

RESEARCH UPDATE

SEPTEMBER 2011

Reducing Bridge Beam End Cracking

Concrete bridge beams need to be strong enough to support the traffic that crosses a bridge throughout its service life. To reinforce these beams, workers cast the concrete around stretched steel strands. As the concrete hardens, it bonds to these strands and holds them in this stretched position, introducing internal stresses into the beam that help it counteract stresses from traffic loads and the weight of the beam itself. This type of concrete is called prestressed concrete.

While these internal stresses are useful for much of the length of the beam, they



Traditional soft sheathing on the ends of prestressing strands (left) was not producing the desired debonding effect in bridge beams. The use of rigid tubing (right) as an alternative made the difference.

are unwelcome at the ends, where they can lead to cracking. Consequently, engineers cover a portion of the ends of the steel strands in plastic sheathing. This prevents these portions of the strands from bonding with the concrete and applying stresses to the beam ends.

Unexplained cracking

Despite the use of plastic sheathing for strand debonding, cracking has been observed in recent years at the ends of prestressed concrete bridge beams. MDOT considered possible causes such as design flaws, poor quality materials or manufacturing errors, but it was determined that specifications were being faithfully followed at every stage of the process.

MDOT initiated an investigation to identify the causes of beam end cracking, assess whether the soft sheathing material used for debonding was achieving the desired effect, and determine whether using more rigid tubing as an alternative sheathing material would produce a

higher degree of debonding. The study was conducted by researchers from Michigan State University.

Understanding the problem

To understand the causes of end cracking and the mechanics of the materials involved, investigators:

- Conducted laboratory tests to characterize steel strands in various degrees of bonding with concrete. This included a study of the mechanical interlock between materials and the presence or absence of bonding behavior.
- Created and tested small-scale bridge beams to examine stress transfer behavior of bonded and debonded strands. The tests used both traditional soft sheathing and alternative rigid sheathing.
- Used computer modeling and numerical simulation of the materials and their interaction to explain and verify effects seen in the lab and the field.

In This Issue: Building a Better Bridge

This issue of *Research Update* focuses on bridges, spotlighting MDOT innovations in bridge preservation made possible through research.

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Reducing Bridge Beam End Cracking

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Prestressing strands are placed in the support formwork before the concrete is cast.

A cost-effective solution

Researchers found that soft sheathing did not completely prevent bonding between the concrete and the strand ends, causing excess stress and cracking. The results of the lab tests and the models were in close agreement, and they demonstrated that the damage was compounded when multiple strands were close to one another.

Researchers also found that replacing soft sheathing material with more rigid tubing would help reduce cracking. The alternative material proved to be an effective way to create more clearance between the steel and the concrete and ensure debonding. This solution carries a small tradeoff in ease of beam construction: The rigid sheathing lacks a split seam along its length that facilitates the application of traditional soft sheathing.

MDOT's bridge committee is evaluating research recommendations to require use of rigid sheathing to achieve the desired debonding effect. Department specifications would not typically call out debonding material at this level of detail, but this research shows that doing so could be a cost-effective solution to bridge beam end cracking.

For more information

Read more about this research project—"Effects of Debonded Strands on the Production and Performance of Prestressed Concrete Beams"—in the *Research Spotlight* available at www.michigan.gov/documents/mdot/MDOT_Research_Spotlight_Debonded_Strands_356315_7.pdf. The research report is available online at www.michigan.gov/documents/mdot/MDOT_Research_Report_RC-1546_354418_7.pdf.

Solid Tubing Makes the Difference

The results of MDOT's investigation of strand debonding confirms experience in the field—concrete bridge beams that meet all production criteria can still encounter problems.

In 2005, MDOT inspectors for the bridge replacement project on I-94 over the Red Arrow Highway in the city of Bridgman identified cracking or spalling in some of the precast concrete box beams produced for the project.

An investigation revealed that although inspectors attributed some of the beam cracking to handling and transport, the beams met design specifications and no issues were found with quality control. New beams produced using an alternate debonding material—solid tubing rather than a slit sheathing—did not exhibit the cracking.



In lab testing, prestressing strands are released at both ends of the beam simultaneously.

