A 6-month road repair that only takes 10 days, at a fraction of the cost? It's reality, thanks to ASU concrete research

University's innovations on Arizona's bridges and railways pave way for state transit savings, safety and sustainability

By Terry Grant, ASU News
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While Arizona’s infrastructure may be younger than its East Coast counterparts, the effects of aging in a desert climate have begun to take a toll on its roads, bridges and railways.

About this story

There's a reason research matters. It creates technologies, medicines and other solutions to the biggest challenges we face. It touches your life in numerous ways every day, from the roads you drive on to the phone in your pocket.

The ASU research in this article was possible only because of

Repairs and replacements come with the challenges of traffic disruption, neighborhood inconvenience and high costs. In addition, concrete sustainability has become a critical goal for federal, state and local agencies as they work to reduce energy consumption and lengthen infrastructure lifespan.

Arizona State University faculty members have been sharing sustainable concrete development expertise in academic and professional construction channels for more than 30 years. But recently, their expertise has been a hands-on contribution to Arizona.

ASU's projects have included designing sustainable, durable concrete bridge deck connection mixtures for state and county transportation departments and creating a fiber-reinforced concrete alternative to rebar for Valley Metro light rail extensions.

Structural engineering professors Barzin Mobasher and Narayanan Neithalath have led the projects and conducted extensive research and testing in the ASU School of Sustainable Engineering and the Built Environment's Structural Mechanics and Infrastructure Materials and Cement and Concrete Materials laboratories.

the longstanding agreement between the U.S. government and America's research universities. That compact provides that universities would not only undertake the research but would also build the necessary infrastructure in exchange for grants from the government.

That agreement and all the economic and societal benefits that come from such research have recently been put at risk.

Learn about more solutions to come out of ASU research at news.asu.edu/research-matters.

Saving the state and county both time and money

The team began work in 2016 with the Arizona Department of Transportation, which was looking to develop an ultra-high-performance concrete (UHPC) to connect bridge elements. The goals were speedy installation to limit bridge closures, enhanced strength and reduced costs by using nonproprietary concrete mixtures that could be produced using local suppliers.

Using an actual-size reinforced concrete section tested under flexure in the ASU lab, the team created specific-use UHPC mixtures with enhanced shear strength, tensile strength, compressive strength and fatigue resistance. The mixtures also offer a time savings.

"A bridge replacement that would normally take six months can now be done in 10 days," Mobasher said following implementation of the recommendations. "To the people who drive over those bridges every day to get to their homes, it is a lifeline.

“It is difficult to change the perception that roadwork is always associated with delays and a waste of time for everyone. To put it into perspective, ADOT can now repair 10 bridges for the time and budget it used to take for only one.”

As the Maricopa County Department of Transportation was beginning to rehab its deteriorating precast concrete slab bridges, ASU’s research for ADOT prompted the county agency to reach out to the team for guidance. The department had been working with out-of-state consultants recommending proprietary mixes, which meant flying in bags of concrete, sand and cement.

As they deteriorate, grouted joints are a long-term problem in the precast type of slabs used for many of Arizona’s bridges. Aging leads to shrinkage cracks, corrosion of the reinforcing steel, and ultimately structural damage to the bridge deck.

“When adding new steel staples to connect the slabs, as MCDOT planned to do, UHPC is a viable replacement for grout and solution to this problem,” Mobasher said.

The UHPC itself contains steel fibers and has impressive compressive strength. This means the repairs will last much longer.

For MCDOT, ASU developed mixtures that use locally sourced materials for a fraction of the cost of proprietary mixtures, and trained local companies how to prepare the mixture. In addition, the ASU team trained about 30 local construction workers to install the mixture on the bridges.

The bridge was operational five days after pouring the UHPC.

“Now MCDOT has expertise that can be mobilized to handle many similar tasks in some of the most remote places,” Mobasher said.

In addition, the federal government has specific grants for agencies working with these materials, which can bring more infrastructure funding into the state, according to Mobasher.

“All of this resulted from what was originally a $120,000 project for one bridge that required bringing in consultants from out of state to pour a proprietary mixture,” he said. “Now funding allocations for that single bridge project can be extended to fixing about 10 bridges.”

MCDOT continues to rehab existing slab bridges by adding steel staples and reworking the original grouted joints with UHPC.

