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Inspection of Wood Beams & Trusses

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ABSTRACT

Facility Condition Evaluation Standards are given for timber trusses and laminated wood arches. Various types of deficiencies are discussed and a rating system is derived and applied to typical deficiencies found in timber structures.

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FOREWORD

This Maintenance and Operations (MO) Manual for Facility Condition Evaluation Standards prescribes the procedures for identifying and evaluating the deficiencies in timber trusses and laminated wood arches.

This manual first defines the types of deterioration and lists the underlying causes of these deficiencies. A rating system is developed, based on the urgency of action required at the level of the public works engineering staff. Inspection equipment and procedures are then explained.

There are separate chapters on Condition Evaluation Standards for timber trusses and laminated wood arches. The various condition ratings are explained and many are illustrated. An inspection format is suggested for each type of structure.

Recommendations or suggestions for modification, or additional information and instructions that will improve the publication and motivate its use, are invited and should be forwarded to the Commander, Naval Facilities Engineering Command (Attention: Code 100), 200 Stovall Street, Alexandria, VA 22332. Telephone: Commercial (202) 325-8181, Autovon 221-0045.

This publication has been reviewed and approved in accordance with SECNAVINST 5600.16.

J. P. Jones, Jr.
Rear Admiral, CEC, U.S. NAVY
Commander, Naval Facilities
Engineering Command

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CHAPTER 1. INTRODUCTION

Section 1. GENERAL

1.1.1 PURPOSE. Wood is one of our oldest building materials and its long-term performance can be observed in buildings that are several centuries old. It does not deteriorate because of age alone. but there are service conditions that have major effects on its durability. Deterioration can be caused by a number of factors such as errors in original design or construction; changes in loading; or inadequate maintenance practices that allow rain entry. Deterioration often advances slowly and is not immediately obvious. By the time it is apparent, trouble may be widespread. Inspection on a routine schedule can identify problems or potential problems before they become severe. Corrective measures at early stages may involve only minor expenses; but if deterioration is allowed to continue. the result may be costly major repairs or even complete demolition of the building.

Data derived from a well organized and executed inspection program can be valuable for planning of new construction that will be free from deteriorating conditions. Also, comprehensive information regarding the current condition of the structure can prevent expensive replacements and loss of operating time during periods of emergency repairs.

1.1.2 SCOPE. The inspector of timber structures needs a basic knowledge of what properties of wood affect its strength. how the conditions of use affect durability. and how deterioration occurs. This knowledge can be applied to inspection procedures for establishing a condition rating system that will inform managers of the requirements for maintenance or repairs. These standards are limited to instruction for inspecting to identify possible problem areas that may require indepth study. and do not include analysis or repair methods. Additional inspection may be required by a professional to determine the exact extent of deterioration and to evaluate its effect on the structure. While many of the principles discussed apply to all wood structures. the emphasis here is on heavy-timber trusses and glulam arches.

1.1.3 FREQUENCY REQUIREMENTS. The frequency of inspection depends entirely upon local situations at the activity, such as those necessitated by accidents, existing or potential biological activity. or the nature of the materials used in the construction. If the structure was properly designed and constructed of adequate and appropriate materials. it is logical that inspections may be spaced further apart than in situations where questionable materials were used in a structure subject to exposure to an adverse environment. The length of time between inspections should not exceed that specified for the Annual Inspection Summary. This inspection does not replace the Annual Inspection Summary.

The climate index map for decay hazard (Fig. 1-1) shows the effect of geographic location on the rate at which decay advances. The most severe location in the United States is the southeastern states where rainfall is high, and the weather is warm and humid. In the northeast and midwest decay advances at a somewhat slower rate. Near the coast in the northwest. decay hazard is moderate, but on the coast it can be severe. Most of the southwest is very dry, so decay is less hazardous.

1.1.4 TERMINOLOGY. The following terms will be used throughout the text:

BRASHNESS. A condition that causes some pieces of wood to be relatively low in shock resistance for the species and, when broken in bending, to fail abruptly without splintering at comparatively small deflections.

CHECK. A lengthwise separation of the wood that usually extends across the rings of annual growth and commonly results from stresses set up in wood during seasoning.

DECAY. The decomposition of wood substance by fungi.

Advanced (or typical) decay. The older stage of decay in which the destruction is readily recognized because the wood has become punky, soft and

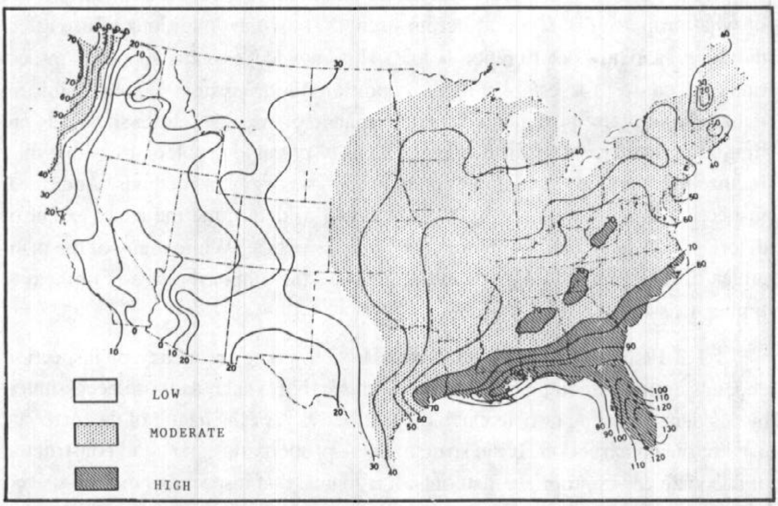


Figure 1-1. Climate index for decay hazard (higher numbers indicate a higher decay hazard).

spongy, stringy, ringshaked, pitted, or crumbly. Decided discoloration or bleaching of the rotted wood is often apparent.

Incipient decay. The early stage of decay that has not proceeded far enough to soften or otherwise perceptibly impair the hardness of the wood. It may be accompanied by a slight discoloration of the wood.

DELAMINATION. The separation of layers in a laminate through failure within the adhesive or at the bond between the adhesive and the laminae.

DENSITY. As usually applied to wood of normal cellular form, density is the mass of wood substance enclosed within the boundary surfaces of a wood-plus-voids complex having unit volume. It is variously expressed as pounds per cubic foot, kilograms per cubic meter, or grams per cubic centimeter at a specified moisture content.

DURABILITY. A general term for permanence or resistance to deterioration. Frequently used to refer to the degree of resistance of a species of wood to attack by wood-destroying fungi under conditions that favor such attack. In this connection the term “decay resistance” is more specific.

FUNGUS. A highly specialized group of primitive plants. Some fungi decompose wood (see decay) while others discolor wood without affecting its strength properties.

GRADE. The designation of the quality of a manufactured piece of wood or of logs.

GRAIN. The direction, size, arrangement. appearance, or quality of the fibers in wood or lumber. To have a specific meaning the terms must be qualified.

Diagonal-grained wood. Wood in which the annual rings are at an angle with the axis of a piece as a result of sawing at an angle with the bark of the tree or log. A form of cross-grain.

Edge-grained lumber. Lumber that has been sawed so that the wide surface extends approximately at right angles to the annual growth rings. Lumber is considered edge grained when the rings form an angle of 45 degrees to 90 degrees with the wide surface of the piece.

End-grained wood. The grain as seen on a cut made at a right angle to the direction of the fibers (e.g., on a cross section of a tree).

Flat-grained wood. Lumber that has been sawed parallel to the pith and approximately tangent to the growth rings. Lumber is considered flat grained when the annual growth rings make an angle of less than 45 degrees with the surface of the piece.

Straight-grained wood. Wood in which the fibers run parallel to the axis of a piece.

GREEN. Freshly sawed or undried wood. Wood that has become completely wet after immersion in water would not be considered green, but may be said to be in the “green condition”.

JOINT. The junction of two pieces of wood or veneer.

Butt joint. An end joint formed by abutting the squared ends of two pieces.

Edge joint. The place where two pieces of wood are joined together edge to edge. commonly by gluing. The joints may be made by gluing two squared edges as in a plain edge joint or by using machined joints of various kinds, such as tongued-and-grooved joints.

End joint. The place where two pieces of wood are joined together end to end. commonly by scarf or finger jointing

Finger joint. An end joint made up of several meshing wedges or fingers of wood bonded together with an adhesive. Fingers are sloped and may be cut parallel to either the wide or edge faces of the piece.

Lap joint. A joint made by placing one member partly over another and bonding the overlapped portions.

Scarf joint. An end joint formed by joining with glue the ends of two pieces that have been tapered or beveled to form sloping plane surfaces. usually to a feather edge, and with the same slope of the plane with respect to the length in both pieces. In some cases, a step or hook may be machined into the scarf to facilitate alinement of the two ends, in which case the plane is discontinuous and the joint is known as a stepped or hooked scarf joint.

Starved joint. A glue joint that is poorly bonded because of an insufficient quantity of glue in the joint.

KNOT. That portion of a branch or limb which has been surrounded by subsequent growth of the stem. The shape of the knot as it appears on a cut surface depends on the angle of the cut relative to the long axis of the knot.

LAMINATED WOOD. An assembly made by bonding layers of veneer or lumber with an adhesive so that the grain of all laminations is essentially parallel.

MOISTURE CONTENT. The amount of water contained in the wood, usually expressed as a percentage of the weight of the oven dry wood.

PRESERVATIVE. Any substance that. for a reasonable length of time, is effective in preventing the development and action of wood-degrading fungi, borers of various kinds, and harmful insects that deteriorate wood.

ROT. (See DECAY).

SHAKE. A separation along the grain, the greater part of which occurs between the rings of annual growth. Usually considered to have occurred in the standing tree or during felling.

CONNECTOR, TIMBER. Metal rings. plates. or grids which are embedded in the wood of adjacent members. as at the bolted points of a truss, to increase the strength of the joint.

TRUSS. An assembly of members, such as beams, bars, rods, and the like, so combined as to form a rigid framework. All members are primarily stressed in tension or compression rather than bending.

Section 2. FACTORS TO CONSIDER

1.2.1 STRUCTURAL PROPERTIES OF WOOD. In appraising the structural value of old lumber, the three principal things to consider are species. quality. and condition. While identification of these items is not expected from this inspection. an understanding of how they influence structural properties may be useful.

1.2.1-A SPECIES. If a strength value is to be assigned. the species must be identified. This can often be done from visual examination. while in other instances it may require a microscopic examination by a trained specialist.

