Testing the strength and stiffness of fire-damaged concrete bridge girders demonstrated girders may retain full structural integrity and could be repaired instead of replaced. Inset: Concrete spall on a girder prior to repair.

RESEARCH SOLUTIONS

Repair options for fire-damaged concrete bridges

Bridge fires are rare, but the damage they cause can require costly repairs or replacement. Iowa DOT decided to replace a prestressed concrete bridge after a 2019 fire, creating an opportunity to closely examine the damaged beams, or girders. After testing the structural capacity and material properties of the affected girders, researchers explored different repair methods and costs relative to replacement. The results demonstrated that visual damage does not necessarily predict structural damage, and repair may be a safe and cost-effective alternative to replacement.

THE NEED

Fortunately, fires on or under bridges are rare. Repairing or replacing a bridge that has been damaged by fire, however, can be costly and disruptive. In 2019, items including a propane tank in a homeless encampment caught fire under a low-clearance bridge on I-29 over Perry Creek in Sioux City. While all eight prestressed concrete girders were affected, the greatest damage was extensive spalling on the girders where the fire was concentrated.

Iowa DOT opted to replace the bridge. The decision created an opportunity to investigate the condition of the damaged girders to understand the fire's effects on their structural capacity and evaluate potential repair methods.

RESEARCH APPROACH

To assess the fire-damaged bridge's serviceability and strength, Iowa DOT facilitated the removal and transport of three beams with varying levels of damage to an

(continued)

"This project will help Iowa DOT determine how much loading a bridge can continue to handle after a fire, and give us greater confidence in our repair methods."

— **JAMES HAUBER,**
Iowa DOT Chief Structural Engineer

agency maintenance yard. There and in the laboratory, investigators assessed the girders' condition to compare to the material design properties through a variety of tests:

- Visual inspection to identify areas of damaged concrete, color changes, and exposed steel reinforcement.
- Load tests to measure strain and deflection.
- Compression tests of concrete core samples to demonstrate the fire's effects on material properties.
- Tension tests of steel strand samples to determine reinforcement strength.
- Maximum shear force tests to determine the girder's ultimate capacity.

Investigators then explored methods for potentially repairing the concrete beams. After placing constructed forms around a damaged girder's bottom flange, the casts were filled with one of three materials: self-consolidating concrete (SCC), ultra-high performance concrete (UHPC), or SCC in combination with fiber-reinforced polymer (FRP) wrap. Loading tests determined the effectiveness of the repair methods. Lastly, an economic analysis compared the costs of repairing the girders to replacement.

WHAT IOWA LEARNED

Despite varying levels of visible fire damage and some exposed steel reinforcement, all three girders performed equally in load testing and their structural integrity remained intact. The measured strain and deflection of all three girders matched the expected range of the material properties' design values.

Three cycles of maximum shear load testing on one girder did not cause failure and investigators observed no cracks. While the compression tests were not conclusive due to the small sample size, one core showed strength greater than design specifications. The steel strands also performed as designed.

While each repair method performed well during load tests, the use of SCC without the FRP wrap was the simplest construction option. While the FRP wrap provided additional protection and strength, its workability and overhead application presented challenges. Similarly, the expense and additional construction effort required for UHPC may outweigh its durability benefits.

Replacing girders is generally more costly than repair, and new girders may provide increased certainty of structural performance and service life. Construction costs, however, do not capture the economic impacts of bridge closures and the resulting traffic delays and detours can be substantial.

Finally, researchers recommended assessing fire-damage susceptibility during initial design and construction for new bridge projects. Recommendations also included identifying various fire vulnerabilities of in-service bridges.

PUTTING IT TO WORK

While Iowa DOT considers every bridge fire on a case-by-case basis, these project results provide a tool to inform future repair strategies. The duration and temperature of the 2019 bridge fire, combined with the known level of structural impact to the girders, will serve as a reference in managing bridge repairs after any future fires.

ABOUT THIS PROJECT

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