ACQUISITION AND EVALUATION OF HAMBURG WHEEL-TRACKING DEVICE

MBTC FR-1044

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FINAL REPORT

MBTC-1044
Acquisition and Evaluation of Hamburg Wheel-Tracking Device

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ABSTRACT

Surrogate performance tests, or "proof" tests, for asphalt mixtures are being evaluated by states to gauge mixture performance potential in the lab. The University of Arkansas constructed, ERSA (Evaluator of Rutting and Stripping in Asphalt) to "screen" mixes with respect to performance potential regarding rutting and stripping. ERSA is modeled after the Hamburg Wheel-Tracking Device. The acquisition and evaluation phase of the project focuses on testing setup and test specimen configuration.

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INTRODUCTION

One of the primary failure mechanisms for flexible (asphalt concrete) pavements is rutting, or permanent deformation in the surface of the traveled roadway. Indeed, the concept of creating hot-mix asphalt concrete (HMAC) mixes with increased resistance to permanent deformation was a major driving force behind much of the asphalt-related research performed under the Strategic Highway Research Program (SHRP). Many states including Arkansas also experience premature flexible pavement failures due to stripping, or the physical separation (usually in the presence of water) of the asphalt binder from the surface of the aggregate in a mix. Recognizing this, researchers included in Superpave (asphalt mixture design procedures arising from SHRP) provisions for evaluating the effect of moisture on mixes.

Volumetric mixture design methods contained in Superpave are purported to produce HMAC with greater resistance to permanent deformation than traditional mixes, primarily due to an increased focus on providing an aggregate structure with greater shear strength. However, Superpave testing equipment and procedures for explicitly evaluating the permanent deformation resistance of a given mix remain under development. In addition, traditional tests for evaluating the effect of moisture on a given mix, such as AASHTO T-283, have proven unsatisfactory in many cases. ***(1)*** To fill this rutting/stripping susceptibility void, many state highway agencies have adopted or initiated development of surrogate "proof" tests for mixes designed using Superpave volumetric and gradation criteria. A good example of such a "proof" test is wheel tracking, in which an HMAC specimen is subjected to repeated passes of a loaded wheel to evaluate its rutting susceptibility. Some forms of wheel tracking tests are performed using a submerged specimen in hopes of also evaluating the stripping susceptibility of the mix.

PROJECT OBJECTIVES

The overall objective of the project was to acquire a wheel-tracking device and to perform some preliminary testing to evaluate its applicability to routine mixture design activities. Helmut-Wund, Inc. of Hamburg, Germany manufactures the original Hamburg Wheel-Tracking Device. At least one vendor in the United States is commercially producing wheel-tracking machines built to similar specifications as the Hamburg device. After observing the operation of two in-service Helmut-Wund machines, it was decided to manufacture a machine "in-house" at the University of Arkansas, using the operating specifications of the Helmut-Wund machine. Thus, ERSA (the Evaluator of Rutting and Stripping in Asphalt) was constructed.

The initial phase of evaluation testing focused on specimen configuration. The testing itself was performed using existing Hamburg test specifications. Specifically, the testing effort was designed to evaluate the following:

- effect of specimen type: cylindrical versus prismatic beam
- effect of compaction type: field versus laboratory
- effect of sawing a "flat face" on each of a pair of specimens for better contact between the specimens during testing (gyratory compacted cylindrical specimens only)

The testing matrix included field specimens taken from completed pavement (both cylindrical cores and prismatic beams) and laboratory compacted specimens (gyratory compacted cylindrical specimens only). Laboratory-compacted prismatic beam specimens may be tested at a future date, contingent upon completion and validation of a laboratory beam compactor.

TESTING PROGRAM

Wheel-Tracking Test Equipment

As discussed previously, ERSA is a wheel tracking machine developed by the Department of Civil Engineering at the University of Arkansas. The testing setup and procedure for ERSA is primarily based on the "Hamburg" type of wheel tracking test; however, ERSA can also be fitted with a pressurized hose and concave wheel similar to the Georgia Loaded Wheel Test. ERSA is capable of testing companion asphalt concrete samples simultaneously at a range of temperatures, and under "wet" or "dry" conditions. A computer-based data acquisition system using linear variable differential transducers (LVDTs) measures the vertical deformation at 75 locations along the profile of the sample. The deformation data may be recorded to a file at any given time interval; to reduce the sheer volume of data, ERSA currently records readings taken at thirty-minute intervals.

