2018-29TS
Published November 2018

LRRB
LOCAL ROAD RESEARCH BOARD

TECHNICAL SUMMARY

Technical Liaison:
Maria Masten, MnDOT
Maria.Masten@state.mn.us

Project Coordinator:
Deb Fick, MnDOT
Deb.Fick@state.mn.us

Principal Investigator:
Manik Barman, University of Minnesota Duluth

LRRB PROJECT COST:
$153,792

MnROAD test cells of fiber-reinforced concrete overlays have shown good results with synthetic fibers like these.

Selecting Structural Synthetic Fibers for Use in Thin Concrete Overlays

Lab testing demonstrated that structural synthetic fibers in thin concrete overlays keep cracks tight and help transfer loads across pavement slabs. Researchers provided recommendations for selecting fiber types and dosages in pavement design.

What Was the Need?

Concrete pavements usually measure 8 to 15 inches thick. For many of these pavements, designers recommend placing dowel bars at the joints during the pour to assist the transfer of wheel load from heavy commercial and agricultural vehicles across concrete slab joints.

MnDOT has found that dowel bars are not effective in a thin concrete overlay, a 4- to 6-inch layer of concrete over an older pavement. These slabs fracture prematurely around the dowels. Adding structural fibers to concrete offers a potential solution. Used primarily to keep cracks from widening, these fibers consist of pieces of thin synthetic material—polymers, carbon fabric, even steel—mixed into the concrete batch.

Many states do not have formal standards for fiber types or characteristics, dosage rates or other specifications for their use. MnDOT currently uses the approved products list created by Illinois Department of Transportation.

Minnesota road engineers agree that fibers work well in concrete, but how well is unknown. Research was needed to determine the optimal physical characteristics of fibers, the amount that should be mixed in to the concrete, and products currently not on the approved products list that may be effective.

What Was Our Goal?

MnDOT wanted to investigate fiber performance in thin concrete overlays, specifically to help identify fibers that are most appropriate in these overlays and recommend acceptable dosage rates for mixing and placing the thin concrete. MnDOT also needed a test procedure and design recommendations or specifications for using fibers.

What Did We Do?

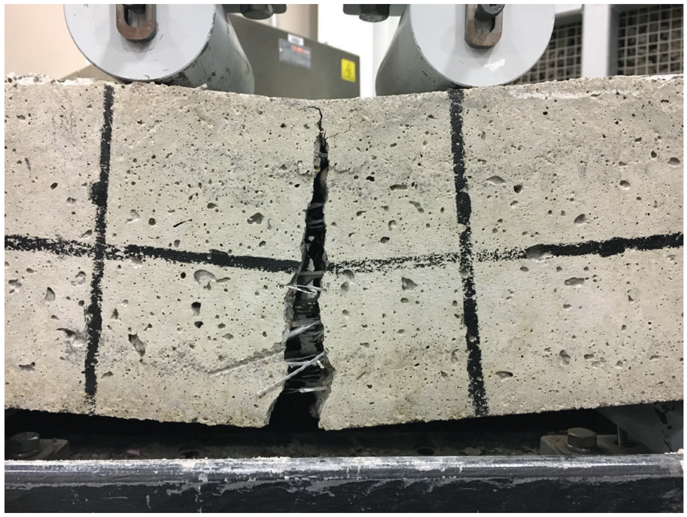
Research began with a literature search and a survey of state transportation agencies identified by the American Concrete Pavement Association as leading users of fiber-reinforced concrete overlays.

Laboratory testing first focused on post-crack performance, relying on ASTM C1609, the nationally recognized testing standard. Investigators tested 10 fibers of various lengths, geometries and stiffness in three dosage levels in concrete, evaluating the impact of fiber properties on post-crack performance.

Testing then turned to joint performance. Researchers used four fibers from the previous lab examination and added a fifth fiber, a synthetic fiber used in MnROAD test cells in 2017, to test load transfer across cracks between sections of fiber-reinforced concrete. Together, the two lab phases tested 11 fibers in 43 concrete mixtures in over 400 samples—10 beams and 10 cylinders each of 30 fiber-reinforced concrete samples for post-crack performance, one plain concrete mix and 12 additional fiber-reinforced mixtures in joint performance testing. Analysis considered post-crack performance, crack width, fiber geometry, dosage, load transfer efficiency and residual strength.

MnDOT
DEPARTMENT OF TRANSPORTATION
RESEARCH SERVICES & LIBRARY

continued



Post-crack performance testing of fiber-reinforced concrete beams shows that after cracking, fibers work to keep cracks from widening.

In the final step, researchers analyzed the collected data and developed recommendations for MnDOT.

What Did We Learn?

Results confirmed that fibers help keep cracks and joints tight and improve load transfer across cracks and joints in thin concrete overlays. This research indicated synthetic fibers provide equal or better performance than steel fibers, which are expensive, heavy and difficult to mix. Dosages less than 0.25 percent fiber volume fraction of concrete mixture did not improve post-crack flexural or load transfer efficiency across the joint.

In lab mixing, longer and stiffer fibers tended to ball and mat with greater frequency than shorter fibers, though researchers developed a mixing method that reduces balling and matting. Fiber dosage, stiffness and shape significantly influenced strength. Embossed, twisted and crimped fibers outperformed straight, flat synthetic fibers; longer fibers with larger diameters outperformed shorter, smaller diameter fibers that inhibit workability.

Fiber shape had moderate influence on load transfer and displacement in joint performance testing. Dosage levels and crack width strongly affected joint performance. Overall, it was found that fibers can increase the load transfer by 30 percent and can reduce the slab displacement by 50 percent.

Researchers suggest designers use trial batches of mixtures, submitting samples to ASTM C1609 testing and selecting fibers based on joint performance results from this study. Graphs and tables from this study correlate fiber properties with post-crack flexural strength and joint performance to help guide selection and dosage.

What's Next?

Researchers recommend fibers with high lateral stiffness and irregular cross sections in lengths between 1.5 to 2.5 inches and at dosage levels no greater than 1 percent fiber volume fraction to avoid balling, matting and unworkability of concrete mixtures. MnDOT will issue fiber requirements so manufacturers can then submit products and test results for evaluation by MnDOT in developing a new approved products list for fibers in concrete pavements.

Future research could focus on validating design recommendations in the field; establishing fresh fiber-reinforced concrete mixture parameters by running slump, air content and other tests of fresh mixes; and analyzing life-cycle costs and benefits.

This Technical Summary pertains to the LRRB-produced Report 2018-29, "Comparison of Performances of Structural Fibers and Development of a Specification for Using Them in Thin Concrete Overlays," published August 2018. The full report can be accessed at mndot.gov/research/reports/2018/201829.pdf.

"This research looked at fiber performance in terms of load transfer to see if fibers can provide an alternative to dowels in thinner concrete pavements."

—Maria Masten,
Concrete Engineer,
MnDOT Office of Materials and Road Research

"We studied many varieties of fibers before writing a specification for using fibers in concrete overlays. This is one step forward in understanding fiber's contribution in concrete pavements or overlays."

—Manik Barman,
Assistant Professor,
University of Minnesota Duluth Department of Civil Engineering

Produced by CTC & Associates for:
Minnesota Department of Transportation
Research Services & Library
MS 330, First Floor
395 John Ireland Blvd.
St. Paul, MN 55155-1899
651-366-3780
www.mndot.gov/research