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Nondestructive Assessment of Wood Members from a Historic Viewing Tower

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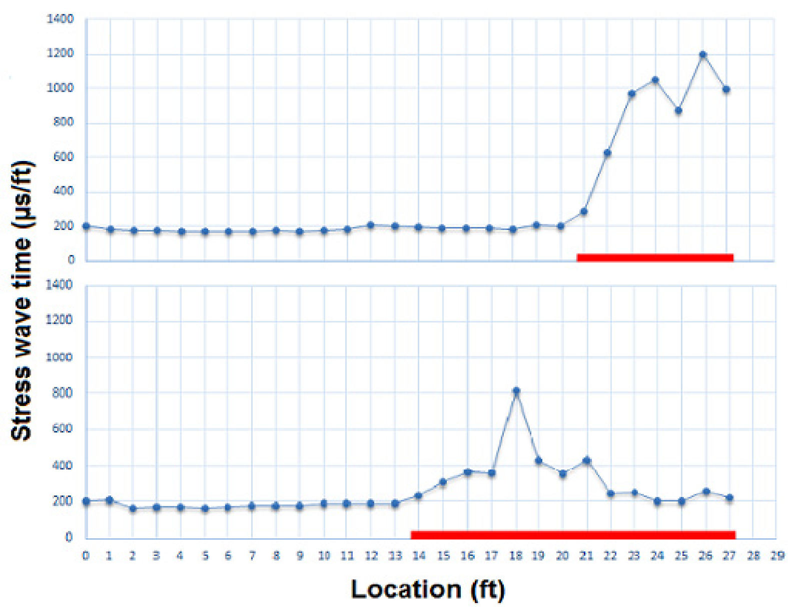

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Abstract

The state of Wisconsin's Department of Natural Resources is responsible for operating one of the largest state park systems in the United States. Peninsula State Park, one of the state's most visited parks, attracts more than one million visitors a year. This park contained one of the most iconic structures in the Wisconsin State Park system, a tall, wooden observation tower that was constructed in 1932. Because of concerns about the structural integrity of several of the large timbers in the tower, it was closed in the spring of 2015 and dismantled in fall 2016 at the request of the Department of Natural Resources. The USDA Forest Service, Forest Products Laboratory, was contacted and asked to conduct an assessment of the timbers after the structure was dismantled. This report summarizes results obtained from our inspection and assessment of the timbers. A brief summary of the nondestructive testing techniques used, observations, and data from tests conducted on the timbers are included.

Keywords: nondestructive assessment, decay, moisture, timbers

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Nondestructive Assessment of Wood Members from a Historic Viewing Tower

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Introduction

The USDA Forest Service, Forest Products Laboratory (FPL), was contacted in late 2015 to assist engineers from the Wisconsin Department of Natural Resources (DNR) in evaluating the condition of timbers in a historic viewing tower located in Wisconsin's Peninsula State Park. Located in Door County, the Eagle Tower (Fig. 1) was a 75-ft (1 ft = 0.3048 m) observation tower that sat atop a 180-ft limestone bluff. From its top platform, one could see Peninsula State Park, surrounding islands in Lake Michigan, and Michigan's Upper Peninsula.

The tower structure was built in 1932. It replaced the original tower built on Eagle Bluff, which was constructed in 1914. This iconic tower stood as a well-known Wisconsin landmark. Peninsula State Park is visited by more than a million people every year.

The DNR periodically examined the structure using visual inspection techniques. Engineers looked for signs of distress, such as failed members and those showing evidence of attack by decay fungi or carpenter ants or nesting activity for local bird populations. After an extensive inspection, the DNR concluded that the main structural members were severely deteriorated and, consequently, closed the structure. The tower was dismantled September 19, 2016.

Figure 1. Eagle Tower, Peninsula State Park, Door County, Wisconsin.

