Practice Points NUMBER 03

Basics of Wood Inspection: Considerations for Historic Preservation

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Introduction

Wood performs well in structures, often for hundreds of years or more, when it is kept dry and protected from the deleterious effects of moisture and biological deterioration. The open construction typical of historic structures, which provides air infiltration into the structure, makes it possible for the wood to dry quickly if it gets wet. Often this type of construction is criticized for permitting drafts through walls and around openings. On the other hand, this characteristic means that older buildings can breathe in such a way that if wood gets wet, it has a chance to dry. Such openness, of course, is not very energy efficient and has been largely eliminated in modern construction.

However, sometimes moisture does get trapped, or the strength requirements of members change. Alterations may have compromised the ability of the wood to dry quickly or may have overloaded the structural members. Architects, engineers, and owners need to know when deterioration has occurred and whether the current strength of the structural members, even when they are oversized and provided more strength than required for the original use, is adequate for implementing a preservation plan for the structure. Wood inspection provides the means to acquire that information.

There are three primary reasons to conduct a wood inspection: concerns about moisture and its effects, deterioration (both physical and biological), and a need to determine material properties. Wood behavior is highly variable, due to different wood species, rate of tree growth (typically measured in growth rings per inch), age of the tree, how the lumber was cut from the log, the presence of defects (such as knots), and end-use conditions (interior or exterior use). It is that variability relative to the use of wood that those working on such structures must understand. This article provides the reader with a brief description of how to conduct a basic wood inspection in a historic structure and why such an inspection may need to be done. A list of references with additional information on each topic is provided.

Fig. 1. *Moisture stain on a sill plate on top of a masonry dome. All photographs by the author.*

The Need for Wood Inspection

Concerns about moisture. Prolonged exposure to moisture can produce undesirable conditions and long-term maintenance issues for wood in a structure, including moisture stains, peeling paint, and warping of lumber and timber. Stains can be the result of a single wetting or of periodic wetting and drying. A leak that was repaired many years ago may have resulted in a stain that has not affected the wood in any substantive way. Such stains are of no consequence structurally and can be ignored, unless aesthetics warrant a repair. In other cases, stains may be the result of periodic leaks in roofs or walls, which may lead to more serious problems, such as decay or warping. Therefore, it is important to determine whether a stain is the result of an isolated historic event or the result of active leaks and ongoing moisture intrusion (Fig. 1). Decay and insect attack are significant problems associated with periodic leaks or moisture intrusion. Measurements of moisture content can identify wood that has moisture levels favorable for the growth of wood-decay fungi.

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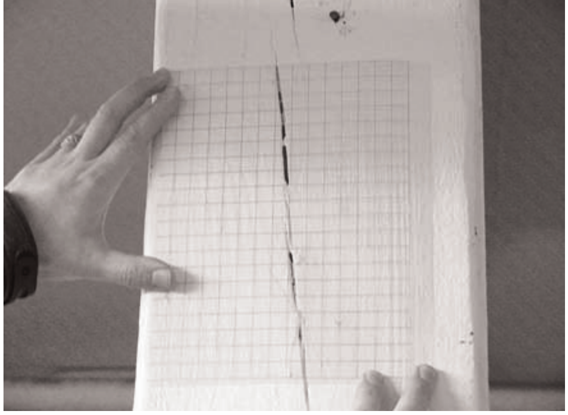

Fig. 2.
Measuring the slope of a drying check on a painted column by using an acetate grid.

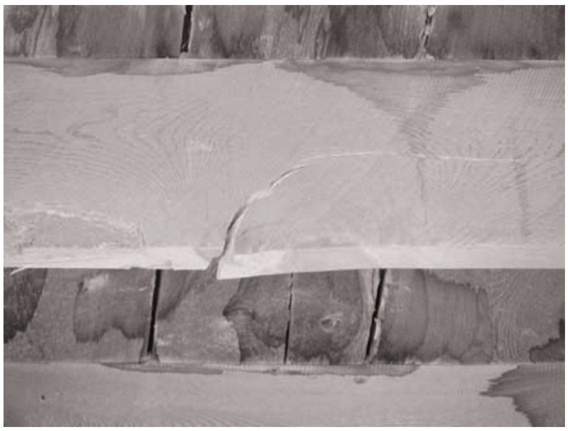

Fig. 3.
Failure of a joist in a silver-mining mill.

