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Inspection of Timber Bridges Using Stress Wave Timing Nondestructive Evaluation Tools

A Guide for Use and Interpretation

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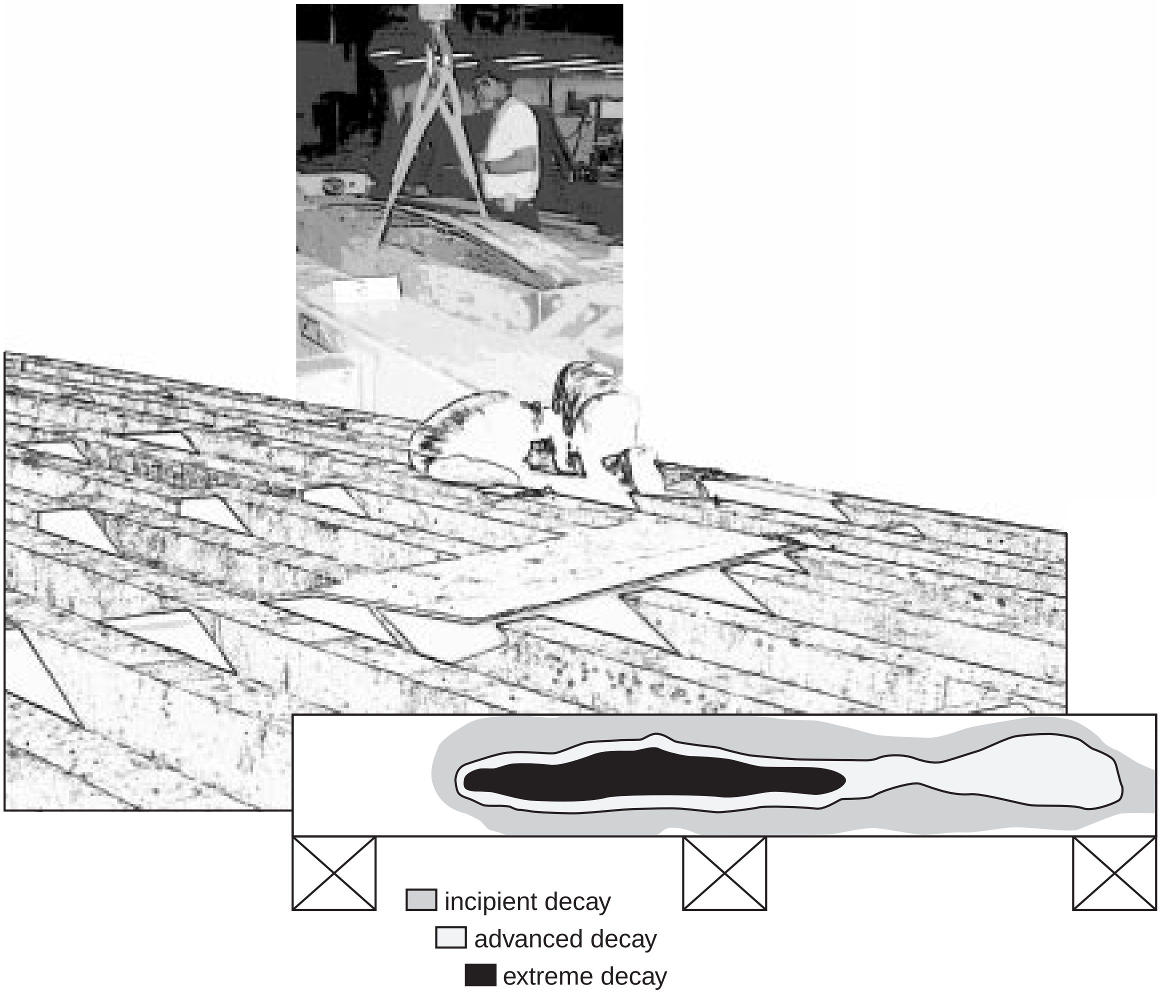

Abstract

This guide was prepared to assist inspectors in the use of stress wave timing instruments and the various methods of locating and defining areas of decay in timber bridge members. The first two sections provide (a) background information regarding conventional methods to locate and measure decay in timber bridges and (b) the principles of stress wave nondestructive testing and its measurement techniques. The last section is a detailed description of how to apply the field use of stress wave nondestructive testing methods. 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, timber bridges

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A Guide for Use and Interpretation

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Introduction

Background

The safe and efficient operation of our nation's transportation system is directly dependent on the performance and maintenance of our vehicular bridge system. According to the 1985 Federal Highway Association (FHWA) national bridge inventory, more than 576,000 bridges in the United States have spans of 6 m (20 ft) or more. Of these bridges, 18% are classified as structurally deficient. In the United States, 41,740 timber bridges with a span of greater than 6 m (20 ft) are currently in use. In addition, another 42,100 are timber decks supported by steel stringers and are classified as steel bridges. Because their average age is approximately 40 years, many bridges are in need of repair or replacement caused by identified or suspected deterioration.