The objective of the work summarized in this report was to nondestructively evaluate the quality of timbers that had comprised the tower after it was dismantled. Several nondestructive techniques were used to assess the condition of the large timber poles from the tower.

History of the Tower in Peninsula State Park

The original tower on Eagle Bluff was constructed in 1914 at a cost of $1,061.92. The tower was 76 ft tall, and it stood 225 ft above Lake Michigan. It was constructed during the summer of 1914 to serve as a fire tower with the expectation it would become a tourist attraction. The ledger of Peninsula's first manager, A.E. Doolittle, lists payment to men for fire watch duty.

A construction crew cut logs and boards from timber in the park using tools and saws available at the time. To erect the tower, they first raised the center pole. Then they used the center pole to raise other support poles. Three trees made up each corner pole, one tree for each level, with platforms between each level. Horizontal landing support beams were added, followed by planks for decking at the three levels.

A telephone line connected the tower to the manager's residence and the local exchange so that fires could be quickly reported. Historical records indicate there was a large buildup of fire-prone material in the park. Peninsula's last significant fire was in 1921.

The original tower was dismantled. Then, Eagle Tower was built in 1932. Foreman Sam Erickson and crew used horses, tractors, trucks, and other machinery. They wrapped cable around nearby trees to raise poles. A stump wrapped with rusty cable can still be seen a short distance from the tower site, along the road leading toward Eagle Terrace (GPS N45.16275 W 87.19730). The poles (western redcedar) came from Washington State.

Although funded with state relief, this was not a Civilian Conservation Corps project.

Eagle Tower was 75-ft tall and stood 250 ft above water level. Safety improvements were made in 1972, including slanting the top deck railings. Hardware and decking were replaced and stained in subsequent years.

Inspection of Eagle Tower

An in-depth inspection of Eagle Tower was conducted in the spring of 2015 because of its age. The inspection, contracted by the DNR, included core sampling to determine the general internal condition of the structural components and overall load-bearing capacity of the structure. The tower inspection report indicated that the structure was in poor condition and should be razed. Subsequent reviews of the tower inspection report supported this recommendation. On May 20, 2015, the tower was closed for public use. Eagle Tower was dismantled on September 19, 2016.

Assessment of Dismantled Members from Eagle Tower

Accepted inspection techniques were used to assess the condition of the timbers from the tower. These techniques are discussed in detail in *Wood and Timber Condition Assessment Manual, Second Edition* (White and Ross 2014). A brief description of the techniques we used follows.

Visual Inspection

The simplest method for locating deterioration in wood members is visual inspection. An inspector observes the structure for signs of actual or potential deterioration, noting areas that require further investigation. Visual inspection is useful for detecting intermediate or advanced surface decay, water damage, mechanical damage, or failed members. Visual inspection cannot detect early stage decay or deterioration.

Several key indicators are looked for in visual inspections: fruiting bodies (evidence of advanced decay), staining or discoloration of members (indicators of water damage), evidence of insect activity (holes, frass, and powder posting), plant or moss growth in a member, deep checks or splits, and failed or missing members.

In our visual inspection of the tower members, we specifically looked for the following: Evidence of water intrusion and subsequent damage, especially near where the legs of the tower were in contact with the concrete pads they rested on and other areas where the exterior of the wood member was compromised, and evidence of structural failure of the timbers.

Sound Transmission

A significant volume of research has been devoted to the use of sound waves for locating areas of deterioration in timber structures, and a practical set of guidelines for their use has been prepared by FPL (Ross and others 1999). The transmission of sound in wood is affected significantly by the presence of deterioration. Consequently, ultrasound and stress-wave-based technologies have been developed and are widely used to inspect wood structures (Allison and others 2008; Brashaw and others 2005b; Clausen and others 2001; Emerson and others 2002; França and others 2015; Ross and others 1999, 2006) and have been used for the assessment of culturally significant historic ships and artifacts (Ross and others 1998, Wang and others 2008, Dundar and Ross 2012).

