



Authors: Priyantha W. Jayawickrama, Ph.D., W. Frank Phillips, P.E., and M. Shabbir Hossain, Ph.D

## Comparative Analysis of the Micro-Deval and Magnesium Sulfate Soundness Tests

RESEARCH PROJECT SUMMARY

For many years the Texas Department of Transportation (TxDOT) has relied on the 5-cycle Magnesium Sulfate Soundness (MSS) Test for the evaluation of bituminous aggregates with respect to their durability. It is generally agreed that the Soundness specification has contributed to improved pavement performance. Nevertheless, this test method suffers from two significant drawbacks. First, the test procedure takes a minimum of 6 days to complete. Second, questions have been raised regarding the repeatability and the reproducibility of this test method.

### Micro-Deval Test

The Micro-Deval (MD) test is an alternative test method that is available for the evaluation of aggregate durability. This test method is currently being used by the Ministry of Transportation (MOT), Ontario, Canada. An AASHTO provisional standard for this test procedure has been introduced as well. In this test method, a 1500 g sample of coarse aggregate is immersed in water for 1 hour and then placed in a steel drum with 2.0 liters of water and an abrasive charge consisting of 5000 g of 9.5 mm diameter steel balls. The

jar, aggregate, water and charge are then rotated at 100 rpm for 2 hours (12,000 revolutions). At the end of 2 hours the aggregate is oven dried and the percent passing 1.18 mm is determined and reported as the Micro-Deval loss (%).

The Micro-Deval test requires only 1 day to complete. Moreover, according to recent findings by the Ontario MOT and the National Center for Asphalt Technology at Auburn, the test method provides good repeatability. Thus, this test method overcomes two shortcomings of the 5-cycle MSS test. Accordingly, this research was initiated with the objective of evaluating the Micro-Deval test procedure to determine its potential for use in TxDOT's aggregate quality monitoring program.



Figure 1. Steel jar and charge used in micro-deval test

### What We Did...

Our research plan for evaluating the Micro-Deval test consisted of two separate phases. Phase I focused on the use of this test method for bituminous coarse aggregates while Phase II focused on flexible base aggregates. For Phase I testing, 52 aggregate sources were selected. These



sources included 31 limestones, 11 gravels, 7 igneous rocks, 2 sandstones and 1 lightweight. Aggregate samples from each of these sources were subjected to the following lab test procedures: (a) petrography, (b) particle shape, (c) particle form, (d) absorption, (e) specific gravity, (f) 5-cycle MSS test (in triplicate), and (g) Micro-Deval (in triplicate). In addition to this, a second series of tests were conducted on 12 selected sources for the specific purpose of determining single lab and multiple lab precision of both MSS and MD tests. Texas Tech, TxDOT Materials and Tests Lab (Austin) and 6 other TxDOT district labs participated in the above round-robin test program. Accordingly, each of the selected 12 sources was tested in 4 labs. Each lab performed 5 repetitions of MSS and MD tests on each of the sources assigned to it. Phase II investigation consisted of a comparative study of the Texas Wet Ball Mill test and the Micro-Deval test for flexible base aggregates. This test series included 20 flexible base aggregate sources. Representative samples from these 20 sources were obtained. Wet Ball Mill and Micro-Deval tests were repeated three times on each of these sources.

### What We Found...

Test results clearly showed that the Micro-Deval test produced more consistent results than the 5-cycle MSS test. Figure 2 shows the standard deviations observed for each of the 12 selected sources when the two tests were repeated 5 times on multiple samples obtained from the same material. For each source the standard deviation (S.D.) for the Micro-Deval test was less than that for the MSS test. The pooled average S.D. for the MSS test was approximately 4.4 times that for the Micro-Deval test.

Figure 3 shows the comparison between standard deviations obtained for the two tests when samples from the same material were tested in four different labs.

