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TECHNICAL SUMMARY

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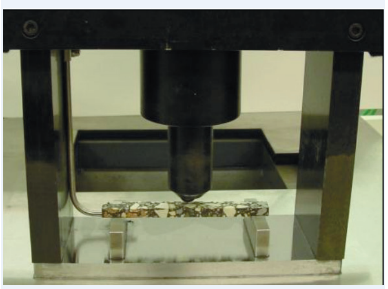
PROJECT COST:
$125,963



Although simpler and less expensive than an SCB test, a BBR test only evaluates the properties of a mixture's coarse aggregates.

Nanotechnology Reduces Cold-Weather Cracking in Asphalt Pavements

What Was the Need?

Lower temperatures frequently cause cracking in asphalt pavements, especially in northern states. Cracking can significantly reduce the durability and life span of pavements and lead to costly pavement repair and rehabilitation.

To improve pavement performance, engineers use additives to modify asphalt mixture binders, the petroleum-based material used in asphalt to coat its aggregate. More recently there has been an interest in modifying asphalt binders using nanomaterials, or materials with particles that have a dimension of less than 100 nanometers. Research suggests that nanoclay, nanosilica, carbon nanotubes, basalt fibers and graphite nanoplatelets (GNP) could improve the performance of asphalt mixtures. In particular, recent research at the University of Minnesota showed that asphalt that uses binders modified with GNP, which consist of graphite layers of less than 10 nanometers thick, has significantly improved mechanical properties at low temperatures.

Adding graphite nanoplatelets to asphalt binders and applying the methodology developed in this project could provide MnDOT with a cost-effective approach to reducing cold-weather cracking and increasing the durability of Minnesota pavements.

However, a comprehensive approach for determining the optimum mix design of GNP-reinforced asphalt binders and mixtures is not available. Further, current test procedures for determining performance are time-consuming and expensive. Research was needed to establish a method that combines computational modeling and simple, inexpensive lab testing to predict the performance of GNP-reinforced asphalt binders and mixtures.

What Was Our Goal?

The objective of this project was to develop a cost-effective method to determine the optimum mix design of GNP-reinforced asphalt binders and mixtures. This method would predict the fracture behavior of these materials using a combination of simple laboratory testing and computer modeling.

What Did We Do?

Researchers developed a method for determining the quantity of GNP to add to an asphalt binder to achieve optimal asphalt mixture performance. The method used a computer model to predict the low-temperature fracture behavior of mixtures based on bending beam rheometer (BBR) tests on fine aggregate mixtures. This test applies a load to the center of a thin, rectangular specimen that has been cooled to a low temperature while its edges rest on two elevated supports, and then measures how the specimen bends over time. The results of this test determine the stiffness of materials and their ability to relax the stresses of contraction.

The BBR test is simpler, less expensive and less labor-intensive than the more accurate semicircular bend (SCB) test, which measures fracture resistance—the way cracks in a material form—by loading a semicircular sample from its apex. However, the SCB test can determine the properties of all the particles within a mixture; the BBR test can only evaluate the mechanical properties of coarse aggregates. To obtain the accuracy of the SCB test without the labor and expense, the computer model developed by researchers in this study uses BBR results as inputs to simulate SCB tests and infer the properties of fine aggregates.

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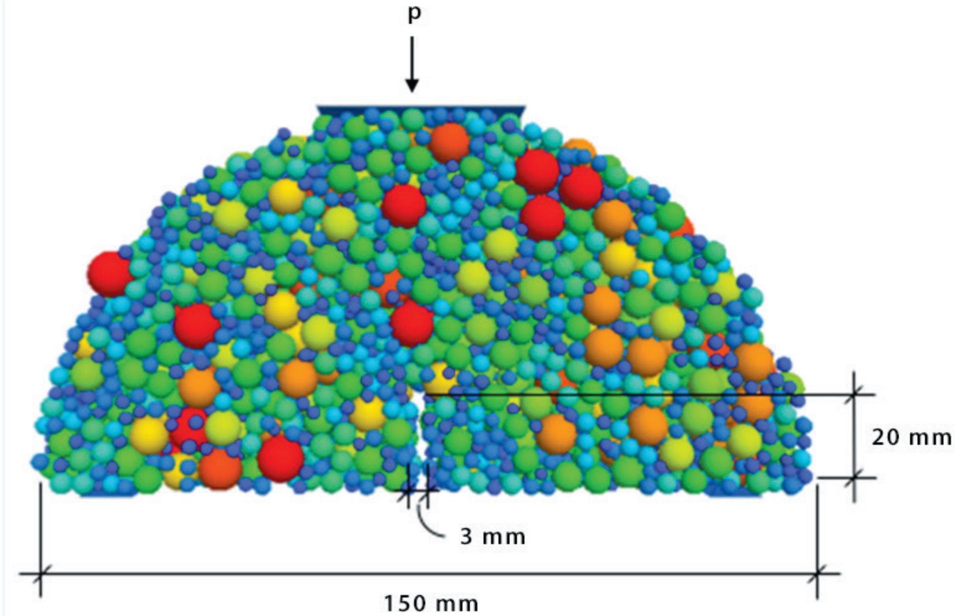

Researchers developed a computer model of SCB tests that can be used to infer the properties of asphalt mixture binders using inputs from the less-expensive BBR test.

What Did We Learn?

Researchers validated their computer model by comparing its results with those of actual SCB tests. They found that the model was able to predict the results of SCB tests for both conventional and GNP-modified mixtures. By performing only a BBR test on the fine aggregates mixture and inputting the results into the computer model, researchers obtained a reasonable prediction of the fracture response of the final asphalt mixtures.

In turn, the model showed that using GNP in asphalt binders can significantly improve the strength and fracture resistance of a mixture compared to mixtures with unmodified asphalt binders. The model can be used as a design tool to determine what percentage of GNP is needed to achieve the necessary tensile strength for a target value of fracture energy.

What's Next?

Using GNP in asphalt binders, in combination with the methodology developed in this project, could potentially provide MnDOT with a cost-effective approach to improving the cold-weather performance of Minnesota pavements, preventing cracking and increasing pavement durability. MnDOT will continue to evaluate the use of GNP in its asphalt mixes.

In an ongoing MnDOT project, "Experimental and Computational Investigations of High Density Asphalt Mixtures," researchers are examining the compaction behavior of aggregates with various binders. Researchers are also interested in developing a test to directly determine the fracture behavior of fine aggregate mixtures.

"Pavement engineering is still largely empirical and can require very costly testing, especially when evaluating fracture behavior. This project developed an innovative way to get the same results by combining modeling with a simple, inexpensive test."

—Jia-Liang Le,
Associate Professor, University of Minnesota Department of Civil, Environmental and Geo-Engineering

"This project gives MnDOT a low-cost way to incorporate the latest nanotechnologies into our asphalt mixtures, reducing cold-weather cracking and increasing the durability of Minnesota pavements."

—Shongtao Dai,
Research Operations Engineer, MnDOT Office of Materials and Road Research

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This Technical Summary pertains to Report 2018-02, "A Mechanistic Design Approach for Graphite Nanoplatelet (GNP) Reinforced Asphalt Mixtures for Low-Temperature Applications," published January 2018. The full report can be accessed at mndot.gov/research/reports/2018/201802.pdf.