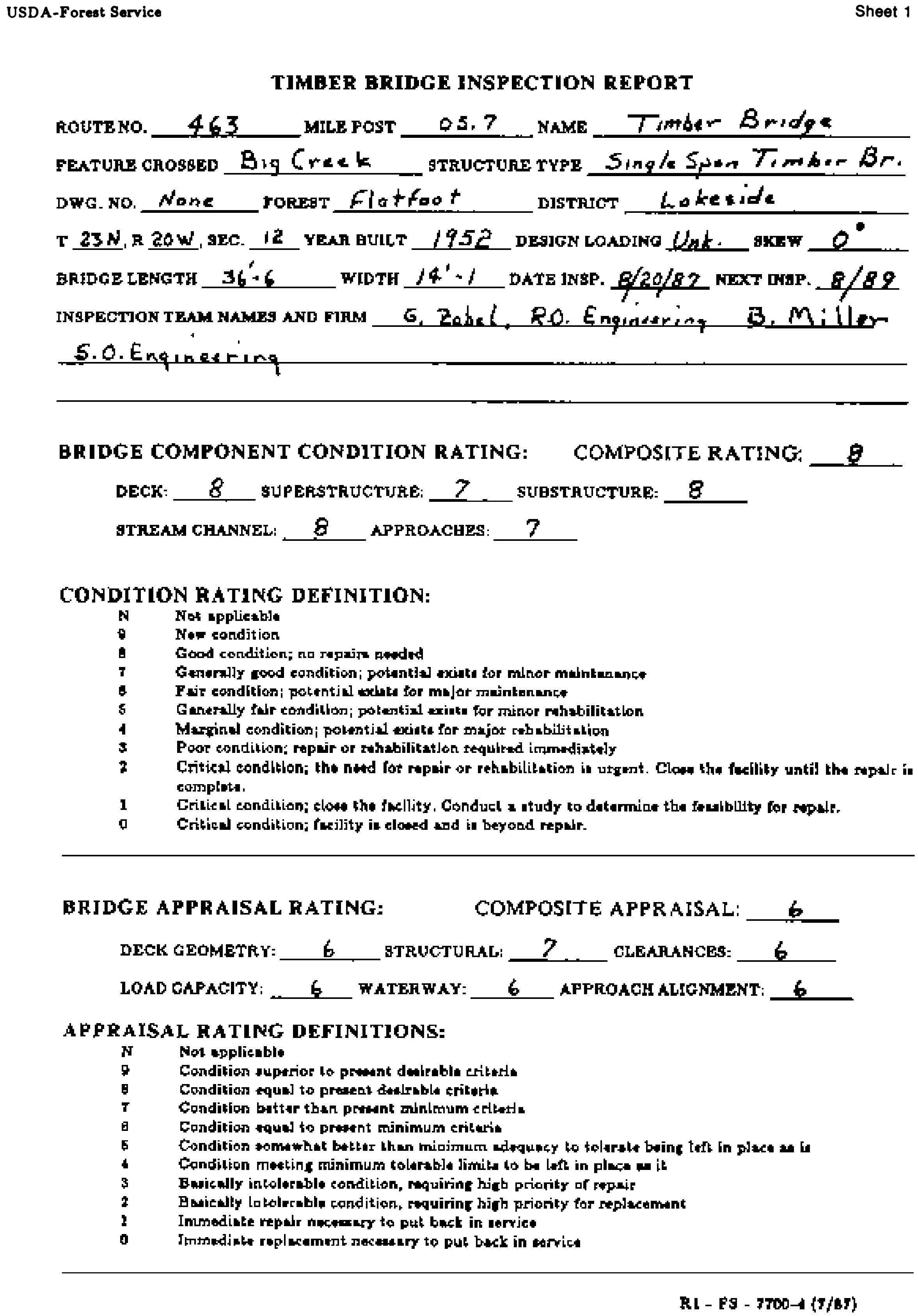
When properly completed, the bridge inspection report is an important document and plays a critical role in ensuring the safety of users and in allocating funds for maintenance and replacement. In addition, it is a legal record that may be an important part of any future litigation. Although specific report formats vary among different jurisdictions and structure types, all must be well organized, clear, and concise. Each report should include a title page; drawings or sketches of the structure, labeling all components; a condition assessment of the structure, by component; a narrative summary of inspection findings; and recommendations for maintenance and corrective action. For large or complex structures, a notebook format is most appropriate. For smaller or less complex structures, standard inspection forms are more practical and convenient. In either case, a complete inspection report should be prepared for each bridge inspection, regardless of the purpose or depth of the inspection. Although no changes may be evident during the inspection, and the condition seems relatively unimportant, accurate documentation of the inspection can be valuable in the future.