Improving Bridge Deck Repair Strategies

As bridge decks age, MDOT must make decisions about how and when to repair them with limited resources. Such decisions require good data about the condition of decks and the anticipated costs and benefits of different repair options.



Investigators verified their damage detection algorithms with the aid of artificially delaminated concrete slabs.

A recent two-part project by MDOT, “ECR Bridge Decks: Damage Detection and Assessment of Remaining Service Life for Various Overlay Repair Options,” focused on developing data and data collection methods for bridges that are strengthened using epoxy-coated reinforcement (ECR) bars.

Automating testing

The first part of this project developed a new method for detecting bridge delamination, the internal cracking and separation between the top concrete layer of a bridge deck and the upper reinforcing steel bars. Because current methods for detecting delamination are labor-intensive and subjective (does it sound hollow when a chain is dragged across the surface?), researchers aimed to automate this process.

They developed a prototype device that uses a sounding rod to impact the bridge deck surface, microphones to receive the resulting sound, and a computerized sound processing system to determine whether delamination is present beneath a given location. While the system is not yet ready for regular service in the field, further development could produce a device that saves MDOT time and money while producing more accurate results.

Quantifying the benefits

The second part of this project focused on quantifying the benefits of bridge decks that have been reinforced with epoxy-coated bars over those that have been reinforced with regular black steel. To do so, researchers exposed concrete test specimens reinforced with both ECR and black steel to artificial weathering and simulated traffic, and then conducted tests to measure stiffness, corrosion and cracking.

Results showed that the estimated life expectancy for bridge decks reinforced with ECR was 2.6 times longer than for decks reinforced with black steel. With this number in hand, MDOT will be able to adjust its bridge deck maintenance schedules to allow for the longer expected service life of bridge decks constructed with ECR. The results may also support changes to future rehabilitation strategies for ECR bridge decks; it may be wise to postpone or skip deep overlay rehabilitation to take full advantage of ECR's long life.

Ultimately, both parts of this project have added to the data and methods MDOT needs to fine-tune its bridge deck repair strategies and make the most efficient use of its limited resources.

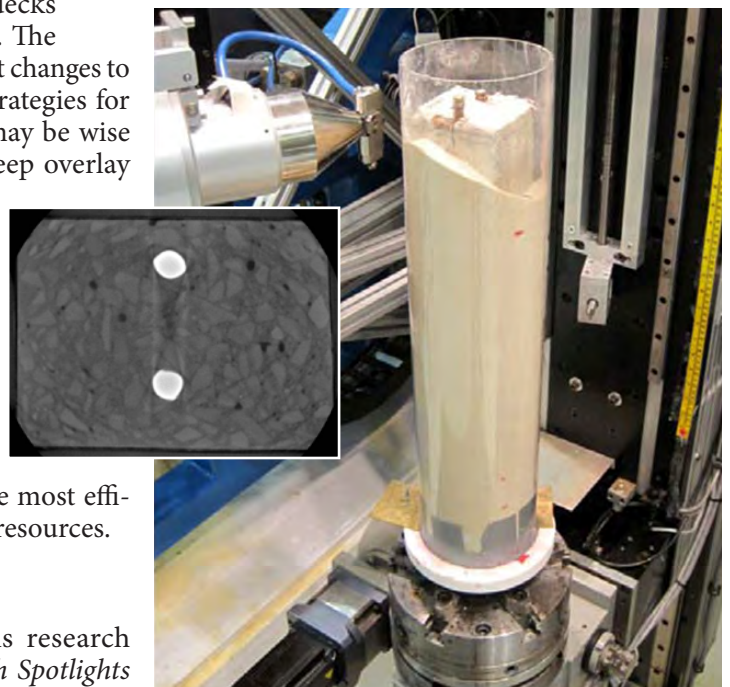
For more information

Read more about this research project in the *Research Spotlights*

available at www.michigan.gov/documents/mdot/MDOT_Research_Spotlight_ECR_Bridge_Decks_Part_1_356768_7.pdf (Part I) and www.michigan.gov/documents/mdot/MDOT_Research_Spotlight_ECR_Bridge_Decks_Part_2_356769_7.pdf (Part II). The research reports are available online at www.michigan.gov/mdot/0,1607,7-151-9622_11045_24249-257449--,00.html.



