



# CROSSINGS

NEWSLETTER OF THE NATIONAL TIMBER BRIDGE INITIATIVE



Editor - Tinathan Coger

Issue 11

February 1993

## In-Situ Pile Length Determination Using Nondestructive Evaluation

**D**uring the late 1980's, nationwide attention was directed toward bridge failures due to scour. Recognizing the need to uniformly evaluate scour, the Federal Highway Administration published a Technical Advisory on the scour of bridges. This Technical Advisory is used by the state Departments of Transportation to address the effects of bridge scour in the design of new bridges and also in the inspection of existing bridges. Under the National Bridge Inspection Standards Program, state agencies are required to evaluate the effect of scour during extreme flooding.

Determining pile length is critical to evaluate the potential effects of scour. Unfortunately, records of timber pile length are typically nonexistent for older bridges. A nondestructive technique has recently been developed to determine the length of in-situ timber piles by Engineering Data Management, Inc. (EDM). With support from the Timber Bridge Initiative Special Projects Program, the technique was developed in cooperation with the Louisiana Department of Transportation.

The nondestructive technique consists of attaching three sensors to the pile above the soil or water line, as shown in Figure 1. Access to the end of the pile is not required. A lag screw is inserted into the pile and struck with a hammer to introduce stress waves into the pile. The two sensors located below the lag

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## Field Performance of U.S. Stress-laminated Wood Bridges

**T**o evaluate the performance of stress-laminated bridge systems built in the United States, the USDA Forest Service, Forest Products Laboratory (FPL), implemented a nationwide bridge monitoring program in late 1988. The purposes of the program are to monitor and evaluate bridge performance in order to develop, confirm, or improve methods of design, fabrication, and construction. This is being accomplished by obtaining information on the performance of different bridge systems and materials in various geographical and environmental conditions. Information on each bridge is normally collected over a minimum of 2 years and includes moisture content, stressing rod force, vertical creep, load test behavior, and condition evaluation.

Stress-laminated deck bridges constructed in the United States have generally provided good performance. The limited performance problems that have been experienced relate to the serviceability rather than the structural (safety) features of the bridges. These problems resulted from the evolutionary nature of the stress-laminated system in the United States, and generally occurred on bridges that were constructed before national standards for design, fabrication, and construction were widely available.

With few exceptions, U.S. bridges constructed early in the program have used lumber at a relatively high moisture content level (24% to 28%); however, three of the bridges included in the FPL monitoring program were built with lumber at a moisture content in excess of 30%. Based on field observations, the FPL currently recommends a maximum wood moisture content of 19% for stress-laminated deck construction to minimize stress loss as the wood reaches equilibrium with the environment.

For monitoring purposes, compressive stress between the laminations is determined by measuring the force in the stressing rods. Field performance of stress-laminated bridges has shown that rod force, and thus interlaminar compression, is an interaction of several factors including wood creep, moisture content changes, and rod anchorage system performance. However, general trends have been observed.

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## WOOD DECK FOR TAMCLIFF TRUSS

**T**amcliff Truss is a one-lane bridge on US 52 crossing the Guyandotte River approximately 2 miles north of Gilbert in Mingo County, West Virginia. The bridge has an approach span of 24 feet with the truss being 200 feet. In 1989, the light weight concrete that was covering the steel grid deck was loose, broken, and falling out. Steel plates had been placed over completely failed sections to keep traffic open.

The bridge has an average daily traffic of approximately 4,000 vehicles which includes coal and timber trucks. The situation was becoming very critical as a detour could be up to 45 miles.

The Division of Highways District Two Bridge Engineer, Wilson Braley, considered overlaying the existing deck with another steel grid or steel plates but either system would require posting the bridge for less than legal highway loads. Braley's goal was to repair the deck while maintaining existing traffic.

In 1989, West Virginia began the Timber Bridge Program and timber was investigated. It was found that with the concrete removed, a 4 inch thick stressed timber deck could be placed over the steel grid and still maintain legal load traffic. West Virginia University assisted in design which resulted in nineteen 10' long x 15' wide panels and three various sized panels to make up the end flair. Stressing bars of 5/8 inch diameter with an ultimate stress of 150,000 psi were placed on 2 foot deters transverse to the bridge. The panels were fabricated with Creosote Treated Red Oak at the Burke, Parsons, Bowlby Plant (BPB) in Spencer, WV. District forces removed the concrete from the grid deck and set the panels. The traffic was stopped for a short period of time and a 10 foot long panel was carried onto the bridge and set in place. A wedge shaped timber was placed at the end of the panel to allow traffic to traverse the 4 inch bump. This procedure was repeated until all panels were set. (The plans specified that each panel be secured to the steel grid deck with four 3/4 inch bolts, but these were never installed and now found not needed.)

