BRIDGES/STRUCTURES AND HYDRAULICS

Research 2019

Innovations from State DOTs

Uniform Quality Assurance Processes Produce Cost Savings

NEW ENGLAND

To ensure their highway infrastructure remains durable, safe, and cost-effective, New England's six state transportation agencies rely on strict quality assurance (QA) processes for accepting precast and prestressed concrete elements during construction projects. Realizing there was an opportunity to achieve significant cost savings if they standardized these processes across the region, the agencies worked together on a New England Transportation Consortium (NETC) study to begin developing a uniform QA system.

Through an in-depth literature review, a survey, and interviews with transportation agency financial personnel from each state, the NETC team identified cost-sharing mechanisms the various agencies can use to share QA resources. NETC coupled this information with a detailed understanding of the states' existing concrete acceptance criteria to develop unified processes for several major QA categories, including producer qualifications, quality control and service manuals, and inspections.

New England's transportation agencies will now be able to streamline concrete plant certifications and QA inspections, reducing the number of inspectors who must visit these plants and saving money. The uniform system will also lower costs for concrete manufacturers, who now have standard, homogeneous rules they can follow when developing precast/prestressed concrete elements for the entire region. As part of this study, NETC compiled a list of upcoming precast/prestressed concrete projects where the states plan to pilot test the new QA processes, and interagency agreements are being developed to share inspection resources. Project web page.

Source: NETC

Northeast Extreme Tee (NEXT) beams stored at a precast facility.

The six bridges/structures and hydraulics research projects

highlighted on these pages were selected by the Research Advisory Committee of the American Association of State Highway and Transportation Officials (AASHTO). They comprise high-value projects from each of the four AASHTO regions, funded primarily through the State Planning and Research (SPR) Program. As the nation's cornerstone state research program, SPR provides Federal Highway Administration funding to the states to address top concerns and identify solutions at the state level. States further address areas of common concern through the Transportation Pooled Fund Program. This publication and its companion featuring high-value safety research complement *Research Makes the Difference 2019*, a compilation of award-winning transportation research across all fields. All of these publications may be found at research.transportation.org.

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Access the electronic edition of this document with project links, as well as more high-value state DOT research projects, at AASHTO's research website, research.transportation.org.

Lightweight Bridge Construction Technique Saves Time and Money

MONTANA

Thanks to their relatively light weight and aesthetic design, steel truss bridges are an attractive alternative to traditional plate girder systems at highway crossings. Such is the case in Montana, where the Montana Department of Transportation (MDT) recently investigated the viability of using prefabricated steel trusses in its accelerated bridge construction projects.

A unique feature of this construction technique is a concrete deck that can be completely cast and attached to the steel truss at the fabrication facility, eliminating the need to do this work on site and saving time and money. Although the technique shows promise, MDT lacked literature on its effectiveness and fatigue limitations. The agency worked with researchers at Montana State University to fill this information gap and assess the viability and performance of the prefabricated steel truss concept at different bridge spans and traffic volumes.

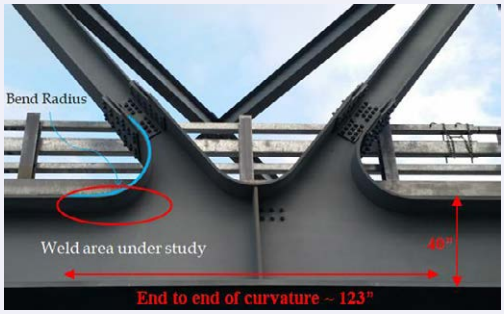
Ultimately, the research team used two- and three-dimensional models to design a 205-foot steel truss featuring economical wide flange vertical members and bolted diagonal member connections. They then compared its performance to a conventional plate girder design of the same span length under both conventional and accelerated bridge construction scenarios. Not only did the prototype meet AASHTO requirements for an infinite-life design, but it also decreased construction and operational costs by 10 percent for conventional projects and 26 percent for accelerated projects. Based on these research results, MDT can now identify design challenges and projects with the right site conditions to exploit this innovative structural system. The agency will soon deploy a prefabricated steel truss structure in the field. Project web page.

Source: MDT

Prefabricated wide-flange beams topped with a composite concrete deck.