In this assessment, we used several simple, commercially available stress wave timers in our inspection. Sensors were placed on opposite sides of a timber. The timber was then impacted, generating a stress wave. The time it took for the wave to travel between the sensors was measured by the timer and recorded. Transmission times for wood from several species are known and were used as a baseline. Transmission times significantly longer than baseline values indicated the presence of deteriorated wood in the Eagle Tower legs.

Microdrilling Resistance

Simple mechanical tests are frequently used for in-service inspection of wood members in structures. Drilling and coring are the most common simple tests used to detect internal deterioration. Both are used to detect the presence of voids and to determine the thickness of the residual shell when voids are present.

Microdrilling resistance is a commercially developed technique originally developed for use by arborists and tree care professionals to evaluate the condition of urban trees and locate voids and decay. It is now being used to identify and quantify decay, voids, and termite galleries in wood beams, columns, poles, and piles (Brashaw and others 2005a). The underlying premise for this technique is that degraded wood is relatively soft and will have low resistance to drill penetration.

Microdrilling resistance tests were conducted in areas of the Eagle Tower timbers that were believed to contain deteriorated wood based on results from our visual assessments and stress wave testing.

Results

Intensive testing of the four large timbers that served as the legs for the tower was conducted. Figures 2 through 5 show the dismantled timbers. Each timber was sawn into three sections prior to testing. Figures 6 through 11 show each of the sections and corresponding test results. One of the legs was severely deteriorated with significant decay throughout its entire length. Another leg had significant deterioration. The other two contained limited areas of deterioration. A visual inspection of many of the horizontal cross members from the tower revealed significant deterioration. One of these members was severely split and was deteriorated along its entire length (Fig. 12).

Conclusions

Based on our visual inspection and testing of the timbers from the tower, the following were concluded:

1. Critical support members of the tower were severely deteriorated. One of the legs from the tower was severely deteriorated along its entire length.
2. Many of the members were significantly deteriorated; they should not be reused in any load-bearing application.

Recommendations

The following are recommended:

1. All of the large timbers should be stored under cover and off the ground. This will minimize further deterioration.
2. None of the members should be reused in any load-bearing application. Reuse of any recovered materials should be limited to non-load-bearing applications, for example, as interior paneling in offices, signage, or craft-type products.

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Figure 2. Materials from the dismantled tower.

Figure 3. Sections from the four timbers that served as legs for the tower. Sections identified as TL#1 through TL#4 were the leg sections that rested on concrete support pads.

Figure 4. Timber sections TL#5 through TL#8 were from the uppermost portion of the tower's legs.

Figure 5. Timber sections TL#9 through TL#12 were the middle section of the tower's legs.