A good inspection report documents detected deterioration and notes any details of the structure that deviate from the as-built drawings. During the course of the inspection, these deficiencies should be noted as they are found in order to avoid loss of detail. The inspector should be as objective as possible, recording what is seen and measured. For timber bridges, it is critical that all decay and its location be accurately and completely described. This must include both the location of the deterioration in specific components and the longitudinal and transverse dimensions of the decayed wood. It is also beneficial for correction to note the probable source of water and its pathway to the decay site. Additionally, the report should note any indication of member weakness or failure, including evidence of excessive deflections, crushing, buckling, cracking, collapse, abnormal looseness of joints, or member displacement at joints. Further investigations should be recommended whenever they are considered necessary, either because the inspector does not have sufficient training or because more sophisticated equipment is required.

Sketches, drawings, and photographs are invaluable for illustrating inspection results and should be used freely to locate, identify, and clarify the condition of the bridge components. Drawings and sketches should define the location and extent of deterioration in sufficient detail and accuracy so that other inspectors or maintenance personnel can easily locate the area in question. When available, as-built drawings or drawings from previous inspection reports can be copied and used for this purpose. Photographs are also very useful for showing structure condition and areas of deterioration. As a minimum, two photos should be included with each inspection report: one of the roadway view looking down the bridge and one of a side elevation. Additional photos showing defects or other important features should also be included when the inspector believes they will be helpful.

Each inspection report should include a summary of inspection findings and the recommendations of the inspector. The summary should outline the general condition of the structure and significant deficiencies encountered during the inspection. It may also include information and recommendations that the inspector believes are necessary to emphasize important inspection findings, including estimates of the materials and work hours required to perform the repairs and maintenance activities.

An example of a good timber bridge inspection report using a standard report format is shown in Figure 13-49. Additional information on inspection reports, including sample formats, is given in references listed at the end of this chapter.[1,52]



USDA-Forest Service **Sheet 1**

TIMBER BRIDGE INSPECTION REPORT

ROUTE NO. 463 MILE POST 05.7 NAME Timber Bridge

FEATURE CROSSED Big Creek STRUCTURE TYPE Single Span Timber Br.

DWG. NO. None FOREST Flatfoot DISTRICT Lakeside

T 23N, R 20W, SEC. 12 YEAR BUILT 1952 DESIGN LOADING Unk. SKEW 0°

BRIDGE LENGTH 36'-6 WIDTH 14'-1 DATE INSP. 8/20/87 NEXT INSP. 8/89

INSPECTION TEAM NAMES AND FIRM G. Zabel, RO. Engineering B. Miller S.O. Engineering

BRIDGE COMPONENT CONDITION RATING: COMPOSITE RATING: 8

DECK: 8 SUPERSTRUCTURE: 7 SUBSTRUCTURE: 8

STREAM CHANNEL: 8 APPROACHES: 7

CONDITION RATING DEFINITION:

N	Not applicable
9	New condition
8	Good condition; no repairs needed
7	Generally good condition; potential exists for minor maintenance
6	Fair condition; potential exists for major maintenance
5	Generally fair condition; potential exists for minor rehabilitation
4	Marginal condition; potential exists for major rehabilitation
3	Poor condition; repair or rehabilitation required immediately
2	Critical condition; the need for repair or rehabilitation is urgent. Close the facility until the repair is complete.
1	Critical condition; close the facility. Conduct a study to determine the feasibility for repair.
0	Critical condition; facility is closed and is beyond repair.

