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Stress Wave Timing Nondestructive Evaluation Tools for Inspecting Historic Structures

A Guide for Use and Interpretation



Abstract

This guide was prepared to assist inspectors in the use of stress wave timing instruments and various methods of locating and defining areas of decay in timber members in historic structures. The first two sections provide (a) background information regarding conventional methods to locate and measure decay in historic structures and (b) the principles of stress wave nondestructive testing and measurement techniques. The last section is a detailed description of how to apply the use of stress wave nondestructive testing methods in the field. A sample field data acquisition form and additional reference material are included in the Appendix. This guide includes all the information needed to begin to utilize and interpret results from stress wave timing nondestructive evaluation methods.

Keywords: Nondestructive evaluation, property evaluation, historic structure

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Preface

The information in this publication is intended for those who inspect historic structures. This report is a minor revision of a 1999 publication entitled *Inspection of Timber Bridges Using Stress Wave Timing Nondestructive Evaluation Tools—A Guide for Use and Interpretation* by Robert J. Ross, Roy F. Pellerin, Norbert Volny, William W. Salsig, and Robert H. Falk, USDA Forest Service, Forest Products Laboratory (Ross and others 1999). The basic technology used to inspect both timber bridges and historic structures is essentially the same.

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Contents

	<i>Page</i>
Introduction.....	1
Background.....	1
Purpose	1
Conventional Methods	2
Exterior Deterioration	2
Interior Deterioration	2
Principles of Stress Wave Nondestructive Testing	3
Effect of Ring Orientation.....	5
Effect of Decay	5
Effect of Moisture Content	5
Effect of Preservative Treatment	6
Interpretation of Stress Wave Velocity Readings	7
Measurement of Stress Wave Transmission Time	7
General Measurement	7
Commercial Equipment	8
Field Considerations and Use of Stress Wave Methods.....	10
Stress Wave Transmission Time	10
Field Data Form	10
Field Measurements	10
Data Analysis and Summary Form.....	10
References.....	12
Appendix—Acquisition Form and Additional Reference Material.....	12

Stress Wave Timing Nondestructive Evaluation Tools for Inspecting Historic Structures

A Guide for Use and Interpretation

Introduction

Background

Until recently, the preservation and restoration of historically and architecturally significant buildings has represented an effort to preserve America's heritage. Now, more tangible factors, couched in economics, may underlie the growing interest in preservation and restoration. Investing in the preservation of older neighborhoods reduces taxpayer-funded costs for extending municipal infrastructure to outlying urban sprawl. In addition, restoration and preservation of structures in older neighborhoods is environmentally sound in terms of recycling building materials and resources.

Wood was extensively used for both interior and exterior applications in the construction of historic buildings, regardless of use (residential, agriculture, commercial, government, religious). Therefore, much restoration and preservation involves solving technical problems associated with the economical use, reuse, and care of wood.

For the most part, information on wood science and engineering is generic to construction practices; that is, it is applicable to both new and restorative construction. This information provides the knowledge base for preservation and restoration. However, detailed science-based information is needed to address problems specific to historic structures, such as problems associated with the deteriorating influence of age and the customarily inadequate and inconsistent maintenance of historic structures. In addition, the restoration of historic structures presents a unique problem. Historic preservation organizations and owners of historic buildings place constraints on allowable construction practices. These constraints involve rigid requirements concerning salvage, reuse, and maintenance of the original materials, such as replacement of deteriorated materials with material of the same species and type as that of the original structure or restoration using state-of-the-art materials and techniques to accomplish the same visual effect as that of the original construction. The focus ranges from an effort to achieve "museum quality" restoration to an emphasis on practical and

economic restoration. In some cases, the kind of restoration may be driven by economic incentives.

Determining an appropriate load rating for a historic structure and making rational decisions about rehabilitation, repair, or replacement necessitate an accurate assessment of the building's condition. Knowledge of the condition of the structure can lead to savings in repair and replacement costs by minimizing labor and materials and extending service life.

The quality, hence value, of a timber inspection depends on the level of experience of the inspector and the inspection tools available. For example, inspecting timber members for decay using hammer sounding is limited in its effectiveness to very experienced inspectors, who must by ear interpret the sound of a hammer blow to the timber member. In addition, hammer sounding is not effective on members greater than 89 mm (3.5 in.) thick. Although methods such as coring and drilling are often used to verify potential trouble spots found with the sounding method, coring and drilling can be rather destructive to the member and potentially open the interior of the member to decay attack.

Although not widely used, nondestructive testing using stress wave timing is an available method that offers the ability to determine the presence of internal decay in timbers. Advanced training to use this method is not required, although the method does require experience in wood inspection. The nondestructive testing method can serve as an additional tool to definitively determine the condition of a timber.

Purpose

The purpose of this document is to provide guidelines on the application and use of the stress wave timing inspection method to locate and define areas of decay in timber members. A review of the basics of stress wave theory is provided, as well as a description of available equipment, practical procedures for field testing, workable forms for gathering evaluation data, and guidelines for interpretation of data. This information was derived from research performed to quantify the ability of stress wave timers to detect decay in

wood, from laboratory and field studies of deteriorated structural members, and most importantly from the experience of inspectors familiar with the use of these devices. Overviews of the properties of wood and important aspects of wood deterioration are also given to provide those unfamiliar with wood the basic information necessary to detect decay.

This guide is intended for wood structure inspectors. The authors have made a concerted effort to provide clear and concise explanations of the operation and use of stress wave equipment for the nondestructive testing of historic structures. For those interested in detailed information on wood properties, stress wave theory, or wood structure maintenance, additional reference material is listed in the Appendix.

Conventional Methods

In this section, conventional methods of inspection are briefly reviewed. Methods to detect deterioration in structural members are divided into two categories: those for exterior deterioration and those for interior deterioration. In both cases, specific methods or tools appropriate to detect and locate decay and their usefulness vary depending on the type and size of the member. Although a variety of inspection methods may be used, 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 encountered.

Exterior Deterioration

Exterior deterioration is the easiest type of decay 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. Commonly used methods include visual inspection and probing. When areas of exterior deterioration are located by these methods, additional investigation by other methods is needed 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 useful for detecting intermediate or advanced surface decay. Visual inspection cannot detect decay in the early stages, when remedial treatment is most effective, and should never be the only method used. Observations that are possible with visual inspection include the following:

- 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; others develop only after decay is extensive. Although fruiting bodies are not common, when

present, they almost certainly indicate a serious decay problem.