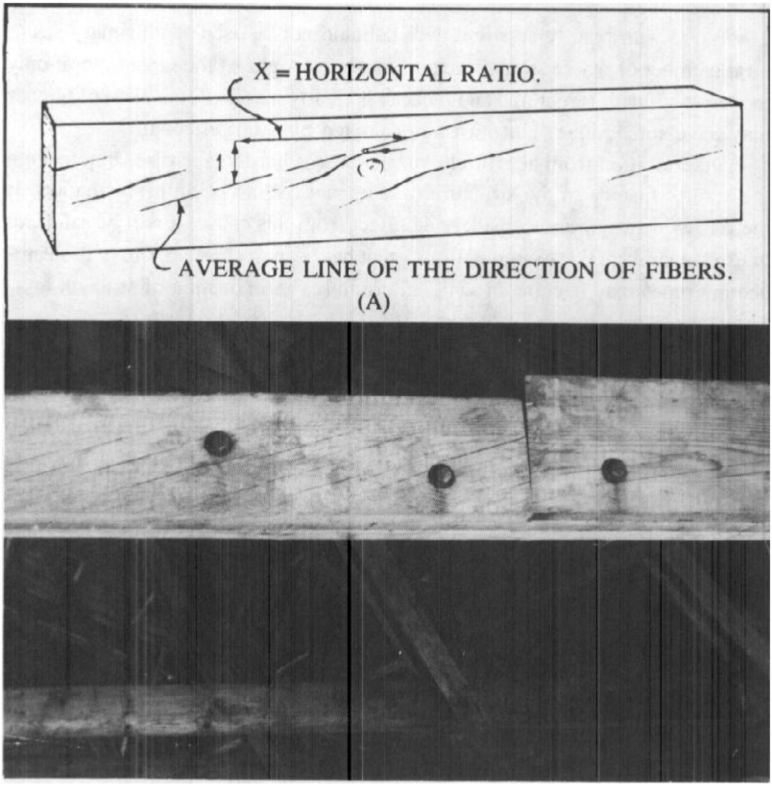
1.2.1-B QUALITY. Within a species, a high-quality piece may have twice the strength of a low-quality piece of comparable size. The principal features affecting the strength of lumber are knots, cross grain. and checks or splits.

The effect of a knot depends on its size and location together with the type of strength property being considered. The strength reducing effect is generally in direct proportion to the portion of the cross section occupied by the knot or to the portion of the width of the surface in which the knot appears. Knots near the bottom edges of members loaded in bending have about twice the strength-reducing effect of those located elsewhere. Knots near the ends of beams have little effect on the strength. Compressive strength is reduced only about half as much as are tensile or bending strength. Knots have only a small effect on lumber stiffness. Since the principal effects from knots are in the distorted grain around the knot, loose knots or knotholes are generally considered to have about the same effect on strength properties as intergrown knots of the same size. Knots have no significant effect on bearing strength (compression perpendicular to grain) or shear strength.

Cross grain is of two kinds, spiral or diagonal. Spiral grain is a growth characteristic in which the wood fibers are inclined spirally around the tree instead of parallel to the axis of the trunk. It is easily detected by the inclination of seasoning checks with respect to the direction of length of the piece. Diagonal grain results from sawing a crooked tree or from not sawing parallel to the bark. and can be detected by the trace of the annual rings on a radial surface. Cross grain is shown in Figure 1-2.

Splits or deep checks reduce the resistance of beams to longitudinal shear. Only those appearing in the sides of beams need be considered.

1.2.1-C CONDITION. It is hard to make more than the most general observations about condition as a factor in appraising structural members. Broadly, if its condition is good. it can be used with working stresses near those for new lumber of its species and grade; if its condition is not good. it should



(B)

Figure 1-2. Slope of Grain. (Slope of grain (A) is indicated by a ratio of vertical to horizontal distance, such as 1 in 10. Slope of grain (B) is evident from checks. The member at the left has a slope of grain much steeper than allowed by structural grades. Slope of grain in the member at the right is low enough to be accepted by some structural grades.)

not be used for structural purposes at all. There are, however, some factors that may be kept in mind.

Moisture content is usually not an important condition factor where wood is protected from rain and not exposed to unusually high humidities. Much old lumber, which has been protected, is at a more or less uniformly low moisture content. Further, large structural wood members have about the same design values whether green or dry. Indirectly, a high moisture content is an unfavorable factor in that it indicates that the member has been subjected to hazards of decay or other deterioration.

Wood with readily apparent decay should not be used as a primary structural member or where strength requirements are high. At the same time, if only moderate strength is required and if decay is clearly localized, the piece of lumber may have some value, but must be evaluated by a professional.

Deterioration from heat or chemical attack is hard to appraise. inquiry into the service history of the structure may uncover some helpful information. If there is evidence of any considerable effect from this cause, it will be safer not to use the lumber. For example, timber that has been in close proximity to steam-heating pipes may become brown and crumbly, an indication of strength loss.

1.2.2 CONDITIONS OF USE. The way wood is used in a building has a major effect on the maintenance required and the potential for problems of deterioration. Wood is affected by exposure to excessive moisture, high temperatures. or excessive structural loads. The age of the building or the time period over which the wood has been exposed to these conditions is also important. The exposure of structural wood to the elements as a result of design features or inadequate maintenance can also be a contributing factor to deterioration.

1.2.2-A HOW THE BUILDING IS USED AND UNUSUAL LOADING. Normal operations carried on in a building can contribute to deteriorating of wood, especially if the function was not considered in the original design. Any operation that involves a lot of water (Fig. 1-3) or steam (Fig. 1-4) increases the potential for the wood to be at a high moisture content and for consequent decay or possibly insect problems. Some examples are shower rooms, swimming pools. and laundries. The high humidity resulting from these operations may cause condensation on cold surfaces with resultant wetting of the wood. Problems may also develop where water contacts wood or where steam from driers or steam lines is close to wood members. Various manufacturing or processing operations may also introduce excessive moisture to the inside of the building. Although adequate ventilation may have been included in the design, these high moisture situations should alert the inspector to a greater potential for decay than in a building that is consistently dry.

Most trusses and arches are designed to support only normal roof loads. Additional loads may overstress structural members. particularly if these are applied over a long period of time. Examples of such loads are mechanical equipment such as air conditioners or elevator motors, antennas or other communication equipment mounted on the roof, hoists hanging from the lower chords of trusses. or other heavy items stored by hanging them from trusses or arches. Some of these loads can be applied temporarily without ill effects, but can cause serious problems over a long time period. A description of any unusual loading and the time over which it has occurred should be noted in the inspection report.

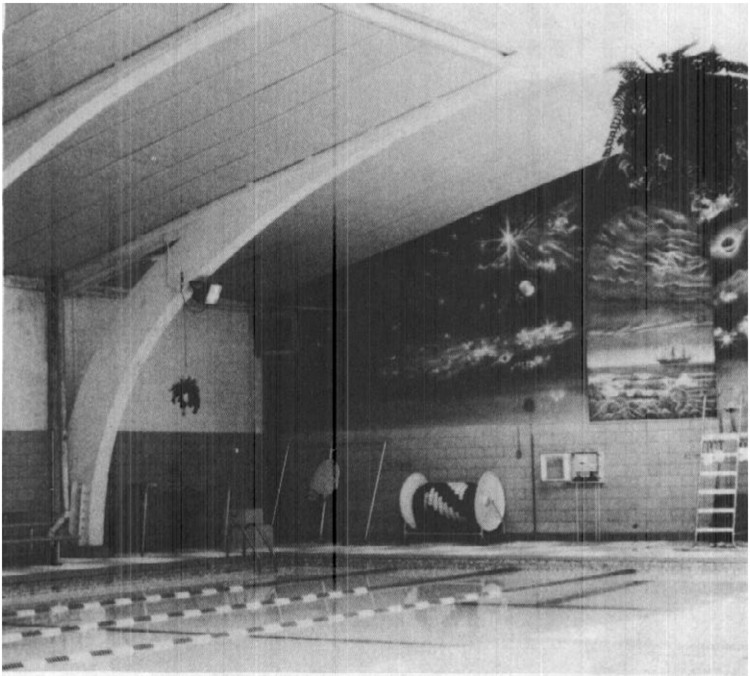


Figure 1-3. Swim Pool Areas. (Swimming pool areas may develop high humidities which increase the potential for condensation and consequent decay problems. Humid air alone will not result in wood wet enough to decay.)

1.2.2-B AGE OF THE BUILDING. Age alone is not a deteriorating factor, but it can be an indicator of the basis for the building design and of how it was constructed. Methods of stress-grading wood structural members have changed over the years, as have methods of assigning allowable stresses, and in some cases species properties have changed, especially when the supply changed from virgin timber to second growth. The design and manufacture of glulam members has also changed. Prior to the late 1940's, adhesives used were not waterproof, so the potential for delamination is greater in buildings of that age. During World War II, the urgency for providing military buildings sometimes resulted in the use of green or only partially dried lumber which later resulted in numerous check and splits as well as loosening of connectors.

1.2.2-C EXPOSURE OF WOOD ELEMENTS. The degree of exposure of wood structural members to rain and other weathering effects is a major factor

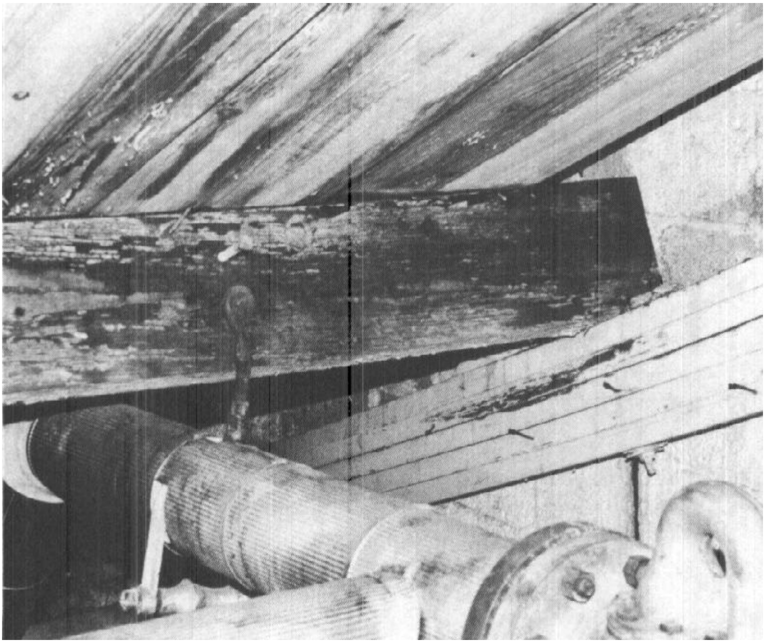


Figure 1-4. Decay Caused by Steam Lines. (Steam lines close to wood components may cause some deterioration of wood due to high temperatures, and leaks in the lines may create moisture problems.)

in the performance of those members. When wood members extend outside the wall, and particularly beyond the roof line, there is a high potential for decay unless they are preservatively treated. If such members are strictly for esthetic effect without serving a structural function, the building may not be endangered; however. when structural support such as an arch base (Fig. 1-5) is outside the building, any deterioration can have a major impact on the safety of the building. Special attention should be given to exposed end grain of wood since water is absorbed much faster in the grain direction than it is absorbed across the grain. Proper flashing over the top and ends of wood members often gives good protection, but total enclosure of the end may accelerate decay by trapping water. Also. ends of members supported on horizontal surfaces may be subject to absorbing water that stands on the surface. If these exposed members are near the ground, lawn watering or backsplash from rain may cause additional wetting. Any ground contact of wood is a major hazard unless the wood has been preser-

