PUTTING RESEARCH TO WORK **BRIEF**

Methods to Determine Long-Term Durability of Wisconsin Aggregates

Wisconsin uses approximately 10 to 11 million tons of aggregates annually in transportation infrastructure projects in the state. The quality of aggregates has a tremendous influence on the performance and durability of roadways and bridges. As sources of quality aggregates dwindle and new recycled/reclaimed aggregates are introduced, it is important that the quality of aggregates used in construction be assessed and controlled through appropriate testing. A number of tests are performed routinely on aggregate sources in Wisconsin. Newer tests such as Micro-Deval are also being performed. It is important to determine whether various tests are related to each other..

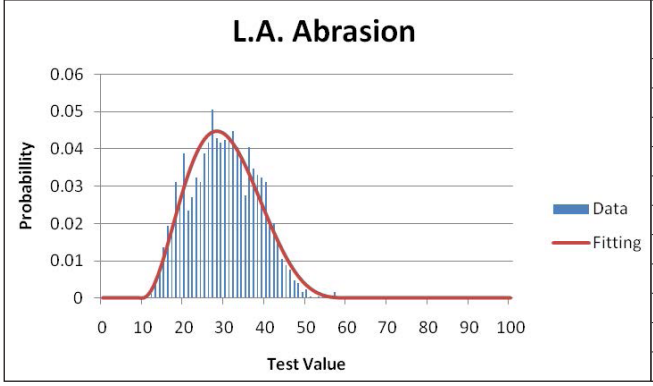
What is the Problem?

There are many comparative aggregate tests in the literature. However, there is limited information correlating various tests to long-term field performance. Previous research showed that field performance can be better represented by the Micro-Deval test. There are many aggregates that may be unsatisfactory in the field but perform satisfactorily in some of the tests. The Micro-Deval test measures abrasion resistance and is reported to have a higher accuracy for assessing durability of aggregates than the LA abrasion or magnesium sulfate soundness tests. There is a need for comparative analysis of different aggregate test data using statistical methods to establish whether different tests such as Micro-Deval are independent or related to each other. If the outcomes of a new test are not correlated with one or more results from other tests, then that test is measuring something different which may or may not be relevant to durability in the field.

Research Objective

The objective of this research was to:

- Assess whether the outcomes of the Micro-Deval and the unconfined freeze-thaw tests are statistically correlated with current standard aggregate tests that are being performed routinely by WisDOT.
- Determine the statistical relationships between the existing standard tests and the Micro-Deval test, if a reasonably accurate relationship can be developed.
- Provide statistical information on the various results included in the Wisconsin database of aggregate tests.
- Determine the effects of unconfined freeze-thaw and sodium sulfate soundness tests on the internal void structures in aggregate samples using X-ray tomography tests.



Percentile	Data	Distribution Fitting
0%	10.90	10.13
10%	18.14	18.70
20%	21.59	21.79
30%	24.63	24.29
40%	26.84	26.58
50%	29.14	28.82
60%	31.61	31.13
70%	34.01	33.65
80%	36.92	36.61
90%	40.03	40.63
100%	56.70	56.46

Histogram, distribution fit, and percentiles for the LA abrasion test results in the Wisconsin aggregate database (pits and quarries included)

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Methodology

Three aggregate test datasets were analyzed in this study:

1) The Wisconsin aggregate test data from years 2000 through 2010. (The tests reported included LA abrasion, sodium sulfate soundness, unconfined freeze-thaw, absorption and specific gravity.)
2) Test data on 69 aggregate sources reported in the Phase I study of this research. (The tests included Micro-Deval test, vacuum absorption test, LA abrasion and impact, aggregate crushing value, sodium sulfate soundness, unconfined freeze-thaw and percent lightweight test.)
3) Data used in a Texas study, Fowler, D.W., et al., "The Prediction of Coarse Aggregate Performance by Micro-Deval and Other Aggregate Tests," Report ICAR 507-1F, International Center for Aggregate Research, University of Texas, Austin, 2006. (The tests performed were similar to those in the Phase I Wisconsin study, but the magnesium sulfate soundness was used instead of sodium sulfate soundness.)

Basic statistical parameters were calculated for the data sets. The histogram for each type of test was plotted and the best statistical distribution was fit to the histogram data. The software programs Crystal Ball and Model Risk were used to find the best fit distributions. To determine correlations between Micro-Deval and other test results, multi-parameter regression analysis was performed on the test data from the Wisconsin database. X-ray tomography tests were also performed to investigate the effect of freeze-thaw and sodium sulfate tests on internal porosity of aggregates.

Results

The results of the multi-parameter regression analysis show that the highest correlation exists between absorption and Micro-Deval with the coefficient of correlation of 0.93. The unconfined freeze-thaw test outcomes cannot be predicted from results of other tests (not correlated). Therefore, the unconfined freeze-thaw test should be part of any test protocol as it measures an aggregate characteristic that cannot be obtained from other tests. Analytical relationships were developed to predict Micro-Deval test outcomes from absorption, LA abrasion, sodium sulfate soundness, unconfined freezing and thawing. For Wisconsin data (Phase I study), the Micro-Deval outcomes with an 18% loss limit were predicted 100% correctly for all aggregate tests performed. The prediction accuracy for a 16% Micro-Deval loss limit was 90%. For the Texas study (Fowler, et al.), the accuracy for the 18% and 16% Micro-Deval loss limits were 85% and 82%, respectively. This lower accuracy would be expected due to a wide variety of aggregates tested in the Texas study.

Based on the statistical analysis of the Wisconsin aggregate test database, the 75 percentile limits for various aggregate tests are: LA abrasion (35.5%), sodium sulfate soundness (5.65%), unconfined freeze-thaw test (6.0%), absorption (fine aggregates) (0.95%), and absorption of coarse aggregates (2.27%).

The results of 3D X-ray tomography tests show that both freeze-thaw and sodium sulfate tests increase pore space and develop cracks on the aggregates but the type and distribution of such void spaces are different in the two tests. The ratio of connected pore space of aggregate particles subjected to freeze-thaw tests significantly increased with a range from 45% to 6,390% while the increase varies from 140% to 4,430% for aggregates subjected to sodium sulfate soundness tests. Such increase with different amounts impact the durability of the aggregate at different levels leading to variable field performance

Benefits and Implementation

The correlations between Micro-Deval and other test results obtained using statistical approaches in this study are valuable to assessing relative significance of various tests for evaluating Wisconsin aggregates. The developed analytical relationships relate the combined results of routine tests to more properly predict aggregate durability, while each test's results individually may not necessarily make such a prediction.

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This brief summarizes Project 0092-10-08,
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Wisconsin Highway Research Program (WHRP) *http://wisdotresearch.wi.gov/whrp*