Test Specimen Preparation

Both prismatic slabs and cylindrical cores may be tested in ERSA. Prismatic field slabs, measuring approximately 600 mm by 600 mm, are cut and extruded from a finished pavement surface. These slabs are trimmed in the laboratory to a testing size of 150 mm (wide) by 300 mm (long). Four test specimens can typically be cut from one field slab, leaving a spare sample block. The bulk specific gravity of the field slab is measured using the spare sample block. Gyratory-compacted cores and field cores (150 mm in diameter) are paired for testing in ERSA.

All test specimens, regardless of configuration, are cast in plaster in an ERSA specimen tray. The specimen trays can accommodate a maximum specimen length of 380 mm, a maximum width of 300 mm, and a maximum depth of 175 mm. During casting, a specimen is wired to a steel plate resting on the specimen tray edges, ensuring the specimen surface is level with the top of the tray edges. After the plaster has set (usually overnight), the steel plate is removed. The prepared samples are then placed in the testing chamber and submerged with water heated to the desired testing temperature.

Data Analysis

One "cycle" in ERSA is defined as two "passes" of the wheel, forward and back. At the predetermined time interval (currently set at thirty minutes), ERSA records the measured deflection/deformation at 75 locations across the wheel; for a complete cycle, a total of 150 data points are recorded (forward and back). To reduce the volume of data, only the 75 deflection data points for the forward stroke are retained and used for calculations. All data points are normalized. Each of the 75 points in the first recorded pass is used to establish a deformation "baseline". All subsequent recorded deformations are calculated as the difference between the actual measured deflection at a particular location and its respective baseline level.

The average, minimum, and maximum deformations, as well as specimen profiles throughout the test can be analyzed. The analysis of deformation data is similar to that reported by Aschenbrener ***(2)***. A typical deformation curve using average deflection will exhibit some initial sample compaction, a rutting slope, a stripping inflection point (a mathematically or graphically determined number of passes at which it is assumed the sample begins to strip), and a stripping slope. If no inflection point or stripping slope is evident, most likely the sample did not strip during the test. Figure 1 illustrates some of the data analysis concepts.

Hot-Mix Asphalt Concrete Sampling

Hot mix asphalt concrete (HMAC) field specimens were obtained from an overlay paving project on Interstate 30 outside Little Rock, Arkansas. Loose mix was sampled from truck beds at the asphalt plant prior to transport to the paving site, located approximately 20 kilometers from the plant. Specimens of loose mix totaling about 110 to 150 kg were taken from each of five trucks sampled. The trucks were followed to the job site, where the location (job station number) corresponding to mix placement was recorded. After paving completion, field cores (150 mm diameter) and prismatic slabs were obtained from those specific locations, to minimize variability between field-compacted specimens and specimens compacted in the laboratory using the loose mix sampled.

Laboratory Compaction

The "loose" HMAC specimens were transported to the laboratory and reheated (at the compaction temperature corresponding to the viscosity requirements for compaction) for sample splitting and specimen compaction. The theoretical maximum specific gravity (G_{mm}) of the field mix was determined using loose specimens from each of the sampled job stations. Likewise, the bulk specific gravity (G_{mb}) of specimens compacted to N_{max} were determined for each sampled station. Using the gyratory compaction curve and recorded height data, the number of gyrations necessary to produce a sample at 6 to 8 percent air voids was estimated.

For each "set" of loose mix sampled, fourteen specimens were compacted using the gyratory compactor to air void contents ranging from six to eight percent. Six of the gyratory-compacted specimens were set aside for testing by AASHTO T-283 (Resistance of Compacted Bituminous Mixture to Moisture Induced Damage). The other eight samples were paired (a pair of cylindrical specimens comprises one wheel-tracking sample) such that companion samples contained similar air voids. Such paired samples were used in the wheel-tracking test to minimize variability with respect to air voids within the sample.

Wheel Tracking Testing

All ERSA wheel tracking tests were conducted using a "standard" setup, based on specifications used for Hamburg wheel-tracking tests. Specimens are submerged in water at a testing temperature of 50 C. A 47-mm (wide) steel wheel loads the specimens with 705 N. Tests are conducted to 20,000 cycles of the loaded wheel or 20 mm rut depth, whichever occurs first.