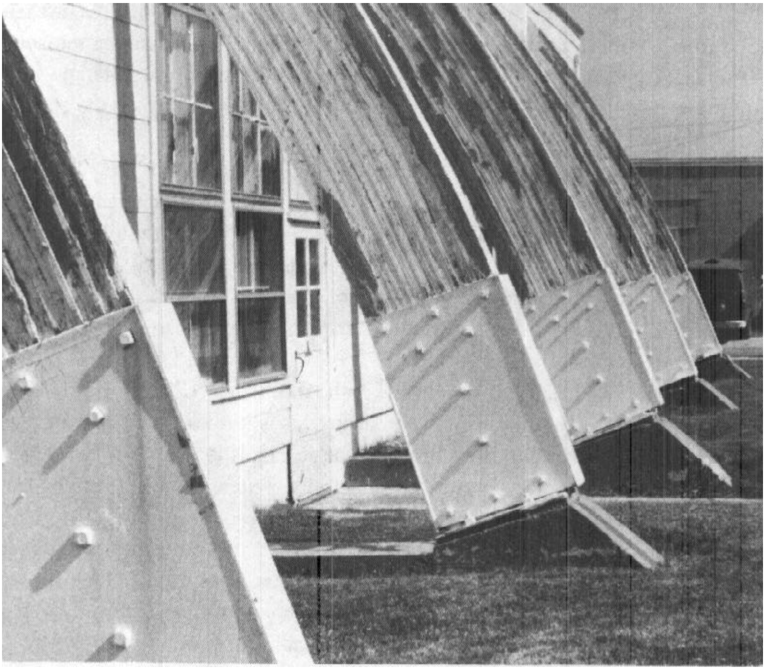


Figure 1-5. Outside Structural Members. (Structural members extending outside the roof line are particularly vulnerable to decay because of exposure to rain. These arches were being repaired at the time the picture was taken.)

vatively treated under very strict quality control. Exposure of wood to water may also be caused by poor maintenance such as failure to repair a leaky roof or other defects that allow rain entry. Skylights are particular hazards for rain entry or for condensation on the inside of the glass where water from either source can wet a wood element. Thus, attention should be given to decay possibilities in structural members adjacent to skylights.

1.2.3 DETERIORATION. Wood does not deteriorate as a result of aging alone. The service life of all commonly used building timbers depends on their being protected from a variety of deteriorating agents. Given the appropriate conditions, deterioration encountered will usually fall into one of three principal categories: (1) biological, (2) physical, or (3) chemical.

1.2.3-A BIOLOGICAL. Biological damage is caused by the normal activities of living organisms such as fungi and insects.

Fungus Damage. Wood decay fungi are primitive plants that obtain their food from wood. If wood is kept in a damp condition (30 pct or higher moisture content) for any length of time, it becomes infected with wood-decay fungi which bring about its decomposition more or less rapidly, depending on the species of fungus and the kind of wood.

The growing stage of fungi consists of microscopic threads called hyphae which in mass form cottony or felt-like growth/ It is hyphae that penetrate and "branch out" within wood and cause decay. When conditions are suitable, fungi produce spore-bearing structures called fruiting bodies (Fig. 1-6). The fruiting bodies of most decay fungi are mushroom or bracket shaped.

Insect Damage. Various types of termites, beetles, carpenter ants. and bees utilize wood as a food source or for nesting purposes. Damage by wood-boring insects can usually be recognized without difficulty (Fig. 1-7). Evidence of their presence may be entrance or departure holes, the size of which depends upon the insect involved. In many instances the accumulation of powdery material in the vicinity of the hole indicates insect activity. Extensive insect activity can result in structural failure of members.

The damage caused by termites is different from that caused by most other insects. Termites work inside pieces of wood, excavating large tunnels and galleries, sometimes hollowing out the wood completely. They never form exit holes on the surface of wood which they most carefully avoid damaging. However, their presence may be evidenced by earthen tunnels which are used for passage from the ground to wood members. Severe damage by termites in the United States is usually limited to warm, temperate areas.

1.2.3-B PHYSICAL. Physical damage may take the form of excessive deflection of structural members, failure of wood members, loosening or failure of connectors, or development of splits. When wood members are loaded to or beyond their design level for a long period, the fibers become permanently elongated or shortened in a process referred to as creep. High or changing moisture contents while the member is loaded has a similar effect. While this creep may not indicate a loss of strength, the deflection or sag that results is usually permanent. In the case of multiple wood members connected together, such as in trusses, the deflection may be due to loose connectors. Joints are loosened by moisture cycling that causes the wood to shrink and swell in thickness, or by the initial drying of wood that causes a gradual shrinking over a long period. Potential connector problems or joint failures may also be caused by splits in the immediate area of the connector, (illustrations are shown under section 3.1.2.). Splits outside the connector area in a tension member are generally not critical if they are parallel to the member axis. Splits in areas with sloping grain are potential failure points. Complete failure of the wood member may be in the form of a fracture through the member cross section or as crushing of the wood fiber.

In glued-laminated members, deterioration may be in the form of adhesive bond failure. This delamination may be from the action of moisture on non-waterproof glue or from an inadequate bond during fabrication. The importance in terms of physical damage depends on the size and location of the delamination relative to critical loading points. If glulam timbers become wet and dry out quickly, severe checking can develop. This checking can be mistaken for delamination because it often occurs near a glueline. Regardless, it is the extent of the checking or delamination that needs to be determined.

1.2.3-C CHEMICAL DAMAGE. If wood comes into contact with certain chemicals such as strong acids or alkalis, some of its constituents may be decomposed and it may disintegrate. Wood that has been damaged by contact with a chemical may be discolored or assume a fuzzy, wooly appearance, owing to the individual fibers having become separated by dissolution of those substances which bind them together in wood.

The type of chemical damage most frequently encountered in wooden structures is that associated with the corrosion of metal fasteners. Wood subjected to constant or frequent wetting assumes a blue-black color adjacent to iron nails, screws, bolts, or other fasteners and, in time, softens to varying degrees.

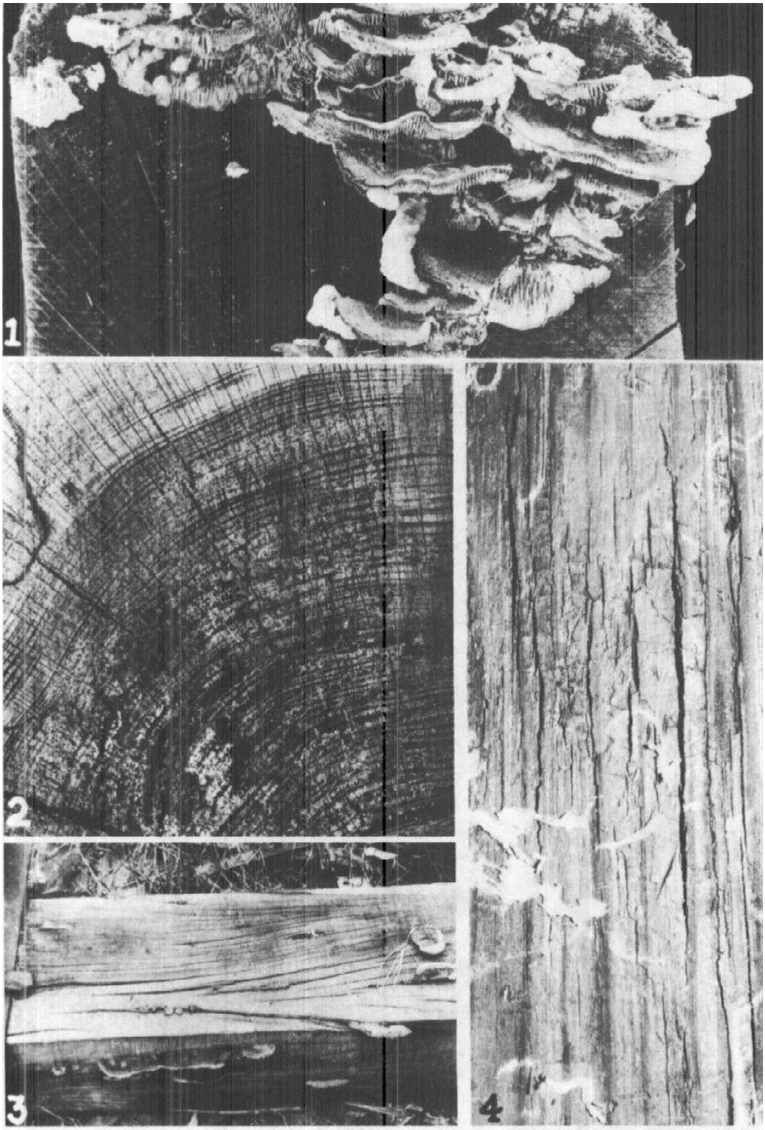


Figure 1-6. Examples of fungal growths and associated decay. (1) Fruiting bodies; (2) Advanced decay; (3) Fruiting bodies without obvious decay on surface of wood; (4) Fungal growth on surface and advanced decay evidenced by checks both across and with the grain. (M31901F)

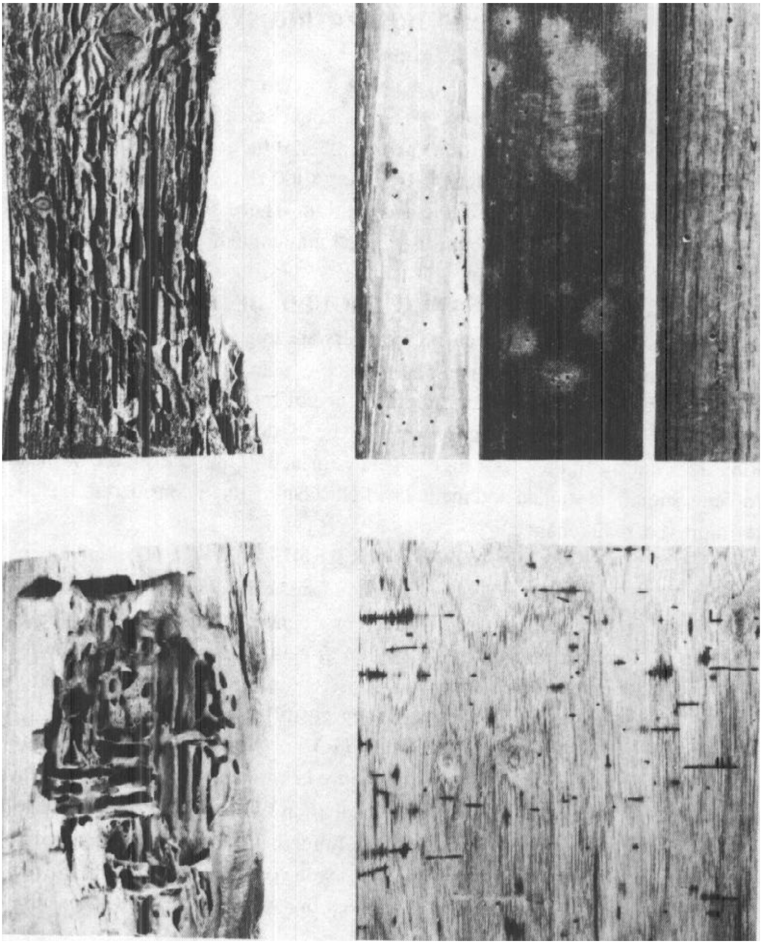


Figure 1-7. Types of insect damage most likely in a building. (Upper left.) Termite attack; feeding galleries often parallel to the grain and containing excrement and soil. (Upper right.) Powder-post beetle attack; emergence holes. prevalently filled with wood flour and not associated with discolored wood. (Lower left.) Carpenter ant attack; nesting galleries usually cutting across the grain and free of residue. (Lower right.) Beetle attack: feeding galleries (made in the wood while green) free of residue and the surrounding wood darkly stained.