- 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. Crushed wood can also be an indicator of decay.
- Staining or discoloration indicates that the wood has been subjected to water and potentially a high moisture content suitable for decay. Rust stains from connection hardware are also a good indication of wetting.
- Insect activity is visually characterized by holes, frass, powder posting, or other signs. The presence of insect activity may also indicate the presence of decay.
- Plant or moss growth in splits and cracks or soil accumulation on the structure indicates that adjacent wood has been at a relatively high moisture content for a sustained period and may sustain growth of decay fungi.

Probing

Probing with a moderately pointed tool, such as an awl or knife, locates decay near the wood surface as indicated by excessive softness or a lack of resistance to probe penetration and the breakage pattern of the splinters. A brash break indicates decayed wood, whereas a splintered break reveals sound wood. 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, which 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.

Interior Deterioration

Unlike exterior deterioration, interior deterioration is difficult to locate because no visible signs of decay may be present. Many methods and tools have been developed to evaluate internal damage, ranging in complexity from sounding the surface with a hammer to sophisticated radiographic evaluation. Tools, such as moisture meters, are also used to help the inspector identify areas where conditions are suitable for development of internal decay.

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 to detect interior deterioration. 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 conditions 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 early 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. Practical experience has shown that sounding only works with members less than 89 mm (4 in.) thick.

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 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, thus moisture content. Moisture meters are most accurate at moisture content levels between 12% and 22%. Pins are available in various lengths for determining moisture content at depths up to 7.6 cm (3 in.).

Although it does not detect decay, the moisture meter helps identify wood at a high moisture content level and is recommended as an initial check for suspected areas of potential decay. Moisture content greater than 30% indicates conditions suitable for decay development, unless the wood in the immediate area is treated with preservatives and there are no breaks in the treatment envelope. If inspection is conducted after an unusually lengthy period of dry weather, moisture levels in the range of 20% to 25% should be used as an indication of potentially decayed conditions.

Drilling and Coring

Drilling and coring are the most common methods used to detect internal deterioration in wood members. 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 are discussed together here. Drilling is usually done with an electrical power drill or hand-crank drill equipped with a 9.5- to 19-mm- (3/8- to 3/4-in.-) diameter bit. Power drilling is faster, but hand drilling allows the inspector to monitor drilling resistance and may be more beneficial in detecting pockets of deterioration. In general, the inspector drills into the member in question, noting zones where the drilling becomes easier, and observes the drill shavings for evidence of decay. The presence of common wood defects, such as knots, resin pockets, and abnormal grain, should be anticipated while drilling and should not be confused with decay. If decay is detected, the inspection hole can also be used to add remedial treatments to the wood. Inspection holes are probed with bent wire to measure shell thickness.

Coring with increment borers (often used for determining age of tree) also provides information on the presence of decay

pockets and other voids. Coring with borers produces a solid-wood core that can be carefully examined for evidence of decay. In addition, the core can be used to obtain an accurate measure of the depth of preservative penetration and retention. To prevent moisture and insect entry, a bored-out core should be filled with a treated wood plug.

Principles of Stress Wave Nondestructive Testing

As an introduction, a schematic of the stress wave concept for detecting decay within a rectangular wood member is shown in Figure 1. First, a stress wave is induced by striking the specimen with an impact device, which is instrumented with an accelerometer that emits a start signal to a timer. A second accelerometer, which is held in contact with the other side of the specimen, serves the leading edge of the propagating stress wave and sends a stop signal to the timer. The elapsed time for the stress wave to propagate between the accelerometers is displayed on the timer.

The terms ultrasonic and sonic are often confused. The velocity at which a stress wave travels in a member is dependent upon the properties of the member only. The terms ultrasonic and sonic refer only to the frequency of excitation used to impart a wave into the member. All commercially available timing units, if calibrated and operated according to the manufacturer's recommendations, yield comparable results.

The use of stress wave velocity to detect wood decay in wood structures is limited only by access to the structural members under consideration. Stress wave velocity is especially useful on thick timbers or glulam timbers ≥ 89 mm (≥ 3.5 in.) where hammer sounding is not effective. Note that access to both sides of the member is required.

Because wood is an organic substance, material properties and strength vary in accordance with the direction in which

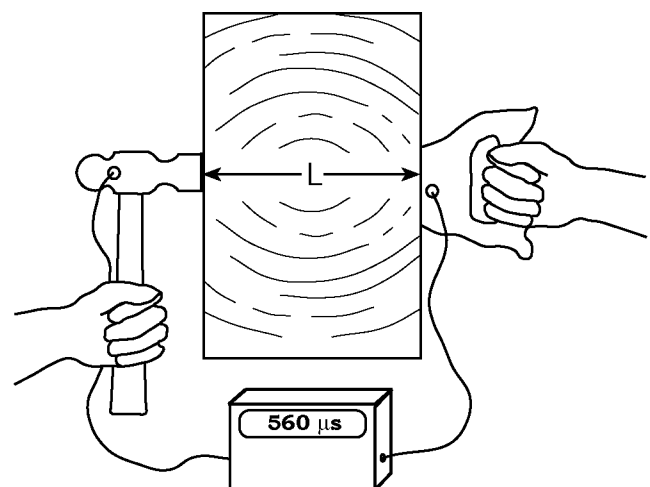


Figure 1—Schematic of stress wave timer.

the wood member is hammered compared with the cell structure orientation. Hammering the end grain of a beam or post will cause a primarily longitudinal shock wave along the length of the cell structure in the timber. Hammering the side or top of the beam will cause a wave across or transverse to the timber cells. The timber cells are arranged in rings around the center of the tree. A stress wave can pass three different ways transversely through a timber. The wave can travel perpendicular (radially) or parallel (tangentially) to the rings, or cross the rings at an angle between 0° and 90° (45° to grain).

The velocity at which a stress wave propagates in wood, as well as other physical and mechanical properties, is a function of the angle at which the fibers of wood are aligned. For most structural members, the wood fibers align more or less with the longitudinal axis of the member (Fig. 2).

