TEXAS TRANSPORTATION INSTITUTE
THE TEXAS A&M UNIVERSITY SYSTEM

Project Summary Report 0-1819-S

Project 0-1819: Evaluation of Shear Strength Property of HMAC for Predicting Performance

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Best Superpave Shear Test Protocol for Predicting Rutting

Approximately 94 percent of paved roads in Texas are asphalt pavements. Permanent deformation or rutting is a major issue for hot mix asphalt (HMA) pavements throughout the nation, including Texas. Each year, rehabilitation and construction require about 12 million tons of HMA. District pavement engineers, area engineers, and laboratory supervisors are constantly faced with decisions regarding selection of the best asphalt mixture design to use in construction or rehabilitation of particular pavement.

The Texas Department of Transportation (TxDOT) and contractors need a method that is capable of verifying that the selected mixture design is not likely to exhibit premature distress during service under the anticipated traffic loading, temperature regime, and pavement substrate. Rutting, a major form of premature distress, is caused mainly by insufficient shearing strength of HMA.

Cox Superpave Shear Tester.

Therefore, a laboratory test method that can verify mixture shearing strength and, hence, rutting resistance would be extremely valuable not only to TxDOT but also to all highway-specifying agencies and contractors who are required to warranty pavement performance.

The Superpave volumetric mixture design process alone does not provide adequate warranty against rutting. The Superpave Shear Tester (SST) was introduced as a component of the Superpave mixture design and analysis system to examine load-related performance of HMA. Current SSTs are capable of using both static and dynamic loading in confined and unconfined conditions. Initially, Strategic Highway Research Program (SHRP) researchers proposed six different SST test protocols to characterize HMA. The six different tests were:

- Volumetric Test,
- Uniaxial Test,

- Frequency Sweep at Constant Height (FSCH) Test,
- Simple Shear at Constant Height (SSCH) Test,
- Repeated Shear at Constant Height (RSCH) Test, and
- Repeated Shear at Constant Stress Ratio (RSCSR) Test.

These six test procedures measure several engineering properties of HMA. Because of a shortage of time, SHRP researchers could not determine which of the test protocols were best suited for predicting the rutting performance of HMA. Excessive time required in performing these tests significantly increases the cost of mixture design. Conducting all of the tests can be confusing and even conflicting. It was desirable to evaluate these Superpave shear test protocols in a systematic experimental program to determine which engineering property is most suitable for measuring the shearing strength of HMA.

Soon after this project began, the American Association of State Highway and Transportation Officials (AASHTO) eliminated the volumetric and uniaxial tests (the only two protocols requiring confining pressure) from the SST protocols because they were shown to correlate relatively poorly with pavement performance when compared to the other SST protocols, and because they were more cumbersome to perform. This action eliminated the need for the large compressor and air seals and significantly reduced the strength requirements of the chamber, thus lowering the cost of future SSTs.

What We Did…

The objective of this research was to evaluate the four remaining Superpave shear test protocols to determine which one is most suitable for predicting asphalt pavement rutting. The ultimate goal was to identify the "best" SST test protocol for evaluating the shearing resistance of HMA.

The Texas Transportation Institute (TTI) conducted a review of pertinent literature to examine current HMA mixture evaluation techniques with an emphasis on permanent deformation. The literature review addressed mechanistic, empirical, and accelerated pavement testing and their relationships to pavement performance.

Researchers and TxDOT engineers developed an experimental program which included planning of the study, selection and acquisition of materials, characterization of asphalt and aggregates, HMA mixture design, and laboratory testing. Four HMA mixtures were developed that ranged from very rut susceptible to very rut resistant. The rut-susceptibility of these four mixtures was evaluated using the Asphalt Pavement Analyzer (APA), 1/3-Scale Model Mobile Load Simulator (MMLS3), and Hamburg Wheel Tracking Device (HWTD). SST evaluations of these four mixtures included FSCH, SSCH, RSCH, and RSCSR.

A comparative analysis of the results from the SST and other laboratory-scale rutting tests indicated that the FSCH was the "best" SST protocol for predicting rutting of HMA mixtures. In order to prepare a precision statement for the FSCH, researchers developed and administered an interlaboratory study conducted at four regional Superpave Centers, the Asphalt Institute, and the Federal Highway Administration.

What We Found…

These findings are based on laboratory testing of four HMA mixtures with widely different properties using four different Superpave SST tests and three laboratory rutting tests.