Determining an appropriate load rating for an existing bridge and establishing rational rehabilitation, repair, or replacement decisions can only be achieved when an accurate assessment of its existing condition is made. Knowledge of the condition of the bridge can lead to savings in repair and replacement costs by minimizing labor and materials and extending its useful life.

The quality, hence value, of a timber bridge inspection depends on the level of experience of the inspector and the inspection tools available. For example, inspecting timber bridge members for decay using hammer sounding is limited in its effectiveness to very experienced inspectors, who must aurally interpret the sound of a hammer blow to the timber member. In addition, hammer sounding is not effective on members greater than 89 mm (4 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 timers is an available method that offers the ability to determine the presence of internal decay in bridge timbers. Advanced training to use this method is not required, although the method does require wood inspection experience. The nondestructive testing method can serve as an additional tool to more definitively determine the condition of a timber bridge.

Purpose

The purpose of this document is to provide guidelines on the application and use of the stress wave timing inspection method in locating and defining areas of decay in timber bridge 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 timber bridges, and most importantly from the experience of timber bridge 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 bridge inspectors. The authors have made a concerted effort to provide clear and concise explanations on the operation and use of stress wave equipment for the nondestructive testing of timber bridges. For those interested in detailed information on wood properties, stress wave theory, or timber bridge maintenance, additional reference material is listed in the Appendix.

Conventional Methods

In this section, conventional methods of bridge inspection are briefly reviewed. Methods to detect deterioration in bridges 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 varies 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 that are 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 sole 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 on bridges, 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 previously discussed. 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 indicate that adjacent wood has been at a relatively high moisture content for a sustained period and may sustain decay fungi growth.

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 that may be sound but somewhat softer than dry wood. It is also sometimes difficult to assess damage in soft-textured woods such as western red cedar.

Interior Deterioration

Unlike exterior deterioration, interior deterioration is difficult to locate because there may be no visible signs of decay presence. Numerous 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. A moisture content greater than 30% indicates conditions suitable for decay development, unless the wood in the immediate area is treated with preservatives and no breaks are occurring 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 determine the thickness of the residual shell when voids are present. Drilling and coring are similar in many respects and are discussed together. 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.

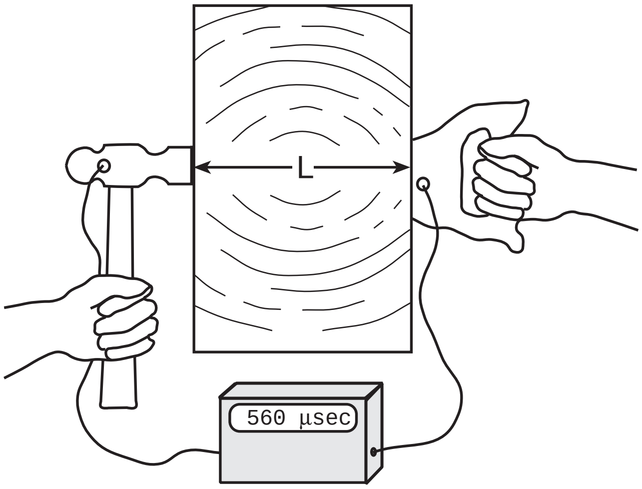


Figure 1—Schematic of stress wave timer.

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 that 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 to 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.

Considerable confusion exists in regards to the terms ultrasonic and sonic. The velocity at which a stress wave travels in a member is dependent upon the properties of the member only. The term 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 timber bridges and other structures is limited only by access to the structural members under consideration. It 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 timber is an organic substance, material properties and strength vary in accordance with the direction timber 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 go perpendicular to the rings (radially), parallel to the rings (tangentially), 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, fibers of the wood 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 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).

