A combination of micro and macrofibers [inset] added to the concrete used in bridge decks can help state and county bridge engineers mitigate various cracking issues.

RESEARCH SOLUTIONS

Fiber-reinforced concrete makes Iowa bridge decks more durable

While concrete decks are often used in bridge structures because of their strength and durability, exposure to heavy traffic loads and environmental stressors can cause cracks to form in the concrete. Adding fibers to the concrete mix can strengthen it and mitigate the risk of cracking, not only during curing but also after the bridge is in service. Researchers identified the optimal types and amounts of fibers to add to enhance crack resistance and extend the service lives of Iowa bridges.

THE NEED

Concrete bridge decks are exposed to various strains and stresses as soon as the concrete is poured. As concrete hardens, water naturally rises to the surface. If the water evaporates too quickly, the concrete shrinks and may crack. Once bridges are in use, their constant exposure to heavy traffic loads, water, corrosive agents, and freeze-thaw cycles can cause additional damage, leading to costly repairs and shortening the bridges' service lives.

Making adjustments to the concrete mix can help reduce shrinkage-induced cracking and strengthen the concrete against mechanical and environmental stressors. Two effective approaches include modifying the cement binder materials and adding fibers to the mix. Research was needed to help Iowa DOT and county engineers choose the proper type and amount of additives to produce a stronger, more durable, yet workable concrete.

(continued)

"This research shows that fiber-reinforced concrete is effective and economical in solving the problem of concrete cracking when it shrinks. We are already implementing fiber-reinforced concrete in several projects."

— **MICHAEL NOP,**
Iowa DOT Bridge Project Development Engineer

RESEARCH APPROACH

To identify strategies to minimize cracking in bridge decks, researchers first investigated how various binder materials affect early-age cracking. These materials can alter how much water is absorbed and, in turn, how much excess water evaporates. The research involved testing concrete mixes made with non-traditional binder ingredients, such as Type K cement, Class F fly ash, and silica fume, for changes in capillary pressure—which correlates with cracking potential—and monitoring the mixes' performance over time.

Next, the research team tested the effect of adding microfibers in different dosages on concrete strength and durability. The mechanical properties were recorded as curing progressed, and researchers tested how easily and quickly corrosive agents were able to penetrate the cured concrete samples.

Finally, the researchers explored a hybrid approach—adding varying amounts of macrofibers (fibers typically longer than 1 inch) to the mixes that contained microfibers. Twenty-four concrete mix combinations containing polyvinyl alcohol, polypropylene, and alkali-resistant (AR) glass macrofibers were tested at different ages up to 56 days after curing.

WHAT IOWA LEARNED

The efforts revealed the concrete mixes most likely to mitigate cracking issues. Recommendations of the most effective binders and the optimal types and amounts of fibers include:

- **Binders**. Of the binder materials investigated, Class F fly ash was found to contribute most to the early-age cracking resistance of concrete. However, researchers recommended that 20% of cement content be replaced with Class C fly ash for a durable yet workable concrete.
- **Microfibers**. Even at low dosages, polypropylene microfibers were effective in reducing early-age cracking potential and enhancing chloride penetration resistance. Researchers recommended limiting the dosage to 0.125% of the mixture volume.
- **Macrofibers**. In general, larger fibers were found to further enhance concrete's strength after it cures. Of the three macrofibers tested, AR glass resulted in superior strength and showed a promising synergy with polypropylene microfibers. Researchers recommended adding AR glass macrofiber at a 0.25% dosage to enhance concrete strength during and after curing.

PUTTING IT TO WORK

This project demonstrated that fiber-reinforced concrete mixes can be produced cost-effectively using readily available materials. As a next step, state and county engineers plan to implement fiber-reinforced concrete in a variety of bridge deck construction and repair projects to ensure its viability across a range of applications.

ABOUT THIS PROJECT

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PROJECT CHAMPIONS:
Curtis Carter, P.E.
Senior Structures Engineer,
Iowa DOT
curtis.carter@iowadot.us
515-239-1185

Michael Nop, P.E.
Bridge Project Development Engineer,
Iowa DOT
michael.nop@iowadot.us
515-239-1233

TECHNICAL ADVISORY COMMITTEE:
Todd Hanson, Jesse Peterson, Steve Seivert, Joseph Stanisz.

PROJECT MANAGER:
Vanessa Goetz, P.E.
State Research Program Manager
Iowa Highway Research Board
Iowa DOT
vanessa.goetz@iowadot.us
515-239-1382

PRINCIPAL INVESTIGATOR:
Behrouz Shafei, Ph.D., P.E.
Iowa State University
Institute for Transportation
shafei@iastate.edu
515-294-4058

IOWA DOT RESEARCH:
iowadot.gov/research
ideas.iowadot.gov

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