The HMAC field mix used in this research could be considered a relatively "good" mix; that is, maximum rut depths for all specimen types did not exceed about 8 mm after 20,000 cycles. Very little evidence of specimen stripping was apparent, either graphically from the rut depth data or by visual inspection of the test specimens. The average maximum rut depth after 20,000 cycles recorded for specific specimen types is used for comparison purposes.

WHEEL TRACKING RESULTS

Figure 2 shows a typical deformation curve recorded during an ERSA test. Table 1 summarizes measured air voids and maximum rut depth results for all specimen configurations. A series of statistical comparisons was performed using the data shown in Table 1. These comparisons included small-sample "t" tests and Analysis of Variance (ANOVA), or "F" tests to determine whether observed differences in mean values of air voids and rut depth are significant. A significance level of $\alpha = 0.05$ was used in all comparisons.

Specimen Groupings

The first series of comparisons concerned differences in mean air voids and rut depth within particular specimen configurations. Some observations arising from the analysis follow.

- Specimens were compacted using the gyratory compactor for each of four locations on the project. Although the level of air voids in the compacted specimens was targeted for 6 to 8 percent, the average measured air voids for specimens representing each location ranged from 3.7 to 7.8 percent. The differences in average air voids among stations are statistically significant. However, it is interesting that average rut depths for gyratory-compacted specimens ranged only from 2.2 to 2.9 mm. The differences in average rut depth among stations for gyratory-compacted specimens are not statistically significant. From a rut depth consideration, therefore, all gyratory-compacted specimens could be grouped for comparison to other specimen configurations. Note that this comparison is for gyratory specimens that do not possess a "flat" sawed face.

- "Sets" of field slabs taken from seven locations were tested. The differences in average air voids between locations were not statistically significant. In addition, the differences in average maximum rut depth between locations were not statistically significant. Statistically, therefore, all field slab results may be grouped for comparison to other specimen configurations.
- The results from four "pairs" of field cores and the field slabs were compared. The difference in average air voids between the cores/slabs was not statistically significant. In addition, the difference in average maximum rut depth between the cores/slabs was not statistically significant. Statistically, therefore, field cores and slabs could be grouped into a single "field compaction" category for comparison to other compaction types.

Effect of Specimen Type

The effect of specimen type (cylindrical versus prismatic beam) was investigated using specimens obtained from the completed pavement, namely, field cores and field slabs. Gyratory-compacted cylindrical specimens are not used in the comparison to avoid including the additional variable of compaction type. The results of the comparison are included in the previous section. To briefly repeat, differences in measured average air voids and average maximum deflection between cylindrical and prismatic beam field specimens are not statistically significant.

Effect of Compaction Type

Gyratory-compacted specimens are compared to field compacted specimens to investigate the effect of compaction type. As shown earlier, field-compacted cylindrical and prismatic beam specimens may be combined into one category of "field compaction". However, to avoid the added variable of specimen type, an additional comparison of field cores (only) and gyratory-compacted specimens was performed. Observations of the two comparisons follow.

- When all field specimens (cores and beams) are grouped and compared to gyratory-compacted specimens, the difference in average air voids is statistically significant. The difference in average maximum rut depth is also statistically significant.
- When field cores (only) are compared to gyratory-compacted specimens, the difference in air voids is statistically significant. The difference in average maximum rut depth is also statistically significant.

Effect of Sawed Faces on Cylindrical Specimens

The effect of sawing a "flat" face on cylindrical specimens prior to ERSA testing was investigated using gyratory-compacted cores only. Table 1 lists measured air voids and maximum rut depths for the tests used in the comparison. For this comparison, specimens were compacted using both "surface course" mix (12.5 mm nominal maximum size) and "binder course" mix (25.0 mm nominal maximum size). The binder mix specimens were not used in any other comparisons, since all field cores and beams were surface mix specimens. The difference in average measured air voids between the sawed / non-sawed specimens was not statistically significant. Likewise, the difference in average maximum rut depth between the groups was not statistically significant.

CONCLUSIONS / DISCUSSION

Based on the data and analyses described, some initial conclusions concerning the effect of specimen configuration on wheel-tracking results are offered.

