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A parametric study to improve suitability of micro-deval test to assess unbound base course aggregates

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ABSTRACT

Micro-deval test provides a measure of resistance and durability of aggregates submerged in water through the actions of aggregate particles and abrasion from steel balls. The presence of water in the test chamber provides a more realistic assessment of field conditions when compared with Los Angeles (LA) abrasion test. Currently there is only one testing procedure in the United States (U.S.) to evaluate the coarse aggregates using micro-deval tests. Previous studies indicate that there has been significant interest in utilizing micro-deval test to assess the suitability coarse aggregates to be used in asphalt concrete and their field performance. However the studies related to evaluating coarse aggregates with micro-deval test for base course applications are very limited. This study attempts to address how the micro-deval testing procedure may be revised to better assess the performance of aggregates considered for the base course. Aggregates with seven different geological compositions were used in the study. Total of 250 micro-deval tests were performed and the results confirmed the repeatability and the suitability of the proposed method to all of the tested aggregates. As part of this study, a threshold is determined for the optimum amount of abrasive charge that should be used in the tests to obtain maximum material loss regardless of the geological make-up of the aggregate. If this approach is followed, a strong relationship between the number of revolutions and percent material loss is achieved. This relationship provides an opportunity to shorten the micro-deval tests and also an approach to assess durability of aggregates at number of revolutions significantly larger than what is prescribed in the existing micro-deval testing procedure. This ability may be used in the future to more realistically relate the long-term durability prediction of aggregates as it relates to field performance of base course.

1. Introduction

The basis of the micro-deval test dates back to early 1900s when it was first developed to evaluate the quality of railroad ballast material [18]. The concept of the original test has not changed drastically over the years as it always consisted of aggregates placed in a chamber with water and rotated, although the micro-deval test known today was first standardized in France during the 1960s. Soon after, in 1963, New York State Department of Public Works (NYSDPW) showed an interest to this test [15]. Over the years, the details of the original test such as the size of the chamber, mass of sample, time of saturation, and amount of abrasive charge and water used in the chamber have changed. For example the original test was based on using 50 kg of sample, the French test method (AFNOR) P18 572 as explained by Jayawickrama et al. [10] is based on using 0.5 kg of sample, and the current Canadian and American test methods are based on 1.5 kg , [14,15,19,7]. The sample size adapted in Canada and U.S. was chosen to obtain better representative sample than the French test method but the amount was limited to 1.5 kg because previous study performed by the [14] showed that the material loss obtained in the test varied if the sample was 2 kg or more.

The test procedure in U.S. was originally developed for the asphalt industry to evaluate the toughness and durability of aggregates to be used in creating asphalt concrete (AC). Extensive number of research has already been performed for this purpose as summarized in the subsequent section of this manuscript. Currently there is also an interest from material and geotechnical engineers in U.S. to relate the micro-deval test to estimate the durability of unbound coarse aggregates used in base layer of pavement systems. However, currently there is only one micro-deval testing standard for all coarse-grained aggregates regardless of

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the applications such as HMA or base course. In this standard the suitability of aggregates for different applications are determined based on suggested thresholds as it relates to percent material loss. However the previous research as presented in the background section of this manuscript shows that the suggested thresholds in this standard do not capture the differences between good and poor aggregates accurately especially for the base course aggregate. Currently, there are no State agencies in the U.S. that incorporates the use of micro-deval test in their specifications to assess the durability of unbound base course aggregates. On the other hand, almost all of the State agencies in the U.S. predominantly rely on the Los Angeles (LA) abrasion test for their assessment. Although LA abrasion test provides an indication of the susceptibility of aggregates to mechanical breakdown, it is by no means a performance test as it is based on oven-dried aggregates subjected to impact (not abrasion between aggregates and no effect of water). As Rogers [19] pointed out, in the field, aggregates are rarely dry and rarely are subjected to large impact as simulated in the LA abrasion test. This fact is also supported by other studies. Richard and Scarlett [18], Wu et al. [21], Jayawickrama et al. [10], and Cuelho et al. [6] showed that the thresholds developed for the LA abrasion rarely correlate well with actual field performance but the test provides an opportunity to relatively compare the ease of mechanical breakdown of one aggregate type compare to another. The inclusion of water in micro-deval test provides a better opportunity to simulate field conditions because in the U.S., almost all road aggregates are already mixed with water even at the facility before they are placed on the back of a hauling truck and leave the quarry. Typically in most instances the aggregates are wetted to water contents equivalent to be slightly higher than their desired content.

