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OFFICE OF TRANSPORTATION SYSTEM MANAGEMENT

TECHNICAL SUMMARY

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PROJECT COST:

$127,535

Carbonate rocks are whiter and softer than noncarbonate rocks and react with an acidic solution to create carbon dioxide.

Prescreening Protocol Could Expand Acceptable Aggregate Sources

What Was the Need?

When building roads, MnDOT specifies high-quality aggregates to use in its concrete pavement mixtures. However, high-quality aggregate resources in Minnesota are being depleted rapidly. The largest part of Minnesota reserves consists of natural aggregate (such as sand and gravel mined from glacial or alluvial deposits), identified by MnDOT as Class C.

MnDOT classifies aggregates as follows:

- Class A: Crushed quarry or mine trap rock such as basalt, diabase, gabbro or related igneous rock types, quartzite, gneiss or granite.
- Class B: Crushed quarry or mine rock such as carbonates, rhyolite or schist, with a maximum absorption of 1.75 percent.
- Class C: Natural or partly crushed natural gravel with a maximum carbonate by weight of 30 percent.

By better understanding aggregate properties, including resistance to freezing and thawing, MnDOT may be able to employ a broader range of available aggregates to build concrete pavements, reducing the costs and environmental impacts of transporting aggregates from far away.

However, MnDOT's current requirements may exclude some high-quality aggregates with acceptable freeze-thaw durability.

What Was Our Goal?

The goals of this study were to:

- Characterize Minnesota's aggregates with a range of carbonate content using a simple, rapid test, such as the Iowa pore index test.
- Relate to Iowa pore index values and other aggregate properties (such as pore structure and absorption) that are known to affect freeze-thaw durability.
- Re-evaluate the current MnDOT specification limits on Class B and Class C aggregates to allow more sources of aggregate to be used in concrete construction.

What Did We Do?

Researchers began by conducting a literature review, which suggested that no single laboratory test can be directly correlated to aggregate freeze-thaw performance in the field. It is common practice to rely on a number of different tests, combined with a history of field performance. Some tests directly evaluate freeze-thaw durability and others evaluate properties related to this durability, including pore structure; mechanical properties; and chemical and mineralogical properties, such as grain size and other indicators of aggregate quality.

Researchers then evaluated 15 aggregate sources from Minnesota; three consisted of 100 percent crushed carbonate rocks (Class B), and the rest were crushed gravel (Class C) with varying percentages of carbonate. Within the crushed gravel sources, the researchers tested both the carbonate and noncarbonate fractions individually and together to determine the properties of the aggregates.

Researchers conducted laboratory tests on these samples for carbonate content, absorption, desorption, specific gravity and pore size distribution. Absorption and desorption

continued

"One crucial result of this project is our quantification of the relationship between the Iowa pore index test and pore structure, an important step toward determining the freeze-thaw durability of carbonate aggregates."

—Kejin Wang,
PCC Engineer, Iowa State University Institute for Transportation

"Current and future research will help MnDOT develop methods for making more rational decisions as to the allowable maximum content of carbonate aggregates in concrete."

—Bernard Izevbekhai,
Research Operations Engineer, MnDOT Office of Materials and Road Research

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Researchers used the Iowa pore index test to evaluate the pore structure of aggregates. This test models the absorption of water into micropores as it is pushed into the aggregate at 35 psi.

are measures of the way in which materials absorb or lose water, and specific gravity is a measure of density. Pore size distribution is an indicator of an aggregate's ability to transport water. If water can move easily in or out of an aggregate, or can't enter the aggregate, research indicates it will be more resistant to freezing and thawing damage.

What Did We Learn?

Laboratory testing of aggregates showed that a maximum 30 percent limit on carbonate content in Class C aggregates may not be the best indicator of freeze-thaw resistant aggregate. Test results from the Iowa pore index test did not consistently predict better freeze-thaw performance from those sources. Because absorption by itself is not an indication of pore size, a better prediction of freeze-thaw performance may be a high specific gravity combined with a low absorption.

The 100 percent carbonate aggregates consistently had a higher absorption and finer pore structure than noncarbonates as well as a lower specific gravity. However, while there was a fairly good correlation between absorption and specific gravity, there was no correlation between carbonate content and absorption or pore size.

Excluding the 100 percent carbonate aggregates, only two sources had a carbonate percentage higher than the MnDOT limit of 30 percent. Only one of the aggregates (which contained 100 percent carbonate) had an absorption higher than the MnDOT specified limit. The two other carbonate aggregates had lower absorption values than natural gravel. Finally, pore structure tests suggested that all but one aggregate (which contained 100 percent carbonate) were at least equal in durability to Iowa DOT's currently Class 3 aggregates classification. Class 3 aggregates are defined by Iowa DOT as having a certain range of particle sizes and producing roads with a durability of at least 20 years.

What's Next?

Researchers recommend adopting the Iowa pore index test as a simple, rapid and effective method for evaluating the pore structure of aggregates. They also recommend that MnDOT re-evaluate its 30 percent limit on carbonate content in Class C aggregates since the quality of carbonate aggregates varies significantly. Aggregates containing more than a 30 percent carbonate portion might be used to produce a freeze-thaw durable pavement if the carbonate portion aggregate has a good pore structure, low absorption and high specific gravity. Because it is not clear which range of pore sizes have the most significant effect on freeze-thaw durability, researchers also recommend further testing to identify critical pore size ranges.

This Technical Summary pertains to Report 2015-14, "Carbonate Aggregate in Concrete," published May 2015. The full report can be accessed at mndot.gov/research/TS/2015/201514.pdf.