Stress wave transmission times on a per length basis for various wood species are summarized in Table 1. Note that stress wave transmission times are shortest along the grain (with the fiber) and longest across the grain (perpendicular

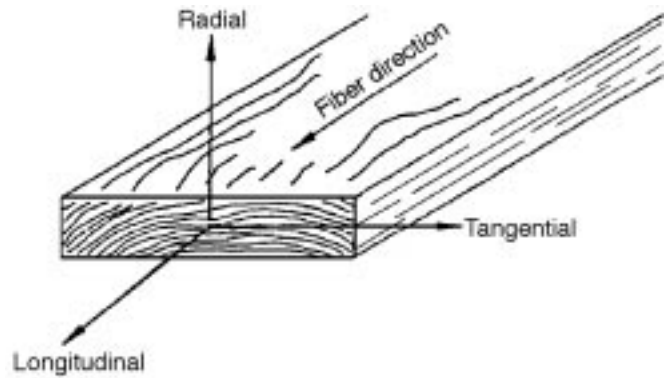


Figure 2—Three principal axes of wood with respect to grain direction and growth rings.

to fiber). Note that for Douglas-fir and Southern Pine, stress wave transmission times parallel-to-the-fiber are approximately 200 μs/m (60 μs/ft). Stress wave transmission times perpendicular to the fiber range from 850 to 1000 μs/m (259 to 305 μs/ft).

Table 1—Summary of research on stress wave transmission times for various species of undegraded wood

Reference	Species	Moisture content (% ovendry)	Stress wave transmission time (μs/m (μs/ft))	
			Parallel to grain	Perpendicular to grain
Smulski 1991	Sugar maple	12	256–194 (78–59)	—
	Yellow birch	11	230–180 (70–55)	—
	White ash	12	252–197 (77–60)	—
	Red oak	11	262–200 (80–61)	—
Armstrong and others 1991	Birch	4–6	213–174 (65–53)	715–676 (218–206)
	Yellow-poplar	4–6	194–174 (59–53)	715–676 (218–206)
	Black cherry	4–6	207–184 (63–56)	689–620 (210–189)
	Red oak	4–6	226–177 (69–54)	646–571 (197–174)
Elvery and Nwokoye 1970	Several	11	203–167 (62–51)	—
Jung 1979	Red oak	12	302–226 (92–69)	—
Ihlseng 1878, 1879	Several	—	272–190 (83–58)	—
Gerhards 1978	Sitka spruce	10	170 (52)	—
	Southern Pine	9	197 (60)	—
Gerhards 1980	Douglas-fir	10	203 (62)	—
Gerhards 1982	Southern Pine	10	197–194 (60–59)	—
Rutherford 1987	Douglas-fir	12	—	1,092–623 (333–190)
Ross 1982	Douglas-fir	11	—	850–597 (259–182)
Hoyle and Pellerin 1978	Douglas-fir	—	—	1,073 (327)
Pellerin and others 1985	Southern Pine	9	200–170 (61–52)	—
Soltis and others 1992	Live oak	12	—	613–1,594 (187–486)
Ross and others 1994	Northern red and white oak	Green	—	795 (242)

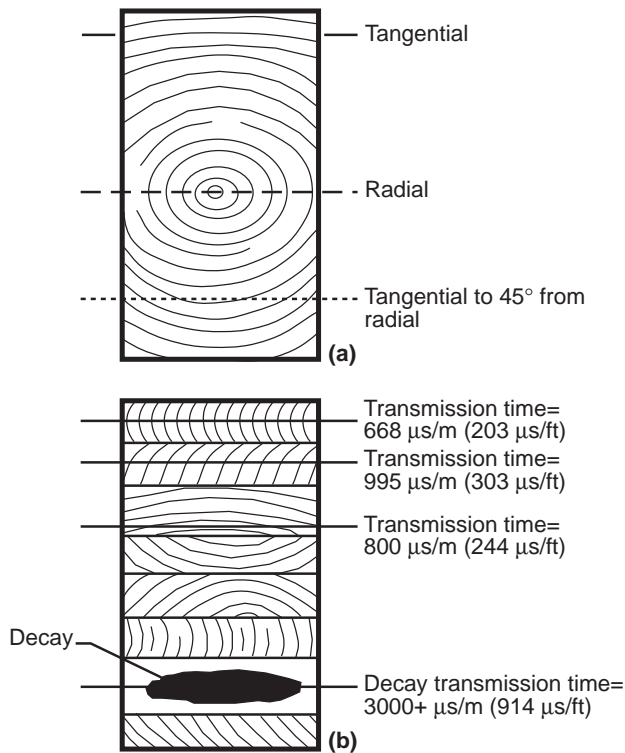


Figure 3—Transverse stress wave paths and transmission times: (a) timber, (b) glulam beam.

Table 2—Typical stress wave transmission times for undegraded Douglas-fir at 12% moisture content

Path length (mm (in.))	Stress wave transmission time (μs)		
	Radial	Tangential	45° to grain
64 (2.5)	43	51	64
89 (3.5)	60	71	88
140 (5.5)	94	112	139
184 (7.25)	123	147	183
235 (9.25)	157	188	234
292 (11.5)	195	234	290
342 (13.5)	229	274	340
394 (15.5)	264	315	392
444 (17.5)	297	355	442
495 (19.5)	331	396	492

Effect of Ring Orientation

Researchers have determined that the longest transverse-to-grain transmission times are found at a 45° orientation to the annual rings. The shortest time is about 30% faster in a path that is radial. Tangential transit times are expected to be about halfway between those noted previously (Fig. 3). Table 2 and Figure 4 show the stress wave transmission time for wood of good quality at 12% moisture content. These

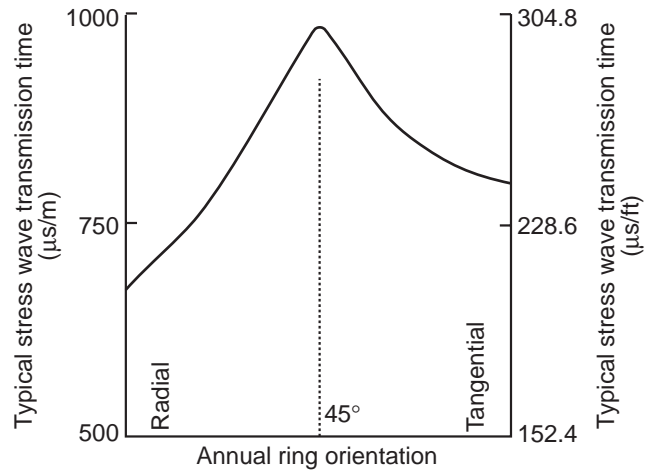


Figure 4—Transverse stress wave transmission time compared with annual ring orientation.

values can vary $\pm 10\%$ for species variation. These times are based on an assumed stress wave transmission time of 668 $\mu\text{s/m}$ radially, 800 $\mu\text{s/m}$ tangentially, and 995 $\mu\text{s/m}$ at 45° to grain.