Researchers subjected ECR specimens to fatigue tests in the lab.



X-ray tomography was one of several methods used to evaluate the performance of ECR specimens. Inset: A representative X-ray cross section; the white circles are the ECR bars.

National Trends

Precast Components Accelerate Bridge Construction

You see the cranes, you hear the trucks, but you can't quite believe you're going to have to drive a mile out of your way just to get around an 80-foot bridge span under construction. Detour routes can be tedious and are often in place for months of required construction time.

A new approach

To accelerate bridge construction and shorten user delay, MDOT has been exploring the use of prefabricated bridge element systems (PBES). PBES uses fully cast prefabricated bridge components shipped to the construction site and erected by crews. This eliminates the need to construct elaborate forms, sometimes at significant heights, pour concrete, and wait weeks for it to cure. Prefabricated bridge elements may shorten construction time, reduce the time crews spend in hazardous settings, lessen environmental impacts to sites and reduce inconvenience to motorists.



Crews work to place a precast panel so they can secure it and continue assembling a bridge abutment.

The technology has been developing for years. "We're taking innovations that are already out there and putting them to use," says Peter Jansson, MDOT structural fabrication engineer. A number of other states have been doing the same, encouraged by the Every Day Counts (EDC) initiative of the Federal Highway

Administration (FHWA). The EDC initiative promotes the adoption of proven technologies to shorten project delivery time, enhance highway safety and protect the environment.

Expanding the use of PBES in Michigan

"We are working to meet the FHWA objectives," explains David Juntunen, MDOT bridge operations engineer, "but MDOT has long been interested in prefabricated bridge element systems."

In 2008, the 250-foot, four-span bridge on Parkview Avenue in Kalamazoo was completed using precast elements for the entire structure above the footings. Although some time savings were lost because of fabrication errors involving the unique deck panels, the project would have taken considerably longer with traditional technologies. Using precast abutment segments—some of which took only eight minutes to place—pier caps, and other elements, bridge crews avoided extensive formwork and curing time that would have impacted the traveling public.

As designers, fabricators and builders become more familiar with PBES technology, costs are expected to come down to approximate those of cast-in-place methods. More than a dozen MDOT bridge projects scheduled from 2007 through 2014 are using PBES of some sort, according to Juntunen.

"Our hope is that they will perform as well as or even better than bridges built with traditional methods," says Juntunen.

MDOT has supported three research projects related to PBES using State Planning and Research funds:



"Designers need to make a paradigm shift from cast-in-place designs to prefabricated element designs."

—David Juntunen
MDOT Bridge Operations Engineer

- "Improving Bridges with Prefabricated Precast Concrete Systems" (completion date: fall 2012)
- "Development and Validation of a Sensor-Based Health Monitoring Model for the Parkview Bridge Deck" (completion date: winter 2012)
- "A Sensor Network System for the Health Monitoring of the Parkview Bridge Deck" (final report available online at www.michigan.gov/documents/mdot/MDOT_Research_Report_RC1536_317702_7.pdf)

For more information

FHWA's Every Day Counts program is working with transportation agencies across the country to accelerate deployment of PBES and other innovative technologies. Learn more about PBES at the Every Day Counts Web site at www.fhwa.dot.gov/everydaycounts/technology/bridges/.

Research in Progress

Prioritizing Bridge Maintenance with Computer Models



A research project expected to conclude in October 2012 will help prioritize bridge maintenance projects like this one in Cheboygan County.

Deterioration of reinforced concrete bridge decks remains a challenge for state DOTs around the country, including MDOT. In climates that require the use of deicing materials in winter, chloride penetration through cracks in deteriorated decks leads to steel reinforcement corrosion as well as concrete cracking and spalling.

In October 2009, MDOT began work on developing more effective models for anticipating and evaluating concrete bridge deck deterioration. Under the direction of Michigan State University's Rigoberto

Burgueño, associate professor of structural engineering, the research team is assessing deterioration mechanisms and evaluating various computational and mechanistic models of deterioration. The research is using National Bridge Inventory data to identify artificial intelligence models that will best suit MDOT's needs, including life-cycle cost analysis models to help recommend and prioritize maintenance activities on existing decks.