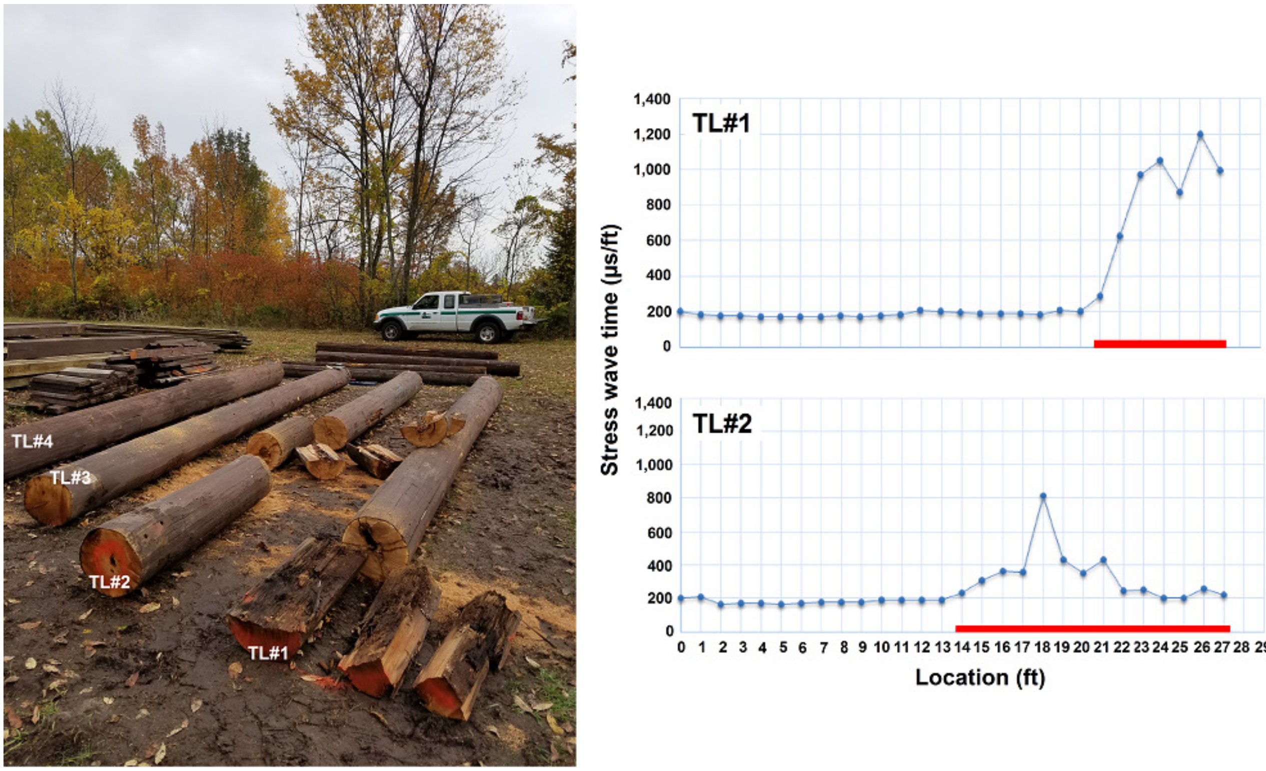

Figure 6. Timber sections TL#1 through TL#4, with corresponding stress wave transmission test results. Test results indicated severe deterioration in sections TL#1 and TL#2.