(Video: {https://vimeo.com/829222248})

Extending the light rail, shrinking costs

While working with MCDOT, Mobasher presented a proposal to the Valley Metro Regional Transportation Authority in metro Phoenix to replace rebar with fiber-reinforced concrete in its planned light rail extension.

The suggestion ultimately led to collaboration between ASU, the transportation authority and Kiewit-McCarthy, the project's construction firm for completion of the Northwest Extension Phase II Project.

Though concrete has great weight-bearing capacity, it doesn't withstand much tension, or the ability to stretch under a load. Traditionally, rebar is used in construction to reinforce concrete and increase its tension capacity.

Rebar, however, is expensive and takes a great deal of time and expense to install. FRC is a cost- and time-saving alternative in railroad tracks and other construction projects. Mobasher has been researching fiber reinforced cement for close to 40 years.

Prior to the light rail project team's approval of the proposal, Mobasher and his team conducted extensive testing, including using actual track slab mock-ups to compare effectiveness between rebar and FRC with steel fibers. The tests also evaluated which mixtures afforded the best crack resistance and crack "healing" properties.

"If the concrete tries to crack due to load, restraint or shrinkage, the fibers intercept the crack and act like internal Band-Aids. They hold it together and allow it to carry more of a load. It's an interlocking mechanism," Mobasher explained.

Overall, the testing confirmed that FRC's superior performance over rebar, demonstrating increased long-term viability, reducing the amount of concrete used and diminishing potential corrosion issues. The designers decided to use fibers to eliminate all the structural rebar, which would have a profound effect on the cost savings.

The change also decreased track slab thickness from 14.5 inches to 12 inches. This not only reduced the amount of concrete used, but it also decreased the amount of excavation necessary to install the rails.

Ultimately, using FRC for 1.6-mile Northwest Extension Phase II not only cut construction time nearly in half, the switch also slashed track installation costs from an estimated $17 million per mile to $5.3 million.

FRC also improves worker safety. Because rebar cannot bear the weight of a person, it can be risky for workers as they step over rebar while pouring and spreading concrete.

“They had to try to feel the rebar and step next to it in a 10x10-inch opening between two rebars in the cage. Since there were two layers of rebar in two different directions, the worker’s leg could get wedged. This is like walking on shredded glass in a dark room while shoveling wet mud that weights about 80 pounds,” Mobasher said. “That is how the previous 25 miles or so was built. We took the rebar cage out, and now workers can finish the slab and walk without tripping in the 12-inch layer.

“It’s still very hard, labor-intensive work, but infinitely more humane. A key mission of sustainable engineering is to focus on long-lasting improvements of the human conditions.”

The extension opened in January 2024, and the innovation was part of the consideration that led the project being named Engineering News-Record’s Best in Class in the Airport/Transit category and one of three finalists for ENR’s U.S. Project of the Year, which will be announced March 17.

Based on the success of the Northwest extension, Valley Metro plans to use the FRC technology for future light rail projects.

“One can be happy conducting research and publishing the results in journal papers or books,” Mobasher said. “But many times, the true joy is when the result of our work finds applications that make people’s lives easier at a fraction of the cost. The DOT and light rail projects address that aspect.”

This story originally appeared on ASU News.