Effect of Decay

The presence of decay greatly affects stress wave transmission time in wood. Table 3 summarizes velocity of stress wave transmission values obtained from field investigations of various wood members subjected to degradation from decay. Note that stress wave transmission times perpendicular to the grain are drastically reduced when the member is degraded. Transmission times for undegraded Douglas-fir are approximately 800 $\mu\text{s/m}$ (244 $\mu\text{s/ft}$), whereas severely degraded members exhibit values as high as 3,200 $\mu\text{s/m}$ (975 $\mu\text{s/ft}$) or greater.

A 30% increase in stress wave transmission times implies a 50% loss in strength. A 50% increase indicates severely decayed wood (Fig. 5). Transverse travel paths are best for finding decay. Parallel-to-grain travel paths can bypass regions of decay.

Weight loss is not a good indicator of decay because considerable strength loss can occur without significant weight loss.

Effect of Moisture Content

Considerable work has examined the effect of moisture in wood on stress wave transmission time. Several studies have revealed that stress wave transmission times perpendicular to the grain of wood follow a relationship (Fig. 6). Note that at moisture content less than approximately 30%, transmission time decreases with decreasing moisture content. Corrections for various moisture content values are summarized in Table 4.

Table 3—Summary of research on use of stress waves for detecting decay in timber structures

Reference	Structure	Wood product	Test	Analysis
Volny 1992	Bridge	Douglas-fir glulam, creosote pressure treated	Stress wave transmission time perpendicular to grain, across laminations at 0.3-m intervals	Sound wood: 1,279 $\mu\text{s}/\text{m}$ (390 $\mu\text{s}/\text{ft}$) Moderate decay: 1,827 $\mu\text{s}/\text{m}$ (557 $\mu\text{s}/\text{ft}$) Severe decay: 2,430 $\mu\text{s}/\text{m}$ (741 $\mu\text{s}/\text{ft}$)
Ross 1982	Football stadium	Solid-sawn Douglas-fir, creosote pressure treated	Stress wave transmission time perpendicular to grain, near connections	Sound wood: 853 $\mu\text{s}/\text{m}$ (260 $\mu\text{s}/\text{ft}$) Incipient decay: – Center of members: 1,276 $\mu\text{s}/\text{m}$ (389 $\mu\text{s}/\text{ft}$) – 38-mm-thick solid wood shell: 2,129 $\mu\text{s}/\text{m}$ (649 $\mu\text{s}/\text{ft}$) Severe decay: >3,280 $\mu\text{s}/\text{m}$ (1000 $\mu\text{s}/\text{ft}$)
Hoyle and Pellerin 1978	School gymnasium	Douglas-fir glulam arches	Velocity of stress wave transmission time perpendicular to grain, near end supports	Sound wood: 1,073 $\mu\text{s}/\text{m}$ (327 $\mu\text{s}/\text{ft}$) Decayed wood: 1,574 $\mu\text{s}/\text{m}$ (480 $\mu\text{s}/\text{ft}$)

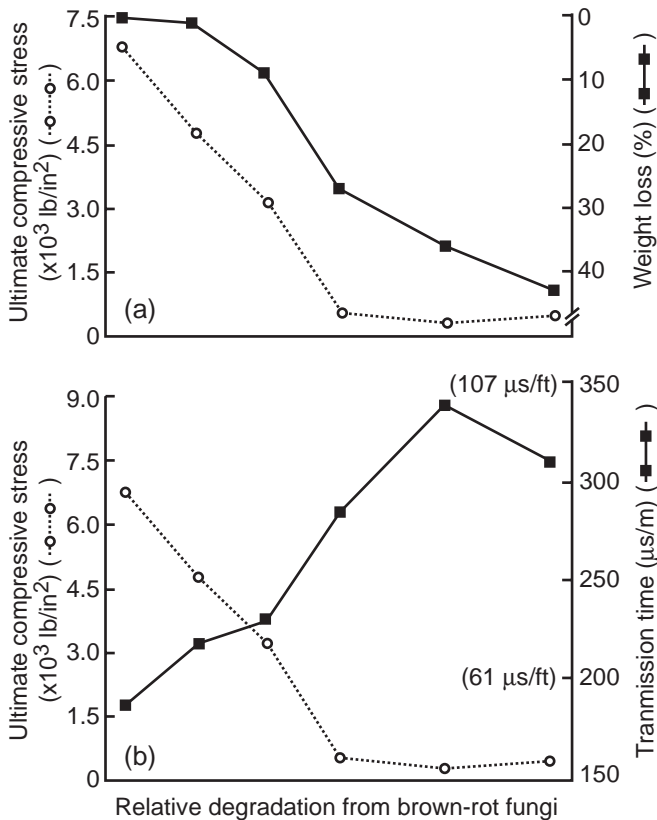


Figure 5—Relationship between stress wave transmission time and fungal degradation (Pellerin and others 1985).

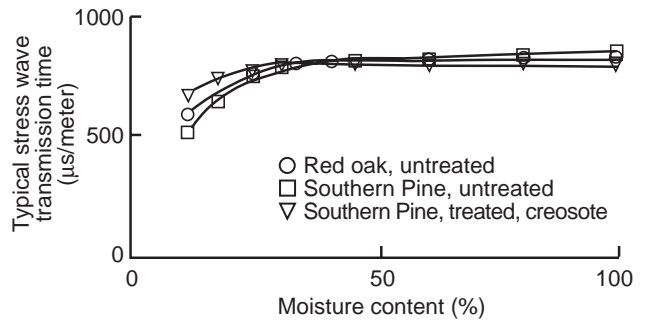


Figure 6—Transverse stress wave transmission times in Southern Pine and red oak piling.

Also note that at moisture content values greater than approximately 30%, little or no change in transmission time occurs. Consequently, there is no need to adjust the measured values for wood that is tested in a wet condition.