Concerns about deterioration. Deterioration of wood can be the result of physical processes (weathering, failure due to overload, mechanical damage, or shrinkage) or biological processes (decay and insect attack). Structural timber will typically have checks on one or two faces, which are due to differential shrinkage of the timber and are part of the natural process as the wood dries (Fig. 2). A check is a separation of wood fibers in a piece of lumber, post, or timber, typically along the length of the piece, that results from the drying of the wood after processing or installation in a structure. Checks are not a defect and do not reduce the performance of the piece structurally, unless two checks on opposite faces join to form a through split. However, if the timber has split through the entire thickness, a more detailed investigation is necessary to determine whether the split is a failure resulting from overload or mechanical damage or whether it is associated with shrinkage around connectors (typically bolts) (Figs. 3 and 4). Differential shrinkage in mortise-and-tenon joints can result in failure of the joint that is restricted by the treenail (wooden peg).

Weathering of wood results from cyclic wetting and drying of the wood, exposure to ultraviolet light, and erosion by wind-blown debris, a process similar to sandblasting. Unlike decay or insect attack, weathering is typically not a significant factor in the failure of wood components and the collapse of a structure. Weathering will change the appearance of wood, but the process is so slow that failure of components due to decay generally occurs long before weathering becomes a major factor in the failure. Weathering seldom damages the wood enough to require replacement, with the exception of shingles and cladding. Weathered wood is often considered aesthetically pleasing (Fig. 5).

Biological deterioration is generally caused by fungal or insect attack. Bacteria can degrade wood but are generally not a concern with historic structures because decay fungi and insects tend to impact material properties more rapidly than bacteria. Thus, the focus of a wood inspection for biological deterioration is typically fungi or insect activity.

All wood is subject to a variety of deterioration mechanisms, the most prevalent being wood-decay fungi, which can ultimately lead to the inability of structural members to perform. Depending on wood species, large timbers will retain moisture internally, frequently causing interior rot with no visible sign of the deterioration on the surface of the wood. Moisture absorption though end grain, checks, or holes provides a highly favorable environment for decay fungi to attack the heartwood at the center of a large timber. The heartwood (the inner growth rings of the tree) typically has more decay resistance than the sapwood (the outer growth rings of the tree). However, even the heartwood of naturally durable species such as chestnut will decay when exposed to enough moisture. Deterioration is a particular concern where the wood is in contact with the ground or with other materials, such as porous masonry, that may allow for moisture to be absorbed into the wood.

Fungi associated with wood include mildew and stain and decay fungi. Fungi propagate from spores present in the air. Mildew grows on the surface of wood and paint and does not affect the strength of the wood. Stain fungi (not to be confused with moisture stains) penetrate the surface of the wood but do not reduce its strength. Decay fungi, however, break down wood components over time. All types of decay fungi — brown rot, white rot, and dry rot — affect the ability of wood to perform its intended function. Although identifying the specific fungus during wood inspection is not essential, identifying the location and extent of deterioration due to decay fungi is important.

Generally, if the moisture content of the wood is less than 20 percent, fungi are unable to grow. Areas with moisture contents between 20 and 30 percent can support the growth of fungi, but the moisture may not be sufficient to support long-term active decay. Moisture contents between 30 and 40 percent are highly favorable for active fungal growth and are often an indication of advanced decay, with symptoms that may include internal voids and surface deterioration. Highly saturated wood (with more than 60 to 80 percent moisture content) typically has insufficient oxygen for fungus to grow; therefore, the decay may be inactive. Insects generally require that moisture be greater than 10 percent to be active and deteriorate the wood. In addition to favorable moisture content, both fungi and insects require suitable temperature and oxygen, as well as the wood as a food source. However, moisture is the controlling factor for decay in historic structures.

The early stage of decay, known as incipient decay, is characterized by discoloration and an initial loss of integrity of the wood. No voids are present. Probing with an awl or a screwdriver may reveal that the surface of the wood is soft or punky. As the decay progresses, the wood integrity deteriorates until small voids develop. This stage is termed intermediate decay. The small voids continue to extend primarily along the wood grain, where it is easier for moisture to move through the wood, but can also extend across the grain. Larger voids develop where the decay originated, and the boundaries of the decay continue to extend, reducing the integrity of the wood and compromising its structural capacity (Fig. 6). At this advanced stage, termed advanced decay, simple probing with an awl or a screwdriver is unlikely to detect the hidden deterioration in internal voids. An increment borer or a portable hand drill may be used to examine wood removed from the interior of larger timbers. However, more advanced techniques, such as resistance drilling, are able to quantify the extent of deterioration rather than simply identify its presence.

