Internal curing has clearly demonstrated its beneficial effects on the performance of concrete bridge decks. The addition of pre-wetted lightweight aggregates to concrete mixtures can help reduce shrinkage stresses by reducing moisture differentials through the depth of a slab.
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As a result, shrinkage cracks at the surface are smaller and tighter, while curling and warping at the slab edge are reduced. Less cracking means that less water and deicing salts penetrate the surface, reducing corrosion of steel reinforcement and extending the useful life of the deck. Less warping at slab edges makes for a smoother pavement and a more comfortable ride.

Research teams are now investigating whether internal curing can offer comparable benefits for concrete highway pavements. Though it will take some time to get a definitive answer, initial indications are promising.

How internal curing works

Internal curing is accomplished by incorporating pre-wetted lightweight aggregates (LWA) into a concrete mixture. Pores in the LWA function as reservoirs that readily release water as needed for hydration or to replace moisture lost through evaporation or self-desiccation. By maximizing cement hydration throughout the interior of concrete, internal curing can contribute to increased strength while reducing autogenous stresses and strains.

Current Research Efforts

Jeffery Roesler, a professor and associate head of civil and environmental engineering at the University of Illinois Urbana-Champaign and president of the International Society of Concrete Pavements, is one of several people conducting research on internal curing of concrete pavements. Dr. Roesler first became interested in internal curing while on sabbatical in South America, where, as along the U.S. west coast, climatic conditions lead to major slab curling issues.

“About five years ago, we started working with internal curing. We did some lab work and modeling, as well as some larger-scale testing outside at the University. We started with a belief that [internal curing] could have a significant impact on moisture curling in concrete pavements. As water is lost from the surface early on after construction, it causes the slab to curl up such that it loses support at the edges. That can lead to premature cracking and some long-term performance problems. We hypothesized that internal curing would reduce this phenomenon, because the moisture content would be more uniform through the slab thickness.

“Our tests show internal curing can reduce slab curling significantly, in some cases by up to 50% in the lab. And with less cracking and less stress at the surface because of the more uniform moisture profile, it’s probably true that you’ll also have a smoother ride because there is less curling. We’d have to have much longer test segments in order to be certain that’s a true statement, but I don’t see any reason to doubt that it’s true,” Roesler says.

From Lab to Field Tests

Encouraged by lab results and keen to improve pavement performance, other researchers have initiated large-scale field testing of internally cured concrete.

One such project involves test sections constructed by the Illinois Tollway Authority on a bypass just west of Chicago’s O’Hare Airport.
One two-lane, 2,000-foot-long section was built in the summer of 2016, and another 1,000-foot-long section was completed in May 2017.

In these tests, the potential reduction of edge curling and warping is seen as a secondary benefit of internal curing, but it’s not the main focus, as the Tollway Authority’s Deputy Program Manager for Materials, Steven Gillen, explains:

“For the tollway system, we want to build continuously reinforced concrete (CRC) pavements as much as we possibly can because they’re the best-maintaining pavement type for a high-volume expressway. With the Tollway in particular, our objective is to minimize traffic interruptions in order to maintain revenue as we operate the system.

But the upfront costs of CRC pavement are the highest of any pavement type. CRC pavement is built without pavement joints or dowels, but with continuous steel rebar. Without joints, tight intermittent cracks develop every three or four feet in the pavement. This method holds the pavement together better, so you don’t see joint deterioration like you see in regular jointed pavements,” Gillen says.

The Authority’s next major project on the horizon is to reconstruct and widen the central portion of the Tri-State Tollway, which is expected to begin in another six years and cost about $4 billion. With that project looming, the Authority hopes to re-engineer the CRC pavement so its upfront costs can be reduced significantly. Internal curing is one of the areas it’s looking at to reduce the thickness and cost.

Gillen says, “[For last year’s test section.] we did a 10-1/2-inch-thick CRC pavement using internally-cured CRC concrete over alternative base designs. It’s not just the internal curing, but other design factors as well, including the subbases underneath the pavement. What we’ve used in the past was an asphalt-stabilized subbase, typically a 3-inch layer of hot-mix asphalt, and then the CRC pavement goes over the top of that. And the asphalt-stabilized subbase sits over top of 9-to-12-inch-thick aggregate subbase.

“We’re looking to replace that 3-inch asphalt base with a cement-treated base. That is a much stronger material that adds strength to the overall pavement system, because it’s also more rigid than the asphalt subbase. Our cement-treated bases are dense-graded and roller-compacted, placed using asphalt pavers just as the asphalt-stabilized bases were. It’s a dry mix no-slump concrete, so there’s really no labor premium compared with the asphalt subbase. We’re even looking into alternative and recycled materials to go into the cement-treated bases so that they can be even more economical.”

“With the CRC subbase and internal curing, we’ve reduced the internally cured slab depth to 10.5 inches rather than the 12-inch slab depth used for the last major reconstruction project in 2008. That allows a reduction in the overall material costs, but the most significant cost impact is the reduction in steel costs,” he says. Research teams are carefully monitoring the test sections for cracking and other conditions and will report on their findings in due time.”

From Testing to Specifications

When the test data collection is complete, the Tollway Authority will provide that data, along with other relevant information, to its design consultants, Applied Research Associates. ARA will input the data into its design program to come up with a pavement design type and thickness. Then the Tollway Authority will do a life-cycle cost analysis of the various pavement types being considered and ultimately select the one with the best grade.
According to Jason Weiss, professor and head of the civil and structural engineering school at Oregon State University, internal curing is already moving from a research context to demonstration projects to actual applications. He says there’s a group of DOT people working now to come up with a specification that can be used for highway pavement design.

“Decision-makers should look at internal curing as another tool in the tool belt, so that if you want to produce concrete bridge decks that crack less, or concrete patches that crack less, or pavements that are less prone to warping, then this is a viable technology to consider,” Dr. Weiss says.

“The theory behind proportioning lightweight aggregates into a mix design has been pretty well worked out at NIST and elsewhere. Therefore we’ve been able to develop a very simple approach, using a spreadsheet where you take your existing concrete mixture and it quickly tells you how to make it an internally cured mixture,” he says.

**From Specification to Installation**

Concrete producers and contractors charged with mixing and placing concrete for internally cured pavements should have a fairly easy time making the necessary adjustments. Because only a fraction of the fine aggregate is replaced, the additional cost of the lightweight material is a relatively minor factor.

There may be some logistical changes needed to accommodate the additional aggregate, and it may take some education to learn how to wet the lightweight aggregate and measure its moisture properties. However, instructional videos and other resources are readily available to help with that. Lightweight aggregate suppliers can also help with that process.

Weiss says the adjustment is well worth the effort: “[Internal curing] means people can install infrastructure elements that should provide longer-lasting and improved service. You reduce maintenance costs, but you also reduce inconvenience for the traveling public so the social costs go down. In most instances, it’s a more sustainable option because you’re not replacing things so often and using as much repair material.”