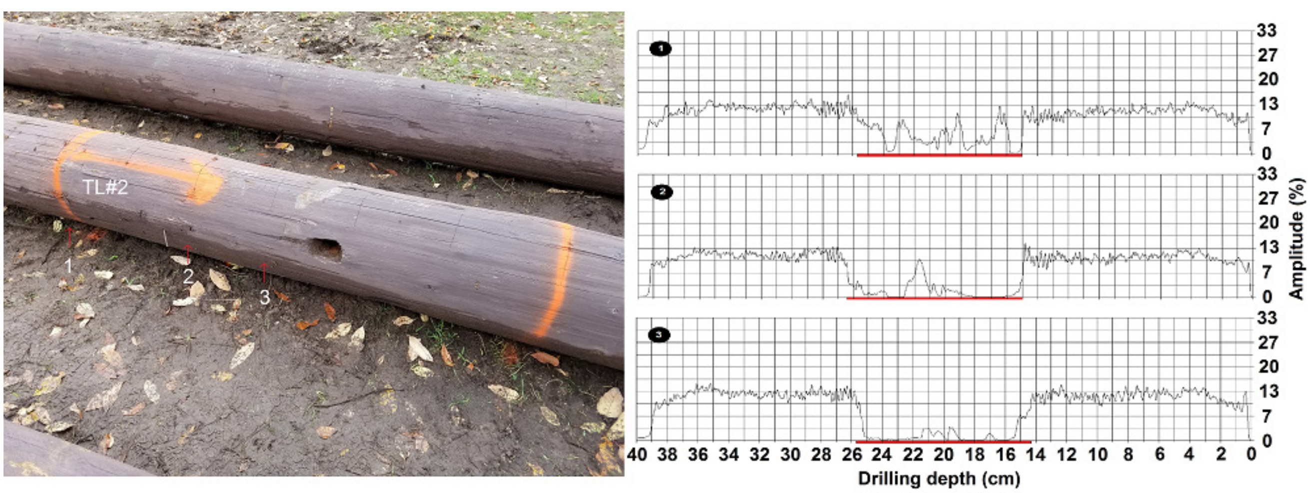

Figure 7. Microdrilling resistance results indicated deterioration in the vicinity of a bird nest in the timber.

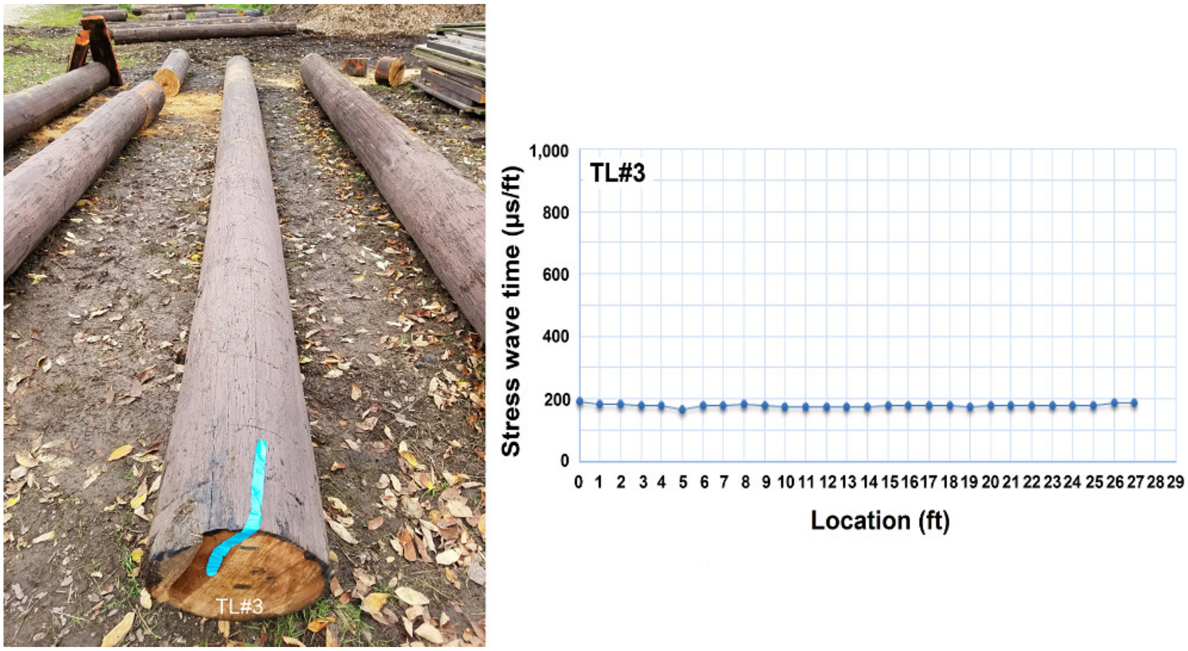

Figure 8. Timber section TL#3 and corresponding stress wave test results. No deterioration was observed.