Effect of Preservative Treatment

Treatment with waterborne salts has almost no effect on stress wave transmission time. Treatment with oilborne preservatives increases transmission time by about 40% more than that of untreated wood. Round poles are usually penetrated to about 37 to 61 mm (1.5 to 2.5 in.), except at their ends where the treatment fully penetrates the wood. Table 5 was calculated to show expected transit time for round poles treated with oilborne preservatives. Note that although

Table 4—Stress wave transmission time adjustment factors for temperature and moisture content for Douglas-fir

Moisture content (%)	Adjustment factors			
	-18°C (0°F)	3°C (38°F)	27°C (80°F)	49°C (120°F)
1.8	0.94	0.95	0.97	0.98
3.9	0.95	0.96	0.98	0.99
7.2	0.93	0.98	1.00	1.01
12.8	0.97	0.99	1.00	1.01
16.5	0.99	1.01	1.03	1.05
23.7	1.05	1.07	1.09	1.14
27.2	1.07	1.10	1.12	1.17

Table 5—Stress wave transmission times for round poles treated with oilborne preservatives

Diameter (mm)	Stress wave transmission time (μs) for various levels of penetration ^a		
	37 mm	61 mm	Full penetration
294	222	240	300
343	254	271	350
392	286	305	400
441	321	338	450
490	350	370	500
539	386	403	550
588	422	436	600

^a1 in. = 25.4 mm.

these data illustrate the effect of oilborne treatments on transmission time, these values should not be used to estimate the level of penetration.

Interpretation of Stress Wave Velocity Readings

The guidelines in this document are useful in interpreting readings that are less than those for sound wood. Voids and checks will not transmit stress waves. Knots will act as parallel-to-grain wood but are usually oriented perpendicular to the long axis of timber.

Based on the direction and length of the path in the wood, wood moisture content, the presence of preservative treatment, if any, and the velocity and transit time for sound wood can be determined. For the transverse direction, note the annual ring orientation and the existence of seasoning checks.

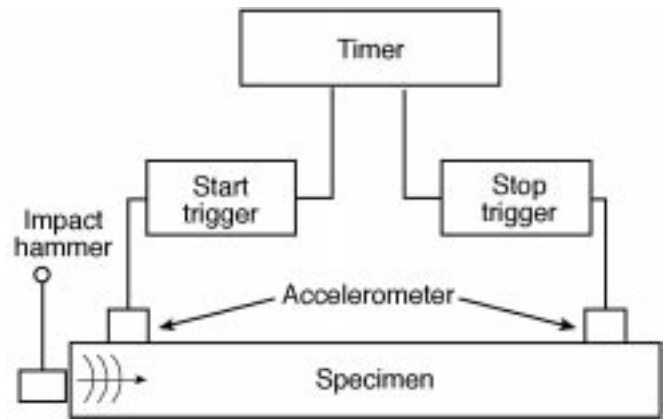


Figure 7—Technique utilized to measure impact-induced stress wave transmission times in various wood products.

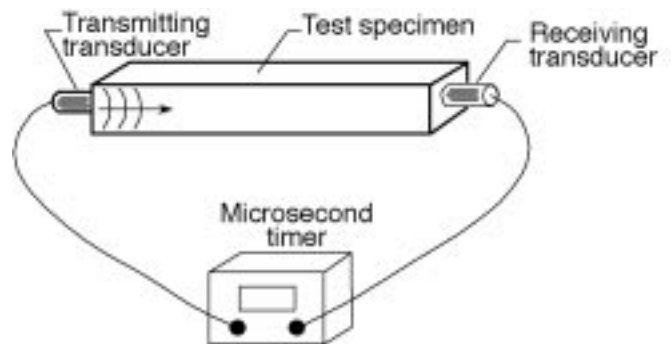


Figure 8—Ultrasonic measurement system used to measure stress wave transmission times in various wood products.

Measurement of Stress Wave Transmission Time

General Measurement

Several techniques can be used to measure stress wave transmission time in wood. The most commonly used technique utilizes simple time-of-flight-type measurement systems. Two commercially available systems that use this technique are illustrated in Figures 7 and 8.

With these systems, a mechanical or ultrasonic impact is used to impart a wave into the member. Piezoelectric sensors placed at two points on the member are used to detect passing of the wave. The time required for the wave to travel between sensors is then measured.

Commercial Equipment

The following types of commercial equipment are available to measure stress wave transmission times in wood. The manufacturer, method of operation, key considerations, and specifications for this equipment are also given.

- **Metriguard Model 239A Stress Wave Timer (Fig. 9)**

Manufacturer—Metriguard, Inc.; P.O. Box 399; Pullman, WA 99163; telephone (509) 332-7526; fax 509-332-0485.

Method of Operation—A mechanical stress wave is induced in a member by a hammer or other means and is detected with accelerometers at two points along the propagation path (Fig. 7). The timer starts when the wave front arrives at the first accelerometer. The timer stops when the wave front arrives at the second accelerometer and displays the propagation time between accelerometers in microseconds.

Key Considerations—It is imperative when using this equipment that the accelerometers are oriented as shown in Figure 10.

Specifications

Power requirements: 9-V battery

Resolution: $\pm 1 \mu\text{s}$

Dimensions: 18 by 23 by 23 cm (7 by 9 by 9 in.) high

Weight: 5.4 kg (12 lb) (including hammer and accelerometers)

A variety of testing techniques can be used to obtain values for velocity of stress wave transmission in wood members in the field. Figure 11 illustrates important aspects of field test set-ups and several commonly used techniques.

- **James “V” Meter (Fig. 12)**

Manufacturer—James Instruments, Inc.; 3727 North Kedzie Avenue; Chicago, IL 60618; telephone (800) 426-6500; (312) 463-6565; fax 312-463-0009.

Method of Operation—The James “V” Meter utilizes an ultrasonic pulse generator to impart a stress wave into the member. As illustrated in Figure 13, two transducers are placed on a member at a fixed distance apart. As the transmitting transducer imparts a wave into a member, the timer unit begins to time passage of the wave. When the wave reaches the receiving unit, the timer stops and displays the transit time in microseconds.

Key Considerations—Coupling of the transducers is key to obtaining reliable results. The surface of the members should be free of debris, mud, or dirt. A coupling agent, provided by the manufacturer, is often used to facilitate the measurements.



Figure 9—Metriguard Model 239A Stress Wave Timer.