BRIDGE APPRAISAL RATING: COMPOSITE APPRAISAL: 6

DECK GEOMETRY: 6 STRUCTURAL: 7 CLEARANCES: 6

LOAD CAPACITY: 6 WATERWAY: 6 APPROACH ALIGNMENT: 6

APPRAISAL RATING DEFINITIONS:

N	Not applicable
9	Condition superior to present desirable criteria
8	Condition equal to present desirable criteria
7	Condition better than present minimum criteria
6	Condition equal to present minimum criteria
5	Condition somewhat better than minimum adequacy to tolerate being left in place as is
4	Condition meeting minimum tolerable limits to be left in place as it
3	Basically intolerable condition, requiring high priority of repair
2	Basically intolerable condition, requiring high priority for replacement
1	Immediate repair necessary to put back in service
0	Immediate replacement necessary to put back in service

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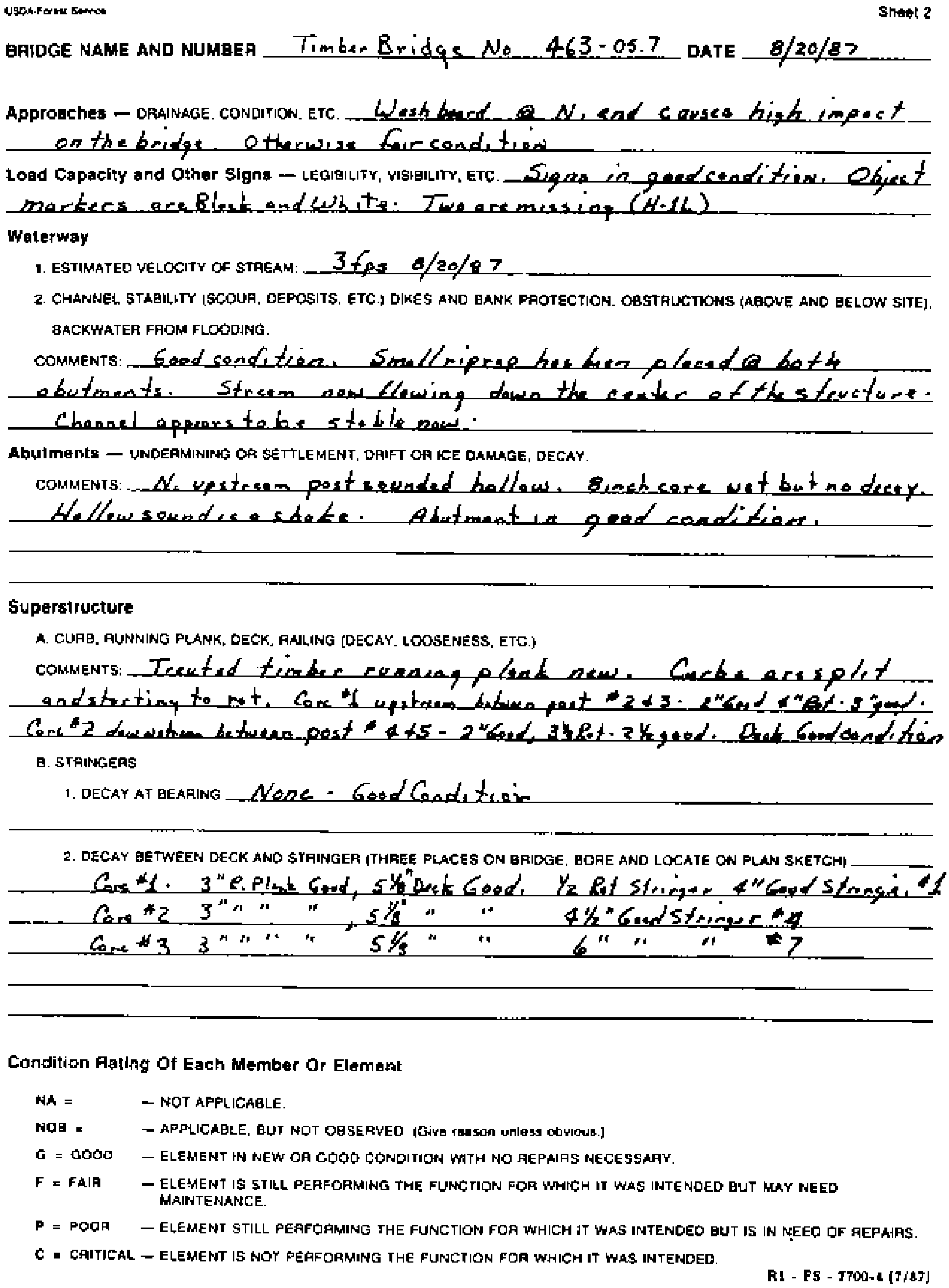
Figure 13-49. - Timber bridge inspection report using a standard report format (courtesy of Duane Yager, USDA Forest Service). See following pages.



