Oregon Department of Transportation

Assessing the Load Capacity of Oregon's Aging Bridges

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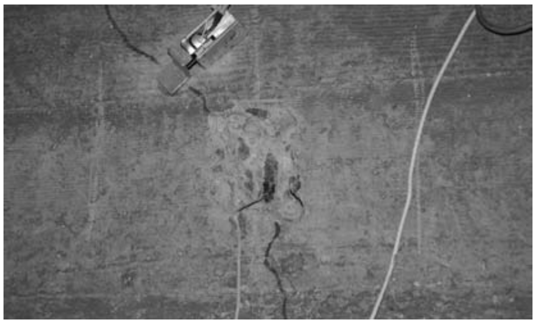
Oregon underwent a boom in bridge construction during the 1950s and 1960s—the era of building the Interstate highways. The bridge of choice in Oregon was the cast-in-place, reinforced concrete deck girder (RCDG) bridge, following the specifications of the American Association of State Highway Officials.[1] In the early 1960s, other states started to build bridges with prestressed concrete. But because of its success with the model, Oregon continued to construct RCDG bridges in accordance with the design codes.



Cracked RCDG bridges were instrumented and monitored.

Problem

The design specifications for RCDG bridges 50 years ago were based on truck loads and traffic volumes that were much lower than those in traffic today. In addition, the accepted practice at that time did not conservatively account for the stresses that beams must accommodate in service. As a result, cracking is common in Oregon's Interstate-era RCDG bridges.

The situation became a priority for the state in 2001, when in-depth inspections revealed the extent of the problem. Of the 555 RCDG bridges owned by Oregon, 487 had structural cracks.

The understanding was that the stresses in some of the reinforcing steel in a cracked reinforced concrete girder could be large enough to cause failure in certain circumstances. In addition, engineers were concerned that the repeated opening and closing of cracks caused by traffic could lead to metal fatigue in the steel reinforcement. Fatigue failure was particularly worrisome, because no visible warning would precede the fracture of an embedded steel bar.

More cracks and wider cracks were considered indications of greater damage and of reduced load capacity. Consequently, the number of bridges with load restrictions increased rapidly as the extent of the problem unfolded, growing from 68 bridges in 2001 to 140 in 2003. Billions of dollars would be needed to repair and replace bridges to maintain freight mobility and highway safety.

[1] As of 1973, the American Association of State Highway and Transportation Officials. *Standard Specifications for Highway Bridges*, published since the mid-1920s, is now in its 17th edition.

Solution

In 2002, the Oregon Department of Transportation (DOT) contracted with Oregon State University to investigate the load capacity and fatigue damage of cracked RCDG bridges. The researchers installed instruments on in-service bridges to determine the stresses on the steel reinforcement in cracked girders. The measurements were made for weeks under ambient traffic conditions and with truck loads of known axle weights. The data were used in computer models and were incorporated into the laboratory portion of the research.

Replicas and Ratings

The researchers constructed full-size replicas of the vintage girders. The replica beams followed the detailing and construction practices of 50 years ago, and concrete and steel were specially ordered to approximate the lower materials strengths of that era. Internal and external sensors were incorporated to monitor the behavior of the beams during the tests.

The replica beams were precracked and loaded to the point of failure, following a protocol that characterized the beam behavior at several load levels. Some beams were subjected to 2 million load cycles—the equivalent of 50 years of heavy truck traffic—before loading to failure.

The research results conclusively indicated that the steel reinforcement in cracked RCDG bridges was not undergoing fatigue damage. Furthermore, cracks did not necessarily indicate that a girder had lost load capacity; in short, the crack density and the crack size were not good indicators of damage level. Instead, the findings showed that the key to load capacity was the detailing of the steel reinforcement, especially how well the longitudinal steel bars that run the length of the beam were anchored at the ends of the beams.

Research revealed that the calculations for the load and resistance factor rating (LRFR)—the newest code for rating bridge capacity—accurately accommodate the effects of cracks. The state-of-the-art load-rating method incorporates realistic operating conditions to achieve rational, consistent, and safe load-rating results.

State-Specific Factors

The LRFR method incorporates consideration of traffic loading or live loads—particularly truck loading—with data that are representative of heavy truck traffic nationwide. The code allows jurisdictions to use their own truck weight data, however, if the local data will result in calculations that have the same reliability.

Researchers at Oregon State University developed a method to analyze Oregon's weigh-in-motion (WIM) data that met the requirements of the LRFR code. Contributing to the quality of the WIM data were state policies that allowed trucking firms easy access to obtain heavy load permits, good enforcement of weight regulations, and few alternatives for truckers to avoid scales. The researchers therefore were able to use the state's WIM data to characterize with a high degree of confidence the heavy live loads that Oregon bridges may experience.

The Federal Highway Administration has approved Oregon DOT's use of the Oregon-specific live-load factors for state highway bridges. Because Oregon DOT is able to quantify its heavy truck traffic so well, Oregon's new live-load factors are less stringent than the national factors, but the state's level of safety remains consistent with that of the rest of the nation. Some bridges that previously had a marginally insufficient load rating and were slated for repair or replacement have been load-rated again and shown to have adequate capacity.

Application

Oregon DOT has adopted the LRFR with Oregon-specific live-load factors, confident that the method provides a high degree of reliability and safety in rating the many cracked RCDG bridges in the state. No extraordinary considerations need to be imposed for metal fatigue.

The shift to LRFR has improved the load rating values for many of the cracked RCDG bridges rated as insufficient under the previous method. As a result, 120 bridges were removed from the list of those to be replaced, and 80 bridges were shifted from the list of those to be repaired or replaced to the list of those that require no work.

Laboratory tests were conducted on large-size, replica beams.

Benefits

From 2001 to 2003, the Oregon legislature allocated nearly $1.8 billion for bridge repair and replacement. After reevaluating the bridge work, Oregon DOT estimates that approximately $0.5 billion dollars can be reallocated from the initial set of bridges designated for repair or replacement to other needed bridge improvements. The research has provided Oregon DOT with a good understanding of the structural health of its aging, cracked RCDG bridges and has helped the agency develop a long-term strategy to address the challenge.

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Additional Resources

Assessment Methodology for Diagonally-Cracked Reinforced Concrete Deck Girders, October 2004. ftp://ftp.odot.state.or.us/tdb/Research/_PUBLISHED%20REPORTS_/Assessment%20Methodologies%20for%20Cracked%20RCDGs/.

Calibration of Live-Load Factors Using Weigh-in-Motion Data, June 2006. www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/LiveLoadFactors.pdf.

Remaining Life of Reinforced Concrete Beams with Diagonal Tension Cracks, April 2004. www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/SPR341.pdf.

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Suggestions for "Research Pays Off" topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (telephone 202-334-2952, e-mail gjayaprakash@nas.edu).