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Developing Flexural Vibration Inspection Techniques for Wooden Bridges

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LRRB PROJECT COST:
$52,980

Electric motors with offset weights are used to create vibrations in the wooden bridge deck that are detected with sensors elsewhere on the deck.

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Researchers improved and automated a vibration testing system for wooden bridges designed to identify changes in the structural health of a bridge over time by monitoring the resonant frequencies of the structure, extending the use of this technique to dowel-laminated bridges.

What Was the Need?

There are more than 50,000 timber bridges in the United States and more than 4,000 in Minnesota, nearly all of which are on rural roads and maintained by local or county transportation agencies. Current inspection procedures are mostly limited to visual inspection of the wooden components of the bridge; these inspections are sufficient for detecting advanced decay, but are inadequate for determining early-stage degradation or internal damage to bridge members. Such inspections are also intensive and time-consuming, leading to inspection intervals that are less frequent than desired by bridge owners.

Deterioration can progress rapidly in wooden bridges, and owners want to address it as quickly as possible to minimize needed maintenance and preserve overall safety for traffic use. In Phase I of this study, researchers investigated the initial promise of using forced-vibration techniques to nondestructively evaluate the health of wooden bridges.

These techniques involve applying a forced vibration to the bridge and examining the oscillations (small deflections of the structure) with instruments attached to the deck. The resonant frequencies of the vibrations reflect the physical characteristics of the bridge, such as the overall rigidity.

Further development of such assessment techniques would enhance the care and maintenance of wooden bridges, especially if they could be used by local personnel to provide timely, inexpensive evaluations of the health of the bridges.

What Was Our Goal?

The goals of this project were to improve and automate a vibration testing system of dowel-laminated bridges and to conduct vibration tests to better understand the potential for the technique in assessing the structural health and condition of Minnesota's wooden bridges.

What Did We Do?

In its early development, the vibration testing system had been limited to short-span timber bridges whose structural integrity is largely vertical, meaning that the main constraint to flexure is provided by the pilings supporting the bridge deck. In this project, researchers applied the vibration technique to dowel-laminated timber bridges, which are built with individual timbers connected side by side and held together with metal spikes, forming a deck much like a laminated butcher-block countertop. Such deck structures display horizontal as well as vertical integrity—behaving more like a plate than a beam—and, consequently, have vibration characteristics different from the previously examined girder-style bridges.

The testing procedure utilized a one-half horsepower DC motor rotating an unbalanced disc attached at the center of the bridge span to vibrate the deck. Accelerometers attached at midspan measured the amplitude of vibration of the deck over a range of frequencies as the revolutions per minute of the motor increased.

continued

"Vibration testing aids inspectors by identifying trends in the structural integrity of the timber that indicate early deterioration."

–Brian Brashaw,
Program Director,
National Resources Research Institute,
University of Minnesota Duluth

"Wood rots from the inside out. With vibration testing, we can get a heads-up before the response becomes a knee-jerk reaction."

–Chris Morris,
Bridge Engineer,
St. Louis County

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Researchers examined the potential for using vibration testing to assess the structural health of dowel-laminated bridge systems—wooden bridges constructed with laminated timbers held together transversely by metal dowels and supported by a spreader beam.

Researchers tested the deck panels of Bridge 53 in St. Louis County prior to, during and after construction, measuring the vibration characteristics of the bridge members throughout the assembly process. They also tested 12 other existing dowel-laminated bridge spans in northern Minnesota of varying ages.

Earlier versions of the vibration testing system relied significantly on operator expertise, and many individual steps were required to obtain and analyze the data. Researchers improved and automated the system using a ruggedized laptop running LabVIEW Windows to control the testing equipment and acquire the data.

What Did We Learn?

The vibration testing showed that the system developed is an effective tool for conducting forced vibration tests. The data acquisition and analysis system easily found the three signature vibration frequencies during each stage of the construction of Bridge 53 and showed that these frequencies increase significantly over the stages of construction. This confirms and quantifies the expectation that vibration testing could probe the bridge's rigidity.

The automated system performed similarly well on the 12 other bridges tested, automatically identifying three peaks in vibration amplitude over a range of vibration frequencies from 14 to 35 Hz. Researchers expect that monitoring the vibration characteristics over time would reveal structural changes correlated with decreasing resonant frequencies that would indicate worrisome deterioration within the bridge. Precise correlation of the level of deterioration with a given set of resonant frequencies requires further study.

What's Next?

Researchers hope to correlate the vibration response of a bridge with various levels of deterioration by building a bridge and tracking the vibration characteristics while forcing rapid decay of the bridge. Additionally, researchers are trying to use advanced monitoring techniques to assess the pilings of the bridges for early decay and rot. Funding for these projects is under consideration.

This Technical Summary pertains to the LRRB-produced Report 2009-40, "Development of Flexural Vibration Inspection Techniques to Rapidly Assess the Structural Health of Rural Bridge Systems: Phase II," published December 2009. The full report can be accessed at http://www.lrrb.org/PDF/200940.pdf.

This study is a continuation of the Northland Advanced Transportation Systems Research Laboratory-funded project CTS 08-22, "Development of Flexural Vibration Inspection Techniques to Rapidly Assess the Structural Health of Rural Bridge Systems." The final report for this project can be accessed at http://www.cts.umn.edu/Publications/ResearchReports/reportdetail.html?id=1692.