Termites and wood-boring insects reduce the cross section of a wood member by either digesting or tunneling through the wood. Subterranean and drywood termites digest the wood as they move below the surface of the wood. Termites can often be detected through the presence of mud tubes on the exterior of either the structure or the individual wood members. The tubes allow the termites to maintain a favorable moisture environment as they move towards a new food source. Wood-boring beetles create holes that are packed with frass (the byproduct of the tunneling process). Carpenter ants and bees leave large clean tunnels in affected wood.

With decay, there is a definite progression from sound wood to punky wood to a total loss of wood fiber, i.e., a void. Unlike decay, insect damage tends to have an abrupt transition between affected and unaffected areas of the wood. Wood that has not been penetrated by insects retains its structural integrity, although there can be a loss of cross section. The loss of cross section directly relates to the load-carrying capacity of the member by reducing the volume of wood available to carry loads. The reduction in cross section, if known, can be taken into account by engineers to determine whether the affected member can still carry the required loads or needs to be reinforced or replaced. For both types of deterioration, moisture is generally required, and the result is a loss of integrity of the wood member, as well as a loss of cross section (Fig. 7).

Concerns about material properties. Material properties are important when wood components carry loads. To determine whether the existing wood can carry the required structural loads, it is important to know the appropriate strength and stiffness properties of the wood. Identification of the wood species is also an important factor, not only to calculate its strength and stiffness but also to determine whether there will be significant differential shrinkage if other woods are used for repairs.

Fig. 4.
Split between bolts caused by wood shrinkage.

Fig. 5.
Weathered cladding, considered aesthetically pleasing.

Although some individuals can identify wood species in the field using a hand lens, the most reliable means to accurately identify species is done by examining anatomical features of the wood under a microscope. Individuals who want to learn how to identify wood species themselves can purchase wood samples and identification handbooks. Wood scientists and wood conservators will identify wood species for a fee. The U.S. Forest Products Laboratory in Madison, Wisconsin, will identify up to five samples without charge, but it typically takes several weeks to get the results.

For new wood construction, structural engineers rely on design values referenced in building codes to determine an acceptable species, size, and grade for a particular load condition. For existing buildings, engineers often rely on current building codes and standards to determine adequacy of the wood members. However, current standards are generally based on lower-quality material than what is found in many historic structures. Since many older buildings were constructed before building codes or design values for wood products were established (and, thus, before grade stamps were used), engineers inexperienced with historic structures or materials are often in a quandary when determining what design values are appropriate. Frequently a species and grade are assumed, leading to wood members being declared structurally deficient. The result is often an overly conservative estimate of design values and unnecessary replacement, repair, and retrofit decisions, with the associated unnecessary project costs.

Although estimates of strength and stiffness can be made by knowing the species, establishing the grade, and therefore the design properties, is more involved. In-situ grading should not be conducted unless the individual is familiar with the appropriate standards and has

Fig. 6.
Decayed beam supporting a timber column.

Fig. 7.
Insect damage on a porch beam, as evidenced by the yellow frass from powder post beetles.

Fig. 8.
Awl inserted to probe the interface between a timber beam and a masonry wall.

the knowledge of how grades are established within the design codes.

Tools for Basic Wood Inspection

There are three "tools" for a basic wood inspection: visual inspection, a sharp probe, and a moisture meter. Equipment used for nondestructive evaluation can give much more information about wood condition, but the use of such tools should be reserved for situations where a basic inspection cannot sufficiently answer the questions of the architect, engineer, or owner. An individual experienced in wood inspection may also use a hammer for sounding or a portable hand drill to gain information about the relative condition of the wood, although neither of these methods allows for quantifying the extent of deterioration: they are best suited for identifying locations that warrant further investigation. A sharp probe will also not allow for quantifying the extent of deterioration in larger members, but it easily detects areas of surface deterioration and should be included in any wood-inspection tool kit.

A visual inspection allows for identifying components that are missing, broken, or in an advanced state of deterioration. Missing components are those that have been removed or have fallen away, frequently due to extensive deterioration. If missing components were intended to provide structural support or protection from the elements (e.g., to prevent moisture intrusion), their replacement may be essential to prevent long-term damage to the structure. This problem often manifests as roof leaks in historic buildings. A small mirror with a telescoping handle and a flashlight are useful when inspecting relatively inaccessible areas.

