STATE OF FLORIDA

Comparison of Rutting Test Results Between Laboratory Tests and Heavy Vehicle Simulator Testing

Research Report
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INTRODUCTION

Many laboratory tests exist to measure the rutting susceptibility of asphalt mixtures. The Bituminous Research Laboratory at the State Materials Office (SMO) has several of these devices. In an attempt to determine which device best correlates to actual rutting observed in pavements, a research study was conducted comparing the rut depths of three asphalt mixtures to the rutting performance measured with the Department's Heavy Vehicle Simulator (HVS), located at the Accelerated Pavement Test Facility at the SMO.

TESTING PLAN

The three mixtures evaluated with the HVS exhibited different degrees of rutting. The mixtures were dense graded, 12.5 mm nominal maximum aggregate size, Traffic Level C, friction course mixtures containing a PG 67-22 asphalt binder modified with 5% ground tire rubber by weight of binder. For this study, the mixtures will be characterized as low, medium, and high rutting, though the actual HVS rutting values were not drastically different. The HVS rut depths at 15,000 passes for the three mixtures were 10.5 mm, 12.8 mm, and 13.6 mm, respectively. Tests were conducted at a controlled temperature of 50 °C at a 2" asphalt depth utilizing a heating system surrounding the loading system of the HVS. A super-single tire, inflated to 112 psi, was used for loading and a 9 kip load was applied in a single direction at a speed of 8 mph.

The laboratory tests that were used in the evaluation were 1) the Asphalt Pavement Analyzer (APA), 2) the Hamburg rut tester, 3) dynamic modulus, and 4) flow number. Specific testing conditions for each laboratory test are as follows.

Asphalt Pavement Analyzer (APA)

Tests were conducted at a temperature of 64 °C, for 8,000 cycles (16,000 passes) of loading, utilizing a 100 lb. load and 100 psi hose pressure. Four samples each were prepared to a height of 115 mm at air void contents of 4% and 7%.

Hamburg Rut Tester

Tests were conducted submerged in water at a temperature of 50 °C, for 10,000 cycles (20,000 passes) of loading, utilizing a 158 lb. load. Four samples each were prepared to a height of 62 mm at air void contents of 4% and 7%.

Dynamic Modulus

Tests were conducted using the IPC Global Superpave Performance Tester. Testing was performed in an unconfined state with a 10 kPa contact stress. Test temperatures were 4, 20, and 40 °C. Testing frequencies were 10, 1, and 0.1 Hz for the 4 and 20 °C temperatures and 10, 1, 0.1, and 0.01 Hz for the 40 °C temperatures. Three specimens for each mixture type were tested.

Flow Number

Tests were conducted using the IPC Global Superpave Performance Tester. Testing was performed with a confining stress of 69 kPa, a contact stress of 50 kPa, and a creep deviator stress of 689 kPa. The test temperature was 54.4 °C. The test duration was set at 50,000 maximum microstrain or 10,000 cycles, whichever occurred first. The flow number was determined using sample intervals of 1, 3, and 5 cycles and it was observed that there was very little difference in the flow number using either of these sample intervals. The flow numbers determined at a sample interval of 3 are the values reported in this paper. Three specimens for each mixture type were tested.

ASPHALT MIXTURE PROPERTIES

The volumetric properties of the three as-produced asphalt mixtures are shown in Table 1. The asphalt binder and gradation properties are nearly identical between the three mixtures. There are small differences in air voids, VMA, and field density between the mixtures. The similarity in the mixture properties explains the relatively small differences between HVS rut depths.

Table 1 – As-Produced Asphalt Mixture Volumetric Properties

Asphalt Property	Mixture ID (based on HVS rut depth)		
	Low	Medium	High
HVS Rut Depth (mm)	10.5	12.8	13.6
Air Voids at N_{des} (75 gyrations) (%)	3.50	3.65	4.20
Voids in the Mineral Aggregate (VMA) (%)	13.2	13.7	13.9
Asphalt Binder (%)	4.92	4.94	4.91
Field Density (% Gmm)	92.4	92.7	93.5
Gradation (% passing)			
3/4"	100	100	100
1/2"	99	99	99
3/8"	90	89	90
#4	64	66	65
#8	47	48	47
#16	37	37	37
#30	30	30	30
#50	17	17	17
#100	6	5	5
#200	3.0	2.8	2.9

DYNAMIC MODULUS TEST RESULTS

The dynamic modulus and phase angle test results obtained from testing at three temperatures and three or four frequencies (depending on the temperature) were input into an Excel workbook received from Advanced Asphalt Technologies, LLC. The workbook then generated the dynamic modulus values at the temperatures and frequencies required as inputs in the Mechanistic Empirical Design Guide (MEPDG) necessary to calculate predicted rutting results for a 20-year design life. In addition, binder testing was conducted to determine the binder complex shear modulus and phase angle values at various temperatures. These values are also required as inputs into the MEPDG. The asphalt mixture dynamic modulus data, binder test data, and some required volumetric material properties were input into version 1.000 of the MEPDG and a level 1 analysis was conducted. The analysis was conducted for Gainesville, FL environmental conditions. A typical granular base, subgrade, and embankment structure was input and typical traffic volumes for Florida conditions were input into the MEPDG.