Research Confirms Reliability of New Gusset-Less Truss Connections

NEW HAMPSHIRE



Source: NHDOT

The Memorial Bridge gusset-less truss connection shows the curved steel transition from the chords to the diagonals where splice plates join the members.

In 2012, the Memorial Bridge in Portsmouth, New Hampshire, was closed due to structural deficiencies. When it reopened a year later, the bridge's steel truss structural system featured a unique "gusset-less" connection. Gusset-less connections remove some of the drawbacks of traditional gusset plate connections, which use more bolts—increasing the locations of stress concentrations and potential corrosion—and cover structural members—making it more difficult to conduct inspections. But published evidence of this innovative design's long-term performance was lacking, as was state protocol for gusset-less inspections, so a New Hampshire Department of Transportation (NHDOT) research project aimed to fill these gaps.

To test the fatigue performance of the gusset-less connection, researchers at the University of New Hampshire, in cooperation with NHDOT, commissioned a scale model of the gusset-less connection and analyzed its structural response under pulsating tensile loading.

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Research Confirms Reliability of New Gusset-Less Truss Connections

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Researchers were especially interested in determining the maximum amount of stress the connection's radiused fillet welds could handle. Finite element models were used to validate the fatigue testing results, which predicted that the Memorial Bridge's gusset-less connection could withstand more than 1.6 million cycles of laboratory-applied fatigue loading cycles before failure. Moreover, the test specimen showed no signs of damage.

As a result of this project, NHDOT now has a reliable procedure it can use to consistently conduct fatigue testing of gusset-less connections. The agency anticipates that the connection will help extend the life of the bridge and that inspections will be more thorough and efficient, taking less time and resources to complete. The absence of damage to the test specimen also confirmed that gusset-less connections have substantial lifespans and can be safely used in future bridge projects. NHDOT will use these project results to develop official protocol for inspecting the Memorial Bridge. Project web page.

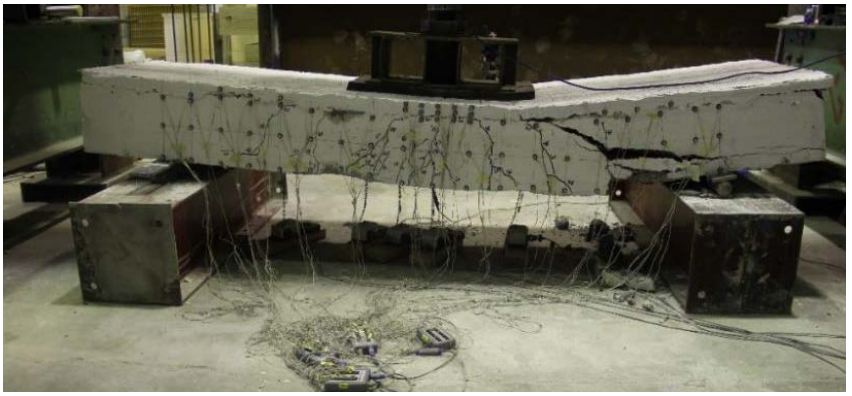
Source: Iowa DOT

Finished UHPC overlay on top of a bridge deck.

Ultra-High Performance Concrete Mix Reduces Bridge Deck Deterioration

IOWA

After ranking as one of the top three states with the most deficient bridges, Iowa saw an urgent need to address bridge deterioration statewide. This deterioration typically starts with cracks that allow moisture and chloride to infiltrate the concrete core and corrode the bridge deck's reinforcement. Exposure to freeze-thaw cycles, traffic loads, and de-icing salt worsens the deterioration, resulting in expensive retrofits or replacements for Iowa's bridge owners.



Source: Iowa DOT

Failure mode analysis in the lab showed that shear cracks did not penetrate to the UHPC layer but turned horizontally and began to separate the UHPC overlay section from the normal concrete base.

In search of an economical solution, the Iowa Department of Transportation (DOT) investigated an innovative bridge overlay method that applies a thin layer of ultra-high performance concrete (UHPC) on top of the normal concrete deck. The agency worked with Iowa State University to field test a new UHPC mix on the Mud Creek Bridge in Buchanan County—the first overlaid bridge of its kind in North America. For a year, researchers conducted destructive and nondestructive performance testing, delamination pull-off testing, and infrared thermal imaging scans at the bridge. They also analyzed the strength of concrete slab specimens with and without UHPC overlays in a laboratory setting.