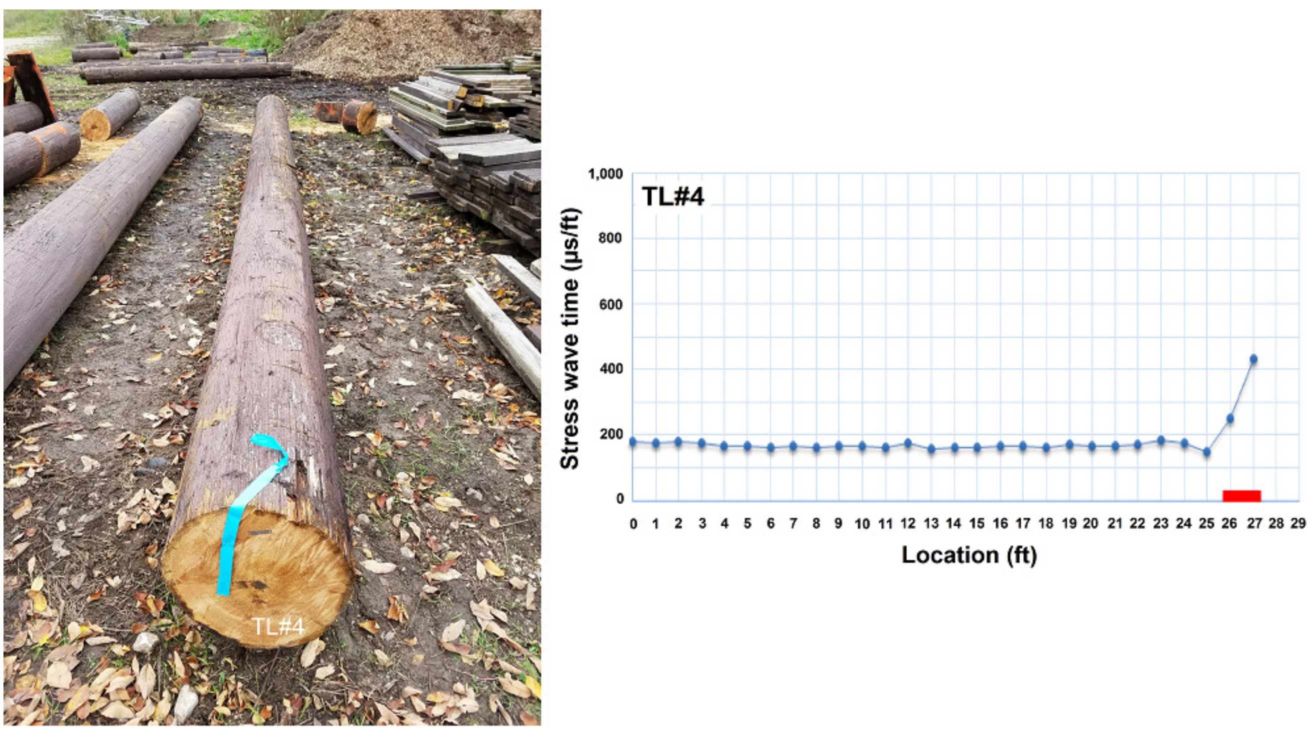

Figure 9. Deterioration was noted for timber section TL#4.

