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**The Utilization of Torture Tests as an Addendum to the Superpave Mix Design System:
A Case Study**

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ABSTRACT

Superpave Volumetric Mix Design System incorporates criteria on materials, mixture volumetric and densification properties, and moisture sensitivity, to develop a mix design that will have reasonable assurance of performance (1). This level of mix design was originally envisioned as the starting point for all mix designs in the Superpave system. For low traffic volume facilities, this would be the only mix design. For higher traffic volume facilities, additional performance testing would be required.

Due to expense, sophistication, and shortage of Superpave performance testing equipment, many agencies have experimented with Superpave Volumetric Mix Design on higher traffic volume roadways, without additional performance testing. Superpave Volumetric Mix Design does not include any mechanical materials characterization tests as required components. However, many users are concerned that they have no assurance, through either a strength or torture test, that the mix will perform. Consequently, many users believe that some additional test is necessary to adequately ensure performance.

This paper addresses a case study where a user agency was uncomfortable with the results of a Superpave volumetric mix design due to past history with the aggregate source, and the design asphalt binder content. The mix design was verified to meet all volumetric mix design criteria. Superpave shear and loaded wheel testing indicated that the mixture should not exhibit premature failure.

Despite the results of this case study, further evaluation of supplemental tests remains necessary to determine their potential role in the Superpave Mix Design System.

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INTRODUCTION

The efforts of the Strategic Highway Research Program (SHRP) produced a comprehensive asphalt mixture evaluation system. This system, the Superior Performing Asphalt Pavements (Superpave) system, is composed of asphalt mixture design and analysis, and pavement performance predictions. Superpave is intended to eventually replace traditional mix design methods. Additionally, the Superpave system will provide a uniform approach of evaluating mixture characteristics and expected performance.

The Superpave system, as first introduced, was comprised of three levels of mix design and analysis. These levels were based on increasing degrees of evaluation as warranted by increasing amounts of traffic. It was early recognized that each level required a similar mix design component as a starting point. This component was a determination of an optimal combination of aggregates and asphalt based on materials, and mixture volumetric and densification criteria. Comprehensive testing and performance prediction of the designed mix were reserved for the higher traffic, Level 2 and Level 3 analysis. As a more descriptive term, Superpave Volumetric Mix Design was subsequently adopted to describe the associated determination of an optimal combination of aggregate and asphalt necessary under all the former three levels. Intermediate Mix Analysis and Complete Mix Analysis are the designations accepted for the previous Levels 2 and 3.

Highway agencies are eager to apply Superpave to the design of critical high traffic pavements. However, because of the complexity of material testing, and the uncertainty of the prediction models associated with Superpave Mix Analysis, these agencies are designing and producing mixtures, even for high traffic pavements, with only Superpave Volumetric Mix Design. While volumetric properties are recognized as being related to pavement performance, uncertainty

exists. It also appears that for the near future many pavements, even with high traffic, will continue to be designed with only the Superpave Volumetric Mix Design system. Reasons for this include the uncertainty of the available models and ultimate cost, and benefits, of the results of a Superpave Mix Analysis. A number of agencies have questioned the need for a test to augment the Superpave Volumetric Mix Design system. If such a test were needed, agencies would need to know what relatively simple test could be performed as part of the mix design system. This paper presents one such evaluation where additional tests were performed to assess their value and applicability to the Superpave Volumetric Mix Design system.

A Superpave Volumetric Mix Design was conducted on a project by a State Highway Agency (SHA). The agency reported that the Superpave criteria were satisfied. However, because of the relatively high asphalt content and past performance history with the aggregates, the agency was concerned about the ultimate performance of the mix. The SHA asked if other tests could be performed to allay their concerns. A testing approach was formulated to first verify the volumetric mix design developed by the SHA. Further testing would then be performed to address the performance concerns.