USDA-Forest Service

Sheet 2

BRIDGE NAME AND NUMBER Timber Bridge No. 463-05.7 **DATE** 8/20/87

Approaches — DRAINAGE, CONDITION, ETC. Washboard @ N. end causes high impact on the bridge. Otherwise fair condition

Load Capacity and Other Signs — LEGIBILITY, VISIBILITY, ETC. Signs in good condition. Object markers are Black and White: Two are missing (H-1L)

Waterway

1. ESTIMATED VELOCITY OF STREAM: 3fps 8/20/87
2. CHANNEL STABILITY (SCOUR, DEPOSITS, ETC.) DIKES AND BANK PROTECTION. OBSTRUCTIONS (ABOVE AND BELOW SITE), BACKWATER FROM FLOODING.

COMMENTS: Good condition. Small riprap has been placed @ both abutments. Stream now flowing down the center of the structure. Channel appears to be stable now.

Abutments — UNDERMINING OR SETTLEMENT, DRIFT OR ICE DAMAGE, DECAY.

COMMENTS: N. upstream post sounded hollow. Birch core wet but no decay. Hollow sound is a shake. Abutment in good condition.

Superstructure

A. CURB, RUNNING PLANK, DECK, RAILING (DECAY, LOOSENESS, ETC.)

COMMENTS: Treated timber running plank new. Curbs are split and starting to rot. Core #1 upstream between post #2 & 3 - 2" Good 4" Rot - 3" good. Core #2 downstream between post # 4 & 5 - 2" Good, 3½ Rot - 2½ good. Deck Good condition

B. STRINGERS

1. DECAY AT BEARING None - Good Condition
2. DECAY BETWEEN DECK AND STRINGER (THREE PLACES ON BRIDGE, BORE AND LOCATE ON PLAN SKETCH)

Core #1. 3" R. Plank Good, 5⅛" Deck Good. ½ Rot Stringer 4" Good Stringer, #1
Core #2 3" " " " , 5⅛" " " 4½" Good Stringer #4
Core #3 3" " " " 5⅛ " " 6" " " #7

Condition Rating Of Each Member Or Element

NA =	— NOT APPLICABLE.
NOB =	— APPLICABLE, BUT NOT OBSERVED (Give reason unless obvious.)
G = GOOD	— ELEMENT IN NEW OR GOOD CONDITION WITH NO REPAIRS NECESSARY.
F = FAIR	— ELEMENT IS STILL PERFORMING THE FUNCTION FOR WHICH IT WAS INTENDED BUT MAY NEED MAINTENANCE.
P = POOR	— ELEMENT STILL PERFORMING THE FUNCTION FOR WHICH IT WAS INTENDED BUT IS IN NEED OF REPAIRS.
C = CRITICAL	— ELEMENT IS NOT PERFORMING THE FUNCTION FOR WHICH IT WAS INTENDED.

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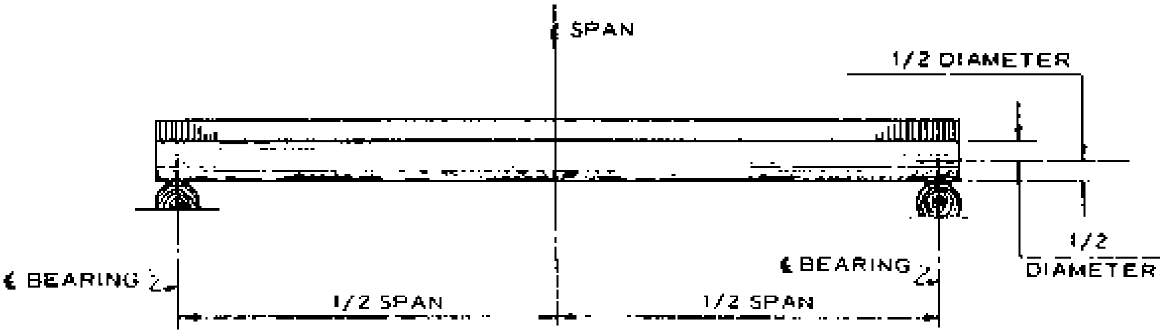
Figure 13-49. - (continued).

