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LOCAL ROAD RESEARCH BOARD

TECHNICAL SUMMARY

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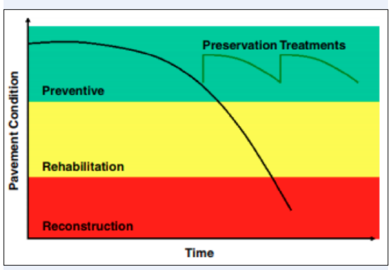
PROJECT COST:
$151,514



Timely preventive treatment, as shown in this chart, keeps pavement in good condition longer.

DEPARTMENT OF TRANSPORTATION
OFFICE OF RESEARCH & INNOVATION

Innovative Materials and Technologies for Sustainable Pavement Infrastructure

> *Researchers investigated two innovative additives to asphalt binders—graphite nanoplatelets and taconite concentrates—that offer possibilities of enhanced damage detection techniques and new ways to restore subsurface cracking through application of microwave energy.*

What Was the Need?

One principle underlying life cycle planning strategies for effective transportation asset management is that performing pavement maintenance when damage is detected substantially extends pavement life. Every dollar MnDOT and local agencies expend on repairs early in a pavement segment's life can save $6 to $10 in future reconstruction costs if that pavement were allowed to deteriorate. However, MnDOT and local agencies need more innovative solutions to address their aging pavement infrastructure, as current materials and technologies cannot keep up with the roadway system's rate of deterioration.

Previous national research involving MnDOT examined graphite nanoplatelets (GNPs) as an asphalt additive. GNPs are extremely small, stacked groups of graphene—single layers of graphite, a common crystalline form of carbon—that exhibit strong electrical conductivity and can enhance polymer strength. Polymer-modified asphalt binders have become the norm throughout North America. GNP's novel characteristics and functionality could allow early detection of subsurface damage and aid in more effective asphalt pavement repair techniques.

MnDOT and local agencies supported further examination of GNPs and taconite concentrates—from iron-bearing sedimentary rock—as additions to asphalt binders, with a focus on possible advances in damage detection, pavement repair and increased durability. The investigators from the national study were engaged with others to continue this study for MnDOT and local agencies.

What Was Our Goal?

The goal of this Local Road Research Board project was to explore the damage sensing and healing capabilities of asphalt binders and mixtures modified with GNPs and taconite concentrates. A related objective was to investigate the thermal bonding capabilities of a novel tack coat material modified with these same materials.

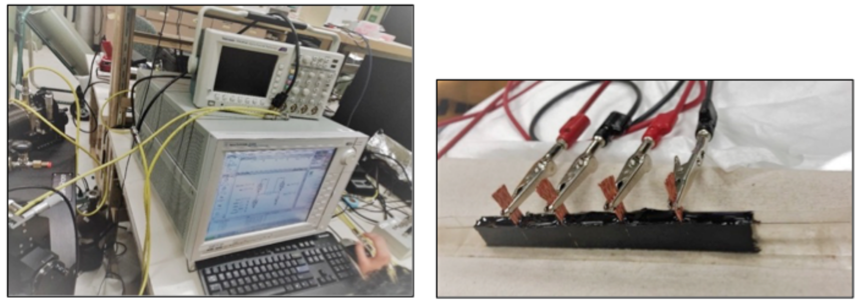
What Did We Do?

Researchers first conducted a literature review to examine current knowledge and practice in nondestructive testing of asphalt pavements. The research team then conducted the project investigations in four parts.

First, they tested asphalt binder samples for electrical conductivity. The team performed four-probe electrical conductivity experiments on four GNP/taconite-modified asphalt mixtures. They prepared samples by mixing an asphalt binder with a portion of GNP material, then poured the mixture into a mold prepared with four electrical probes arranged to be embedded in the solidified binder. Two outside probes delivered current while the two inside probes measured voltage. Through this process, they determined the mixture ratios required to facilitate measurable voltage within the asphalt binder samples.

In the second step, researchers addressed how the electrical conductivity of the asphalt binder containing GNP/taconite could be used to detect damage in an asphalt sample. Researchers

continued



Researchers tested the electrical conductivity of asphalt mixtures using strip samples with GNP/taconite added. Four electrical probes were inserted into samples: Two outer probes delivered current while two inner probes measured voltage within the sample.

developed a mathematical model to show the relationship between extent of damage in a sample and the change in electrical conductivity. They performed four-probe electrical conductivity experiments on samples of GNP/taconite-modified binders with different notch depths cut into them, representing cracks. The focus of this study was limited to the case where the damage is a discrete macrocrack, a common kind of localized damage.

Then they investigated the application of microwave energy to GNP/taconite-modified asphalt as a means of healing subsurface cracking. Researchers prepared a sample asphalt pavement piece and inflicted damage to it in the laboratory. Then they exposed the sample to microwave energy and reexamined the electrical conductivity of the sample.

In the final step, researchers investigated the ability of microwave energy to enhance the bonding of a GNP/taconite-modified tack coat, a coating to integrate two layers of asphalt. This interface is a common weak point in asphalt pavements.

What Was the Result?

The literature review described a few nondestructive methods to detect damage to pavements, such as ultrasonic and ground penetrating radar. This research adds to the technologies and methods.

Researchers showed that 6% additions of GNP and taconite concentrates to asphalt binder resulted in an electrically conductive material. The damage detection investigation tracking electrical resistance in cracks seemed successful initially, but later tests were confounded by moisture in the sample: the first tests completed in dry January, the second in humid June. Water is electrically conductive; humidity in the sample conducted electricity across cracks and compromised the data.

The microwave investigation was successful. The application of microwave energy to a damaged sample of GNP/taconite material restored it to its original state. Using microwave energy to enhance tack coat strength showed some promise, but variation among results was too high to allow conclusions. Testing of more specimens is indicated.

What's Next?

The project's testing of innovative materials for damage detection methods and for the healing of pavement microcracks was promising. Researchers recommended that testing through MnDOT's MnROAD outdoor laboratory be undertaken next.

"This project's results support the development of new asphalt materials with GNP/taconite additions. They can aid in early damage detection and provide asphalt healing and improved interlayer bonding through microwave technology."

—Juan Pinero, Supervising Engineering Technician, Hennepin County

"This research developed GNP/taconite-modified asphalt mixtures—a new type of asphalt material that can be healed of microcracks with microwave heating. This novel material provides a cost-effective means of early repair and rehabilitation of asphalt pavements."

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

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