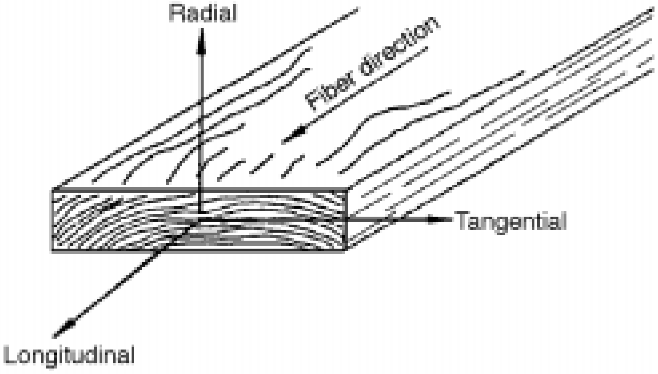


Figure 2—Three principal axes of wood with respect to grain direction and growth rings.

Table 1—Summary of research on stress wave transmission times for various species of nondegraded 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)

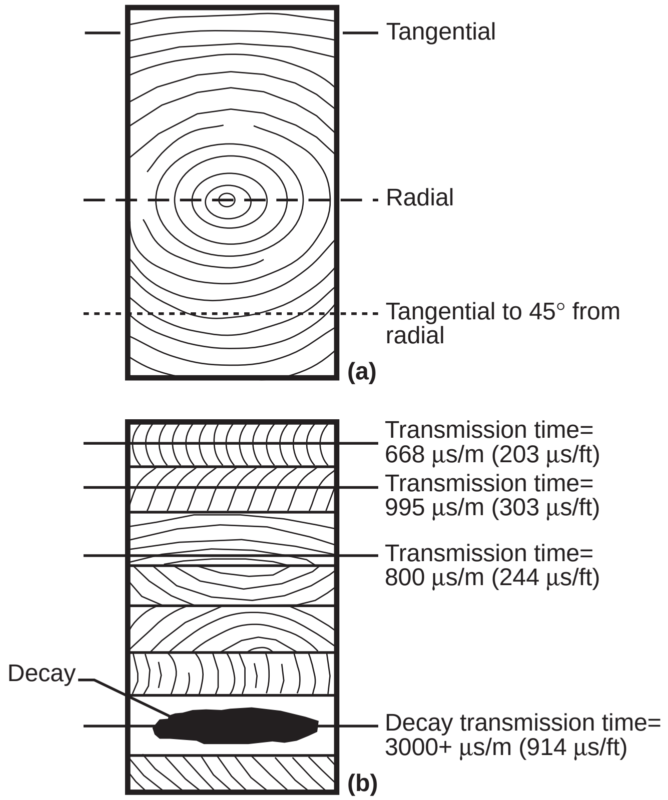


Figure 3—Transverse stress wave paths and transmission times: (a) timber, (b) glulam beam.

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

Path length		Stress wave transmission time (µs)		
(mm	(in.))	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 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 values can vary ±10% for species variation. These times are based on an assumed stress wave transmission time of 668 µs/m radially, 800 µs/m tangentially, and 995 µs/m at 45° to grain.

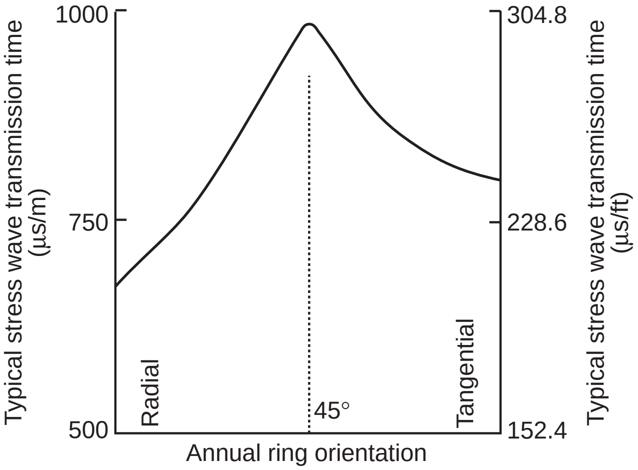


Figure 4—Transverse stress wave transmission time compared with annual ring orientation.

