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DEPARTMENT OF TRANSPORTATION

RESEARCH SERVICES & LIBRARY

TECHNICAL SUMMARY

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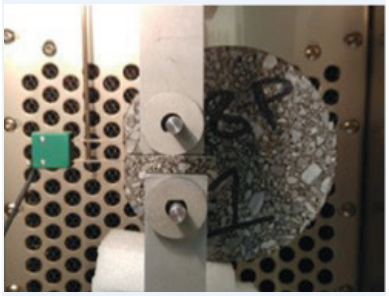
PROJECT COST:
$89,910



The disk-shaped compact tension test determines fracture energy of pavement samples, a strong predictor of cracking performance.

Research Confirms Low-Binder Asphalt Pavement Mixtures Prone to Cracking

What Was the Need?

Introduced in 1993, Superpave has successfully helped transportation agencies in northern regions design asphalt pavements that are less susceptible to thermal cracking. When tested, Superpave-compliant designs were found to resist both rutting and thermal cracking.

Gradation-based design approaches have also allowed for the use of coarse-graded, low asphalt binder mixtures. These mix designs establish a maximum aggregate size and reduce the range of usable gradations. Such coarse-graded designs meet MnDOT specifications because the maximum aggregate size falls within the acceptable gradation range. However, the reduced fine aggregate content made possible by the use of coarse aggregates leads to a mix that, while still within specifications, offers less surface area to be coated by the asphalt binder and can encourage unwelcome permeability in the field. To win low-bid competitions, contractors have embraced these low-binder, coarse-graded designs to reduce binder and aggregate costs.

Transportation engineers noticed that these pavements seemed to "gray out" or lose their dark color more quickly than previous asphalt designs. These pavements also seemed to grow somewhat more brittle and were less able to rebound from loading. Such asphalts are thought to be prone to quicker failure than mixes with finer aggregate and more binder. Road designers typically attribute thermal cracking and potholing in low-binder asphalt to the increased permeability that leads to water incursion and freeze-thaw damage.

Research shows that low-binder asphalt mixtures are susceptible to premature cracking. The current use of coarse-graded mix designs should be adjusted to narrow the gradation difference between larger and smaller aggregates in the mixes. While research suggests that such mixes should be used sparingly in Minnesota, it did not provide definitive data suggesting the practice should be stopped altogether.

What Was Our Goal?

The goal of this project was to determine how well low-binder asphalt pavements perform and whether current designs make sense in terms of cost–benefit and durability. Researchers would identify any relationship between reduced bitumen use and potential for cracking, and would suggest changes to specifications for coarse-graded asphalt pavement mixtures to prevent such cracking issues.

What Did We Do?

Researchers worked with MnDOT to identify 10 pavement locations in Minnesota that used 13 coarse-graded, low-binder asphalt mix designs. Investigators extracted data on cracking, roughness and other factors for these sites from MnDOT's pavement management system. The research team then visited the sites and inspected the pavements.

Researchers developed a coring plan, and field samples were cored for volumetric analysis to determine the binder, aggregate, air void level and other properties of each mixture. They also tested permeability and dynamic modulus, and conducted fracture energy testing to determine cracking resistance.

continued

"The pavement mechanistic-empirical simulations, low disk-shaped compact tension fracture energy and higher permeability all indicate a shorter pavement life for these mixes."

—Jerry Geib,
Research Operations Engineer, MnDOT Office of Materials and Road Research

"With coarser mixtures, excessive cracking will occur in a very short time. We recommend that MnDOT adopt perfomance-testing specifications and conduct mechanical testing like fracture energy, fracture toughness and modulus measurements, which the agency has already started."

—Eshan Dave,
Assistant Professor, University of New Hampshire Department of Civil and Environmental Engineering

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Cracking was extensive for most of the low asphalt binder mixtures. These coarse-graded asphalts prove susceptible to thermal and transverse cracking, and even to potholing from freeze-thaw damage.

Investigators used performance modeling to analyze the test results of pavement properties and project pavement durability. Then they compared the projected performance to actual field performance. From this assessment, they drew recommendations for modifying specifications for MnDOT low-binder, coarse-graded asphalt mixtures.

What Did We Learn?

This study suggests MnDOT should reduce its use of coarse-graded asphalt mixtures, but the findings did not provide sufficient data to justify prohibiting the use of coarse-graded, low-binder asphalt designs.

Low-binder mixtures were prone to thermal and transverse cracking. Their high permeability left them vulnerable to premature moisture and freeze-thaw damage. Field and laboratory testing and modeling demonstrated that coarser mixtures produce excessive cracking in a short period of time. Thin overlays of 3 inches or less crack more quickly than thick overlays of 4 to 6 inches. Mechanistic-empirical simulations showed that low-binder asphalt mixtures were significantly inferior to higher-binder mixtures in terms of thermal cracking.

Most of the high-cracking mixtures showed low fracture energy in testing, suggesting the value of fracture energy testing and modeling. Disk-shaped compact tension testing showed that higher permeability mixtures correlate reasonably well with lower fracture energy. Eight of the 13 mixtures were more permeable than recommended, and six significantly so. Typical volumetric properties poorly predicted cracking.

To better project pavement performance, researchers recommend that MnDOT maintain volumetric testing-based specifications, but add performance testing-based specifications and testing designs for fracture energy, fracture resistance, modulus and other parameters. For Superpave designs, investigators suggest using a narrower aggregate gradation range, reducing the gradation gap between minimum and maximum aggregates in mixes.

What's Next?

Although the research validates MnDOT engineers' anecdotal concerns, the pavements evaluated were mostly overlays, which are known to be susceptible to transverse cracking because of flaws in underlying pavement layers. MnDOT may weigh the results and adjust specifications, but would likely require further study of coarse-graded mixture performance before ruling out its use or identifying situations in which coarse-graded mixtures may be the best option. Additional research could consider the use of nonuniform lift designs for asphalt pavements, varying mixes for each lift in the structure rather than using a single, uniform mix for every layer in the full depth of the pavement.

This Technical Summary pertains to Report 2017-27, "Impact of Low Asphalt Binder for Coarse HMA Mixes," published June 2017. The full report can be accessed at mndot.gov/research/reports/2017/201727.pdf.