- For the surface mix tested, gyratory-compacted specimens exhibited similar behavior in terms of rutting resistance, regardless of the level of air voids in the specimens. Although not shown, analysis of data collected for the binder mix tested yielded this same conclusion.
- Field cores and prismatic beams exhibited similar behavior in terms of rutting resistance, suggesting that specimen configuration (cylindrical versus prismatic beam) is not a significant factor in performing wheel-tracking testing.
- Gyratory-compacted specimens exhibited significantly lower rut depths in ERSA than field mixes obtained from the completed pavement. It is noted, however, that the gyratory-compacted specimens also exhibited significantly lower air voids than field-compacted mixes. Based on observations of the testing and data analysis, however, it is felt that the measured differences in air voids are not sufficient to explain the magnitude of differences in maximum rut depths.
- Sawing a flat face on paired cylindrical specimens prior to testing does not have a significant effect on rutting performance as measured by the wheel-tracking test.

Ultimately, it would be desirable to use gyratory-compacted specimens in a wheel-tracking test during the mix design process. All volumetric design activities are performed using gyratory-compacted specimens; the compactor is readily available in any mix design laboratory. Results from field-compacted specimens seem to indicate cylindrical specimens (cores) and prismatic beams perform similarly in wheel-tracking tests.

A problem arises, however, in the relative performance of gyratory-compacted specimens compared to field-compacted specimens. Additional testing could show whether in fact gyratory specimens are more rutting-resistant than corresponding field placements, and whether results obtained from gyratory specimens must be adjusted to estimate the subsequent field performance of the mix.

The data and analysis presented here certainly indicate some usable results. However, there remain some limitations. Only one field mix is represented by the data. In addition, unfortunately (or fortunately, since the mix is in service), the mix is resistant to both rutting and stripping as indicated by the relatively low magnitudes of rut depths recorded. Additional testing is warranted, particularly with relatively "poorer" mixes, before the results reported here can be fully validated and implemented.

RECOMMENDATION

Based on the results presented here, it is recommended that Hamburg-type wheel tracking tests be further evaluated/validated for use in routine asphalt mixture design. Subsequent studies should focus on documenting the effects of test parameters, and on establishing specific laboratory rut-depth "pass/fail" criteria for mixes. In addition, results from Hamburg-type machines (e.g. ERSA) should be compared (and correlated if possible) to results from other wheel-tracking machines, namely, the Asphalt Pavement Analyzer/Georgia Loaded Wheel Test.

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2. Aschenbrener, T., Evaluation of Hamburg Wheel-Tracking Device to Predict Moisture Damage in Hot-Mix Asphalt, In *Transportation Research Record 1492*, TRB, National Research Council, Washington, D.C., 1995, pp.193-201.

Table 1 Summary of Wheel-Tracking Test Results

Station	Specimen Type	Number of Observations	Air Voids (%) Average	Air Voids (%) Standard Deviation	Rut Depth (mm) at 20,000 Cycles Average	Rut Depth (mm) at 20,000 Cycles Standard Deviation
98+00	Gyratory Surface	4	6.0	0.7	2.2	1.1
103+00	Gyratory Surface	4	5.5	0.3	2.1	0.7
106+25	Gyratory Surface	4	5.7	0.2	1.6	0.3
108+00	Gyratory Surface	4	6.8	0.2	1.8	0.3
98+00	Field Slab	3	7.7	0.1	9.4	0.9
103+00	Field Slab	3	7.0	0.1	11.3	4.9
106+25	Field Slab	4	8.3	0.1	6.8	1.7
124+90	Field Slab	2	6.0	0.1	4.3	1.9
128+50	Field Slab	4	7.0	0.1	5.7	1.7
133+32	Field Slab	4	8.3	0.1	8.9	3.0
135+70	Field Slab	4	4.8	0.1	8.7	2.9
	Field Core	4	7.4	0.4	6.2	1.8
	Non-Sawed Faces	8	6.0	0.8	2.1	0.9
	Sawed Faces	8	5.8	1.2	2.2	1.1

