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Project Summary Report 9-558-S
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Project 9-558: Superpave Performance Testing

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PROJECT SUMMARY REPORT

Evaluation of Simple Performance Tests on HMA Mixtures

The Federal Highway Administration (FHWA) and the National Cooperative Highway Research Program (NCHRP) have sponsored or are sponsoring research projects that will lead to the development and validation of advanced materials characterization models and associated laboratory testing procedures for hot mix asphalt (HMA) (i.e., NCHRP Projects 1-37A, 1-40, 9 19, 9-29, and 9-30).

Additionally, the two organizations are sponsoring development of a product currently called the *2002 Pavement Design Guide*, which will lead, in part, to improved methods for designing flexible pavements and characterizing HMA material properties. The recommended test methods for the design guide focus on the complex modulus (E*) or dynamic modulus of compacted HMA materials but also involve accumulated axial strain from a repetitive loading test (flow number) and tertiary axial strain from a static test (flow time). This series of tests has been termed simple performance tests.

FHWA desires to study these simple performance test procedures using commonly employed HMA materials from departments of transportation (DOTs) within the central United States region and compare the E* of these mixtures with results from other established laboratory tests. The results of this research project will provide practical information to state DOTs in the central region of the country regarding how their standard mixes respond to the simple performance tests. And just as important, if not more so, the results will show how standard mixtures respond to the new test procedures and may provide information useful for subsequently setting or adjusting criteria.

What We Did...

Nine HMA mixtures were obtained from state DOTs in the south central region of the United States—including the states of Arkansas, Arizona, Louisiana, New Mexico, Oklahoma, and Texas—with varied degrees of reported field performance. Two Texas mixtures included in this project were: one stone-filled and one coarse matrix high binder (CMHB) mixture. One mixture was designed in the Texas Transportation Institute laboratory using rounded gravel and sand with a PG 64-22, which was intended to be rut susceptible. Researchers designed two additional mixtures using a highly polymer-modified asphalt, PG 64-40, to evaluate the tests using mixes with low modulus but high recovery. The selected asphalt had a polymer content near 6 percent, whereas a usual value is about 1 to 2 percent. One of the mixtures containing PG 64-40 asphalt was designed using crushed river gravel aggregate and the other using rhyolite aggregate.

All mixtures were characterized using the three simple performance tests (dynamic modulus, flow number, and flow time), Superpave SST–frequency sweep at constant height, and the Asphalt Pavement Analyzer (APA) as a torture test to simulate pavement rutting. Selected mixtures were subjected to Hamburg testing. Figure 1 shows a specimen prepared for testing in a dynamic modulus tester.

Specific objectives of this research project were to:

- Evaluate applicability of current test procedures and equipment for measuring HMA mixture properties with particular emphasis on complex modulus.

- Provide state DOTs in the south central region familiarity with the proposed E* parameter and generate information on performance of selected HMA mixtures in the new tests.
- Extend the application of the protocols to gap-graded (e.g., stone-filled asphalt or coarse matrix high binder) mixtures.
- Provide feedback to FHWA and others regarding the practical issues associated with implementation of the new test procedures.
- Compare results from E* test results with other established tests (e.g., Superpave shear test–frequency sweep @ constant height [SST-FSCH], APA, and Hamburg) by analyzing HMA mixtures studied in other research efforts.
- Evaluate specially designed HMA mixtures that may exhibit low dynamic modulus but high recovery of strains (i.e., HMA containing a highly polymer-modified soft asphalt; e.g., PG 64-40).

Figure 1. A Hot Mix Asphalt Specimen Prepared for Testing Waits in a Dynamic Modulus Tester.

What We Found…

Table 1 summarizes rankings of the different mixtures based on parameters from the tests performed.

The following items summarize the findings from this work:

- Flow time slope and flow number value provided the best correlations with the APA rut depth.
- The correlation between the APA rut depth and the flow time value was better than that between APA rut depth and flow number.
- APA rut depth correlated with the flow number and flow time parameters better than the APA creep slope correlated with these values.
- The correlations of the APA test parameters with dynamic modulus and frequency sweep at constant height tests were not as good as correlations of the APA test parameters with the flow time and flow number test parameters. Similar results were found in other studies in which relatively low dynamic modulus values were observed for heavy-duty asphalt mixes in contradiction to the field performance, APA, and permanent strain test results.
- The correlations of E*/sin ϕ or G*/sin δ with the APA test parameters were better than correlations of E* and G* alone with these parameters. This difference could occur because the phase angle captures the viscoelastic behavior of the mix, which is also responsible for the permanent deformation rather than the resilient modulus values alone.
- The correlations of E* or G* with the APA parameters were better at lower test frequencies than at the higher frequencies. However, these values did not show strong correlations.
- The overall rut depth from APA tests to 8000 strokes correlated better with all other parameters as compared to the APA creep slope.
- Correlations of Hamburg rutting with the other test parameters were similar to the correlations between the APA rut depth and those same parameters. Flow number value, flow time slope, E*/sin ϕ @ 1 Hz, flow number slope, and flow time value were among the best five correlations both with Hamburg and with the APA rut depths.
- In the Duncan Multiple Range Test, flow time slope and flow number slope were able to separate the mixes into six Duncan groups of statistically