Visual inspection also allows for the detection of past or current moisture problems as evidenced by moisture stains on the exposed surface of the wood. Further, visual inspection enables detection of external wood-decay fungi or insect activity as determined by the presence of decay fruiting bodies, fungal growth, insect bore holes, mud tubes, or wood removed by wood-destroying insects. Visual inspection provides a rapid means of identifying areas that may need further investigation.

Probing the wood with a sharp pick or an awl enables rapid detection of voids in the wood that may not be visible on the surface. Internal decay is often masked by the lack of evidence on the exposed surface of the wood. For advanced decay where large internal voids are present near the surface, probing can detect evidence of potentially serious deterioration. For internal voids in large timbers more advanced inspection methods are generally required to detect the void. Even for the early stage of decay, probing can reveal areas that have experienced sufficient deterioration due to decay fungi by allowing for easy entry of a sharp probe, although no void is yet present. Wood without incipient decay tends to offer more resistance to probing, due to its higher density and more intact internal wood structure (Fig. 8).

The true moisture content of wood can be determined only by oven drying a sample removed from a structure. However, portable moisture meters using electrical capacitance or electrical conductance can display the approximate moisture content of wood.

Capacitance-type meters measure the electrical field within a small area of a piece of wood (Fig. 9). They do not require penetration of probes into the wood and generally provide the average moisture content throughout a certain depth, typically less than an inch; however, a wet surface (e.g., rain on a window sill) can dramatically affect the reading. These meters are particularly useful for measuring the moisture content of interior and exterior woodwork (doors, windows, trim, etc.) and dimension lumber.

For thicker material, such as structural timber, a conductance meter, often called a resistance moisture meter, will provide a better indication of the internal moisture content. A conductance-type meter conducts electric current through wood between two probes (Fig. 10). The probes, which come in different lengths, can be inserted into the wood to various depths, thus allowing for determining the moisture content at different depths of larger timbers. This technique is useful in determining whether wood is drying or taking up moisture.

Advanced Investigative Techniques

In the interest of saving the maximum amount of historic fabric while not altering or scarring the materials during investigative probes, preservationists often look to nondestructive testing methods to answer questions about the evaluation and identification of materials, conditions, and alterations made to structures over time. However, they are not part of a basic wood inspection and are not generally needed for most wood assessments. When the information revealed from a basic inspection is insufficient to make informed decisions, then advanced investigative techniques should be considered. Only a few nondestructive techniques have proved useful in historic-preservation projects. The most commonly used methods are:

- stress-wave analysis, used to locate advanced decay
- resistance drilling, used to quantify the loss of material due to decay or insect damage
- digital radioscopy, used to view hidden conditions and construction

Where to Look

Determining the condition of wood components is the most common reason for conducting an inspection. Knowing what parts of a structure to inspect and what tools to use depends on the goal of the inspection. The inspection should begin with looking for problems where they are most likely to occur in a structure. Missing or failed components, moisture stains, the presence of fungal fruiting bodies, decayed wood, insect bore holes, mud tubes, or frass are indicators that need closer investigation. An inspection should focus on likely problem areas, such as:

- wood in contact with the ground
- wood that exhibits moisture stains
- wood with visible decay
- roof penetrations, such as around chimneys and vents
- attic sheathing, framing lumber, and timbers
- sill beams and wall plates, particularly when they are in contact with masonry
- floor joists and girders, particularly where they rest on exterior walls
- openings (doors and windows)

Fig. 9.
Capacitance-type moisture meter being used on window sill.

Fig. 10.
Conductance-type moisture meter being used on a timber column in contact with the ground.

Fig. 11.
Timber sill and wood cladding in contact with stone foundation.

- material interfaces, such as wood and masonry, particularly beam pockets (Fig. 11)
- exterior woodwork, including cladding, shingles, and soffits
- porches
- crawl spaces and basements
- areas of the structure that have been altered

It is essential to remember that the purpose of the inspection is to provide data that can be used to answer questions raised by the architect, engineer, or owner about the condition of the wood. If the wood has moisture stains, are the stains recent, as indicated by high moisture-content readings, or is the wood sufficiently dry that the stain likely occurred long ago? If decay is present, can it be active, as indicated by moisture-content reading greater than 20 percent, or is the decay fungus dormant? Are splits due to normal drying checks, or is it an indication of failure of that component? If so, was the failure due to loads exceeding the capacity over time, or could it be due to a one-time occurrence? The inspector should ask these types of questions. Sound technical data about the current condition of the wood are necessary for effective repair and replacement decisions to be made. Such data are the result of a thorough wood inspection.

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