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 nondegraded Douglas-fir are approximately 800 µs/m (244 µs/ft), whereas severely degraded members exhibit values as high as 3,200 µs/m (975 µs/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 been completed to examine the effect that moisture in wood has 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: 1279 µs/m (390 µs/ft) Moderate decay: 1827 µs/m (557 µs/ft) Severe decay: 2430 µs/m (741 µs/ft)
Ross 1982	Football stadium	Solid-sawn Douglas-fir, creosote pressure treated	Stress wave transmission time perpendicular to grain, near connections	Sound wood: 853 µs/m (260 µs/ft) Incipient decay: – Center of members: 1276 µs/m (389 µs/ft) – 38-mm-thick solid wood shell: 2129 µs/m (649 µs/ft) Severe decay: >3280 µs/m (1000 µs/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: 1073 µs/m (327 µs/ft) Decayed wood: 1574 µs/m (480 µs/ft)

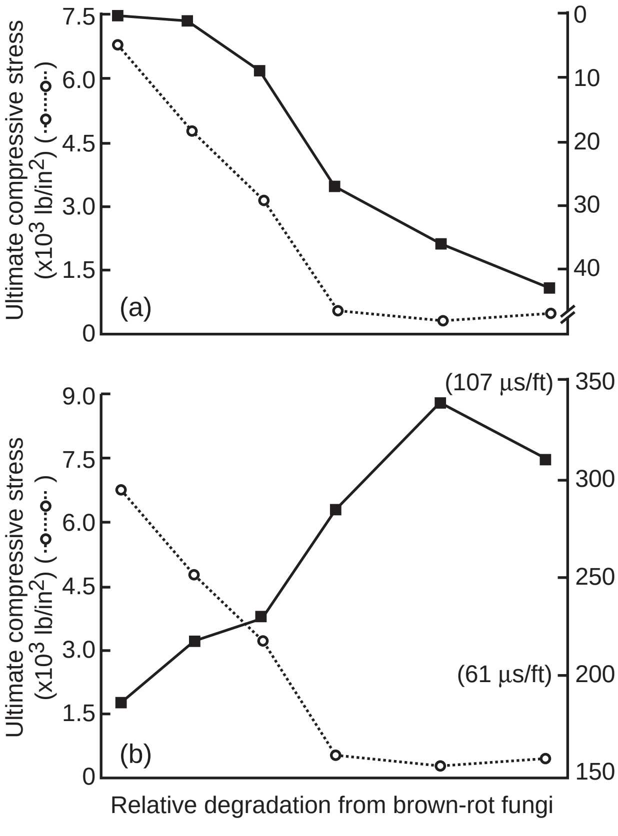


Figure 5—Relationship between stress wave transmission time and fungal degradation (Pellerin and others 1985).

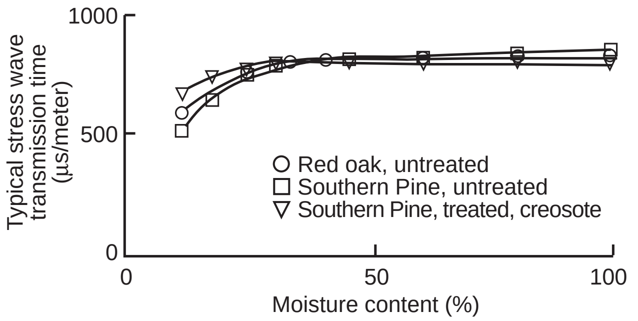


Figure 6—Transverse stress wave transmission times in Southern Pine and Red oak piling.

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 the 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 travel time for round poles treated with oilborne preservatives. Note that although these data illustrate the effect oilborne treatments

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		
	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

have 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, its moisture content, the presence of preservative treatment, if any, the velocity and travel time for sound wood can be determined. For the transverse direction, note the annual ring orientation and the existence of seasoning checks.

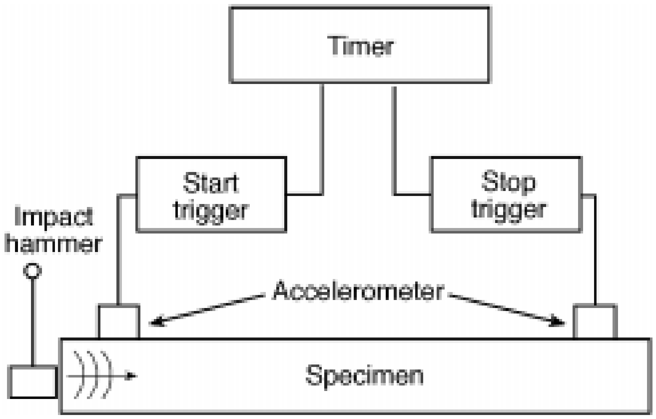


Figure 7—Technique utilized to measure impact-induced stress wave transmission times in various wood products.