This research includes the creation of software capable of modeling the complex deck deterioration process. Researchers are establishing effective models of corrosion initiation and propagation, and the study remains on schedule for completion in October 2012.

Contact Project Manager Pete Jansson at janssonp@michigan.gov to learn more about this ongoing project.

Current MDOT Bridge Research

Project Title	Start Date	End Date
High Skew Link Slab Bridge System with Deck Sliding Over Backwall or Backwall Sliding Over Abutments	Fall 2008	Fall 2011
Investigate Causes and Develop Methods for Preventing Falling Concrete from Bridge Decks or Falling Deck Concrete Hazards: Reasons, Detection and Mitigation	Fall 2009	Spring 2012
Identification of Causes and Solution Strategies for Deck Cracking in Jointless Bridges	Fall 2009	Winter 2012
Development and Validation of Models for Concrete Bridge Decks	Fall 2009	Fall 2012
Review and Revision of Overload Permit Classification	Fall 2010	Spring 2012
Implementation of Sustainable and Green Design and Construction Practices for Bridges	Fall 2010	Fall 2012
Improving Bridges with Prefabricated Precast Concrete Systems	Fall 2010	Fall 2012
Development and Validation of a Sensor-Based Health Monitoring Model for the Parkview Bridge Deck	Winter 2010	Winter 2012
Evaluation of Prestressed Concrete Beams in Shear	Fall 2011	Fall 2013
Side-by-Side Probability for Bridge Design and Analysis	Fall 2012	Fall 2013
Evaluating Prestressing Strands and Post-Tensioning Cable in Concrete Structures Using Nondestructive Evaluation (NDE) Methods Including Joint Shear Wave Analysis	Fall 2012	Fall 2014
Design and Construction Guidelines for Strengthening Bridges Using Fiber-Reinforced Polymers (FRP)	Fall 2012	Fall 2014
Remote Monitoring of Fatigue-Sensitive Details on Bridges	Fall 2012	Fall 2014
Evaluation of Bridge Decks Using Nondestructive Evaluation (NDE) at Near Highway Speeds for Effective Asset Management	Fall 2012	Fall 2014

Program News

Department structure: We are pleased to announce that MDOT's research program is now part of the Bureau of Field Services. This places research with field services and field operations in a bureau that includes MDOT region staff and statewide bridge and pavement experts. This new structure will help further align research projects with MDOT's statewide needs.



"I look forward to my work on SCOR as an opportunity to bring focused attention to MDOT's strategic research priorities and help guide the path of transportation research at the national level."

—Greg Johnson
MDOT Chief Operations Officer

Committee appointment: Greg Johnson, MDOT chief operations officer, was recently appointed to a four-year term as one of the four Midwest representatives on the American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on Research (SCOR). The 16-member committee is made up of four members from each of the association's four regions; members may be reappointed once.

This committee plays a critical role as AASHTO's driving force for transportation research and innovation, representing the association's interests in research activities for all modes of transportation.

In one of its key responsibilities, SCOR serves as program manager for the National Cooperative Highway Research Program (NCHRP)—an applied research program collaboratively funded by state DOTs at a level of approximately \$40 million per year. NCHRP's focused, problem-solving research addresses areas such as highway planning, design, construction, operation and maintenance.



VISION: *To be a recognized leader in coordinating applied research and implementing results by identifying cutting-edge research topics, implementing research results and coordinating development of research projects. Our core strength results from a highly integrated network of dynamic partnerships among transportation professionals.*

The ORBP Team

Main ORBP Office

VACANT, Engineer of ORBP
Trudy Schutte, Executive Secretary
Wen-Hou Kuo, Statistician
Angela Nelson, Department Analyst

MDOT Statewide Library

Alexandra Briseno, Librarian

Best Practices/Legislative Initiatives

André Clover, Administrative Engineer

Transportation Research Program

Michael Townley, Section Manager
Annette Nealey, Administrative Assistant
VACANT, Research Analyst
Homer Sprague, Statistician

Contact Us

Phone: 517-241-2780

E-mail: mdot-research@michigan.gov

Web site: www.michigan.gov/mdotresearch

