Center for Transportation Research
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Project Summary Report 7-4977-S
Project 7-4977: Relationship Between Aggregate Properties and Hamburg Wheel Tracking Results
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PROJECT SUMMARY REPORT

Relationship Between Aggregate Properties and Hamburg Wheel Tracking Results: A Summary

Introduction

Aggregates, through internal friction, must transmit the wheel loads to the underlying layers and must also be resistant to abrasion and polishing due to traffic. Aggregates are subject to crushing and abrasive wear during manufacturing, placing, and compacting hot mix asphalt concrete (HMAC), and, therefore, must be hard and tough to resist degradation and disintegration at different stages. A series of different tests are used to ensure that aggregates carry required characteristics for use in HMAC.

Within the last few years, the Texas Department of Transportation (TxDOT) has been using the Hamburg Wheel Tracking Device (HWTD) to evaluate the moisture susceptibility of HMAC. During these tests, it was noticed that softer aggregate underwent severe abrasion under the wheels of the HWTD. Therefore, a research project was sponsored by TxDOT for a period of one year to evaluate the relationship between aggregate properties and the results from the HWTD.

Three limestone, four gravel, one sandstone, and three igneous rocks were considered in the project. These eleven aggregates provided a good coverage of different aggregate types used in Texas.

A series of tests were performed on the aggregates. The tests included magnesium sulfate soundness, Micro-Deval loss, L.A. abrasion, British Pendulum polish value, and acid insoluble residue. Asphalt-aggregate mixtures were prepared according to specific mix designs received from various districts. The mixtures were compacted with a Superpave gyratory compactor. The prepared specimens were tested with the HWTD. The HWTD-tested specimens were evaluated by the British Pendulum equipment to quantify the aggregate polishing caused by HWTD. The final step included performing gradation analysis of the extracted aggregates to evaluate the changes from the original gradation caused by the damage and degradation produced by HWTD.

In general, limestone aggregates exhibited the highest level of degradation and gravel aggregates demonstrated the toughest resistance to degradation. At the same time, in general, limestone aggregates exhibited the lowest level of stripping and gravel aggregates demonstrated the lowest resistance to moisture damage.

Objective and Methodology

The main objective of this project was to determine the relationship between the test results from the HWTD and the aggregate properties obtained from tests such as Micro-Deval and L.A. abrasion. Once such a relationship is established, the aggregate behavior in the Hamburg test could assist in deciding whether a specific aggregate will bear enough strength to be used in the field and whether it will provide good performance. For this purpose, aggregates with known performance and available historical data were obtained from a series of different sources. Aggregate tests were performed on the procured materials. HMAC specimens for testing and comparison were prepared using these aggregates. The properties of the polished and distressed aggregates after wheel tracking were evaluated and compared with their original condition, as a minimum, through extraction and gradation analysis. The results from the HWTD test were evaluated through correlation with aggregate tests such as soundness loss, Micro-Deval loss, L.A. abrasion, and polish value.

What We Did...

The objective of this project was finding a method to quantify or categorize the extent of aggregate degradation caused by the HWTD, and determine if there were any relationships between the HWTD test results and the aggregate properties such as soundness loss, Micro-Deval Loss, L.A. abrasion, and polish value.

To achieve this goal, it was decided to approach the laboratory work in several steps. The first step was selecting and gathering aggregates from different sources. Attempts were made to include aggregates of various types. Limestone, gravel, sandstone, and granite were all included. This was followed by procurement of asphalt binders for preparing asphalt-aggregate mixtures corresponding to specific mix designs. Specimens were compacted using the Superpave Gyratory Compactor (SGC) and then tested by the Hamburg Wheel Tracking Device. The HWTD-tested specimens were evaluated by the British pendulum device to quantify the aggregate polishing caused by the HWTD. The final step included performing gradation analysis on the extracted aggregates to evaluate the changes from the original gradation caused by the damage produced by the HWTD.

Parallel to the work described above, a second set of aggregates for performing tests on aggregate were prepared. A series of tests including L. A. abrasion, soundness loss, polish value, and Micro-Deval loss were conducted on the aggregates. The high-quality, intensive testing for the aggregates was conducted by TxDOT personnel.