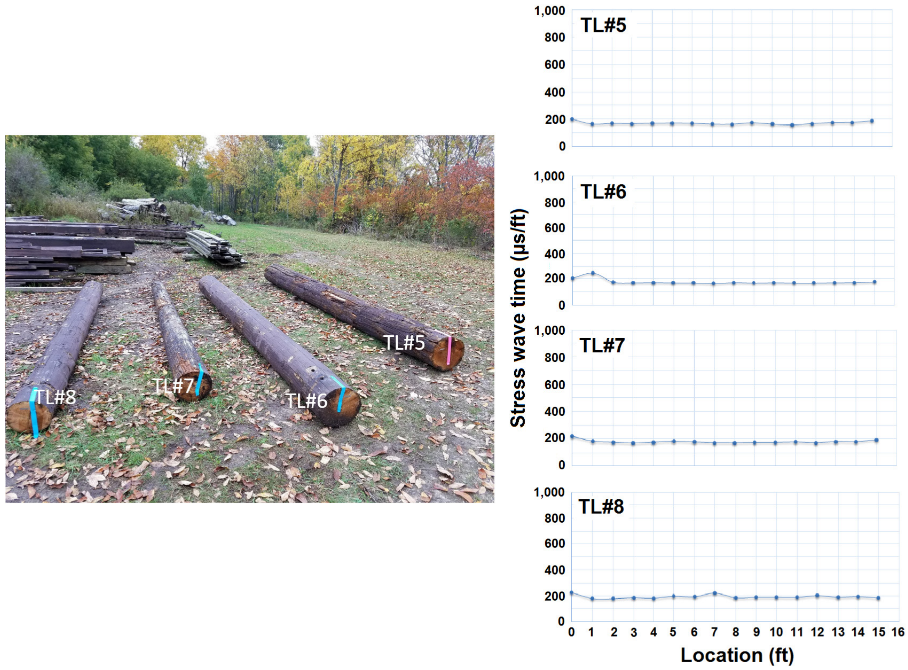

Figure 10. Results obtained from stress wave tests of the uppermost sections of the tower's legs.

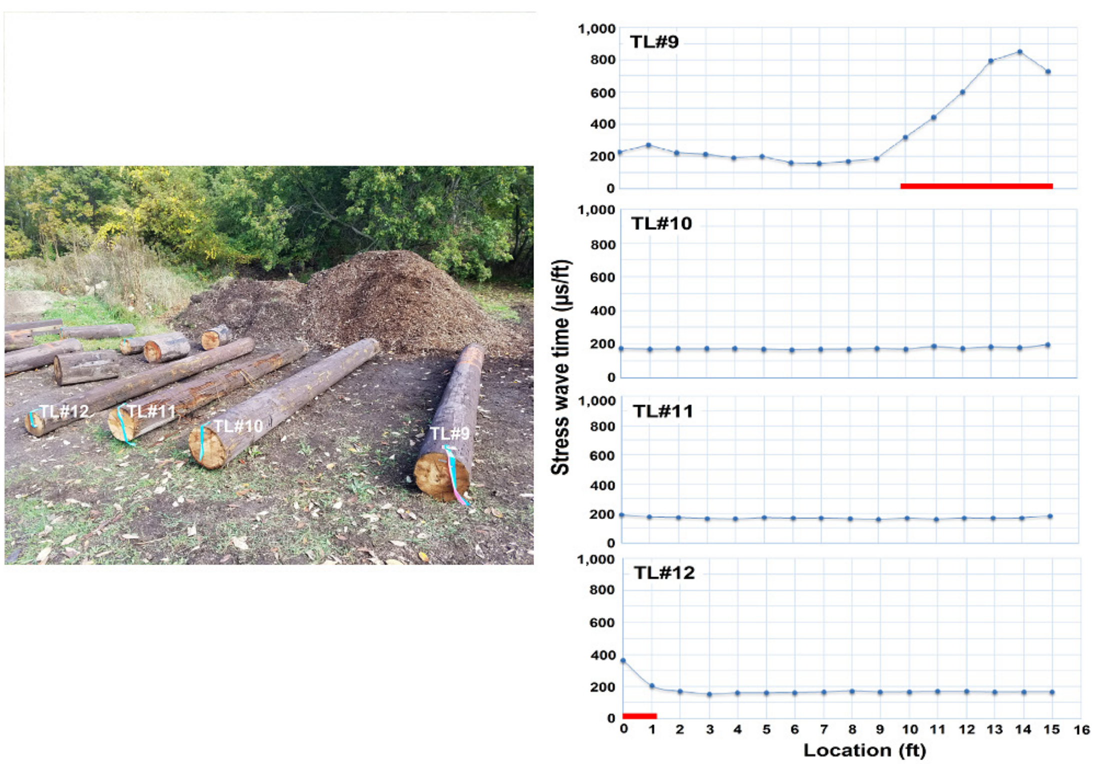

Figure 11. Test results from the middle sections of the tower's legs.

Figure 12. Horizontal support member that contained severe deterioration.