On October 27, 1992, nearly two years after installation, Dick Bowlby of BPB and Don Rude observed the deck.

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## Field Performance ... *continued from page 1*

Moisture content at the time of construction is one of the most influential factors in maintaining rod force.

When the top of the bridge deck was not protected with an asphalt wearing surface, localized moisture content increases in the deck top have caused swelling followed by wood crushing at the stressing rod anchorage plates.

Substantial decreases in rod force have been attributable to wood crushing at the anchorages for the stressing rods. Crushing has been most severe when the discrete plate anchorage system is used in conjunction with softwood laminations at a high moisture content level.

Bridges included in the FPL monitoring program are located at various U.S. locations. Several of the bridges are subjected to annual temperature variations of 100(degree) F (56 degree C) or more. Temperature changes and the associated thermal expansion and contraction of bridge materials have not been shown to significantly affect rod force levels. Work in this area is continuing and more definitive conclusions will be forthcoming.

The purpose of the anchorage system for stressing rods is to distribute the rod force into the deck without causing wood crushing along the outside laminations. When crushing does occur, force reduction in the stressing rods can be substantial.

For the rectangular steel bearing plate configuration, performance has been somewhat mixed. When used on soft-wood lumber species (Douglas Fir and Southern Pine), the plates have caused crushing in the outside laminations. When properly designed, the discrete plate configuration used on red oak laminations has shown virtually no crushing and has performed well.

As a structural material, wood is subject to permanent deformation as a result of long-term sustained loads. This phenomenon, known as creep, has been evidenced in stress-laminated decks. One advantage of stress-laminated decks has been the ability to camber bridges with butt joints to offset the dead-load deflection and the additional creep deformation.

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## Field Performance ... continued from page 2

Load tests have been conducted on numerous stress-laminated decks to assess behavior under a loaded condition and provide data for evaluating proposed design procedures. In all cases, load tests have shown that stress-laminated decks act as large orthotropic plates.

Stress laminated decks have no joints; therefore, the induced stress sufficiently prevents vertical movement of the individual laminations, and asphalt cracking or deterioration has not been observed on stress-laminated decks. Even on decks designed for standard HS-20-44 highway loads with a live-load deflection as large as 1/300 of the bridge span, no cracking or deterioration of the asphalt wearing surface has been apparent during the initial 2-year monitoring period.

Adequate corrosion protection of the steel-stressing system has been a primary consideration since the development of stress-laminated deck systems. Bridges built in the United States have also used galvanizing as a means of corrosion protection for the stressing rods and anchorage hardware. Over a relatively short monitoring period of 2-1/2 years, no signs of rod corrosion have been observed on galvanized surfaces. However, in several cases where anchorage nuts were not oversized to compensate for rod galvanizing, damage occurred to the rod galvanizing when the nuts were forced onto the rods during construction. Failure to adequately field coat the damaged areas resulted in minor corrosion at the rod ends. This situation can be avoided by using nuts of the proper size or field coating damaged areas with a cold galvanizing compound.

*NOTE: This article is summarized for publication by the TBIRC staff. For copies of this complete publication, contact USDA Forest Service, Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705-2398; Phone: 608-231-9268*

## WOOD DECK ... continued from page 2



*Photo courtesy of Dick Bowlby, Burke, Parsons and Bowlby, Inc.*

There was no rutting of the oak deck and panels were still aligned as set, even though the bolts were never installed. Some of the panels rocked under traffic which was probably due to the steel plates that were left on the steel grid. Rude and Bowlby also observed a dowel laminated unpaved pine deck on a bridge in the Gilbert area that had been in service approximately 15 years with minimal traffic and rutting was about 1-1/2 inches deep. This showed that oak is superior to pine for an unpaved wood bridge deck.

