RESEARCH ADMINISTRATION
Bureau of Field Services
Michigan Department of Transportation

Research Spotlight

Carbon fiber post-tensioned cables reduce bridge deck cracking, extend service life

Side-by-side box-beam bridges are low-cost and easy to construct, but it is difficult to inspect the interior beam webs, which can hide potential defects such as cracking and other deterioration. A new design reduces these problems and could double the service lives of the bridges by optimizing the post-tensioning process and replacing steel post-tensioning cables with stronger, corrosion-resistant carbon fiber composite cables (CFCC).

Project Information

REPORT NAME: Use of Unbonded CFCC for Transverse Post-Tensioning of Side-by-Side Box-Beam Bridges

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MDOT Project Contact

Matt Chynoweth

Bridge Field Services Division
Michigan Department of Transportation
6333 Old Lansing Road
Lansing, MI 48917
chynowethm@michigan.gov
517-322-3322

Problem

Researchers conducted tests on a half-scale side-by-side box-beam bridge model in order to find a post-tensioning configuration that will minimize longitudinal cracking and significantly extend the performance lives of these bridges.

A large majority of grade crossings require short- to medium-length bridges. MDOT and local agencies often rely on side-by-side box-beam designs that are low-cost and easy to rapidly construct. Box beams are a very structurally efficient shape, and the beams are prestressed, or strengthened along the length of the beam, with steel strands. The beams are then placed side-by-side and transversely post-tensioned with steel cables that run laterally through the beams via hollow ducts. The cables are stressed using a hydraulic jack, which imparts compressive stresses into the beam cross section, helping live load distribution and deflections. To help evenly distribute the loads caused by this post-tensioning, the cable ducts are supported by diaphragms that are integrated into the beams at regular intervals.

Despite the many advantages of these bridges, they are prone to longitudinal cracking in the shear keys between beams, which reflect upward into the deck slab above the joints between beams. This

(continued)

> *"We're hoping that the use of carbon fiber composite cables and the design developed in this study could give us a bridge with a 100-year service life."*
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> **Matt Chynoweth**
> Project Contact

cracking can cause an unbalanced load distribution across the post-tensioning cables and can lead to other forms of deterioration, including corrosion of the steel reinforcement within the beams. The cracking also can impact ride quality.

Approach

One promising method for preventing cracking is to increase the force of transverse post-tensioning (TPT) and adjust the number of transverse diaphragms cast into the box beams. The use of carbon fiber composite cables complements these goals, since the materials in these cables make them comparable in strength to steel cables, but grouting of the ducts is not required. Using computer modeling and a laboratory scale model, researchers set out to determine the optimum level of post-tensioning for these cables as well as the most effective number of transverse diaphragms.

Research

Researchers began by designing and constructing a half-scale side-by-side box-beam bridge model. They then conducted load distribution tests on this model for several different TPT configurations involving different post-tensioning levels and numbers of diaphragms. They conducted these tests with the bridge model in three different conditions: uncracked, cracked and repaired. While the deck slab was uncracked, the researchers used sensors to evaluate the strain in the post-tensioning cables. Finally, the researchers monitored beam deflection and post-tensioning forces as they loaded the bridge at its mid-span to the point of failure.

The researchers also conducted a computer simulation of a wide range of side-by-side box-beam bridges with different spans and different widths to establish the right number of diaphragms and level of TPT forces for preventing cracking.

Results

The test results showed that transverse post-tensioning significantly improved the load distribution among side-by-side box beams, and that increasing post-tensioning levels improved the overall behavior of the bridge model. The load distribution was better with five diaphragms than with three for a given span length, but different post-tensioning levels had little influence on the transverse strains that developed between the diaphragms. The final load test showed that loads were evenly distributed until failure, and none of the carbon fiber composite cables ruptured.

Computer modeling suggested that the longitudinal cracks between adjacent beams in side-by-side box-beam bridges are not caused by live loads alone. They are caused by a combination of live loads and temperature variations within the structure that lead to differing amounts of expansion and contraction. The development of these cracks can be delayed by using the optimum number and arrangement of diaphragms, which varies with bridge length, and the optimum level of post-tensioning force. The researchers developed design charts to help engineers determine these optimum values, and these charts have been published in the MDOT Bridge Design Guides. The use of high-strength concrete in the deck slab also can slightly reduce the amount of TPT force required per diaphragm.

Value

Using carbon fiber composite cables and the diaphragm design recommendations developed in this project will help reduce cracking and other deterioration in side-by-side box-beam bridges, and could as much as double their service lives. MDOT has built several bridges with this new design, and will continue to gradually expand its use while evaluating its performance. MDOT is also leading a related pooled fund study, TPF-5(254) for the development of a CFRP prestressed bulb-T beam superstructure, and is engaged in NCHRP Project 12-97 to develop The AASHTO LRFD Bridge Design Specifications for the design of bridges that use carbon fiber reinforced polymer materials for prestressing and post-tensioning. MDOT also was recently awarded Lead State status by the AASHTO Technology Implementation Group (TIG).

Research Administration

Principal Investigator

Nabil Grace

Lawrence Technological University
21000 West Ten Mile Road
Southfield, MI 48075
ngrace@ltu.edu
248-204-2556

Contact Us

PHONE: 517-636-4555

E-MAIL: mdot-research@michigan.gov

WEB SITE: www.michigan.gov/mdotresearch

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