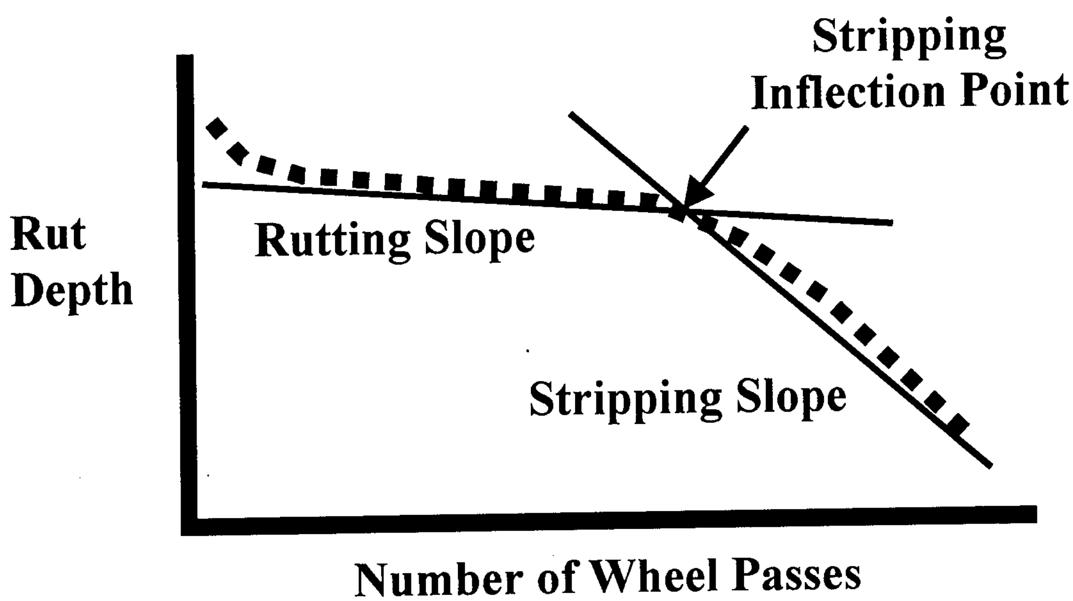

Figure 1. Wheel Tracking Data Analysis

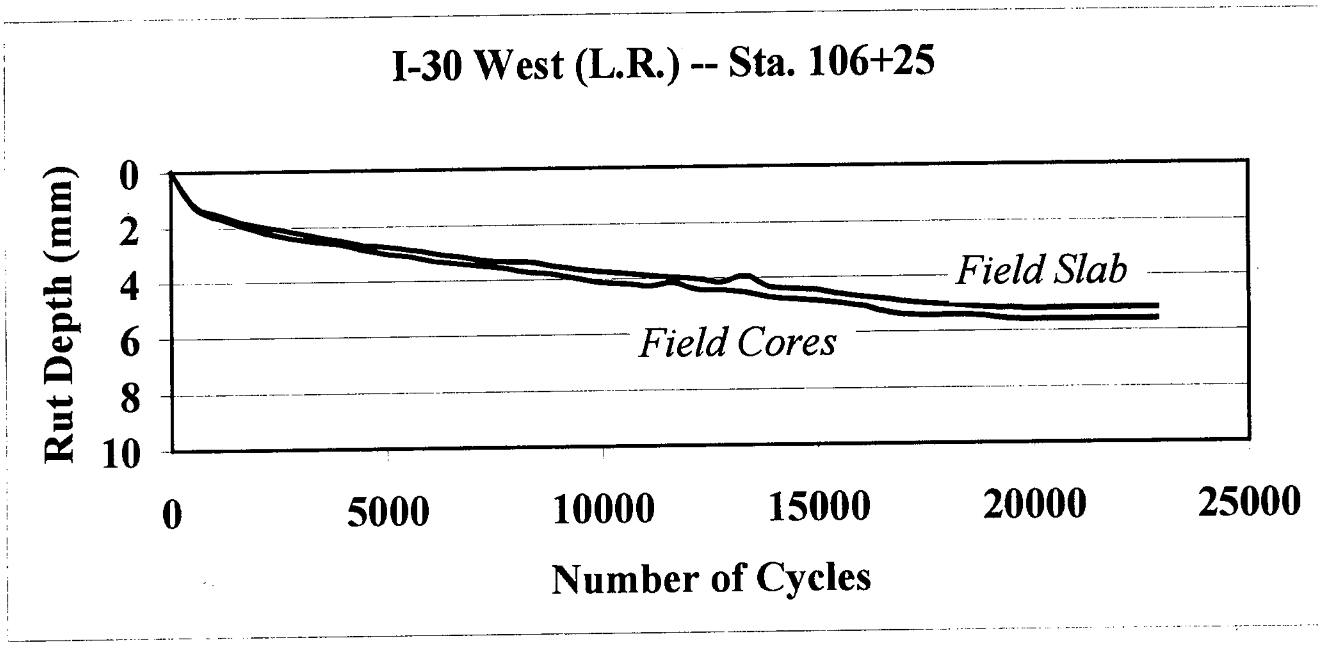

Figure 2. Typical ERSA Wheel-Tracking Test Result