While it is highly recommended that asphalt be placed on a timber deck, the additional weight would have overstressed the truss. The bridge will be replaced in 3 to 5 years and exposure to the weather was not a consideration. The ability of a stressed oak deck to withstand the heavy traffic without asphalt paving exceeds performance indicated in written material on this subject.

It should be noted that with a stressed timber deck traffic is traveling with the wood grain which is probably why rutting is not occurring. On most timber bridges, traffic travels at right angles to the grain which tends to tear the fiber and leads to rutting.

In summary the project was a success and solved a critical problem at a cost of \$12 a square foot for material which included bolts and hardware that were never used.

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*Mr. Don Rude has 20 years public experience and 20 years private experience as a civil engineer. He assisted in initiating the work in the timber bridge program for the West Virginia Department of Highways in 1989. Mr. Rude retired from WVDOH in 1991.*



## In-Situ Pile Length ... continued from page 1

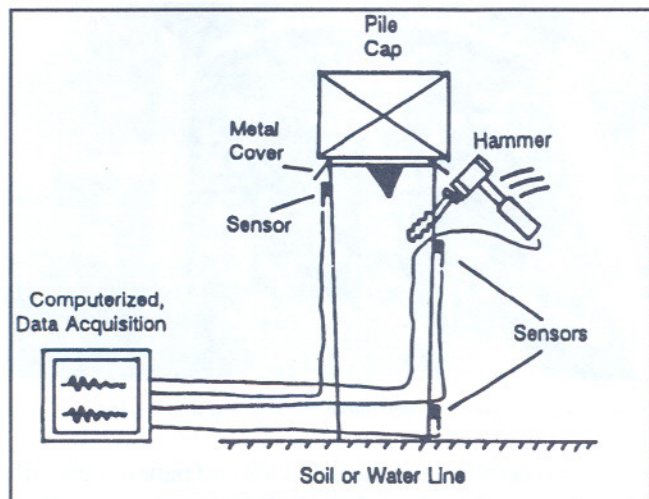


Figure 1. Hammer Impact and Sensor Locations.

screw are used to determine the velocity of the stress wave in the dry portion of the pile. The single sensor opposite the lag screw is used to determine the resonant frequency of the pile.

The stress waves induced from the hammer impact are reflected at the ends of the pile and evolve to a resonant frequency. Since resonant frequency is dependent on the pile length and stress wave velocity, pile length can be calculated. This fundamental theory formed the basis for the successful technique.

The nondestructive technique is designed to evaluate length, but may indirectly determine pile quality. For example, resonant frequency information from decayed piles is different from piles that are not decayed. By comparing frequency information from all of the piles in a bent, a skilled user may be able to identify suspect piles. This technique was used during the field studies and was able to identify a pile that was broken at the mud line.

Additional cooperators who provided bridge sites for field testing were the Colorado Department of Transportation, Burlington Northern Railroad and Union Pacific Railroad. Six bridge sites were utilized in Colorado and Louisiana for field testing of 18 piles. Timber pile lengths ranged from 19 to 60 feet. The nondestructive technique provided length estimates that were accurate to  $\pm 15\%$ . The relationship between actual and predicted pile length is shown in Figure 2 within the 15% boundary lines.

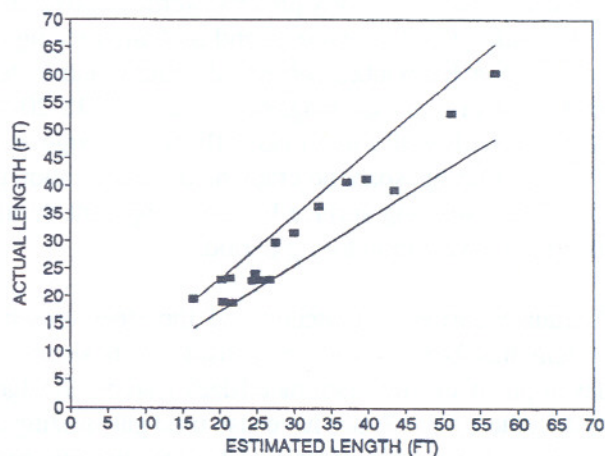


Figure 2. Plot of Actual and Estimated Pile Lengths.

A copy of EDM's report is available from the Timber Bridge Information Resource Center. For additional information, please contact Rob Brooks or Allan Burk at EDM, Inc. Phone: (303)223-0457.

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