PUTTING RESEARCH TO WORK **BRIEF**

Reliability-Based Inspection Intervals for Sign Supports

While the latest AASHTO design specifications for sign support structures, issued in 2001, include provisions for fatigue design of structural supports, Wisconsin has many sign support structures in service that were designed before these fatigue provisions were issued.

WisDOT recently encountered problems with two smaller sign support structures designed before 2001, which raised concerns about similar structures now in service. Inspection of a failed sign support structure revealed that recently installed bolts were loose, leading to premature fatigue failure. In a second case, a routine inspection discovered a welded connection that exhibited cracking over 50 percent of its circumference, which was not present at the last scheduled inspection. WisDOT would like to determine why these structures failed, and identify design changes and retrofit measures that could have prevented the failures—and that could prevent similar problems in the future.

What's the Problem?

A previous WHRP study, Project 0092-00-16, "Structural Analysis of Sign and Luminaire Support Structures," evaluated the performance of overhead full-span sign support structures. Other research has examined cantilevered sign support structures and considered potential causes of unsatisfactory performance. Reliability-based research on smaller sign support structures, like the two that recently encountered problems, has yet to be completed.

If WisDOT can quantify when smaller sign support structures designed before 2001 are likely to begin to show signs of fatigue-induced cracking, inspection intervals can be based on reliable statistical models rather than a uniform four-year inspection cycle.

Research Objectives

The objectives of this three-phase research effort include:

- Applying fatigue reliability analysis along with current knowledge of fatigue lives of connections to assess fatigue-induced fracture risk in WisDOT's sign support structures.
- Recommending the most effective retrofit strategies in instances where fatigue-induced fracture is likely.
- Assigning inspection cycle frequencies for sign structures and their components.

In the project's first phase, researchers focused their efforts on collecting and synthesizing data. This analysis will lay the groundwork for additional testing and recommendations as the project continues.

Methodology

Working with WisDOT staff, researchers selected for study several types of connections and structure configurations that are commonly used in sign support structural systems throughout the state. Both the bolted and welded parts of the connections were evaluated.

Researchers gathered and synthesized fatigue testing data from related research projects, looking for connection details similar to those found on Wisconsin sign support structures. Fatigue testing data included test results for connections that had been treated with retrofit measures designed to improve connection performance. These included ultrasonic impact treatment, a proprietary system of metal improvement that uses ultrasonic energy; and mechanical peening, a process that uses hammers to work a metal's surface to improve its material properties and improve fatigue life. Researchers reviewed related studies to further assess potential retrofit measures.

To allow for analysis of stresses and strains caused by wind, researchers compiled historical wind speed and direction data from the National Climatic Data Center for eight Wisconsin cities. Using this

Investigator

"This project is the first comprehensive, reliability-based analysis of sign support structures. That analysis is important for understanding performance and setting appropriate inspection intervals."

–Christopher Foley
Marquette University
chris.foley@marquette.edu

This double-arm sign support structure over Wisconsin Avenue at Interstate 43 in Milwaukee is an example of the type of sign support being evaluated.

data, researchers developed a database of wind speed and direction models that can be used for fatigue life simulation, and identified locations that may be suitable for in-field monitoring.

Results

Results from the first phase of the research effort determined the design of the project's next phases:

Phase II: In the lab, researchers will create connection configurations that simulate those used in the field, then subject them to loading cycles that replicate the stress ranges resulting from wind or truck-induced gusts until the connections show fatigue cracking. New tests at stress ranges of 6 ksi and 15 ksi will supplement other researchers' test results and allow for strengthening of the statistical models used to predict fatigue life.

Researchers will apply retrofit measures to some of the cracked specimens, and then subject the specimens to additional loading cycles to determine the retrofit measures' effectiveness. Retrofit measures to be tested may include mechanical hammer peening or the MBX Bristle Blaster, a new tool used for corrosion removal that may serve as a portable method of mechanically peening the surface of the base metal to smooth geometric discontinuities resulting from welding.

In the field, researchers will select and instrument one or two signs in Green Bay or Milwaukee, areas where Phase I analyses indicated the presence of sustained winds from a variety of directions. Field data will be used to validate the results of a probability model for average wind speed distribution.

Phase III: Researchers will develop a handbook of effective retrofit measures and recommended inspection cycle frequencies using the results of Phase II's lab testing and field instrumentation. In addition, some Phase II field studies will be finalized during Phase III.

Benefits

This project contributes to the eventual creation of appropriately timed inspection cycles for WisDOT sign support structures that can mitigate the risk of fatigue failure—saving money, assuring safety and limiting inconvenience to the motoring public. Application of effective retrofit measures will also contribute to improved fatigue life of sign support structures.

Further Research

Researchers have begun work on Phase II of this project; Phase III is expected to conclude by fall 2011.

This brief summarizes Project 0092-08-14, "Fatigue Risks in the Connections of Sign Support Structures: Phase I," produced through the Wisconsin Highway Research Program for the Wisconsin Department of Transportation Research Program, 4802 Sheboygan Ave., Madison, WI 53707.

Daniel Yeh, WisDOT Research and Communication Services

Project Manager

"The results of this multiphase research effort will enable WisDOT to modify its inspection cycles using a risk-based analysis, providing for a more efficient, cost-effective approach to the inspection process."

–Travis McDaniel
WisDOT Bureau of Structures
travis.mcdaniel@dot.wi.gov

Co-investigators:
Baolin Wan, Mathew Weglarz, Matthew Hellenthal, Jordan Komp, Andrew Smith and Joseph Schmidt, Marquette University

Brief prepared by
CTC & Associates LLC
ctcandassociates.com