BRIDGE NAME & NO. Timber Bridge No. 463-05.7 DATE 8/20/87

B. STRINGERS (CONTINUED)

3. DECAY OF STRINGERS: BORE TO A DEPTH OF AT LEAST HALF THE DIAMETER OF THE STRINGER. AFTER THE HOLES HAVE BEEN BORED, THEY SHALL BE FILLED WITH A 5 PERCENT SOLUTION OF PENTACHLOROPHENOL AND PLUGGED WITH A ROUND WOOD STOCK SOAKED IN THE PENTACHLOROPHENOL SOLUTION.



Elevation

Condition of Stringer*

STRINGER NO.	℄ BEARING @ ABUTMENT NO. 1	℄ SPAN	℄ BEARING @ ABUTMENT NO. 2
1	#1 Top Stringer 87 1/2" Rot 4" Good		
2			#6 Side Stringer 87 4" Good
3			
4		#2 Top Stringer 87 4 1/2" Good	
5	#5 Side Stringer 87 4 1/2" Good		
6		#4 Side Stringer 87 5" Good	
7			#3 Top Stringer 87 6" Good
8			
9			

*DESCRIBE THE LOCATION OF THE DETERIORATED PORTION OF THE STRINGER. EXAMPLE: CENTER 3", OUTSIDE 2", NO DECAY, ETC.

Comments:

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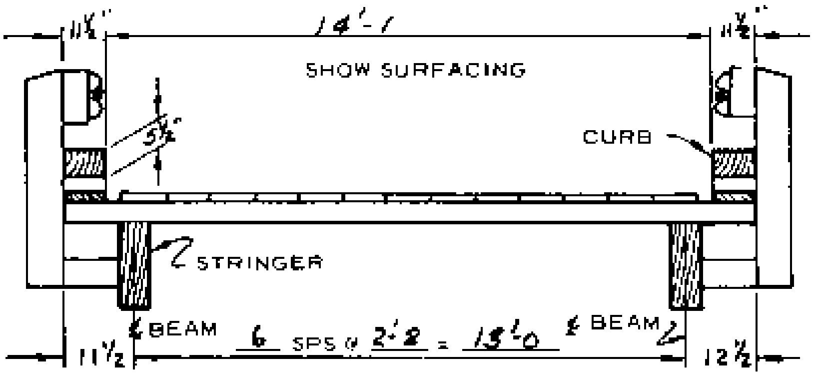
Figure 13-49. - (continued).

SINGLE SPAN TIMBER BRIDGE

BRIDGE NAME (STREAM) Big Creek BRIDGE NO. 463-05.7

Dimensions



Cross Section

Rail Post

WIDTH 2½"

DEPTH 9½"

LENGTH 5'-6½

SPACING 6'-3

Deck

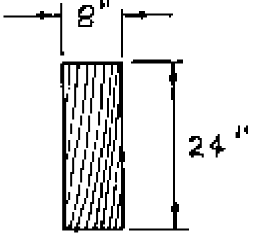
DIMENSION 5¾" x 1½"

TYPE

PLANK

NAIL LAMINATED Treated

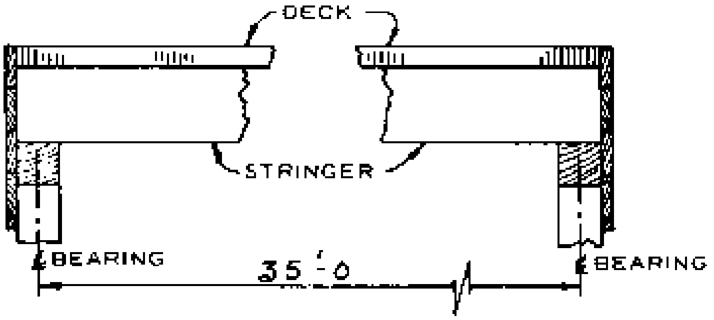
GLUE LAMINATED



Stringer

SOLID SAWN (SPECIE) D.Fir (TREATED) ______ (UNTREATED)

