Research in Progress

National Center for Wood Transportation Structures
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Development of a Smart Timber Bridge—Moisture Sensor Investigation for Historic Covered Bridges

Recently, much attention has been given to the development of an intelligent infrastructure. The idea is to develop and deploy civil systems that have sensors integrated such that the condition and performance of the system can be reported on continuously and, generally, remotely. To date, work in this area has focused on two primary areas: sensor development and performance algorithm development. New sensor technologies suitable for embedment and rugged enough to withstand the manufacturing process will be key components for smart bridges. The design of algorithms that include performance boundaries for a number of key parameters will be important for interpreting the monitoring data into a format easily usable by bridge managers.

Gallon House Covered Bridge located at Silverton, Oregon, is a Howe Truss design.

Development of embeddable moisture sensors that are reliable and accurate for the longer term will help to identify areas with potential for decay activity. One key requirement for decay activity in wood is a moisture content greater than 20%. Sensors will be strategically placed in areas of the bridge superstructure prone to water intrusion and early decay. In situ moisture contents that exceed 20% will trigger further inspection and remedial actions. This incipient decay detection approach will be highly valuable for historic covered bridges that have been recently rehabilitated with glulam bridge materials.

Background

Several recent technological advances have resulted in the development of cost-effective sensing and communications systems. Although not yet turn-key systems, the potential exists to develop timber bridges that, using quantitative sensed information, report on their performance and condition. Cooperatively and separately, the Iowa State University Bridge Engineering Center and the USDA Forest Products Laboratory (FPL) have been working on sensing systems specifically for timber bridges.

Electrically based sensors that measure temperature and relative humidity were previously investigated at FPL. In these studies, the sensor was placed into a member via a plugged core hole, and data originating from the sensor were converted to an equilibrium moisture content value based upon empirical relationships. Bridge monitoring projects that utilize these in-situ moisture content sensors are currently underway in Europe. However, the reliability of this field method over the long term has not yet been reported.

Objectives

The objective of this work is to continue advancing timber-specific sensing capabilities with a specific interest in the application of moisture sensing for historic covered bridges.

Partners of the National Center for Wood Transportation Structures

Iowa State University of Science and Technology
100 Years of Service Forest Products Laboratory 1910–2010
National Park Service
U.S. Department of Transportation Federal Highway Administration

Approach

This study will be completed in a series of tasks:

Task 1: State-of-the-art review of deterioration sensors—The research team will seek information on three specific types of sensors for detecting moisture content, ferric ions, and lignin loss. The focus of this effort will be to identify optical or electrical sensors that can be integrated into broader monitoring system architecture. The research team will accomplish this task by performing a domestic and international literature review.

Task 2: Small-scale sensor evaluation—Assuming that potentially suitable sensors can be identified in Task 1, small-scale evaluations of these sensors will be completed. Small-scale specimens will be designed and fabricated with the previously identified sensors. Testing of the sensors will include a review of survivability and accuracy/sensitivity of measurements. These small-scale specimens will be fabricated at a local glulam fabrication facility.

Task 3: Constructability review—To ensure that the sensors can be integrated into production-type bridge girders, two full-scale beams will be designed (including size, lamination types, sensor types/placement) and constructed at a local glulam fabrication facility. The constructability of the system will be determined by evaluating the operability of the sensors after beam fabrication and through personal accounts of fabrication personnel.

Task 4: Fatigue testing—The beam to be fabricated in Task 3 will be subjected to fatigue testing to evaluate the operability of the sensors under repeated loadings. It is envisioned that this testing will be continued for approximately 1,000,000 cycles.

Task 5: Final Report—Results of the work described in Tasks 1–4 will be summarized in the final report for this investigation.

Expected Outcomes

A comprehensive final report which documents all phases of the project. The final report will include recommendations for (1) sensor types for measuring the metrics known to be related to timber bridge deterioration and (2) types of sensors likely to survive the fabrication process and provide long-term stability under cyclic loadings.

Timeline

Target completion dates for the five study tasks are as follows:

Task 1—April 2011

Task 2—January 2012

Task 3—August 2012

Task 4—June 2013

Task 5—July 2013

Cooperators

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