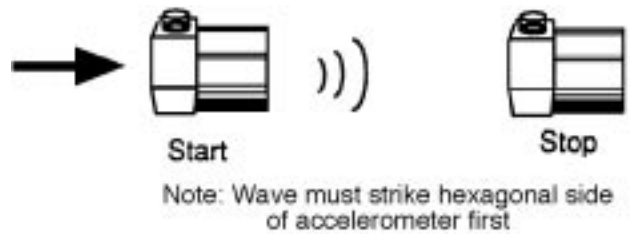


Figure 10—Necessary orientation of accelerometers.

Specifications

Power requirements: rechargeable NI-CAD

- **Sylva Test (Fig. 14)**

Manufacturer—Sandes SA, Zone industrielle, Case postale 25, CH-1614 /Granges/Veveyse, Switzerland; telephone (021) 907 90 60; fax 021 907 94 82.

Method of Operation—The Sylva test unit utilizes an ultrasonic pulse generator to impart a stress wave into a member. Two transducers are placed on a member at a fixed distance apart. A transmitting transducer imparts a wave into the member, and a receiving transmitter is triggered upon sensing of the wave. The time required for the wave to pass between the two transducers is then coupled with various additional information, such as wood species, path length, and geometry (round or square section), to compute modulus of elasticity.

Specifications

Power requirements: rechargeable batteries

Dimension: 29 by 20 by 12 cm (11.5. by 7.9 by 4.7 in.) high

Weight: 2.3 kg (5.1 lb) (instrument only) 5.7 kg (12.6 lb) (instrument with carrying bag and accessories)

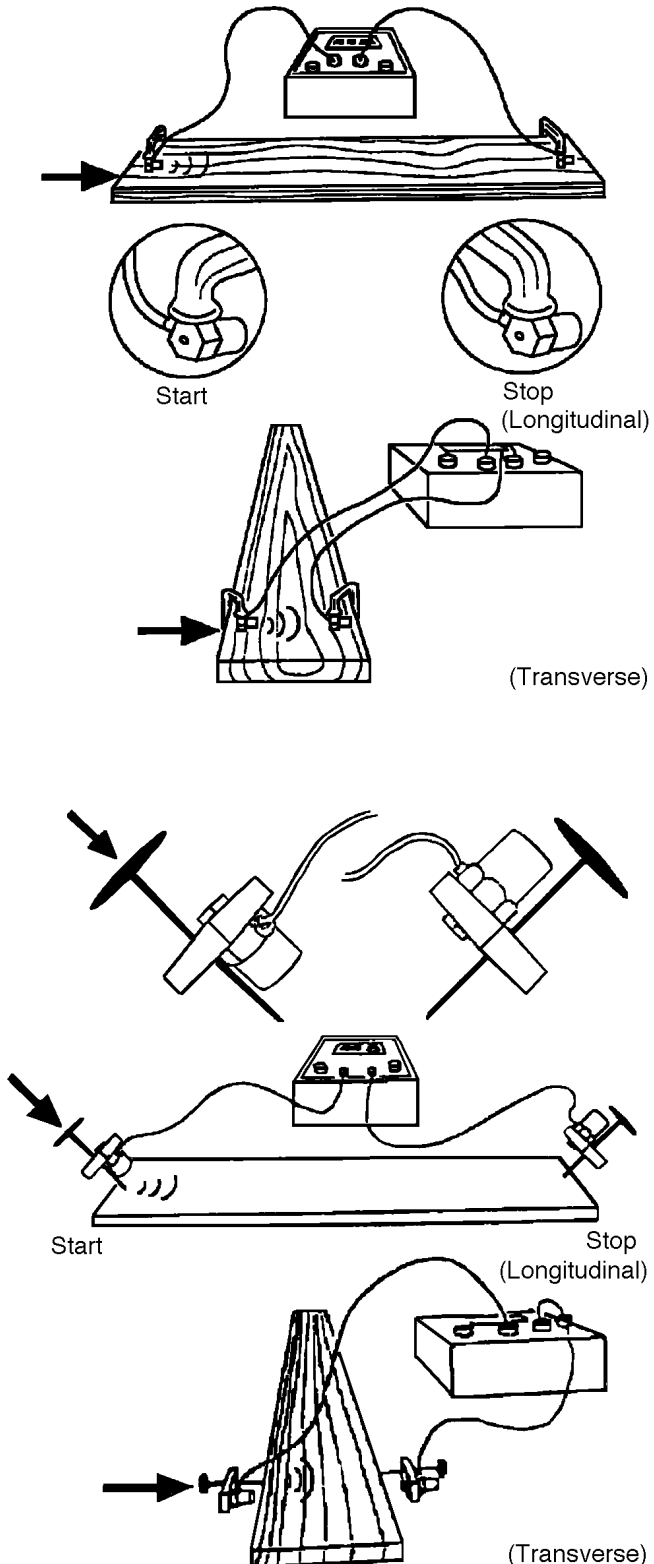


Figure 11—Important aspects of field setups for commonly used techniques.

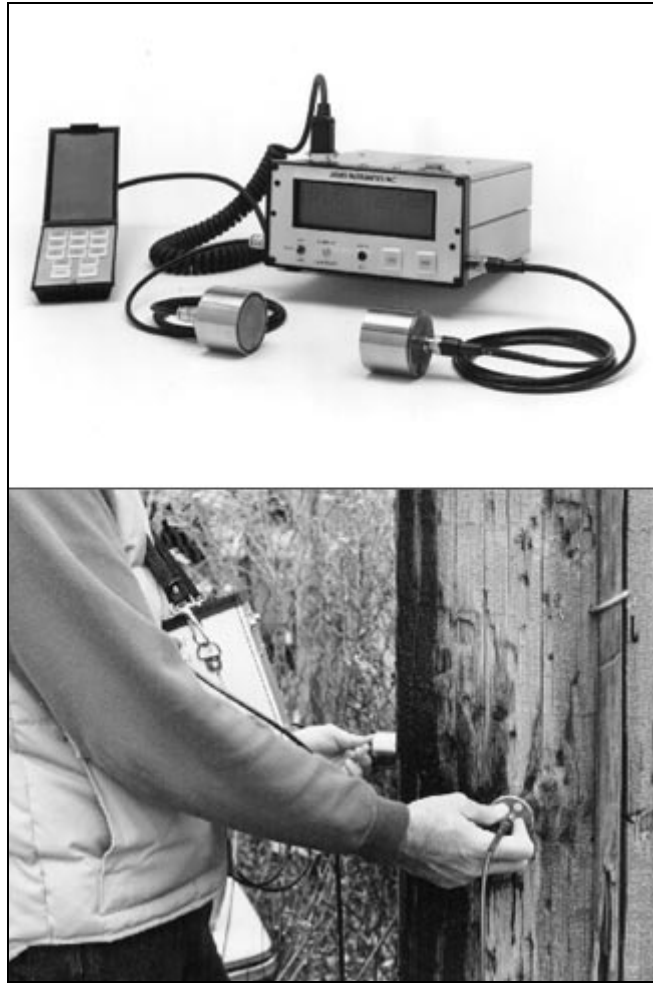


Figure 12—James V-Meter.