LAMINATED ______ (TREATED) ______ (UNTREATED)



Elevation

Guardrails

BRIDGE GUARDRAIL

TIMBER (SIZE)

STEEL FLEXBEAM Double - 12gauge

OTHER

NONE

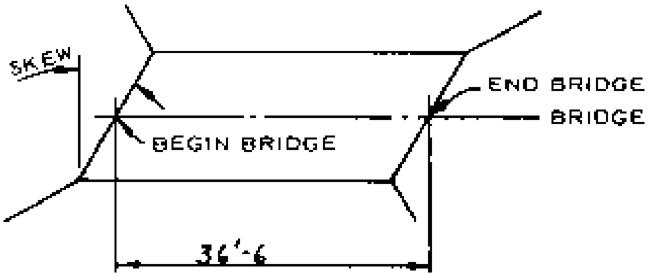
APPROACH GUARDRAIL

FLARED END Cable Anchored

"BURIED END" SECTION

OTHER

NONE



Plan

Wearing Surface

STEEL PLATE RUNNING PLANK (SIZE)

TIMBER RUNNING PLANK (SIZE) 3x12" (TREATED) ______ (UNTREATED)

GRAVEL (DEPTH)

ASPHALT

NONE

Skew

(LEFT OR RIGHT AHEAD)

0° ✓ 15° ___ 30° ___ 45° ___

Clear Height

DISTANCE BETWEEN BOTTOM OF STRINGERS AND STREAMBED 5'-3"

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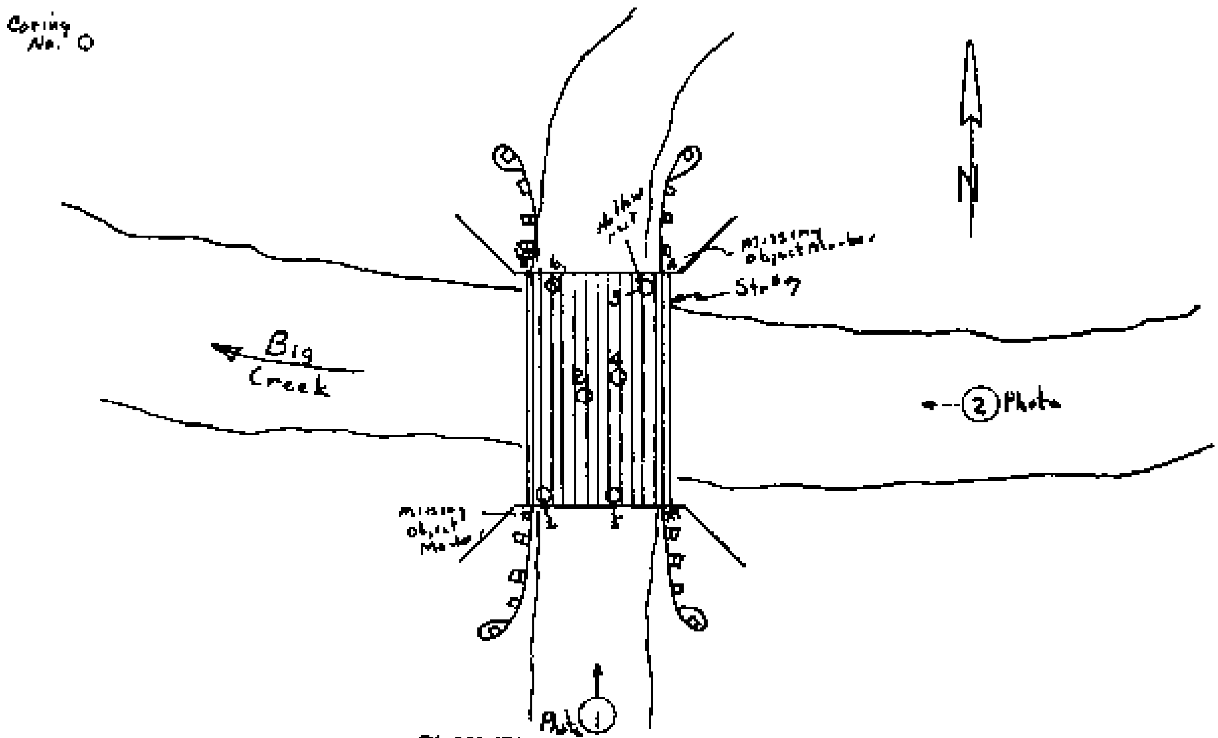
Figure 13-49. - (continued).