The Hamburg Wheel Tracking Device (HWTD)

The HWTD, shown in Figure 1, has been developed for predicting rutting potential and moisture susceptibility of HMA specimens.

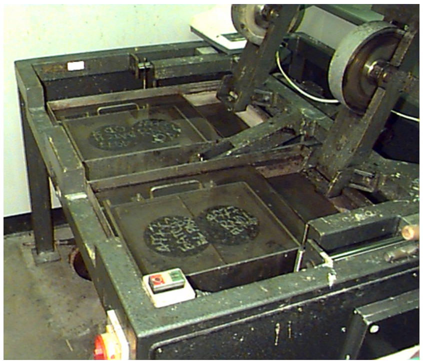

Figure 1. Hamburg Wheel Tracking Device

Originally, a pair of cubical or beam specimens were tested simultaneously. This type of HWTD specimen is typically 260 mm (10.2 in.) wide, 320 mm (12.6 in.) long, and 40 mm (1.6 in.) deep. However, with the increasing use of the Superpave Gyratory Compactor, TxDOT has been using cylindrical specimens for testing with the HWTD. The cylindrical specimens are 150 to 300 mm in diameter and 62 mm thick, compacted to 7±1 percent air voids. The setup takes advantage of four cylindrical specimens, two per steel wheel of HWTD.

Typically, a pair of two cylindrical samples, each two specimens assembled together, are tested under water simultaneously with two steel wheels moving concurrently through a crank connected to a flywheel. The steel wheel is approximately 47 mm (1.85 in.) wide and loads the sample with 705 N (158 lbs). The two specimens are attached together to provide the required length for a continuous path for the wheels. In order to have sufficient width, a small segment of each specimen is removed to create a smooth surface before the two specimens are attached together.

Rut depth measurements are taken at the center of each pair of specimens by a linear variable differential transducer (LVDT). The wheel performs 53±2 passes per minute over each pair of two cylindrical samples. The test automatically stops at 20 mm of deformation or 20,000 cycles, whichever occurs first.

The deformation and slope measurements are customarily reported as a function of number of wheel passes. The results from the HWTD are the post-compaction consolidation, creep slope, stripping slope, and stripping inflection point. At 50°C, most of the specimens were failing within 1-1/2 to 3 hours from the time the test was initiated. Failure occurred when the specimens reached 20 mm of permanent deformation.

In this research project, an important tool used to evaluate the aggregate degradation was comparison of the aggregate gradation before and after testing with the HWTD. Therefore, it was important to ensure that all the material was procured after completion of the HWTD test.

What We Found...

For this research project, extensive aggregate testing as well as testing with the HWTD provided a considerable amount of valuable information. The analysis of the data was conducted in the light of the project objective: quantifying the aggregate degradation that occurred after tests with the HWTD.

Visual Observation of the Specimens

Visual evaluation of the specimens indicated moderate to severe damage because of testing specimens with a PG 64 binder at 50°C. This was indeed desired because the idea was evaluation of the aggregate toughness in the test through close interaction of the wheels with the aggregates. Figure 2 shows specimens before and after the test.

Figure 2. Specimens before and after HWTD Test

The severity of aggregate degradation varied for different sources. In general, these degradations could be classified as high, intermediate, and low levels (Figs. 3, 4, and 5, respectively).

Figure 3. Specimen after HWTD Test (smooth surface-high degradation)

Figure 4. Specimen after HWTD Test (intermediate degradation)

Figure 5. Specimen after HWTD Test (rough surface-low degradation)

Quantifying Aggregate Degradation

The aggregate gradations were determined before and after the wheel-tracking tests. A series of different parameters were calculated for these gradations to provide a means of quantitative comparison. The parameters used for this purpose included difference in gradation for specific aggregate sizes and area between gradation lines before and after the HWTD. The intensity of aggregate degradation, as quantified by the preceding parameters, was correlated with aggregate properties such as L.A. abrasion, soundness loss, polish value from the British pendulum test (BPT), and Micro-Deval. This evaluation was performed knowing that not all correlations would be meaningful. Additional testing was also performed on the aggregates, such as acid insoluble, and solid polish value.

The last set of data included in the analysis was the output information from the HWTD test. Different parameters from the output were calculated in order to find whether any good correlation was possible. These parameters were the total deformation, deformation at stripping inflection point (SIP), creep slope, stripping slope, number of cycles to failure, number of cycles at SIP, and finally, number of cycles at 17 mm of total deformation. These results were compared to the area between gradation lines and L.A. abrasion.