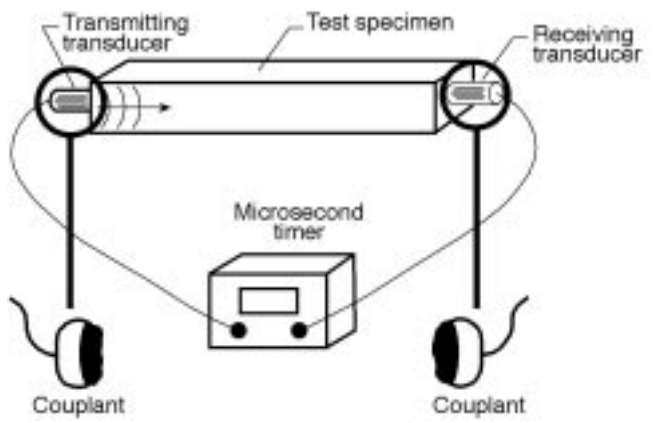


Figure 13—Ultrasonic measurement system used to measure stress wave transmission time in various wood products.

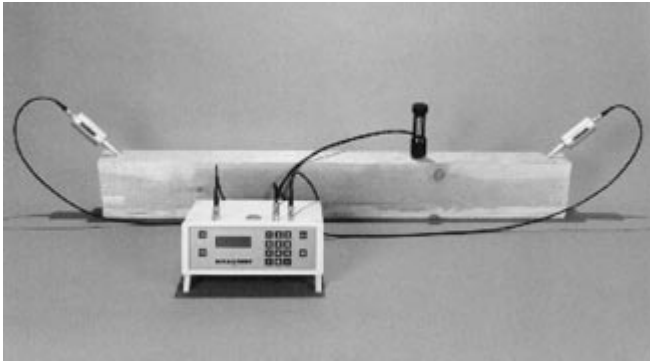


Figure 14—Sylva test.

- **Impulse Hammer—Electronic Hammer**

Manufacturer—IML; Instrumenta Mechanik Labor GmbH; GroBer Stadtacker 2; D-69168 Wiesloch; Germany; telephone (49) 06222–8021; fax 49 06222–52552.

Method of Operation—The electronic hammer is an instrument in which the time required for a stress wave pulse to pass through a member is measured. It uses an impact to induce a wave to flow in the member.

Specifications

Power requirements: 7.2-V rechargeable battery
Weight: 4 kg (8.8 lb)

Field Considerations and Use of Stress Wave Methods

Stress Wave Transmission Time

Figure 15 outlines the general procedures used to prepare and utilize stress wave nondestructive evaluation methods for fieldwork. Before venturing into the field, it is useful to estimate stress wave transmission time for the size of the members to be inspected. Preceding sections provided information on various factors that affect transmission time in wood. This information can be summarized, as a starting point, by simply using a baseline transmission time of 1,575 $\mu\text{s}/\text{m}$ (480 $\mu\text{s}/\text{ft}$). A transmission time (per length basis) less than this would indicate sound material. Conversely, transmission time greater than this value would indicate potentially degraded material. Using this value, the transmission time for a member can be estimated by knowing its thickness (path length) and the following formula:

$$T_{\text{baseline}} (\mu\text{s}) = 1300 \times \text{WTD}$$

where

T_{baseline} is baseline transmission time (μs), and

WTD is wave transmission distance (path length) (m).

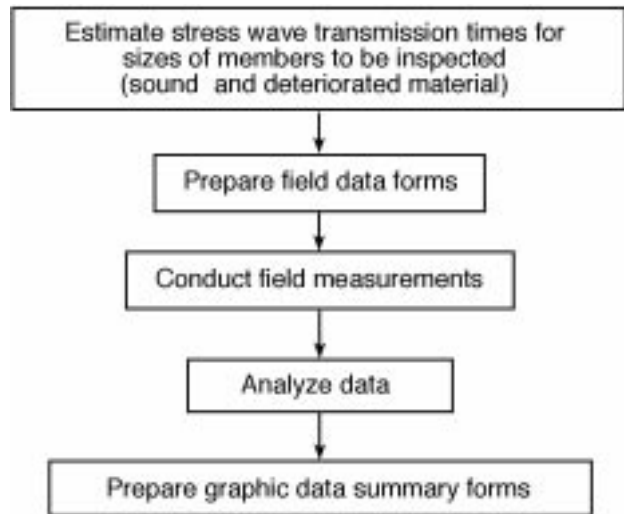


Figure 15—General procedures used to prepare and use stress wave timing methods for field work.

[Conversion to English (inch–pound) units: $400 \times \text{WTD}$, where WTD is wave transmission distance (path length) in feet.]

Note that we chose lower values to be conservative. By knowing this number for various thicknesses, fieldwork can proceed rapidly.

Field Data Form

An example of a typical field data acquisition form is included in the Appendix. Key items to include on the form are the name, location, and number of the structure, name of inspector, and date of inspection.

Field Measurements

Field use should be conducted in accordance with the instructions provided by equipment manufacturers. In the field, extra batteries, cables, and sensors are helpful. Testing should be conducted in areas of the member that are highly susceptible to decay, especially in the vicinity of connections and bearing points.

Note that the baseline values provided serve as a starting point in the inspection. It is important to conduct the test at several points at varying distances from the suspicious area. In a sound member, little deviation is observed in transmission times. If a significant difference in values is observed, the member should be considered suspect.

Data Analysis and Summary Form

Data should be presented in an easy-to-read manner. Figure 16 illustrates various data summary forms, which readily show the presence and extent of degradation.