Main image

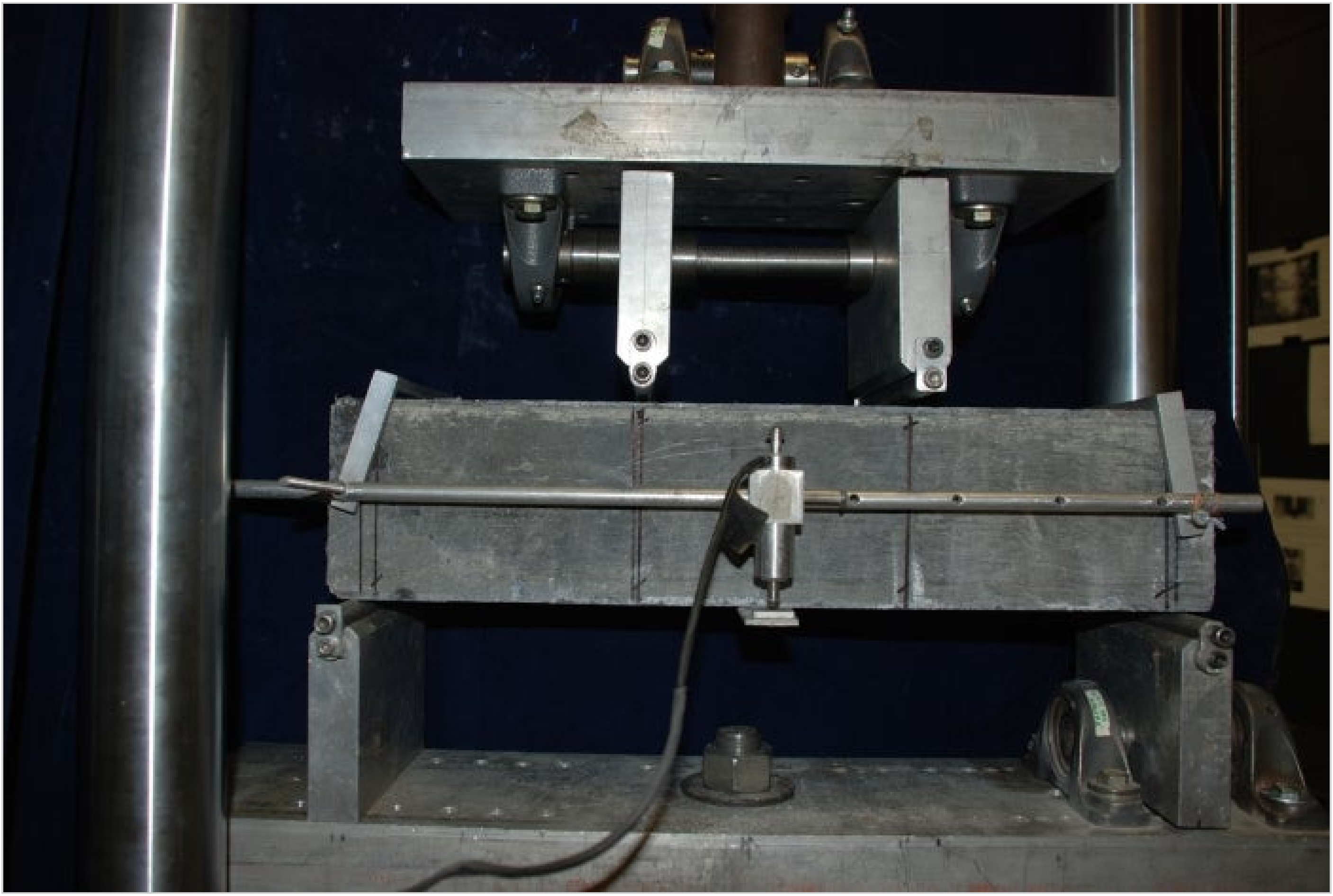
Maricopa County Department of Transportation workers apply an ASU-developed ultra-high-performing concrete between slabs on the Palo Verde Bridge over the Roosevelt Canal in Buckeye, Arizona, just south of the Buckeye airport. Photo courtesy of Barzin Mobasher/ASU

Text image(s)

Workers from Arizona Materials spread fresh concrete over the last section of the northern spur of the Phoenix Metro Valley light rail extension. Fiber-reinforced concrete enhances worker safety by eliminating the need to step over rebar while they pour and spread concrete. Photo by Charlie Leight/ASU News

Gallery

The "staples" used to connect bridge slabs for the Centennial Bridge in Maricopa County had become degraded. New staples were inserted and supported by ultra-high-performance concrete (UHPC) developed by ASU.



Small, 14-inch test beams of ultra-high-grade concrete were created for testing and validation in an ASU laboratory. A full, 8-foot connection beam was later cast and tested to ensure that the UPHC "glue," which is three times stronger than traditional concrete used for connecting precast bridge slabs, would do the job.

Bridge slab connectors prepared for application of ultra-high-performance concrete developed by ASU.

Workers apply ASU-developed ultra-high-performing concrete between slabs on the Palo Verde Bridge over the Roosevelt Canal in Buckeye.

Rectangular, full-scale mock-up slabs having a single track were created for flexural and fatigue load testing. Shown here is the version with conventional steel rebar before the addition of concrete.

This mock-up version of the slab was used to contain fiber-reinforced concrete alternative to rebar construction.