Section 3. CONDITION RATING SYSTEM

The inspection should result in a rating for the condition of each truss or arch. A rating system from 0 to 100 has been developed with the number 100 rating indicating the best condition, and number 0 the worst.

1.3.1 NO ATTENTION REQUIRED. A 100 rating is used to designate a truss or an arch that is in excellent condition. There should be no sign of deterioration of any type. The building is well maintained, and there is no indication of any potential problem.

1.3.2 SOME MAINTENANCE SHOULD BE CONSIDERED. A number 80 rating indicates structural members are in good condition, but there are potential problems. There may be evidence of a decay hazard such as water stains, or surface molds indicating the presence of free water or high humidity levels. Slight delamination or checking may be evident in glulam arches. This rating does not mean there is a high urgency for action, but the source of these problems should be studied and methods of eliminating them considered, including improved maintenance.

1.3.3 MAINTENANCE OR REPAIR REQUIRED. A 60 rating means some deterioration has occurred, but has not reached critical levels. Some localized decay or insect infestation is evident or connectors have become loose. Moderate delamination may exist in glulam arches. Slight deflections may be observed. Maintenance in the near future is required to prevent deterioration from advancing to the next level, requiring costly repairs.

1.3.4 NEEDS IMMEDIATE ATTENTION. A rating of 40 means major deterioration has occurred, and localized failure is imminent. This condition may be indicated by noticeable deflections, critical areas of decay or termite damage, or major delaminations in glulam arches. Immediate attention is required to evaluate the safety of the building as well as to consider measures to correct the unsafe conditions and to prevent failures that would add significant costs to repairs needed.

1.3.5 THE BUILDING IS UNSAFE. The number 20 and below rating means localized failures, severe decay or termite damage, or severe displacement of members has occurred, making the building unsafe. In glulam arches the failure may be extensive delamination. This rating should be reported immediately to the Public Works Officer for consideration of closing the building.

CHAPTER 2. INSPECTION METHODS

Section 1. EQUIPMENT

The actual equipment necessary for examination of wood trusses and glulam arches is relatively simple. It should include adequate means of lighting; hand tools for measuring. probing, and boring; and an instrument for measuring moisture content of wood. To augment written notes in the case of unusual circumstances, a camera may be included.

2.1.1 LIGHTING. Trusses are often located in dark areas of the building, so some type of light that is adequate and convenient is needed. In some cases a trouble light may be used. Where examination is at extreme heights or otherwise inaccessible locations a strong flashlight may be more convenient.

2.1.2 LIFTS. Some method of reaching the top of the building from the inside must be provided. In warehouses, cranes that run the length of the building may give easy accessibility. The use of a cherry-picker is another possibility. Where roofs are not as high, examination may be done with ladders, platforms on forklifts. or front-end loaders.

2.1.3 LINEAR MEASUREMENTS. A small measuring tape should be available to measure defects such as width or length of checks and splits. A length of fishline or other type of cord may be needed to stretch between truss ends to check the amount of deflection of the truss at the center. Also, a thin feeler or thickness gauge is needed to measure depth of checks or delamination.

2.1.4 PROBING. A moderately pointed tool such as an ice pick or fine-bladed screwdriver is useful in detecting decay that extends close to the surface.

2.1.5 SOUNDING. A hammer or other suitable tool is needed to rap the outside surface of a timber. The resulting sound may indicate the presence of interior deterioration.

2.1.6 DRILLING. The removal of chips with an auger bit (1/4-or 3/8-in.) is used to determine the presence of internal deterioration.

2.1.7 TREATED WOOD PLUGS. Where boring is done, treated plugs are used to close the resulting holes.

2.1.8 MOISTURE CONTENT. A moisture meter with 3-inch insulated pins is needed to determine moisture content.

2.1.9 PHOTOGRAPHY. A camera that will take pictures with good resolution is desirable to provide a record of unusual circumstances. A good flash attachment is also desirable.

Section 2. PROCEDURES

While general procedures can be recommended, the location. identification and description of the damage depends largely on the individual skill of the inspector. An inspection team should consist of at least two individuals, one inspector and one serving as an assistant for recording observations, handling tools. etc.

2.2.1 VISUAL OBSERVATION. The general condition of heavy timber trusses and glulam arches can be determined by visual observation. Some observations may indicate that more indepth study is needed, but much can be learned by observing physical condition and signs of fungus and insect infestation.

2.2.1-A PHYSICAL. The most obvious indication of physical damage is a sagging roof. If possible, sight along the top of the building to observe overall visible sag as well as individual trusses or arches sagging more than those adjacent to them. Inside the building, sighting across the bottom chords of trusses can reveal major sag of one truss relative to others. Also, sight along the base of several glulam arches to see if there is outward deflection. Where trusses appear to be sagging, the amount of sag should be measured. Simply measuring the distance between the bottom chord and a level surface below may be possible where the "I" beam of a crane spans the width of the building. Measure with a steel tape at each end and at the center. For distances more than 3 feet between the lower chord and top of the crane, it may be necessary to use a plumb line to assure vertical measurement. The amount of sag is the difference between the center measurement and the end measurements. If no level surface is available for reference, stretch a line between nails at each end of the lower chord and measure the vertical distance between the lower chord and the line at the center of length. Nails should be at the center of the bottom chord, and measurement should be made to the center of the bottom chord.

Observe all splits in the wood members. Particularly note split in the connector area and diagonal splits that extend to the edge of a wood member (see section 3.1.2). Also look for fractures completely or partially through the cross section of members. Check all glulam members for delaminations, and record general location in the arch.

Look for separations between members at joints which indicate obvious looseness of connectors. Also look for bolt holes where split-ring connectors were intended but not installed (Fig. 2-1).

2.2.1-B DECAY. Decay may result in abnormal coloration of the wood. The first indication of decay is often the appearance of brown streaks or blotches (Fig. 2-2). As wood approaches advanced stages of decay, it loses luster and

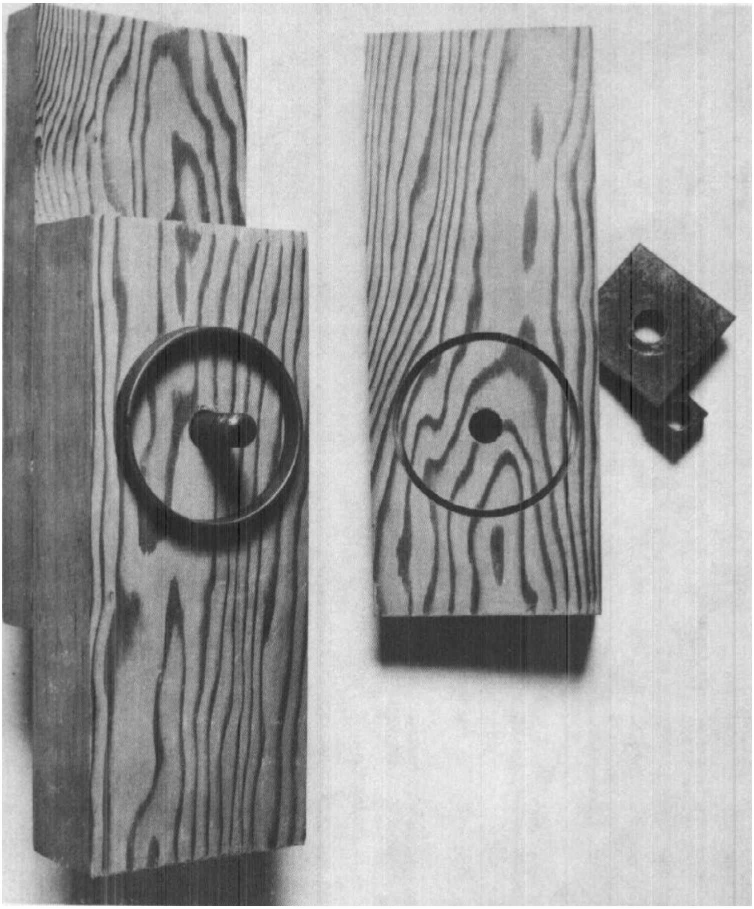


Figure 2-1. A split-ring connector installed in one member. The facing member has been drilled to receive the connector. Where the joint between facing members is not tight, probe through the connection with a thin metal to determine if the connector was installed or not.

may exhibit notable changes in color. Of course, prior to making judgments based on color it is necessary to be familiar with the normal, uninfected wood.

Sound, healthy softwood has a pleasant, fresh, resinous smell, while decayed wood usually has a “mushroomy” and stale odor. When testing the soundness of a member by boring into it, it is helpful to smell the borings. The presence

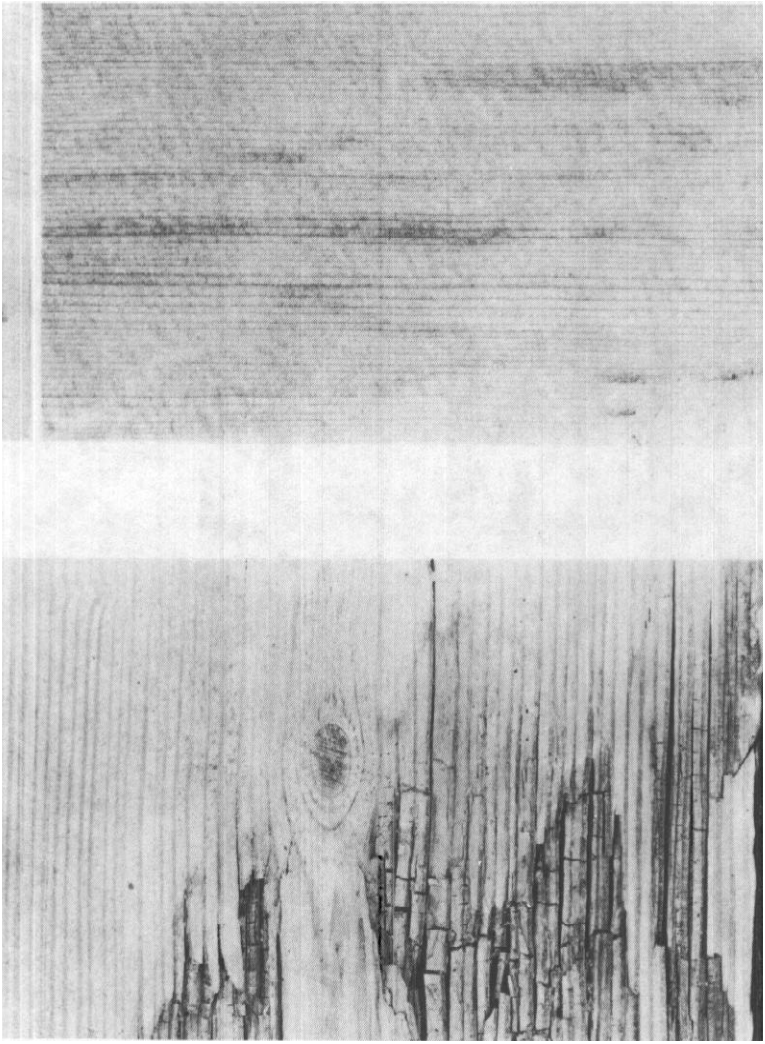


Figure 2-2. Stages of decay. (Top) Early stage evidenced by discoloration in surface and, at left. in end grain. (Bottom) Late stage, with cracked and collapsed wood. An abnormal brown color will be imparted to the wood by this type of decay.

of a musty. moldy smell, though indicative of conditions favorable to decay. does not necessarily indicate the presence of decay.