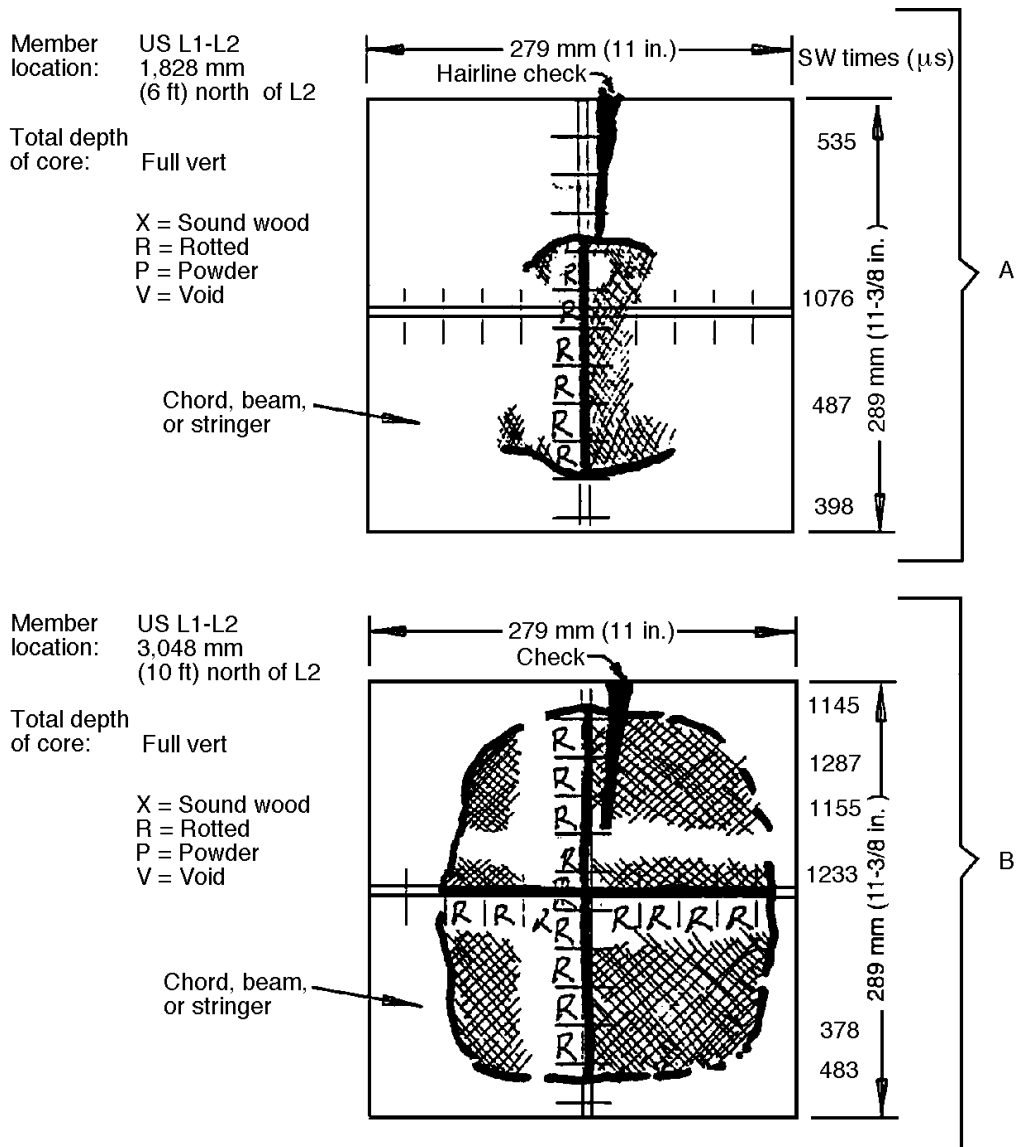
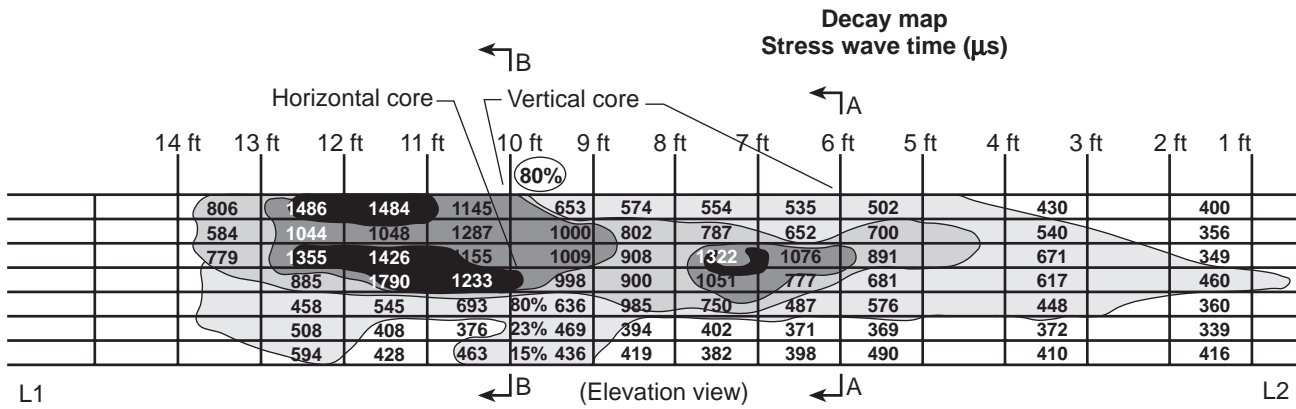


Figure 16—Examples of overall summary form (top) and data summary form (sections)(bottom).

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Appendix—Acquisition Form and Additional Reference Material

This Appendix includes an example of a typical field data acquisition form. Additional reference material on wood properties and stress wave theory is also provided.

Data Log—Stress Wave Transmission Times

Structure's name _____

Location _____ Date _____

_____ Equipment _____

Inspector _____

Member	Location	WTD	Equipment reading (μ s)	Transmission time (μ s/m) (μ s/ft)	Condition	Grain orientation

Data Log—Stress Wave Transmission Times

Member	Location	WTD	Equipment reading (μs)	Transmission time (μs/m) (μs/ft)	Condition	Grain orientation

Additional Reference Material

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