RUTTING TEST RESULTS

The test results from each of the rutting tests (HVS and laboratory) and the asphalt layer rutting results, as calculated by the MEPDG, are shown in Table 2.

Table 2 – Rutting Test Results

Rutting Test Method	Mixture ID (based on HVS rut depth)		
	Low	Medium	High
HVS Rut Depth (mm)	10.5	12.8	13.6
APA @ 4% AV (mm)	6.7	5.5	6.6
APA @ 7% AV (mm)	7.0	6.9	8.6
Hamburg @ 4% AV (mm)	2.4	2.4	2.4
Hamburg @ 7% AV (mm)	4.8	5.1	5.7
Flow Number	1578	124	1046
MEPDG Asphalt Rutting (mm)	10.2	10.2	10.2

Discussion of Test Results

The APA and Hamburg rutting test results for specimens compacted to 4% air voids are less than the corresponding rutting test results for specimens compacted to 7% air voids, which follows expected trends. For comparable samples, rut depths for the Hamburg specimens were less than those tested with the APA, most likely due to the lower testing temperature for the Hamburg test. Based on past experience testing a wide variety of Superpave mixtures at the SMO with the APA, the rut depths encountered for these three mixtures would classify as medium-rutting mixtures.

To ascertain whether the laboratory tests were able to rank the mixtures in the same order as the HVS in terms of rut depth, the laboratory rut depths for each test were labeled as low, medium, or high and listed in Table 3, along with the HVS results. For this ranking, the HVS test results are considered the benchmark against which the laboratory test results are compared against.

Table 3 – Rutting Test Rankings

Rutting Test Method	Rut Test Result	Rank	Rut Test Result	Rank	Rut Test Result	Rank
HVS Rut Depth (mm)	10.5	Low	12.8	Medium	13.6	High
APA @ 4% AV (mm)	6.7	High	5.5	Low	6.6	Medium
APA @ 7% AV (mm)	7.0	Medium	6.9	Low	8.6	High
Hamburg @ 4% AV (mm)	2.4	3-way Tie	2.4	3-way Tie	2.4	3-way Tie
Hamburg @ 7% AV (mm)	4.8	Low	5.1	Medium	5.7	High
Flow Number	1578	Low	124	High	1046	Medium
MEPDG Asphalt Rutting (mm)	10.2	3-way Tie	10.2	3-way Tie	10.2	3-way Tie

The Hamburg tests performed at 7% air voids were the only tests to rank the rutting depths in the same order as the HVS. The APA tests performed at 7% air voids reversed the low and medium rutting mixtures, but the APA rut depths were very close to each other, at 7.0 mm and 6.9 mm for the low and medium rutting mixtures, and are within the variability of the test procedure. The Hamburg tests performed at 4% air voids and the MEPDG calculated rutting ranked all of the mixtures exactly the same. The flow number tests correctly ranked the low rutting mixture but reversed the medium and high rutting mixtures. The flow number test results for the HVS ranked medium mixture appear suspect and may be in error. The APA tests performed at 4% air voids did not rank any of the mixtures correctly.

Though the Hamburg tests performed at 7% air voids ranked the rutting depths in the same order as the HVS, it is difficult to conclude that some of the other tests conducted are not suitable laboratory rutting tests. The difference in the low and high HVS rutting depths (10.5 mm and 13.6 mm) is marginal and can be considered within the variability limits of the HVS, when testing multiple sections of the same mixture type. Since the gradations and asphalt binder contents of the three mixtures are very similar, one could conclude that the laboratory rut depths should also be nearly the same. This was the case for the Hamburg tests performed at 4% air voids and the MEPDG calculated rutting values.

CONCLUSIONS

The rutting performance of three asphalt mixtures was compared between HVS testing and four laboratory test procedures. The laboratory tests conducted were the APA, Hamburg, dynamic modulus, and flow number test procedures. The APA and Hamburg tests were each performed at two air void contents (4% and 7%). Of the four tests procedures, the Hamburg test conducted at 7% air voids was the only test that correctly ranked the mixture performance in the same order as the HVS. It should be noted that more research will be conducted to validate this with future HVS test sections, due to the fact that the difference between the lowest and highest rutted HVS sections for this experiment was not that significant.