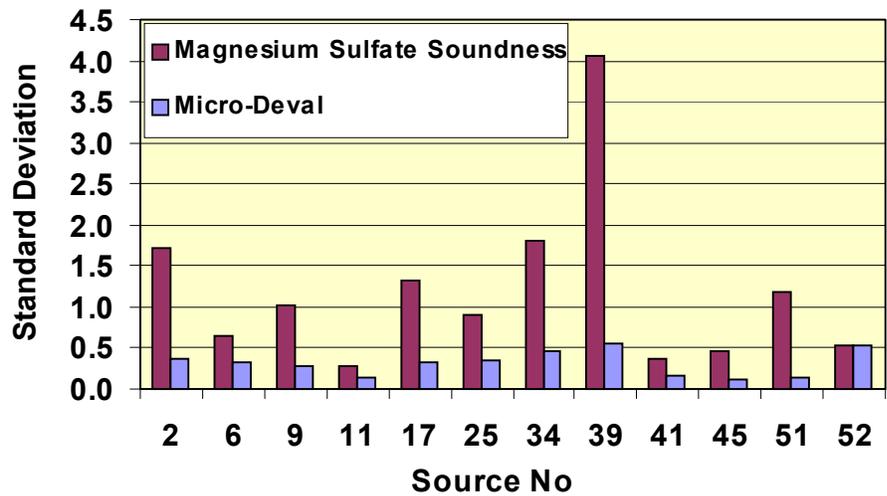


Figure 2. Repeatability of MD vs. MSS test

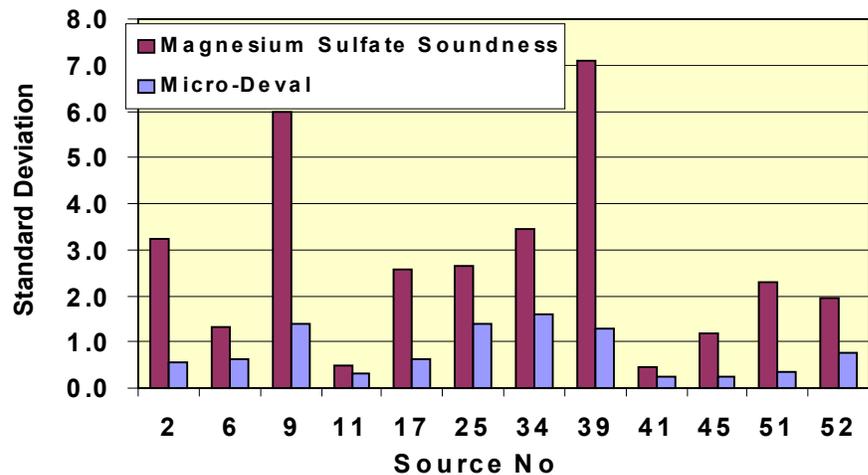


Figure 3. Reproducibility of MD vs. MS Tests

Once again, the Micro-Deval test produced more consistent results for each of the 12 sources than the MSS test. In this case, the pooled average S.D. for the MSS test was 3.6 times that for the MD test.

The next step in this research was the development of precision statements for both the MD and MSS tests. These precision statements specify the maximum acceptable difference between results obtained from two tests conducted in the same lab or in different labs on the same material.

The second test series in Phase I of this research included all 52 sources. The findings showed that the percent loss recorded by both the MD and MSS tests were closely related to aggregate absorption. Both test parameters increased with increasing absorption. However, between these two tests the MD test showed less sensitivity to aggregate absorption than the MSS test. In other words, the Micro-Deval percent loss was higher for low absorption aggregates but lower for high absorption aggregates. The next step involved a regression