The presence of fruiting bodies (Fig. 1-6) or “mushrooms;” indicates that decay is present in members where the bodies occur. Fruiting bodies may appear at any stage of deterioration.

When decay has reached an advanced stage, it is usually quite easy to decide if the deterioration in a member is due to decay. especially if fungal growths (fruiting bodies) are present. There may be localized depression or sunken faces (Fig. 2-2) over decay pockets which extend close to the surface of the member. Many times advanced stages of attack are accompanied by shrinking of the wood and appearance of cracking in cubical patterns. Evidence of retained moisture over a period of time, especially at the junction of timbers. often indicates attack.

A number of conditions provide visual evidence of possible decay. Area exhibiting these conditions should be inspected carefully. Evidence of water. such as watermarks, indicate areas which may be or may have been at a high moisture content and thus should be investigated. Rust stains on wood surfaces show possible excessive wetting, particularly if the source of the iron is a wood-penetrating fastener. Appreciable growth of moss or other vegetation on wood surfaces or in checks or cracks is evidence of potentially hazardous wetting. Special attention should be paid to wood adjacent to water-trapping areas such as within joints where end-grain surfaces occur and at interfaces between members.

2.2.1-C INSECT. Damage by wood-boring insects is described in 1.2.3a.

2.2.2 INTERIOR INVESTIGATION.

2.2.2-A SOUNDING. Sounding is accomplished by rapping on the outside surface of a member with a hammer. If the hammer does not rebound or produces a dull or hollow sound, deterioration probably exists. This method requires considerable experience and can be considered truly diagnostic only where decay is relatively severe and, in large members. extends to areas near the surface. Wood members suspected of containing internal decay. as a result of sounding. must usually be bored to verify the diagnosis.

Sounding can also be used to detect loose connectors. Rapping on a bolt head will produce a clear, solid ring if the connector is tight. A loose connector will produce a hollow sound with more vibration than a tight one. Experience is also necessary to effectively evaluate these sounds.

2.2.2-B BORING. Boring is the most dependable and widely used technique for detecting internal decay. This method has the advantage of permitting direct examination of an actual specimen from the questioned area. Use of this method should be limited to areas with conditions suitable for decay. In taking boring samples, it is important to use sharp tools. Dull tools tend to crush or break wood fibers, which changes the appearance of samples. Inspectors should carry extra bits in their supply of equipment because cutting edges are easily damaged beyond practical field maintenance by striking hidden fasteners. Bored holes may become avenues for decay unless properly treated. Following shavings extraction. a wood preservative should be squirted or mopped into the hole and the hole then plugged with a snug-fitting preservative-treated wood dowel.

2.2.2-C PROBING. Decay soon causes wood to become softer and to lose its strength. If decay is suspected, the area should be probed with a pointed tool and its resistance compared with that of obviously sound wood. Probing may reveal the presence of decay by excessive softness or lack of resistance to probe penetration. Early decay may also be detected by jabbing the probe into wood and prying down. Sound wood usually breaks out in long splinters, and decayed wood is brittle and breaks out in short pieces with abrupt across-grain breaks (Fig. 2-3). Probe in areas where water is likely to have been absorbed or trapped by wood such as end-grain or side-grain faces adjacent to joints, deep checks, and adjacent to penetrating fasteners. In large members, particularly if preservative treated, neither probing nor sounding are effective in detecting decay at deep locations. For most critical appraisal of members likely to to develop hidden decay. boring is necessary.

2.2.2-D MOISTURE CONTENT. Where excessive moisture in wood is suspected. a moisture meter is used to determine moisture content. Pins of the moisture meter must be driven to near the center of the wood member for accurate determination. Specific instructions are included with individual meters.

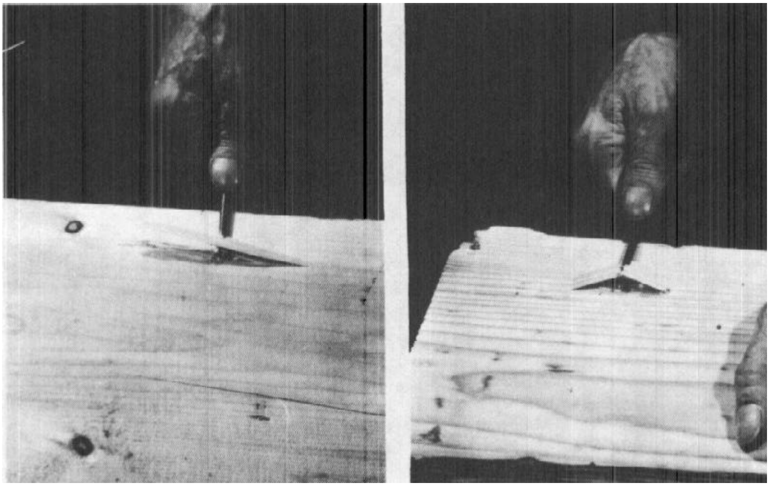


Figure 2-3. The pick test for early decay. (Left) Sound wood pries out as long slivers. (Right) decayed wood breaks abruptly across the grain without splintering.

CHAPTER 3. INSPECTION OF WOOD TRUSSES

Section 1. SIGNS OF DISTRESS

Elements of a typical heavy-timber truss are shown in Figure 3-1. Any of the following signs of distress (Figs. 3-2 through 3-6) indicate a need for more detailed investigation as described under PROCEDURES in Chapter 2. Since trusses are often supported by heavy-timber columns, these columns should be evaluated at the same time. The same principles of deterioration apply. Specific application to columns is discussed under various signs of distress.

3.1.1 DEFLECTION. Most trusses will deflect some, so that unusual deflection is the main concern. Many trusses are built with camber (upward deflection) such that deflection under dead load results in the bottom chord being horizontal. Generally, the downward deflection (sag) should not exceed the total span divided by 180. This calculates to 2 inches to 30 feet (360 in.), 4 inches in 60 feet (720 in.), or 6 inches in 90 feet (1,080 in.). Deflections less than these amounts may be considered slight, and given a rating of 60 or above.

Greater deflections should be easily visible (Fig. 3-5), and these should be measured and the amount recorded. If repairs are not made after inspection, the amount of deflection should be compared during successive inspections to see if the truss is stable or is continuing to deflect more. Excessive deflection is always a signal to look for causes such as loose connectors, decay in wood members, or a fracture in the lower chord.

3.1.2 CHECKS AND SPLITS. The importance of checks and splits depends partly on the type of stress in the member. In single-span trusses, lower chords of trusses are stressed in tension; top chords are stressed in compression. Diagonals may be stressed in either tension or compression depending on the type of truss.

Normally, checks are of relatively little importance unless they become water traps. If they are extensive and deep, their seriousness may be evaluated from the following guidelines on splits, on a basis of their relative importance compared with splits.

At the ends of the members stressed in compression parallel to the grain, such as top chords, checks and splits may be disregarded, provided there is no evidence of slip from the wedging action of connectors and bolts.

For members stressed in tension parallel to the grain, such as bottom chords, splits outside the connector area that are approximately parallel to the grain (Fig. 3-2B) may be disregarded. However, splits with a slope greater than 1 in 8 should be noted.

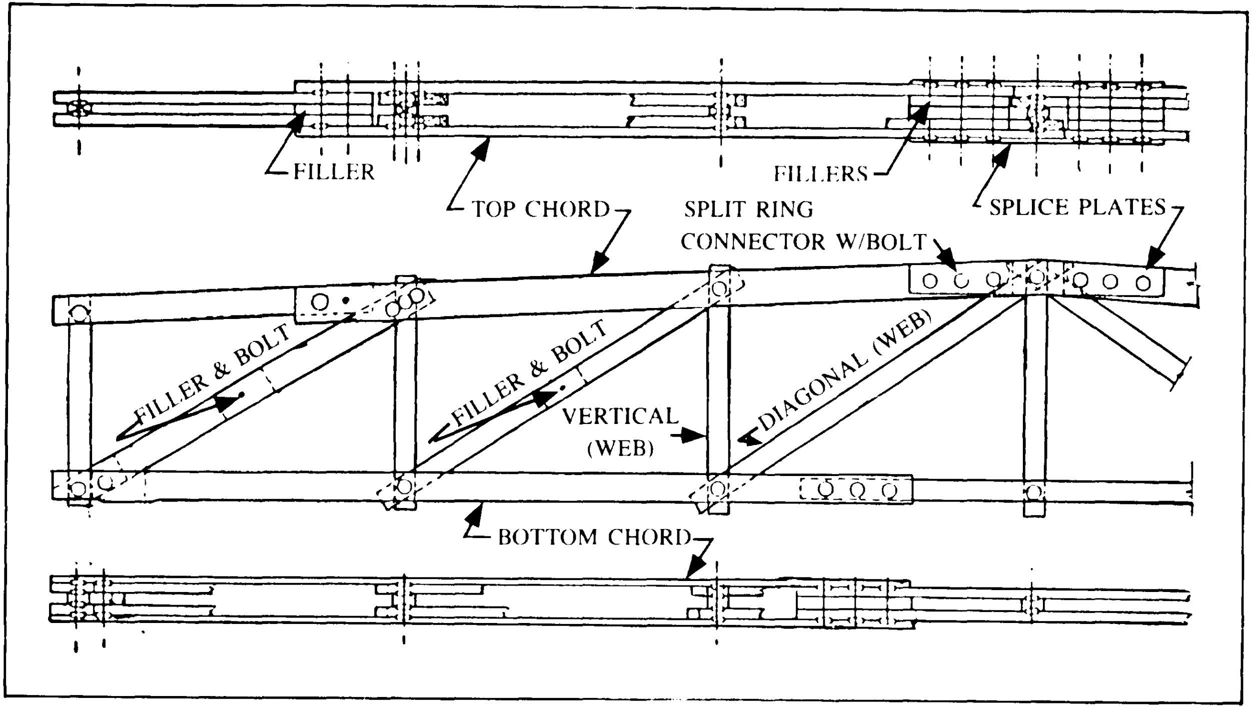


Figure3-1. Elements of a typical heavy-timber truss are shown in this elevation plus top and bottom view.

For tension members with connectors (bolts or split rings) loaded parallel to the grain. a single split within the connector area may be disregarded if the opening is less than 3/16 inch for connectors of 2-5/8 inches or less in diameter. and less than 1/4 inch for connectors up to 4 inches in diameter. All measurements of opening of splits should be made at the end of the member. If there is more than one split in the connector area. the total opening of the splits should not exceed 1-1/2 times that for one split. Splits of any width should be considered significant if they are within 1/4 inch of the edge of a connector that is 2-518 inches or less in diameter or within 1/2 inch of the edge of a connector that is up to 4 inches in diameter.

For end splits in either tension or compression members with connector loads acting in a direction other than parallel to the grain. the suggestion above for treating tension members should be applied at the ends of the pieces.