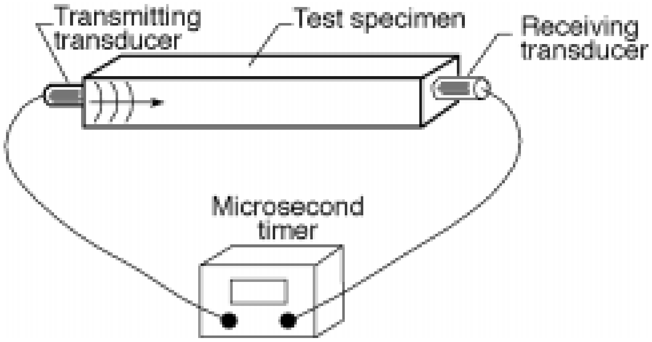


Figure 8—Ultrasonic measurement system used to measure stress wave transmission times in various wood products.

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 are placed at two points on the member and 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: ±1 μs
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 a fixed distance apart on a member. As the transmitting transducer imparts a wave into a member, the timer unit begins timing 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.

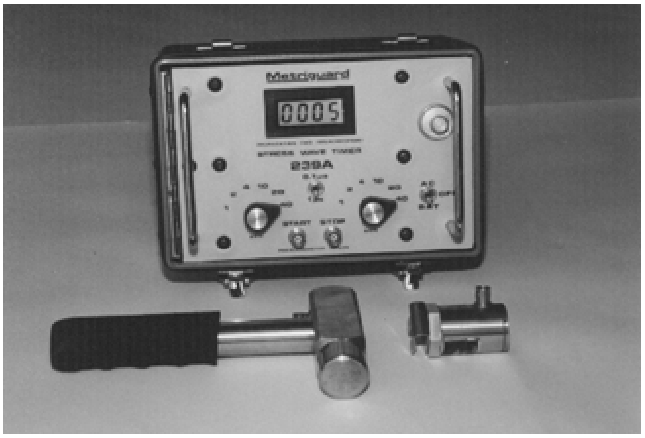


Figure 9—Metriguard Model 239A Stress Wave Timer.

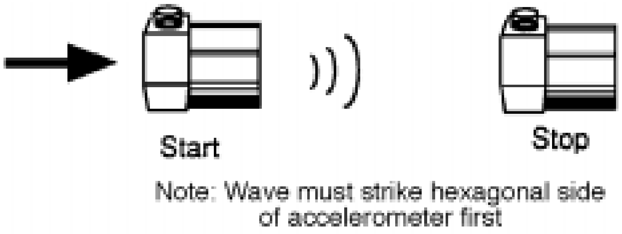


Figure 10—Necessary orientation of accelerometers.

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 a fixed distance apart on a member. A transmitting transducer imparts a wave into the member, and a receiving transmitter is triggered upon sensing of the wave. The time it takes 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) 56 N (12.6 lb) (instrument with carrying bag and accessories)

