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PUTTING RESEARCH TO WORK

BRIEF

Monitoring Loading and Environmental Effects on Bridge Performance

In 2002, Wisconsin completed construction of the Land Bridge on WIS 131, the first bridge in the state to use high-performance steel, or HPS, which is lighter and easier to weld than regular steels and more resistant to fatigue, fracture, weather and corrosion. Prior to construction of the bridge, the researchers for the current study performed laboratory tests to evaluate the fatigue resistance properties of the steel to be used. These tests are discussed in the report "Fatigue Strength of Steel Beams with Hybrid HPS70W/A588W," sponsored in part by the Innovative Bridge Research and Construction Program of the Federal Highway Administration. The report is available from the WisDOT Library.

What's the Problem?

A pilot project was initiated to assess the performance of the HPS bridge members as well as to evaluate the response of the structure to actual traffic and environmental loads under in-service conditions through monitoring of strain, temperature and displacement. Monitoring of an actual bridge provided an opportunity to validate the laboratory values obtained in the earlier study and supply WisDOT with additional tools to evaluate the specifications for design and construction of bridges using HPS. Both AASHTO's standard specifications for bridge design and the recently implemented Load and Resistance Factor Design specifications, or LRFD, assume the use of non-HPS steels. This pilot project and related research provided a case study to assess the impact on these design methods of using a material with improved properties.

Research Objectives

The two primary goals of the structural monitoring program implemented in this study were to evaluate the in-service stresses of the Land Bridge and to determine the actual load distribution caused by truck wheels on the bridge deck and tub girders.

Methodology

Researchers monitored the Land Bridge from 2004 to 2008 to evaluate stress cycles caused by both live and thermal loads. Live loads such as moving traffic are temporary with a relatively short duration; thermal loads involve strains in steel due to expansion and contraction with daily and seasonal temperature cycles. To evaluate the impact of dynamic and environmental loading, researchers instrumented the inside of the bridge's box girders to measure:

- **Strain,** using electrical resistance and vibrating wire strain gages, which evaluate stresses to a structure by detecting very small deformations and movements within it.
- **Temperature,** using thermistors, of both the bridge's steel and surrounding air.
- **Displacement,** using linear variable differential transformers, measuring the bending of the bridge at its midpoint caused by traffic loads and changes in the bridge's length caused by thermal expansion.

Finally, researchers evaluated how loads were distributed on the Land Bridge. For a given bridge design, AASHTO specifications allow engineers to determine how loads will be distributed among components, and the maximum load each component can withstand before failure. These design equations apply only to straight box girders. The Land Bridge is unique in that its box girders are slightly curved, providing actual field data on the load distribution caused by the use of curved box girders.

To evaluate load distribution, researchers conducted both field testing and a three-dimensional

Investigator

"The results of this study showed that the current AASHTO specifications yield only approximate wheel load distribution factors for curved box girder bridges. Additional research might provide more accurate factors."

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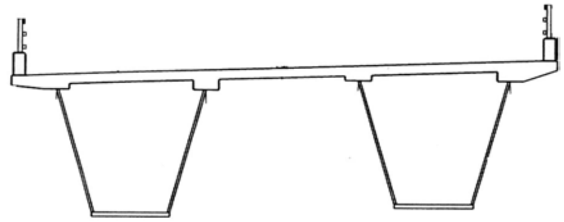
East side of bridge, looking north



Section through bridge, looking north

Wisconsin's first bridge using high-performance steel was completed in 2002 on WIS 131, between Ontario and Lafarge. Called the Land Bridge, it spans about 275 feet and is supported by two side-by-side box girders—hollow beams with box-shaped trapezoidal cross sections.

computer simulation, and then compared these results to the load distribution predictions calculated using both AASHTO standard and LRFD equations. Field tests involved using the installed strain and displacement sensors to evaluate the effects of loading the bridge with trucks of a given axle weight and spacing in 15 different configurations of placement and speed.

Results

Structural monitoring showed that live load stresses were small and infrequent, with traffic load patterns not changing significantly over the four years of monitoring. Though fewer in quantity, thermal stress cycles were greater in magnitude, including those caused by differences in thermal expansion between parts of the bridge exposed to the sun and those in shadow. Both traffic and thermal stresses were smaller than the fatigue stress threshold values prescribed by AASHTO, implying an infinite design life.

The load distribution study showed strong agreement between field tests and computer modeling. However, the different design procedures yielded varying abilities to predict actual load distributions. AASHTO standard specifications yielded predictions that were overly conservative, with values that were approximately 30 percent higher than those given by the field tests and computer modeling results. Conversely, AASHTO LRFD specifications were not conservative enough, underestimating load distributions by approximately 12 percent. Researchers concluded that these discrepancies were due to fundamental differences between the design methodologies and because both sets of design specifications were not intended for use with curved box girders, and thus could only provide approximate load distribution factors for the slightly curved tub girders used on the Land Bridge.

Benefits, Implementation and Further Research

Researchers found that thermal stresses can be substantial and recommended that further research on thermal effects be conducted on structures that are larger and more heavily traveled than the Land Bridge. Because AASHTO standard and LRFD specifications currently cannot provide adequate calculations of live load distributions for curved box girders, researchers also recommended further research in this area.

Project Manager

"We were impressed by the magnitude of the thermal stresses seen in this study; they were far greater than we imagined."

–Travis McDaniel
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