In some cases splits completely divide a column into two parts resulting in the parts acting as two smaller columns This condition necessitates an engineering analysis to determine if the column is structurally adequate. This situation should receive a 40 rating (Fig. 3-5E). These splits should also be checked to see if they are trapping water or providing a termite pathway.

3.1.3 LOOSE CONNECTORS. Connectors that appear loose either by sighting a gap between members or by sounding should be noted as loose and requiring attention. Inspections made during the first 3 years should include checking each bolt with a torque wrench. This should accomodate any initial drying of the member. Older trusses should be checked with a torque wrench if there are signs of excessive sag or indications of rain leakage in the vicinity of connector. Visual observation may be adequate for older trusses that have remained stable for several years.

3.1.4 EVIDENCE OF DECAY. Dry wood will not decay. Moisture content of wood is one of the most significant factors regarding wood decay because considerable water is necessary for fungus growth. Thus during inspection of roof trusses for decay, it is important to survey the area for any source of moisture that will sufficiently wet wood. Column bases are particularly vulnerable when they are supported directly on concrete because they may pick water up from the concrete (Fig. 34C). Water necessary for decay development in roof trusses can come from several sources: (1) rainwater leaks through the roof, (2) snowmelt, (3) condensation and (4) piped water in a leaking line.

3.1.4-A RAIN WETTING. Most rainwater wetting of roof trusses will be by gravity flow through leaks in roofs. With a good light source, survey the roof area for evidence of discoloration in wood caused by water leaks. Water leakage may be indicated by dark streaks or other stains on the wood surface. Special attention should be given to areas where watermarking or other evidence of roof leaks occurs.

3.1.4-B WETTING FROM CONDENSATION. Condensation results from cooling of air on contact with a cold surface. In many situations condensate does not accumulate in damaging amounts and may be dissipated quickly. However, accumulation of condensate may lead to growth of surface molds or decay. Particular attention should be given to skylights or high windows, shower rooms, laundries, and in living quarters because of the high humidities possible there.

3.1.4-C WETTING BY PIPED WATER. Major leaks in water pipes are usually found and corrected before serious damage occurs. However, minor leaks may not be detected for some time and can be a major source of water supporting decay. Check for signs of leaks wherever water pipes or steam pipes are near trusses.

Section 2. RATING SYSTEM

3.2.1 RATING GUIDE. The condition rating system is based on 100 points as discussed in Chapter 1. A rating of 100 indicates perfect condition, and a rating of 20 and below indicates a failure situation. Intermediate ratings means various levels of maintenance are required. Following are illustrations (Figs. 3-2 - 3-6) that show ratings to be assigned for various conditions. These will provide a guide in assigning an overall rating on the inspection format.

The rating derived from the inspection format, page 3-6, can be determined according to the following rules:

(1) For each truss, a rating of 0 to 100 is ascribed to each distress condition.

(2) The lowest rating for any distress condition becomes the overall rating of the truss.

(3) Where two adjacent trusses have overall ratings of 40, the ratings of both shall be changed to 20.

Building No. 90

Building Size 600 ft x 105 ft

Truss Span 100 ft

Date of Inspection 8-15-85

Building Age 41 Years

History of Use Warehouse-Intermittent heating

Truss No.	Rating 0-100								COMMENTS: Type and location of failures. Other problem areas. If deflection or displacement is significant, list amount. Unusual circumstances. Attach photographs of significant details.
	Deflection	Column Condition	Connection Problems	Splits	Fracture	Decay	Insect damage	Overall rating	
3	40	100	100	60	100	80	100	40	Deflection—Lower chord 6½″ Splits—End splits in connector area Decay—Water stains in upper chord
4	100	60	100	60	100	80	100	60	Column—Decay at base Split—Diagonal split in lower edge Decay—Discoloration near leaking steam line

S A M P L E

Section 3. INSPECTION FORMAT

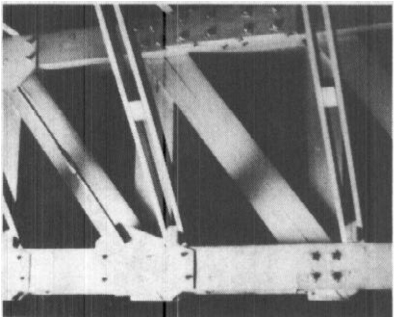


Figure 3-2. Trusses with rating 100. (A) No indication of deflection (sag) in the bottom chord and no signs of a decay problem.

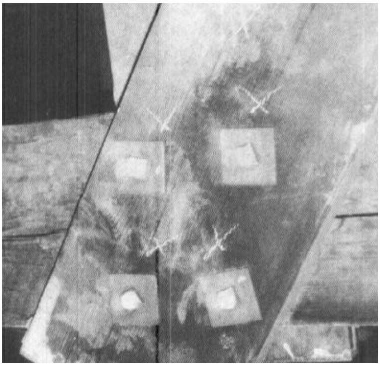


Figure 3-2. (B) No significant splits exist in the connector areas. The split shown is in the tension chord and does not pass through a connector. "X" marks were used as a "check off' for a previous inspection.

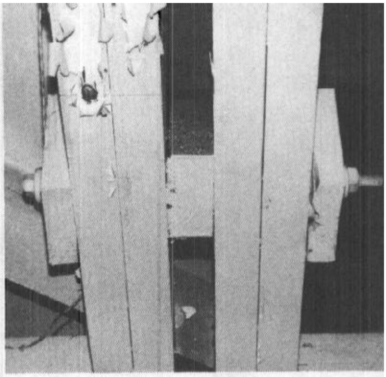


Figure 3-2. (C) All connectors are tight.

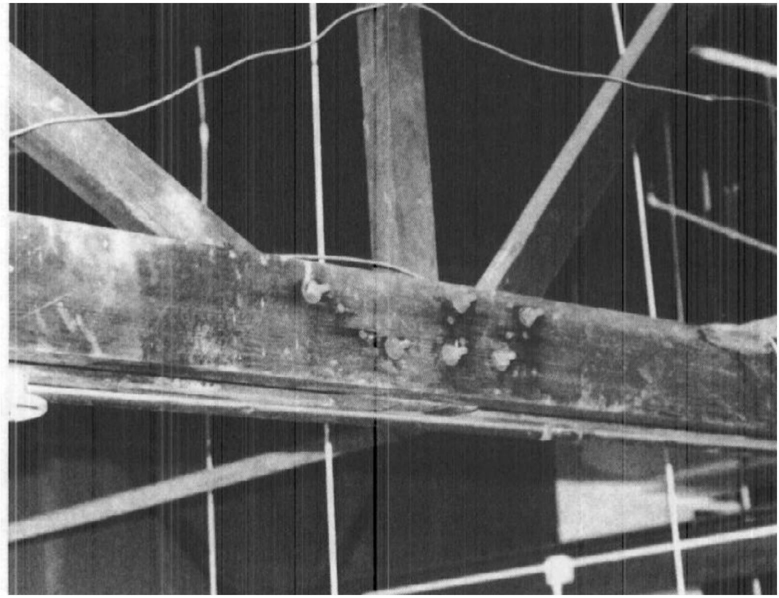


Figure 3-3. Trusses with rating 80. No deflection, significant splits, or loose connectors. Staining around connector indicates a constant moisture problem with possible decay.

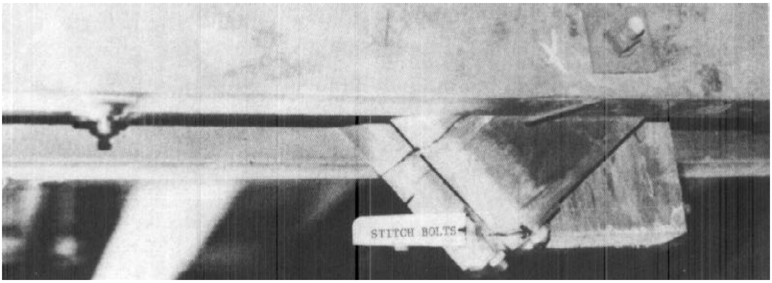


Figure 3-4. Trusses with rating 60. (A) End splits in the connector area. These have been stitch bolted. The rating applies to the condition before stitch bolting.

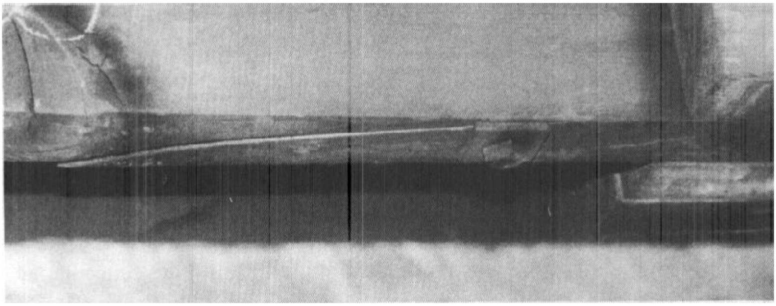


Figure 34. (B) Diagonal split in the lower edge of a structural member. This split was caused by the diagonal spike knot.

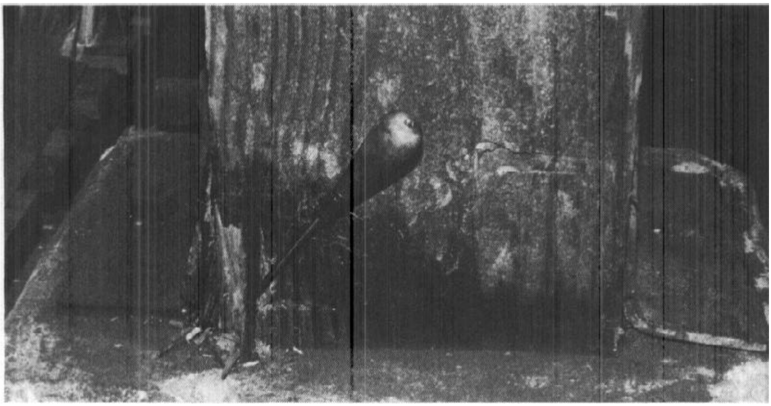
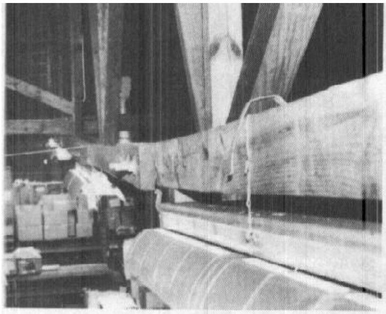
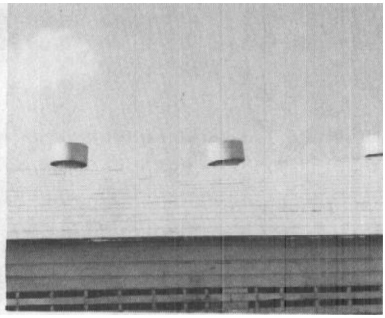


Figure 3-4. (C) Localized decay is evident at the column base. Decay may extend beyond the dark area, so the entire area should be carefully examined.