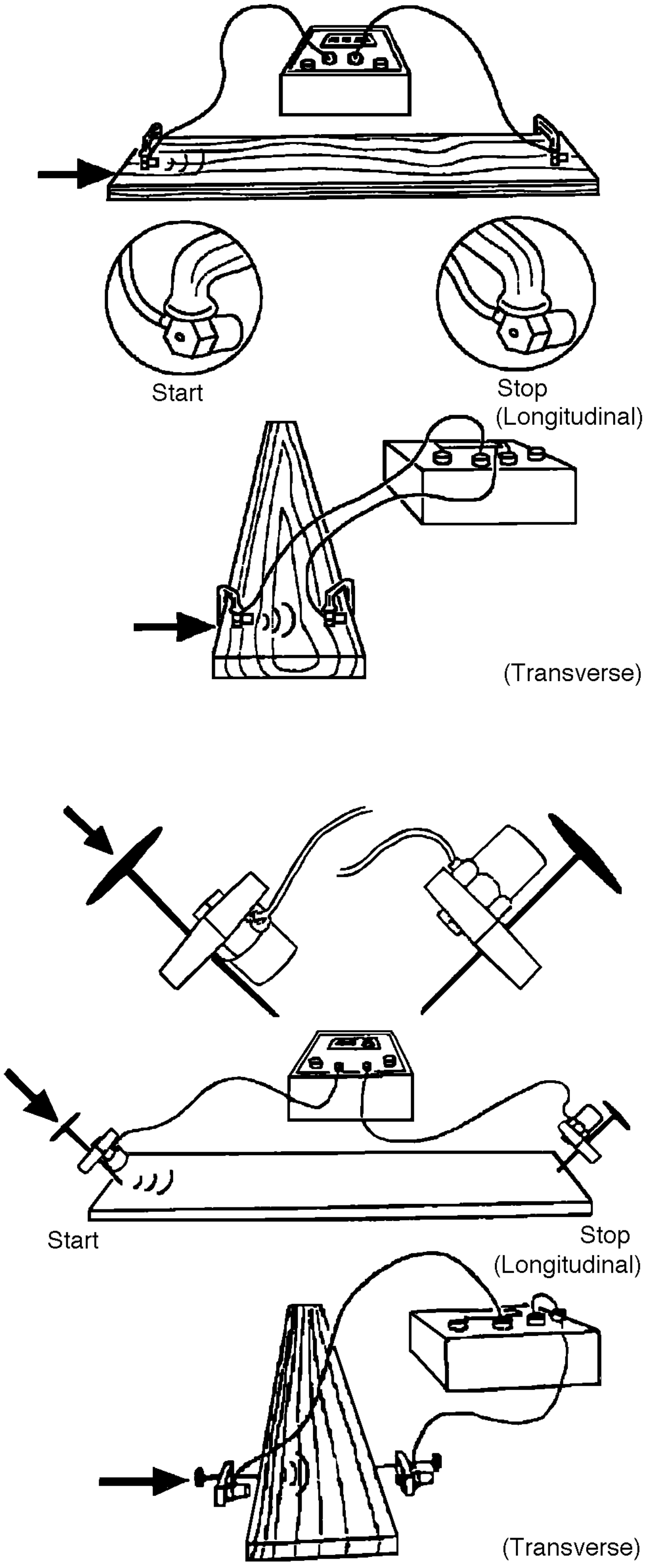


Figure 11—Important aspects of field set-ups for commonly used techniques.

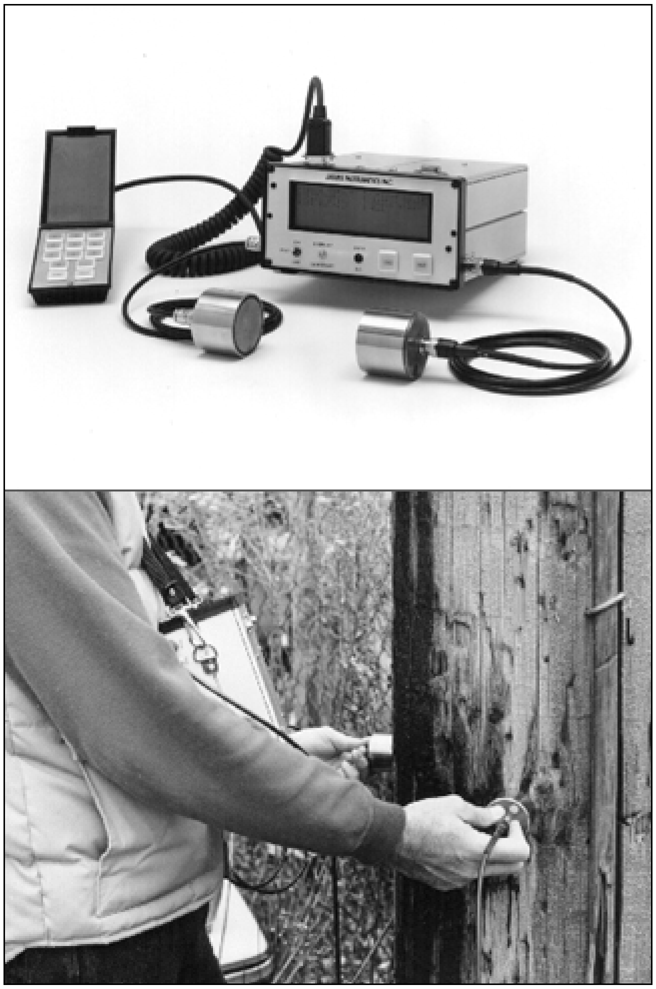


Figure 12—James V-Meter.