Conclusions...

The following conclusions are drawn based on the extensive tests conducted for this research and the analysis conducted on the test results.

- In general, limestone aggregates exhibited the highest level of degradation and gravel aggregates demonstrated the toughest resistance to degradation.
- Based on the visual observation of the specimens after testing, in general, limestone aggregates exhibited relatively better moisture damage resistance than the gravel aggregates.
- Aggregates with higher polish value from the British Pendulum test exhibited higher LA abrasion loss.
- A strong correlation was observed between the polish value and the solid polish value.
- In general, aggregates with higher degradation also had higher LA abrasion and higher Micro-Deval loss.
- It was possible to determine three main levels of degradation in the HWTD: severe, moderate, and mild. The table below (from Research Report 7-4977-1, Chapter 3, Table 3.4), shows the ranges observed on the aggregate results from this research project.

Level of Degradation	Loss Area	Difference in Gradation (%)	L.A. Abrasion Loss (%)	Micro Deval Loss (%)	Soundness Loss (%)	P.V. Loss (%)
Severe	>13	>27	>25	>12	>16	>40
Moderate	8-13	19-27	20-25	5-12	7-16	34-40
Mild	<8	<19	<20	<5	<7	<34

The Researchers Recommend...

Aggregate characteristics play a major role regarding performance of HMAC. Investigating aggregate behavior under the rolling wheels in the laboratory provides valuable information regarding the aggregate toughness and how the aggregate may behave once placed in the hot mix asphalt concrete in the field. Including aggregates of different sources in this research provided a valuable database of such information. The results of this research project can be used to improve specifications for utilizing aggregates in HMAC and to provide better means of controlling the quality of the aggregates to be utilized. Tests used in this project could be conducted for other binders and at other temperatures. If the same trend is observed, then the results could be used to develop a set of criteria for selection of aggregates based on the results from the HWTD. It is recommended that TxDOT investigate the possibility of including such criteria into specifications.

The method used to develop the results presented in the preceding table is based on quantifying the change in the aggregate gradation after exposure to the tracking wheels of the Hamburg device. This change in aggregate gradation is captured and quantified through the concept of loss area, defined as the area between gradation lines before and after the wheel tracking. The results presented in the preceding table should be validated through field investigation. Once such validation is established, the results could be implemented in discriminating between high- and low-quality aggregates.

This one-year project provided valuable information in regard to the relationship of the aggregate degradation in the HWTD and aggregate properties. This research provides a strong and useful foundation for further evaluation of the HWTD potential in identifying aggregate properties. It is recommended that the following four activities be pursued to enhance the findings of this research and to use these findings.

- The project should be expanded to include a larger number of aggregates from different sources.
- Rather than using different aggregate gradations for different aggregates, a single gradation should be used to reduce the number of variables affecting the results.
- One of the outputs from the HWTD is the deformation profile of the specimen upon completion of the test. Current TxDOT software does not store the digital information on this profile. A close look at this profile through this research indicated that this deformation profile has great potential for differentiating between different aggregates once the shape of the profile is quantified. It is proposed that during further research, the profile should be taken into account. For this purpose, it is important that the software be upgraded to a level that it becomes possible to store the digital information of the profile in the system.
- Perform a series of test sections behavior to validate the results from the HWTD. Different aggregates will be used in these sections with the same gradation and the same binder.

For More Details...

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The research is documented in the following report:

7-4977-1 *Relationship Between Aggregate Properties and Hamburg Wheel Tracking Results*

To obtain copies of a report: CTR Library, Center for Transportation Research,
(512) 232-3138, email: ctrlib@uts.cc.utexas.edu

TxDOT Implementation Status
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The findings of the research project were very limited due to the small number of tested aggregates. TxDOT will not implement the results of this study until a more comprehensive study is completed. Research project 0-1707 "Long-Term Research on Bituminous Coarse Aggregates" involves work in this area and may produce more implementable results.

For more information, contact: Dr. German Claros, P.E., Research and Technology Implementation Office, at (512) 465-7403 or email gclaros@dot.state.tx.us.

Your Involvement Is Welcome!

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