A



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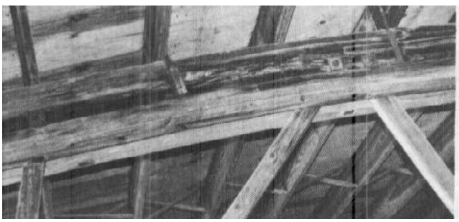

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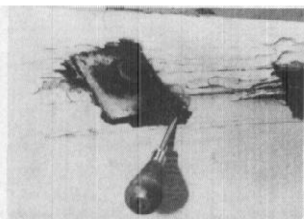

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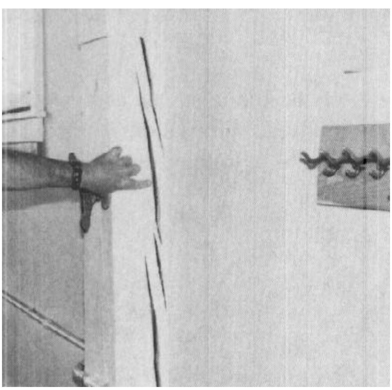

E

Figure 3-5. Trusses with rating 40. (A) Excessive deflection in lower chord. (B) Leaning stacks indicate differential roof deflection. (C) Severe decay in top chord as evidenced by depression of the surface, but no complete failure. (D) Evidence of severe decay in connector area and consequent loss of holding power. (E) Splits in a column such as this require indepth study but may not significantly affect the load-carrying capacity.

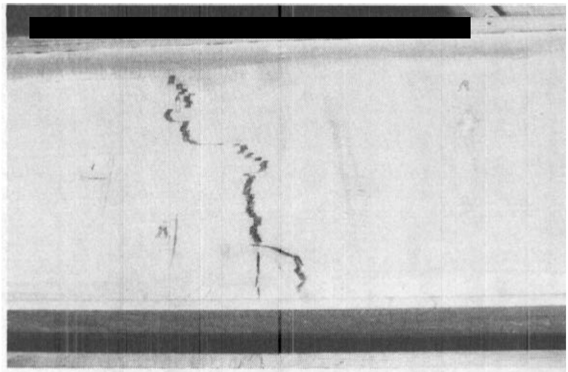

Figure 3-6. Trusses with rating 20. (A) Complete break at a knot in lower chord (has been repaired with splices top and bottom).

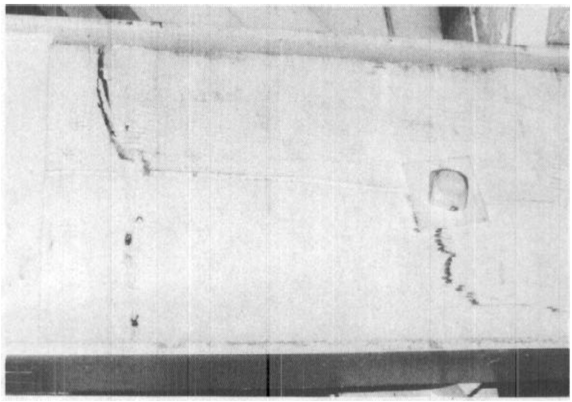

Figure 3-6. (B) Complete break at connector in lower chord and at a spike knot.

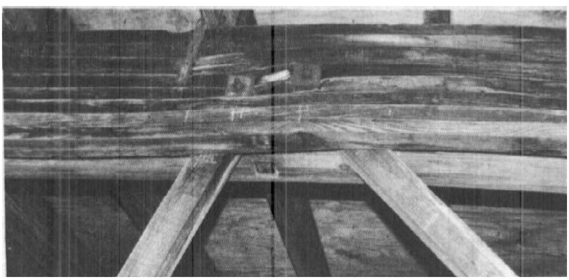

Figure 3-6. (C) Failure of top chord due to decay. Roof leaks were obviously present prior to replacement of the roof.

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CHAPTER 4. INSPECTION OF GLULAM ARCHES

Section 1. SIGNS OF DISTRESS

Elements of a typical glulam arch are shown in Figure 4-1. Any of the following signs of distress (Figs. 4-2 - 4-6) indicate a need for more detailed investigation as described under PROCEDURES in Chapter 2.

4.1.1 DEFLECTION. Arches should maintain their original shape without noticeable change unless there is a problem such as delamination. loose connectors. or some type of wood failure. Excessive deflection at the crown can usually be detected visually by the flat appearance instead of the continuation of the curve. There may also be evidence of crushing or splitting at connectors. In extreme cases there will be a downward deflection at the crown joint. Such a deflection will often result in roof leaks and be accompanied by water stains. The amount of deflection is difficult to assess since there is no reference point unless measurements from the crown to the floor were recorded at the time of construction. In some cases an estimate of the deflection can be made by comparing the crown-to-floor distance with that of an arch that appears in good condition. Any flattening of the crown should receive a rating of 60. A slightly downward deflection should be rated 20 (Figs. 4-6B and 4-5C).

Because of the outward thrust at the ends of the arch. some outward displacement may occur. Such displacement may be evident as a slight offset at the connector (Fig. 4-6B). Either of these conditions is serious enough to require a 20 rating.

4.1.2 DELAMINATION. Delamination of arches fabricated prior to the late 1940's is often an indication of a water problem since the adhesives before that time were not waterproof. Delamination also may result from poor bonding techniques coupled with seasonal cycling of moisture content. Three factors that affect the degree of strength reduction caused by delaminations are size. location, and frequency. The most serious delaminations extend completely through the cross section of the member. This makes the member in that area act as two smaller members. Single complete delaminations near the top or bottom of the cross section may be rated at 80 (Fig. 4-3A). If these delaminations are 3 feet or more in length, or located near the center of the cross section, the rating should be 60. More than one delamination in the same cross section or any delamination near a connector should result in a 40 rating (Fig. 4-5A). Numerous delaminations or any delamination directly through a connector should be rated 20. At the lowest rating there should also be signs of deflection or displacement. Where delaminations do not extend through the member. their depth should be measured with a thickness guage and noted under comments.

4.1.3 CHECKS AND SPLITS. Because glued-laminated arches are made up of relatively thin members that have been individually dried, checks and splits are much less common than in the larger timbers used in trusses. They would usually be limited to one lamination so their effects would be minimal. Where they do occur, the guidelines presented in section 3.1.2 would apply.

4.1.4 SPECIAL CONNECTOR PROBLEMS. Tightness of connectors should be visually observed as discussed under procedures. Also look for any sign of movement of the connector relative to the wood member. Such movement would result in splitting or crushing of the wood by the connector and would require a rating of 40 (Fig. 3-5D). Connectors exposed to rain. condensation, or other wetting may provide entry for water into associated wood and create a decay hazard. Any decay in the connector area would rate 40, or lower if displacement of the arch relative to the connector had occurred.

4.1.5 EVIDENCE OF DECAY. The same general principles of decay apply to glued-laminated arches as discussed in section 3.1.4 for trusses. One difference is that arches often extend outside the building with the ends beyond the roof line and resting on concrete abutments. These ends are not only exposed to rain but also the drying effects of the sun which can produce deep checks that are traps to catch water. Such checks as well as delaminations are especially susceptible to decay unless the wood is preservative treated.

Follow the procedures listed under section 2.2 to examine for decay. Special attention should be given to three areas: (1) *The arch end region immediately at or above the base connection.* This is the most susceptible area for decay because of water entrapment behind the metal collar and wetting of the end grain. (2) *The exterior exposure just outside of where the arch penetrates the building wall.* The concentration of water running off the roof as well as the joints at the wall interface around the arch has a high potential for trapping water. (3) *The crown of the arch where two segments join.* Although thus area is protected by the roof. any deflection may cause water ponding on the roof. Also. indoor water vapor may condense at or above the arch, particularly in high-humidity buildings such as those with swimming pools.

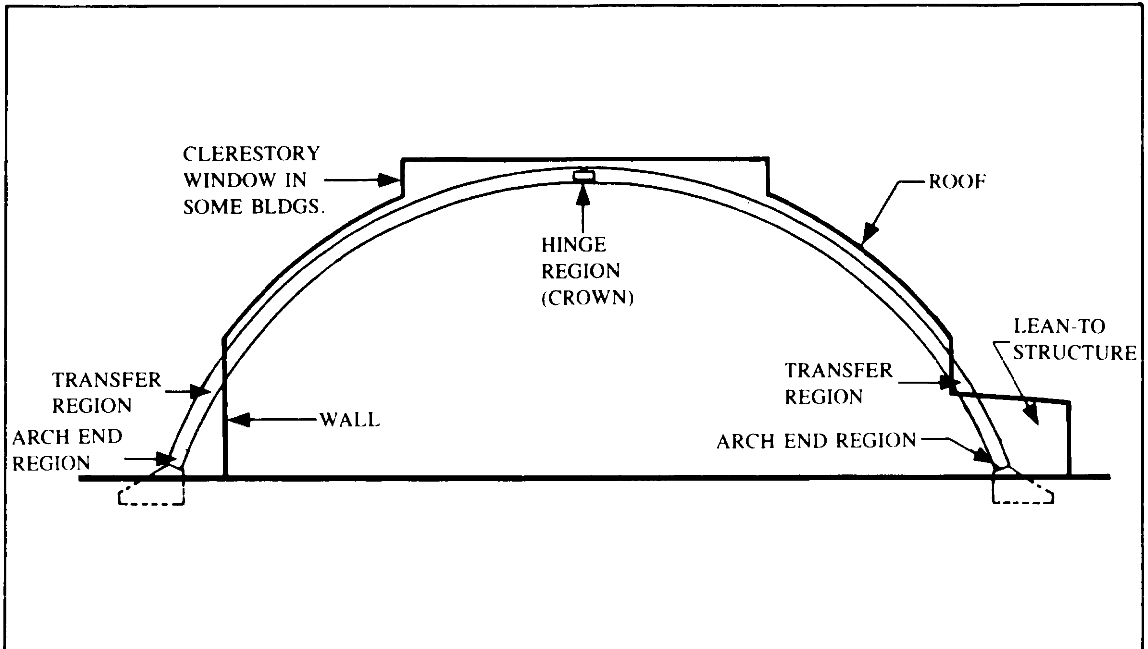

Figure 4-1. (Sketch) Elements of a three-hinged glulam arch and a commonly used roof system are shown in this schematic of a building cross section.

Section 2. RATING SYSTEM

4.2.1 RATING GUIDE. The condition rating system is based on 100 points as discussed in Chapter 1. A rating of 100 indicates perfect condition. and a rating of 20 or below indicates a failure situation. Intermediate ratings mean various levels of maintenance are required. Following are illustrations (Figs. 4-2 - 4-6) that show ratings to be assigned for various conditions. These will provide a guide in assigning an overall rating on the inspection format.

The rating. derived from the inspection format. page 4-6. can be determined according to the following rules:

(1) For each arch, a rating of 0 to 100 is ascribed to each distress condition.

(2) The lowest rating for any distress condition becomes the overall rating of the arch.

(3) Where two adjacent arches have overall ratings of 40. the ratings of both shall be changed to 20.

Building No.	500	Date of Inspection	8-15-85
Building Size	600 ft x 105 ft	Building Age	42 Years
Arch Span	100 ft	History of Use	Recruit drill hall-gymnasium

Arch No.	Rating 0-100								COMMENTS: Type and location of failures. Other problem areas. If deflection or displacement is significant, list amount. Unusual circumstances. Attach photographs of significant details.
	Displacement	Delamination	Connection Problems	Splits	Fracture	Decay	Insect Damage	Overall rating	
9	60	80	100	100	100	60	100	60	Decay—Localized decay at base Displacement—Outward displacement at base about 1½ inches. Delamination—Slight
10	100	40	100	100	100	100	100	40	Delamination—Extreme delamination at upper hinge. Crushing at top.