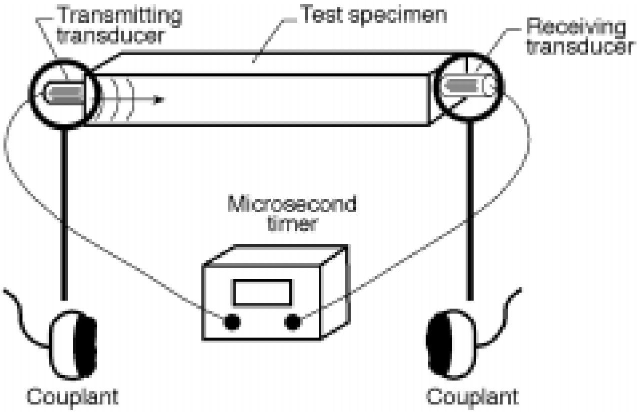


Figure 13—Ultrasonic measurement system used to measure stress wave transmission times in various wood products.

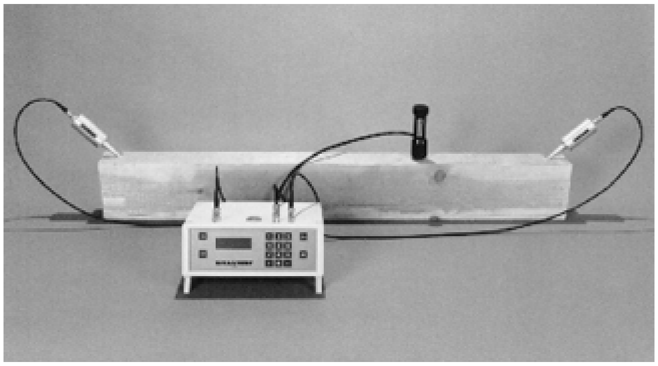


Figure 14—Sylva test.

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 it takes 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 field work. 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 1575 µs/m (480 µs/ft). Transmission time, on a 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, you can estimate the transmission time for a member by knowing its thickness (path length) and the following formula:

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

where

T_{baseline} is baseline transmission time (µsec), and
WTD is wave transmission distance (path length) (m).

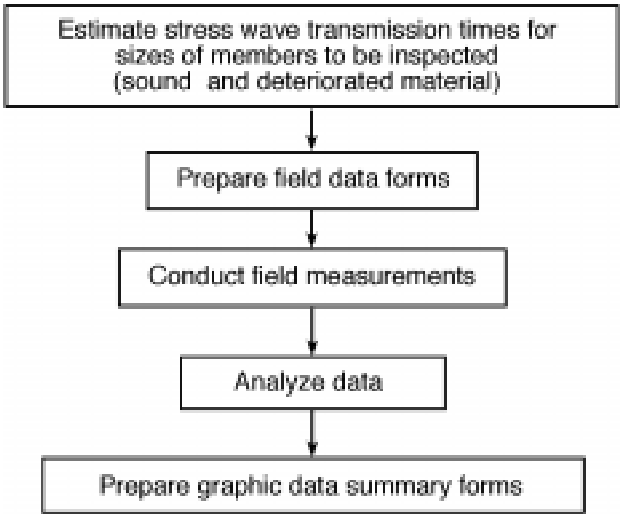


Figure 15—General procedures used to prepare and use stress wave timing methods for field work.

[English formula: 400 × WTD where WTD is wave transmission distance (path length) (ft).]

By knowing this number for various thicknesses, field work 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 bridge name, location, number, inspector, and date of inspection.