- At higher temperatures, the complex shear moduli (G*) of all four mixtures were similar at lower frequencies, and they increased exponentially with increasing frequency and diverged significantly.
- The mixture designed to exhibit the lowest shear strength (rounded river gravel) always yielded the highest shear phase angle (δ). This finding indicates the gravel mix is the most compliant (or rut susceptible) of the four mixtures.
- Shear phase angle of the four mixtures varied appreciably with frequency for the mixtures tested at 68°F and 104°F, but not at 39°F. This indicates that the mixtures are much more sensitive to permanent deformation at the higher temperatures.
- The river gravel mixture, the most rut-susceptible mixture, yielded the lowest G* and highest δ. The stone matrix

asphalt (SMA) mixture, the most rut-resistant mixture, yielded the highest G* and lowest δ.

- The river gravel mixture exhibited the highest maximum strain and permanent strain and the lowest elastic recovery.
- Elastic recoveries of all mixtures were similar at any given temperature.
- Maximum shear strain and permanent shear strain increased in the SSCH tests when the temperature increased from 39°F to 68°F but decreased from 68°F to 104°F. This fact suggests that sufficient permanent shear strain occurred at 68°F to consolidate the specimen such that it resisted further strain at 104°F. Therefore, testing of the same specimens at all three temperatures, as called for in AASHTO TP7-01, is inappropriate.
- The three laboratory wheel-tracking devices ranked the four mixtures. See Table 1 for rankings.
- Rankings by the APA and HWTD were the same. However, in the APA results, rutting measurements of the granite Superpave and limestone mixtures were not significantly different ($\alpha = 0.05$). In the HWTD test, rutting measurements of the granite SMA and granite Superpave were not significantly different, and the limestone mixture exhibited considerable stripping.

Table 1. Ranking of Four HMA Mixtures by Three Wheel-Tracking Devices.

	APA	HWTD	MMLS3
BEST	Granite SMA	Granite SMA	Granite SMA
	Granite Superpave	Granite Superpave	Type C Limestone
	Type C Limestone	Type C Limestone	Granite Superpave
WORST	Type D River Gravel	Type D River Gravel	Type D River Gravel

- The HWTD test results depend on both the shearing properties and moisture susceptibility of the mixture. The HWTD showed no significant difference between the granite SMA and the granite Superpave mixtures. This was probably due to the relatively high coefficients of variability of the HWTD.
- The MMLS3 appears to be the most sensitive loaded-wheel tester, in that it was the only one of the three to separate the four mixtures into four significantly different groups.
- Variability of the FSCH test is very high, and the precision is poor. For example, the average shearing modulus of limestone and river gravel mixture at 104°F and 10 Hz were 138 ksi and 38 ksi, respectively, whereas their precision value was as high as 118 ksi for the limestone mixture and as high as 22 ksi for the gravel mixture. For the same situation shear phase angle precision varied by 9° to 12°.

The Researchers Recommend…

The researchers recommend the FSCH test as the best of the SST protocols for evaluating rutting. The FSCH and the RSCH were the leading SST tests. Both ranked the mixtures in the same general order as the three loaded-wheel testers, and both showed fair sensitivity in their measurements. Although the RSCH test gave slightly more sensitivity than the FSCH test, the FSCH test provided other important advantages.

The FSCH test yields two fundamental material properties (complex shear modulus and shear phase angle), which are useful in predictive models for both rutting and fatigue cracking. The RSCH test provides permanent shear strain, which is not a fundamental material property but a test value and is thus dependent on the test parameters. Controlling strain to a low level, as in the FSCH test, minimizes damage to the test specimen more than the stress control used in the RSCH test.

Because the FSCH test exhibited high variability, TxDOT should use other alternate tests for routine evaluations of rutting resistance of HMA paving mixtures.

For More Details. . .

The research is documented in:

Report 1819-1, *Evaluation of Superpave Shear Test Protocols*

Report 0-1819-2, *Precision Statistics of Frequency Sweep at Constant Height Test*

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TxDOT Implementation Status March 2004

TxDOT will not implement the FSCH test using the SST protocol. The complexities of the equipment involved and the execution of the test procedure would require a dedicated technician and expensive equipment. The application of this test to routine testing is not practical. Other tests such as the complex modulus are being evaluated for implementation.

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

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