S A M P L E

Section 3. INSPECTION FORMAT

Figure 4-2. Glulam arches with rating 100. No sign of deflection or deterioration.

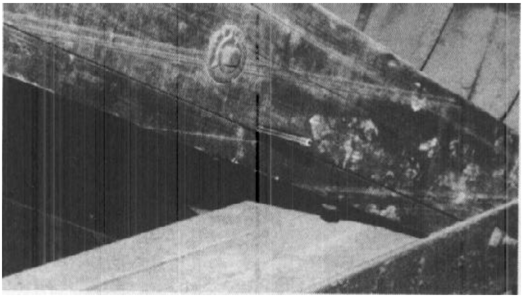

Figure 4-3. Glulam arches with rating 80. (A) This slight delamination near outer edge of a section of arched top chord of a truss would result in a rating of 80 if it were part of an arch.

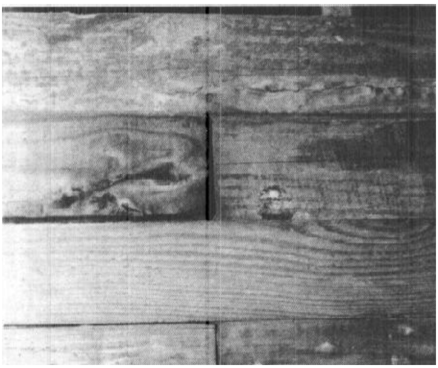

Figure 4-3. (B) Slight delamination associated with butt joints in a glulam section. Butt joints are potential sources of structural problems and are not permitted by today's standards. If found in glulam arches, these non-structural joints should be specifically noted.

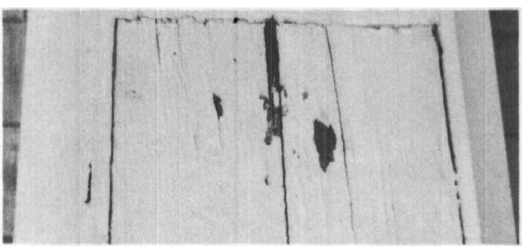

Figure 4-3. (C) Discoloration at the split in an arch base indicates possible localized decay.

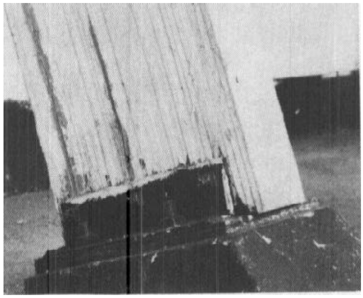

Figure 4-4. Glulam arches with rating 60. (A) Evidence of localized decay at concrete abutment indicated by the area adjacent to the concrete abutment.

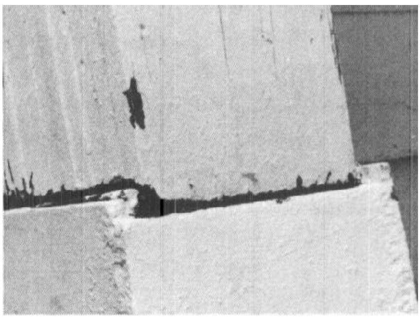

Figure 4-4. (B) Dark area is evidence of localized decay at the top of the metal collar.

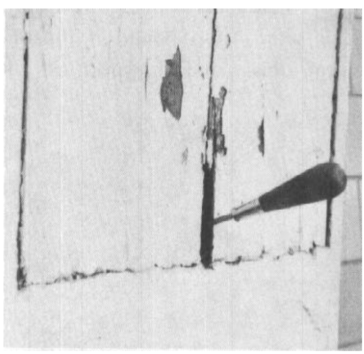

Figure 4-4. (C) Area of localized decay is easily probed with a screwdriver at the base of an arch.

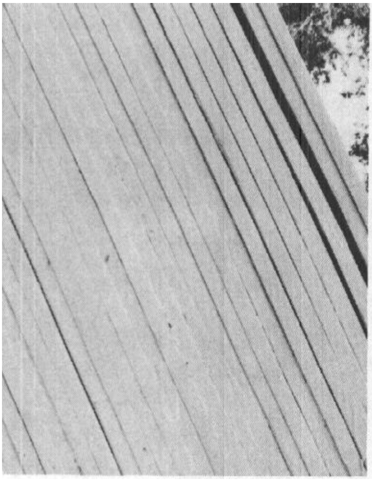

Figure 4-5. Glulam arches with rating 40. (A) Severe delamination in a localized area in the outer laminations.

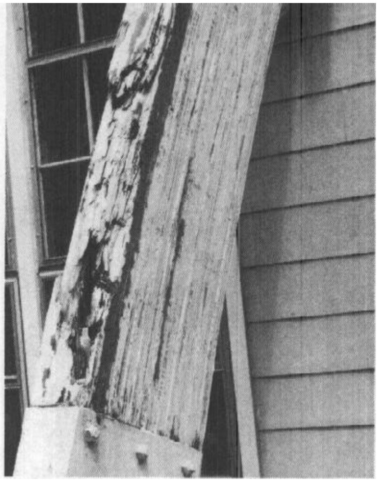

Figure 4-5. (B) Severe decay in outer laminations. With any evidence of arch settlement, this would represent a rating of 20.

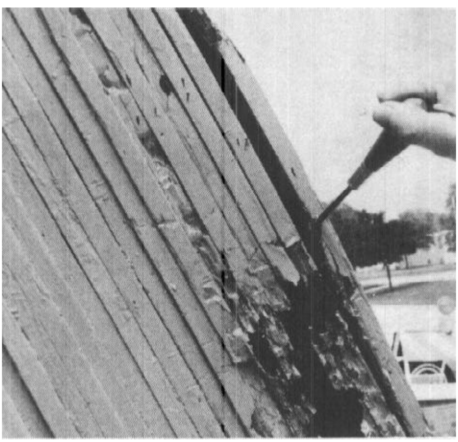

Figure 4-5. (C) Combination of delamination and severe decay. This condition was limited to the outer one-fifth of the member; any more extensive decay and delamination or any evidence of settlement should be rated as 20.

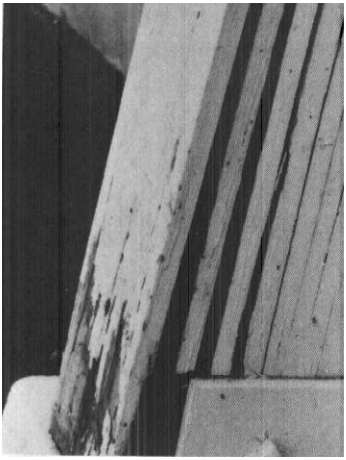

Figure 4-6. Glulam arches with rating 20. (A) Severe delamination with accompanying failure evidenced by outward displacement.

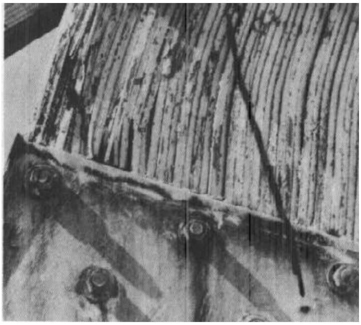

Figure 4-6. (B) Outward displacement evidenced by bend in laminations.

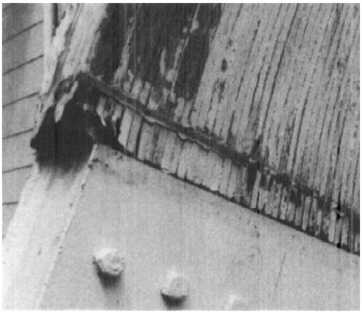

Figure 4-6. (C) Outward displacement evidenced by shear at the arch base.

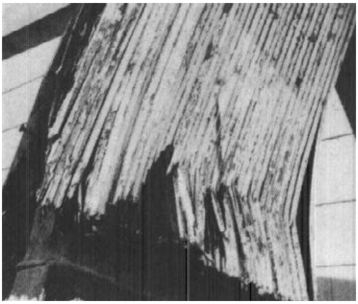

Figure 4-6. (D) Severe decay and failure of laminations.

Chapter 5. USE OF CONDITION EVALUATION STANDARDS

The inspection and rating of glulam arches and heavy timber trusses will be useful only if evaluated and used as a basis for action. While the higher ratings may require only a cursory review, the facilities engineer must conduct a more detailed inspection of the structures that receive lower ratings. Such an inspection may result in reclassification of the structure. If the inspection verifies the need for action, further study may be required to establish the cost of repairs, and possibly to evaluate the economics of making repairs versus demolition and replacement of the building. A suggested implementation method for the inspection results is shown in flow chart form in Figure 5-1.

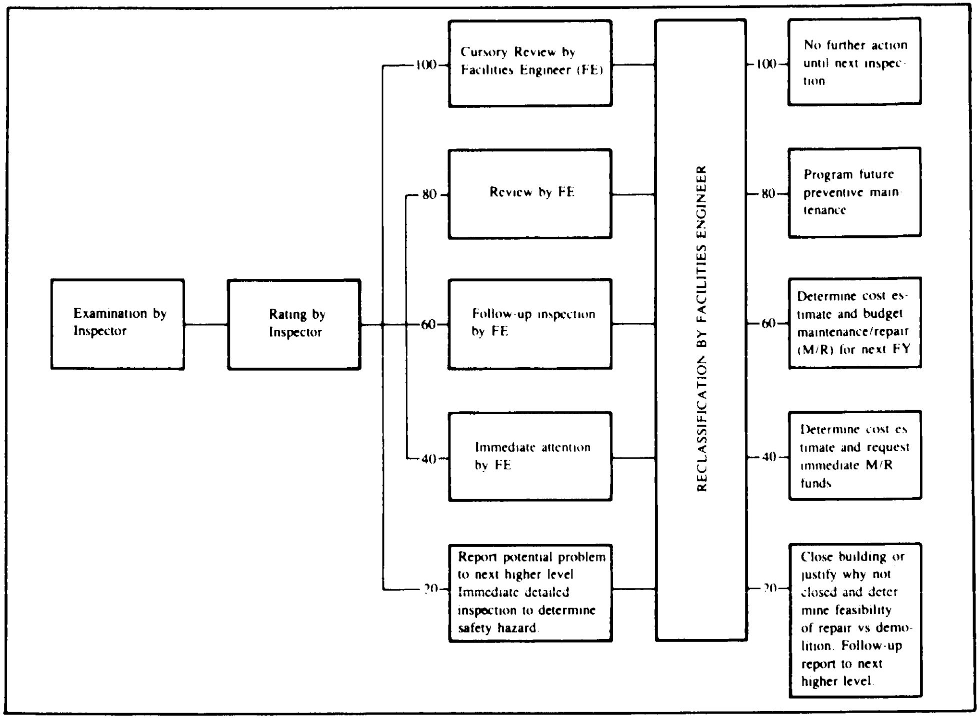

Figure 5-1. Suggested implementation method for glulam arches and heavy timber trusses.