Pavement with potential

Salisbury Bypass project yields hard data on high-performance concrete roads

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Though Maryland's eastern shore is only 100 miles from downtown Washington, D.C., it appears to be a world removed. Small towns and farmland recall an earlier time when the biggest problem facing highway engineers was how to keep cars from backing up behind a slow-moving tractor.

For most drivers passing through the area, those fields and roadside stands are just a blur on the way to or from the beach. Maryland's oceanfront resorts attract millions of visitors every year.

The Maryland State Highway Administration (MDSHA) has just completed a project designed to eliminate a major bottleneck on that well-traveled route: the U.S. Rte. 50 Salisbury Bypass. The divided, four-lane, seven-mile bypass connects U.S. Rtes. 13 and 50. By routing traffic around the heart of Salisbury, Md., the bypass, in the words of then-Gov. Parris Glendening, is "giving Main Street back to the citizens of Salisbury while providing a safer, more convenient trip to the beach."

Completed three months ahead of schedule, the bypass opened in the spring of 2003 and has won awards from the American Concrete Institute, the American Society of Civil Engineers and the American Road & Transportation Builders Association.

This low-lying coastal region of the eastern shore, situated between the Atlantic Ocean on the east and Chesapeake Bay on the west, is exposed not only to typical freeze-thaw cycles of the Mid-Atlantic region, but also exposure to salt air. The bypass is heavily traveled, especially in the summer months, and handles a significant amount of commercial traffic.

In addition to providing a quicker route to the beach, the bypass reduces congestion for local residents. Before the bypass was completed, the route through downtown Salisbury included 16 traffic signals. Now motorists go through only two traffic lights east of the city.

Help from beneath

The Salisbury Bypass offers another, less visible benefit: It will provide hard data to help engineers evaluate the potential of high-performance concrete for highway pavements.

Buried beneath the new pavement, an array of sensors collect information on three segments of the highway: a control segment using a traditional pavement mix and two test segments using high-performance concrete. The data, to be collected over a two-year period and analyzed at the Civil Engineering Department of the University of Maryland, will provide good estimates of how long these high-performance pavements will last under actual conditions.

Vicki Stewart, statewide chemical/concrete/cement team leader for the Maryland State Highway Administration, said that MDSHA is keenly interested in researching high-performance concrete pavements. "The potential savings to the state from extended-life pavements are enormous. These data will allow us to develop solid life-cycle cost analyses of these pavements. We'll be able to quantify the benefits in real dollars.

And, they'll allow us to evaluate and compare the performance of different approaches."

Don't worry about the money

While high-performance concrete has been widely used in highway construction for bridge decks and other applications requiring high strength and durability, cost concerns have limited their use in pavements.

However, as highway engineers grapple with the costs of replacing aging roadways, greater attention has been given to life-cycle costs and the use of advanced materials to extend the life of pavement from 35 to as much as 75 years.

Even with higher first costs for materials, the case for high-performance materials is compelling over the long term. Materials costs are a small fraction of the labor and engineering costs associated with a repaving project. The economic impact can be even greater, including financial hardships for area businesses and countless hours of lost time to commuters. A pavement that lasts an extra 35 to 40 years appears to be an increasingly attractive investment to highway engineers and administrators.

That analysis makes sense not only to MDSHA, but also to the Federal Highway Administration (FHWA), which helped fund the pilot project, and to Lafarge North America, which supplied the cement and technical assistance for the study.

Highway engineers also will be reassured by the fact that high-performance doesn't necessarily mean exotic. These concretes are modifications of proven mix designs. The Lafarge NewCem-brand slag cement used in the pilot project, for example, has been used in road construction for more than three decades.

One of the key determinants of the life expectancy of concrete pavement is cracking. If the tensile stresses due to shrinkage or an applied load exceed the tensile strength of the concrete, the concrete will develop cracks. Cracks can disrupt the integrity of the slab and allow moisture and other contaminants into the concrete, which can lead to disintegration of the concrete.

The pilot project was designed to evaluate two different approaches to reduce cracking. One test section uses low-shrinkage concrete (LSC), reducing the potential for random cracking and curling. The other test section uses fatigue-resistant concrete (FRC). Small synthetic fibers are added to the mix during batching to provide additional tensile strength to the slab. These fibers have been shown to reduce cracking by 80 to 100%.

35 years will go by quickly

Thirty-five years is a long time to wait to find out how well a pavement performs. MDSHA and the FHWA turned to technology to shorten the learning curve, using embedded sensors to monitor the pavement's performance under actual traffic conditions.

The test pavement consists of approximately 2,400 ft of straight, level highway, extending across both eastbound lanes of traffic. The pavement is divided into three 800-ft sections—one control section and two test sections—so they are exposed to precisely the same traffic and weather conditions.

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Except for the concrete mix, design criteria are identical for all three sections. The pavement is 10 in. thick over a sub-base of 8 in. of graded aggregate base. Epoxy-coated dowels are used to tie pavement sections together.

The control section uses MDSHA PCC Mix No. 7, the standard mix specified by MDSHA for concrete pavements.

One test section uses the FRC mix, which conforms to the standard Maryland mix but contains synthetic fibers added to the mix at the batch plant at the rate of 1 lb per hundredweight.

The LSC also conforms to the standard mix, but uses a larger-sized coarse aggregate—Maryland No. 357—in place of the standard Maryland No. 57 aggregate. The larger aggregate size helps stabilize the size of the slab and control shrinkage.

All three mixes used NewCem slag cement, supplied by Lafarge. "The portland-slag blend was used primarily to mitigate alkali-silica reactions with the aggregates used in the concrete," said Stewart. Alkali-silica reactivity (ASR) can occur between the alkalis in portland cement and silica aggregates. In the presence of water, these reactions can form an expansive gel, leading to cracking. The slag cement in the NewCem blend reacts with the alkalis in portland cement, keeping them from reacting with the silica aggregates.

Other characteristics of NewCem also contribute to extended pavement life. NewCem provides higher ultimate compressive and flexural strength when combined with standard portland cement. It also reduces the concrete's permeability to water, chlorides and other aggressive agents, reducing the potential for pavement deterioration.

The University of Maryland performed laboratory evaluations of all mix designs and are evaluating data from the embedded sensors to monitor performance under actual conditions. The following properties are being evaluated:

- Compressive strength;
- Flexural strength and toughness;
- Restrained shrinkage;
- Shrinkage; and
- Flexural fatigue.

Seeing what's missing

In addition to materials used in the test sections, the entire project includes additional measures to extend the life of the pavement:

- The pavement employs 15-ft joint spacing. By reducing the size of the slabs, tensile stress is reduced;
- The project is the first in the U.S. to require a warranty from the contractor for concrete joint performance for a period of three years; and
- The shoulders, which were originally specified as hot-mix asphalt, were upgraded to concrete at the recommendation of the contractor, Cherry Hill Construction Inc. Concrete shoulders are expected to reduce maintenance and last longer.

Preliminary data are undergoing analysis, with the first results expected late in 2003. The analysis uses software developed by the American Concrete Institute to estimate the life of the pavement.

"We recognized the potential for high-performance concrete to extend the life of roadways," said Stewart. "What's been missing, however, are field results to support a solid cost-benefit analysis. We believe the results of these tests will help highway engineers across the country to make better decisions about when and where to use high-performance mixes." RB

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