The new UHPC mix proved to be an attractive option for Iowa DOT bridge projects, showing higher tensile strength, lower permeability, and more fatigue resistance than normal concrete. These properties will result in increased crack resistance, less moisture and chloride penetration, and longer lifespans for Iowa's bridges—ultimately providing significant construction and maintenance cost savings. While this project focused on hand-placed UHPC, Iowa DOT is currently building on its success by investigating mechanical methods for overlay placement. Final report.

Compatible Guardrail Devices Protect Bridge Workers from Falls

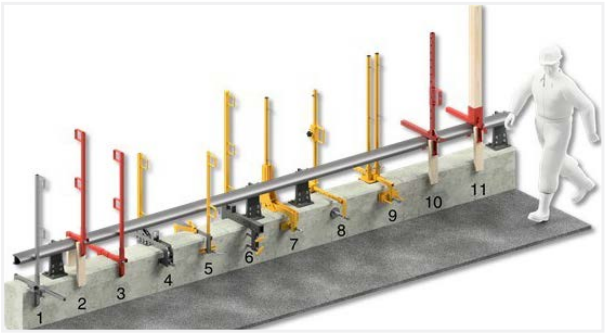
NORTH CAROLINA

Falls from bridge decks are a common hazard that bridge maintenance workers face. A contributing factor in these incidents are guardrails that do not meet OSHA's recommended barrier height requirements (42 ± 3 inches). This is especially problematic in North Carolina, where 88 percent of bridge guardrails are 39 inches or lower. Rather than making costly guardrail retrofits, the North Carolina Department of Transportation (NCDOT) investigated the use of fall protection supplementary devices (FPSDs).

FPSDs feature components such as lumber blocks and adjustable clamps that can be temporarily attached to guardrails to add height. However, it takes substantial time for workers to figure out which FPSD is compatible with a particular guardrail. NCDOT and researchers at NC State University sought to eliminate this inefficiency by identifying appropriate FPSDs for 22,000 bridge guardrails across the state.

Using virtual prototypes, the researchers tested the compatibility of different FPSDs with all existing guardrails. They also identified device characteristics that enhance safety and productivity, as well as criteria for NCDOT to select the most advantageous FPSDs. Subsequent field tests with NCDOT bridge maintenance workers helped determine which devices best reduced physiological and physical demands.

In addition to addressing a nationwide safety issue, this research project recommended an FPSD (the CC120) that offers wide-ranging benefits to NCDOT's workforce and is compatible with the state's 13 most common guardrail types. NCDOT's Safety and Risk Management Unit will share these results with bridge engineer supervisors and safety professionals at four regional training sessions, and the agency is creating an FPSD installation video for transportation workers. Project web page.



Source: NCDOT

Temporary fall safety barriers (for testing).

New Bridge Design Guides Address Local Agency Needs

MICHIGAN

Source: MDOT

Poor condition of a locally owned bridge in Michigan.

One-thousand of the nearly 6,500 locally owned bridges in Michigan are structurally deficient. However, many of the counties, cities, and villages responsible for these bridges lack the guidance necessary to replace them—instead relying on larger-scale Michigan Department of Transportation (MDOT) plans that don't fit their project or previous local designs that may not be cost-effective or durable. To better meet these needs, MDOT and researchers at Wayne State University developed a set of bridge design guides tailored to the state's smaller, local agencies and low-volume roads.

Through stakeholder consultation and an extensive review of existing bridge plans, the researchers identified four viable designs: galvanized steel girders, spread box beams, side-by-side box beams, and bulb-tee girders. A subsequent life cycle analysis compared the long-term costs of each and was used to refine the bridge designs even further. The end result of this research was a final set of guides that include detailed instructions for all four bridge types, covering varying widths (30, 34, and 40 feet), spans (20 to 110 feet), and skews (0 to 30 degrees).

Using these guides during bridge replacement projects, local agencies can expect to see design, construction, maintenance, and other life-cycle cost savings, as well as reduced design uncertainties and increased bridge quality. The guides will also help them meet Federal Highway Administration requirements for quality control/assurance. MDOT is currently leading an outreach effort to promote the guides and their benefits among local agencies statewide, most recently presenting these research results at the 2018 Michigan Bridge Conference. Research brief.