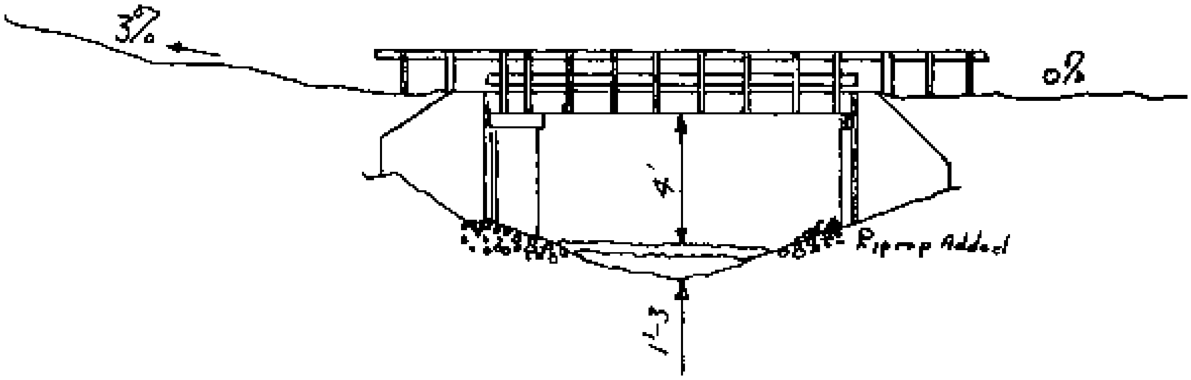
Sheet 5

BRIDGE NAME AND NUMBER Timber Bridge No 463-05.7 **INSPECTION DATE** 8/20/87

Sketches (If changed from last inspection)



PLAN (Show north arrow)



ELEVATION LOOKING Downstream
(Direction)

Figure 13-49. - (continued).

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Sheet 6

USDA-Forest Service

BRIDGE NAME AND NUMBER Timber Bridge No. 463 05.7 **INSPECTION DATE** 8/20/87

Pictures (Elevation, Approach Views, Views and Others of Significance)

1. APPROACH LOOKING North
(Direction)

2. PROFILE LOOKING Downstream
(~~Up~~/Down Stream)

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Figure 13-49. - (continued).

13.5 STRENGTH LOSS FROM DECAY

Bridge members infected with decay fungi experience progressive strength loss as the fungi develop and degrade the wood structure. The degree of strength reduction depends on the area of the infection and the stage of decay development, whether advanced, intermediate, or incipient. In the advanced or intermediate stages, wood deterioration has progressed to the point where no strength remains in infected areas. At this stage, suitable detection methods can be used by the inspector to accurately define the affected areas with some degree of certainty. At the incipient or early stages of development, detection is much more difficult and the effect of strength loss varies among types of fungi.

Little information exists on assessing strength loss at the incipient stages of decay, but several researchers have correlated strength to weight loss in small wood samples. These investigations found that strength loss associated with some brown rot fungi can be as high as 50 to 70 percent when the weight is reduced by only 3 percent or less.[25,30] These findings are especially significant for timber bridges because (1) most bridge decay is from brown rot rather than white rot fungi, (2) incipient brown rot decay, with its minimal weight loss, is difficult to detect, and (3) the effects of brown rot fungi usually extend a substantial distance away from areas where decay is visible.

Although the strength effects for white rot fungi may be less than those for brown rot, differentiating between the two is not possible in the field. Thus, all decay should be assumed to be significant. In light of the large strength losses associated with early brown rot development, it is recommended that no strength value be assigned to wood showing evidence of decay in any stage of development. Although this approach may result in a slightly conservative evaluation in some instances, it is the only safe approach for assessing strength, given the large number of variables involved. Although numerous cores may be taken to define the decayed area, the possibility remains that the entire area of infection will not have been sampled. Additionally, decay will continue to further reduce strength unless immediate maintenance actions are undertaken to arrest its growth.

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