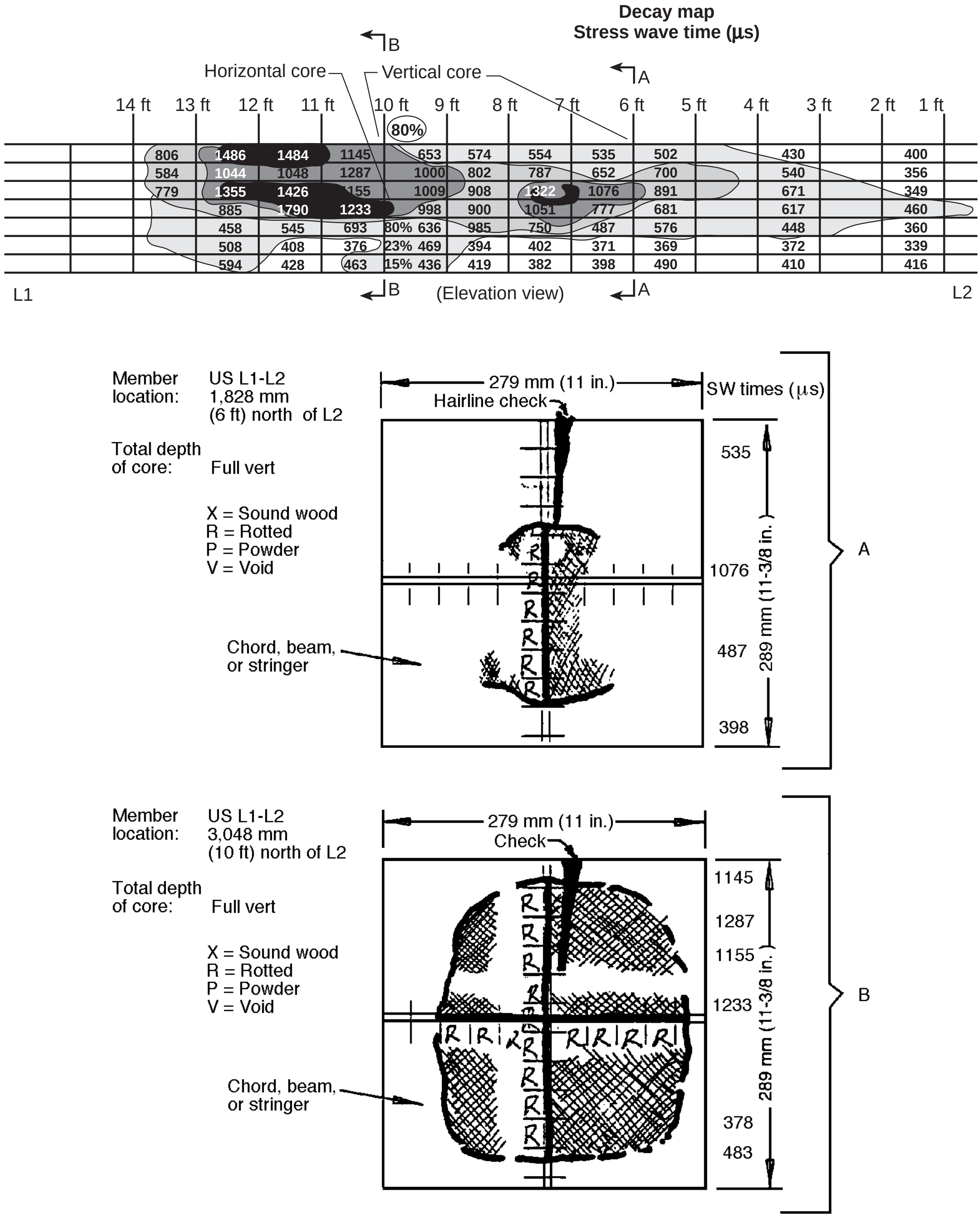
Field Measurements

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 degrading, 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 away from the suspect 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

When data have been gathered, it is useful to present them in an easy to read manner. Figure 16 illustrates various data summary forms. From these, the presence and extent of degradation can readily be seen.



806	1486	1484	1145	653	574	554	535	502		430		400
584	1044	1048	1287	1000	802	787	652	700		540		356
779	1355	1426	1155	1009	908	1322	1076	891		671		349
	885	1790	1233	998	900	1051	777	681		617		460
	458	545	693	80% 636	985	750	487	576		448		360
	508	408	376	23% 469	394	402	371	369		372		339
	594	428	463	15% 436	419	382	398	490		410		416

Member location: US L1-L2
1,828 mm
(6 ft) north of L2

Total depth of core: Full vert

X = Sound wood
R = Rotted
P = Powder
V = Void

Member location: US L1-L2
3,048 mm
(10 ft) north of L2

Total depth of core: Full vert

X = Sound wood
R = Rotted
P = Powder
V = Void

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

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Appendix—Acquisition Form and Additional Reference Material

Included in this Appendix is an example of a typical field data acquisition form. Additional reference material on wood properties, stress wave theory, or timber bridge maintenance is also provided in this Appendix.

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Data Log—Stress Wave Transmission Times

Bridge name ______________________________ Bridge number ____________________

Location ______________________________ Date ____________________

______________________________ Equipment ____________________

______________________________ ____________________

______________________________ ____________________

Inspector ____

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

Page _________ of _________

Data Log—Stress Wave Transmission Times

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

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