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Dynamic Evaluation of Wood Bridges

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Abstract

A project to investigate the dynamic behavior of wood bridges was recently initiated by Iowa State University; the USDA Forest Service, Forest Products Laboratory; and the Federal Highway Administration. The first phase of this project will involve the evaluation of stress-laminated bridge decks to determine dynamic characteristics. This paper describes the background, objectives, and research methods for this project.

Introduction

Wood has been used as a bridge material in the United States for hundreds of years. Despite the exclusive use of wood bridges during much of the 19th century, the 20th century has brought a significant decline in the percentage of wood bridges relative to those of other materials. At the present time, approximately 10% of the bridges listed in the National Bridge Inventory are wood (FHWA 1992). Recently, there has been a renewed interest in wood as a bridge material and several national programs have been implemented to further develop wood bridge systems. As a result of the

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Timber Bridge Initiative and the Intermodal Surface Transportation Efficiency Act, which were passed by Congress in 1988 and 1991, respectively, funding has been made available for timber bridge research (Duwadi and Ritter 1994). A portion of this research is aimed at refining and developing design criteria for wood bridge systems. As part of this effort, a project to investigate the dynamic characteristics of several different types of wood bridges has been initiated as a cooperative research study between Iowa State University, the Forest Products Laboratory, and the Federal Highway Administration. The first phase of the project to assess the dynamic characteristics of stress-laminated deck bridges is described in this paper.

Background

Highway bridges must be designed for the dynamic loads imposed by passing vehicles. Traditionally, bridges have been designed for static loads and a factor is applied to increase loads to compensate for the dynamic effects. In the current American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Highway Bridges, the dynamic allowance is applied as an impact factor (AASHTO 1992). The impact factor is computed based on span length and is limited to a maximum of 1.3. Historically, AASHTO has not required the application of the impact factor to wood bridges because of the ability of wood to absorb shock and carry larger loads for short durations than for long periods.

Recently, the exclusion of wood bridges from dynamic loading requirements has been questioned. Many in the design community feel that some adjustment for dynamic effect is appropriate for wood bridges. Unfortunately, little information is available to support changes to current design standards. Although a great deal of analytical and experimental research has been focused on the dynamic characteristics of steel and concrete bridges, very little has been done on wood bridges. To develop accurate dynamic design criteria for wood bridges, research is needed to characterize and quantify dynamic characteristics for different wood bridge types.

Objective and Scope

The objective of this phase of the project is to experimentally determine the dynamic characteristics of stress-laminated wood bridge decks and develop an analytical model that accurately predicts dynamic behavior. The project scope will involve field testing and analytical modeling of 8 to 10 stress-laminated wood decks with different geometry, material, and roadway approach conditions to determine static and dynamic response. This information will be used to develop recommendations for strength and serviceability design criteria for potential inclusion in the AASHTO Standard Specifications for Highway Bridges.

Research Methods

The research methods for this project will be considered in two areas, experimental methods and analytical methods.

Experimental Methods

The experimental portion of the project will involve field load testing of 8 to 10 stress-laminated bridges to determine bridge behavior. Testing will utilize three-axle dump trucks loaded to approximately the legal limit. The vehicles will be placed on the bridge in different transverse positions depending on the bridge width. On two-lane bridges two transverse positions will be used: one with the vehicle centered on the bridge cross section and one with the vehicle in the designated lane. For single-lane bridges only the centered load position will be used. On all bridges, vertical bridge displacements will be measured at centerspan and quarterspan locations at a number of transverse locations. Static and dynamic displacements will be measured at common locations for comparison purposes. The displacement data will be collected using direct current displacement transducers (DCDTs) and an electronic data acquisition system. For static testing, displacement readings will be taken before, during, and after vehicle loading. For dynamic testing, displacements will be measured every 0.01 seconds as the test vehicle crosses the bridge. The vehicle velocity and location during dynamic testing will be monitored using tape switch transducers placed at various locations along the bridge length.

For static testing, the vehicle will be placed longitudinally on the bridge to produce the maximum displacement at centerspan. For dynamic testing, several cases will be considered for different vehicle speeds and approach roadway conditions. Initially, the test vehicle will be run across the bridge at a crawl speed (approximately 8 km/h) to produce a non-dynamic load displacement profile. Tests will then be made at several incremented vehicle velocities within the posted speed limit and safe operating limit for the site. This series of dynamic tests will be conducted using existing approach roadway conditions. The road approach roughness will then be changed to a “rough” condition and displacements will be measured again at the same vehicle positions and test velocities previously used. The “rough” condition will be obtained by placing an artificial bump on the approach end of the bridge to cause an increase in dynamic response.

Analytical Methods

In addition to the experimental portion of the project, analytical work will be completed to model bridge dynamic response. Each of the bridges will be modeled using the commercially available finite element program ANSYS. The predicted response will be compared to the measured response to verify the analytical model. The model will then be used to provide further information on bridge response at locations other than those monitored during experimental work. Additionally, analytical work will be completed to evaluate the response of bridges with different geometry, material (wood species), and roadway approach conditions.

Presentation of Results

The results of the project will be presented in a final report that will be prepared at the conclusion of the experimental and analytical work. Plots of bridge displacement at a particular location versus the vehicle location along the span will be generated. The longitudinal dynamic response will be characterized by comparing these plots for static and dynamic load tests for DCDT locations along the length of the bridge. Transverse effects will also be determined by comparing similar responses at transverse DCDT locations. The effects of vehicle velocity and road approach roughness will be determined from the corresponding load tests and the crawl speed loading.

The effect of dynamically loading the structure will be presented as a dynamic amplification factor computed as the ratio of the maximum dynamic displacement to the corresponding static displacement at the same location. Based on experimental and analytical determinations of the dynamic load factor for various conditions, recommendations will be formulated for strength and serviceability dynamic design criteria.

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