Table 1. Rankings of Mixtures by Parameters from Different Tests.

Mixture Number	APA Rut Depth	APA Creep Slope	G* @ 10 Hz	G*/sin δ @ 10 Hz	G* @ 1 Hz	G*/sin δ @ 1 Hz	E* @ 10 Hz	E*/sin ϕ @ 10 Hz	E* @ 1 Hz	E*/sin ϕ @ 1 Hz	Flow Time	Flow Time Intercept	Flow Time Slope	Flow Number	Flow Number Slope
NMVado	1	1	1	1	1	1	1	1	1	1	1	4	2	1	4
NMBingham	2	4	3	2	2	2	2	2	2	2	2	3	1	2	2
TXWF	3	8	5	5	5	5	5	3	4	4	5	5	4	5	7
64-40RHY	4	3	12	12	12	9	10	8	8	5	7	11	6	6	1
OK	5	6	4	4	4	3	9	10	10	11	4	1	5	4	3
AZ	6	5	9	9	9	10	6	6	6	7	6	9	7	7	10
TXBryan	7	2	2	3	3	4	3	4	3	3	3	2	3	3	5
64-40RG	8	9	11	11	10	11	12	11	11	8	8	6	9	11	6
LA	9	7	7	7	8	7	7	9	9	10	9	7	10	8	8
ARTL	10	10	8	8	7	8	4	5	5	6	10	12	8	9	9
ARLR	11	12	10	10	11	12	11	12	12	12	11	10	11	12	11
ROG	12	11	6	6	6	6	8	7	7	9	12	8	12	10	12

equivalent values. These results were much better than those with the flow time or flow number values.

- Based on the APA rut depth, the PG 64-40 + rhyolite mix can be placed in the second or third of six Duncan groups in terms of ranking. The mix can therefore be said to perform better than most of the other mixes since it is in the top 33 to 50 percent of the mixtures. In contrast, the PG 64-40 + river gravel mix was ranked in the fourth of six Duncan groups.
- Based on the Duncan grouping for dynamic modulus, the PG 64-40 + rhyolite mix was placed in the fifth or sixth of six groups when E* values are compared at 10 Hz and in the fourth or fifth of five groups when the values are compared at 1 Hz. This ranking means that the E* values placed this mix in the worst 33 percent of the mixtures. The PG 64-40 + river gravel mix was placed in the sixth of six groups and fifth of five groups when E* values are compared at 10 and 1 Hz, respectively. These groupings are quite contrary to those for the APA parameters.
- The results using E*/sin ϕ were similar to those using E* with the difference that there were only four different Duncan groups, and the PG 64-40 mixes were placed in the last two groups.
- Similarly, when using SST-FSCH results, the PG 64-40 mixes were placed in the last groups.
- Flow time slope and flow number slope categorized the PG 64-40 + rhyolite mixes in the top groups similar to APA rut depth. Based on this finding and assuming that APA relates well to pavement rutting, flow number value and flow time slope appear to relate well to predicted rutting in a pavement.

The Researchers Recommend...

The scope of this study is relatively limited; however, it raises a question about the ability of the dynamic modulus test to properly characterize the benefits of modified asphalt binders. Parameters from the flow number and flow time tests provided better correlations with the torture test (APA) than dynamic modulus.

It appears that the American Association of State Highway and Transportation Officials (AASHTO) *Design Guide* will recommend implementation of the dynamic modulus test for design of asphalt pavements. Users should understand that dynamic modulus is a strength test related to asphalt pavement layers subjected to vehicular loads at highway speeds and may not relate to rutting resistance of HMA paving mixtures. Therefore, tests other than dynamic modulus should be employed to ensure acceptable rutting resistance of HMA paving mixtures.

For More Details...

The research is documented in:

Report 558-1: *Evaluation of Simple Performance Tests on HMA Mixtures from the South Central United States*

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