The study described in this manuscript is conducted to provide a methodology to better assess the durability of the aggregate considered for the unbound base course in pavement systems. As part of this study, a threshold is determined for the optimum amount of abrasive charge that should be used to evaluate durability, which is different than what is suggested in the existing standard for micro-deval test method. It is demonstrated in this article that implementing this threshold provides consistent repeatable results regardless of the geological origin of aggregates. Also, based on this determined abrasion amount, a relationship can be established between the number of revolutions and percent material loss, which provides an opportunity to shorten the micro-deval tests and also make an assessment of durability at number of revolutions significantly higher than what is prescribed in the existing testing standard. This manuscript is written to describe the results obtained in this study, which provides an opportunity for a future study to evaluate the relevancy of these findings to use micro-deval test for quality control measure in the field as it relates to assessing the uniformity of the aggregate durability (based on the opportunity to shorten the test) and better relate the laboratory durability assessment to predict field durability performance (based on being able to predict material loss on much larger number of revolutions without having the need to significantly extend the duration of the testing).

2. Background

The following literature review is included to summarize how the micro-deval test has been historically used in the asphalt industry. The literature is also summarized to demonstrate the interest in using the micro-deval test to assess the durability of the coarse aggregate for base applications in pavement systems as well as the challenges to obtain consistent results and relating the existing test results to assess the field performance.

2.1. Comparison of micro-deval test with other tests to assess suitability of aggregates to create asphalt concrete mixtures

Wu et al. [21], Rangaraju et al. [17], Prowell et al. [16], Brandes and Robinson [3], and Lang et al. [13] are among the researchers that compared the results from micro-deval tests with other durability tests of the coarse aggregates that are considered for asphalt concrete. Wu et al. [21] evaluated aggregates from 16 different locations and compared the results from aggregate impact, LA abrasion, freeze-thaw, aggregate durability, and magnesium sulfate tests with micro-deval test. The researchers found that micro-deval test is one of the best available tests to assess aggregate quality. Rangaraju et al. [17] focused on evaluating aggregates from 23 different sources in South Carolina and found no correlation between micro-deval test and LA abrasion and sulfate tests. The researchers also noted that LA abrasion test was not suitable to even distinguish between good and fair to poor performing aggregates based on field performance rating. Prowell et al. [16] developed a National Cooperative Highway Research Program (NCHRP) report and in the study pointed out a good correlation between the magnesium sulfate soundness and micro-deval tests of coarse aggregates but also stated that neither of the test results were able to demonstrate any difference in rutting resistance between coarse and fine graded aggregates for Superpave mix designs. Brandes and Robinson [3] performed a comprehensive study specifically evaluating the long-term performance of HMA pavements in relation to the durability of basaltic aggregates found in Hawaii. The researchers have investigated LA abrasion, sulfate soundness tests, and micro-deval test for this assessment. Results indicated micro-deval test has correlated well with the sulfate test but not with the LA abrasion test. When field performance was compared with laboratory micro-deval test data, it was difficult to assess the reliability of micro-deval test to predict field performance because the presented data only had a coefficient of determination (R-squared) of 0.39. Lang et al. [13] performed one of the most recent and comprehensive comparisons of 117 different aggregate sources with 15 different geological compositions collected from majority of the States in the U.S. As in previous studies, the researchers compared the difference among micro-deval and other soundness tests and concluded that micro-deval test provided the best results to classify aggregates either as good or poor performers but stated that each agency should develop a specific criteria, including a performance history versus micro-deval material loss to provide accurate performance of forecasting. Hossain et al. [8] compared the micro-deval test results with absorption, LA abrasion, magnesium sulfate, and freeze-thaw tests of twenty coarse aggregate samples. The results showed that micro-deval test provided better repeatability than the magnesium sulfate and freeze-thaw tests.

The above-summarized studies show that when compared with other available durability assessment methods, in general micro-deval test appear to provide a better estimate to distinguish between aggregates considered for the asphalt concrete mixtures. There is also a recent attempt by Lane et al. [12] to combine micro-deval test with other tools to improve the assessment of the coarse aggregates to be used in asphalt concrete. In their study the researchers suggested combine the micro-deval test with image analyses to assess the aggregate morphology (i.e., shape, angularity, and surface texture) and to shorten the test procedure. Modified micro-deval test is proposed with 300 g of coarse aggregate with 200 g of silica sand and 1250 g of abrasion and 750 g of water. The results showed the validity of the proposed method but it was noted that further investigation needed to relate these findings with field durability assessments.