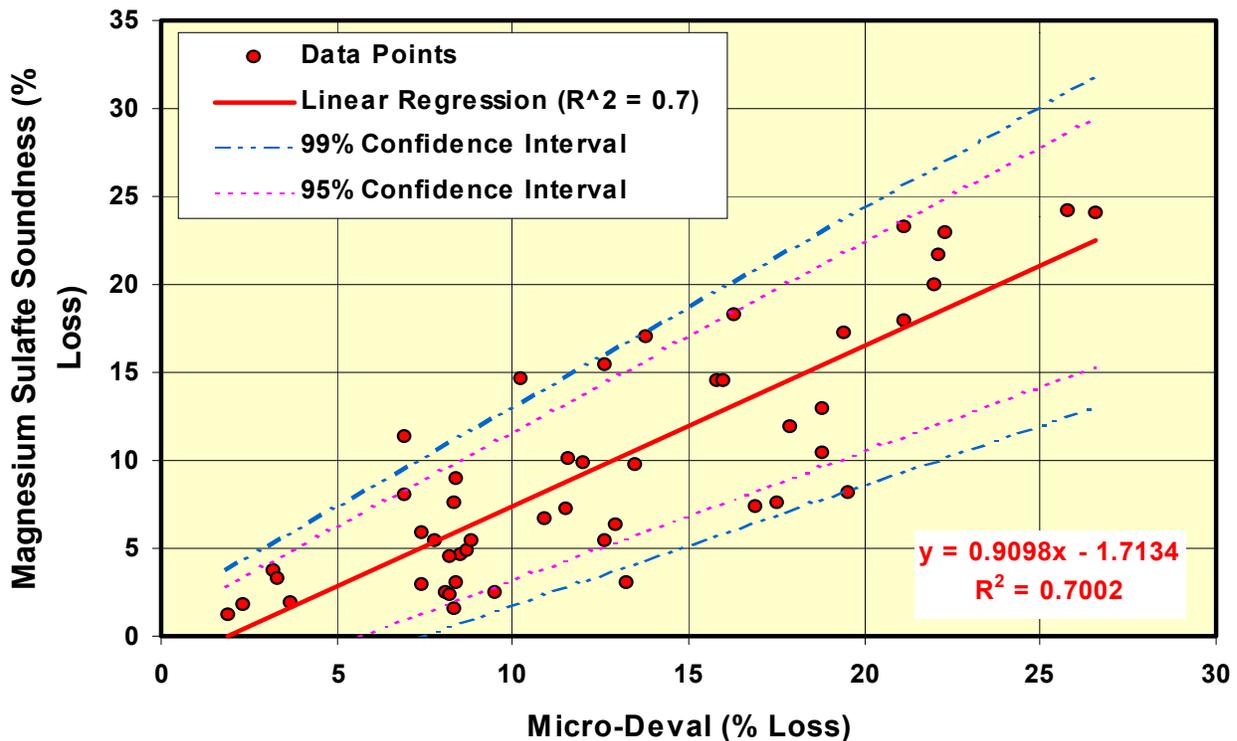


Figure 4. MSS vs. MD Correlation for low MSS materials

analysis between the MSS and the MD test results. The best correlation between the two test parameters was a second order polynomial with an  $R^2$  of 0.78. Alternatively, a bilinear regression relationship could be developed by dividing the data set into two separate parts: those aggregates with MD loss < 25% and those with MD loss > 25%. Figure 3 shows the regression that one obtains for low MD loss category. The  $R^2$  for this relationship is 0.70. The corresponding 95% and 99% confidence bands are shown as well.

Finally, Phase II research findings revealed that there is an excellent correlation between Wet Ball Mill and Micro-Deval test results. However, in the case of flexible base aggregates, the Wet Ball Mill test showed better repeatability (pooled S.D. = 0.53) than the Micro-Deval test (pooled S.D. = 0.95).

## The Researchers Recommend...

Based on the findings from this research study, the researchers make the follow-

ing recommendations with regard to the use of the MD test for aggregate quality control purposes:

(a) There is fair correlation between the MD and MSS test results. However, the agreement between the two test parameters, especially for aggregates with high MD/MSS losses, is not strong enough to establish new specification limits based on the MD test. Therefore, we recommend that the department continue to use the MSS test as the primary basis for aggregate quality control with respect to durability. The MD test is recommended for use as a supplementary test.

(b) Until changes can be made to improve the multiple lab variability of soundness test, all soundness testing should be conducted at a centralized location, such as the Materials and Test laboratory in Austin.

(c) Micro-Deval is a quick test procedure that can be used to determine whether the quality of material in a given stockpile has deviated significantly from the rated value assigned to that source. This type of quality monitoring will be es-

pecially desirable in the following situations: (i) aggregate sources that have historically demonstrated high variability, (ii) sources that have very high production rates, (iii) pavement construction projects involving high performance HMA that require better quality control. Accordingly, we recommend that the department implement a procedure to monitor time variability in aggregate quality through frequent testing using the MD test method.

d) The department should explore the possibility of developing alternative specifications based on the MD test in the future. A necessary prerequisite to this is a comprehensive database on the laboratory and field performance of all bituminous aggregates sources. Therefore, we recommend that the department continue its current efforts to develop such a database.

(e) For flexible base aggregates, the currently used Wet Ball Mill test has proven to be superior to the Micro-Deval test and therefore, no change in the current material qualification procedure is recommended.



### ***For More Details...***

The research is documented in the following report:

Report No. TX/99/1771-1R: *Comparative Analysis of the Micro-Deval and Magnesium Sulfate Soundness Tests* by Frank Phillips, Priyantha W. Jayawickrama, M. Shabbir Hossain and Thomas M. Lehman, October 2000.

Research Supervisor: Priyantha W. Jayawickrama, Ph.D.

Project Director: Rob G. Comey, P.E.

**To obtain copies of the reports, contact the Research and Technology Implementation Office, (512) 465-7644.**

## **TXDOT IMPLEMENTATION STATUS**

**July 2001**

*By: Dr. German Claros, P.E.*

Implementation of Micro-Deval equipment was approved on 12/12/00 (IPR 5-1771). This IPR covers the purchase cost of twenty-two Micro-Deval units to equip all the districts and the Bituminous Branch of the Materials and Pavements Section, Construction Division. This test will be used as a screening test for the magnesium sulfate soundness test. The Soils and Aggregates Branch of the Materials and Pavements Section is responsible for the implementation project. A training course for all the district personnel is also included in the IPR.

For more information contact; Dr. German Claros P.E. Research and Technology Implementation Office (512) 467-3881, [gclaros@dot.state.tx.us](mailto:gclaros@dot.state.tx.us).

## **Your Involvement is Welcome...**

This research was performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration. The content of this report reflects the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FWHA or TxDOT. This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. Trade names were used solely for information and not for product indorsement.