TESTING PLAN

The project was divided into two phases. The first phase was designed to verify that the trial mixture met all the Superpave mix criteria, including: aggregate requirements such as fine aggregate angularity; volumetric properties; densification properties; and moisture sensitivity. All of these Superpave criteria are essential to a pavement's ultimate success. However, questions have arisen whether supplemental torture, or fundamental materials characterization testing is also needed to adequately minimize pavement distress.

The second phase examines potential supplemental tests to determine their need as part of the Superpave Volumetric Mix Design system.

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Phase 1: Volumetric Mix Design

The trial mixture had already been evaluated by the user agency using Superpave volumetric mix design criteria. Since the trial aggregate blend had been selected by the user agency, no evaluation of different design aggregate structures was necessary. As such, all of the aggregate testing was performed on the combined blend. The testing plan for Phase 1 included aggregate testing, verification of the trial mixture design asphalt binder content, and moisture sensitivity testing.

The aggregate stockpiles used for this mixture consisted of a coarse and fine aggregate from the same source. The aggregate was a moderately absorptive limestone (1.5% water absorption) referred to as Plattin limestone. Two sizes were used in the mixture. The coarse aggregate had a gradation with 100 percent passing the 19-millimeter sieve, mostly retained (76%) on the 4.75-millimeter sieve. The manufactured sand was well graded with 93% passing the 4.75-millimeter sieve and 8.4% passing the 0.075-millimeter sieve. The combined gradation is illustrated in Figure 1.

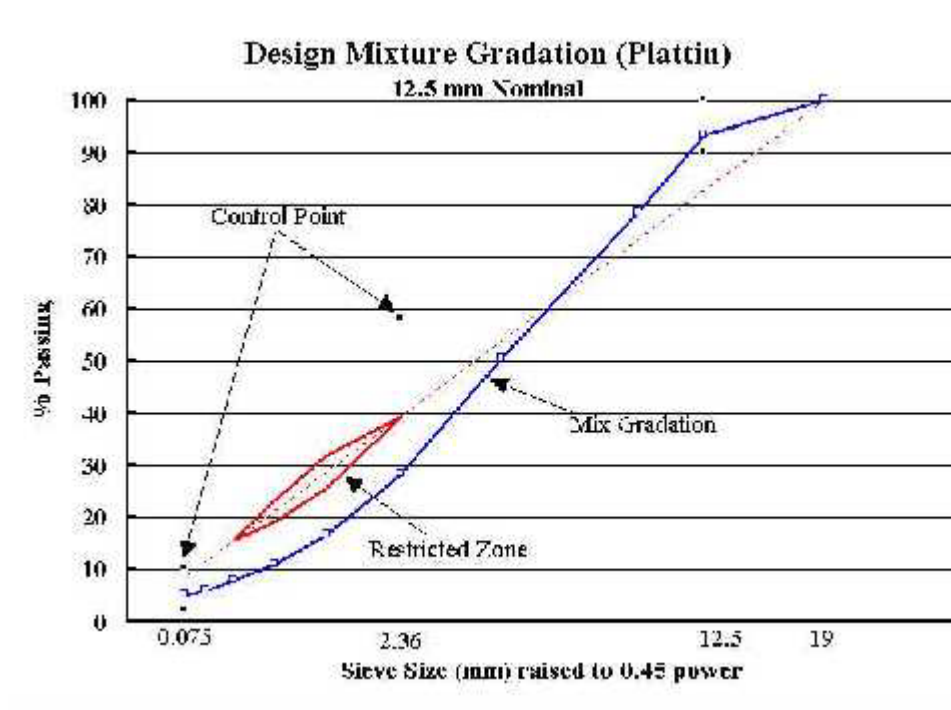


Figure 1

As indicated in Figure 1, the combined aggregate gradation resulted in a rather coarse 12.5-millimeter nominal mixture. A verification of the combined aggregate properties is shown in Table 1. The criteria are based on the assumption that the design traffic will be three to ten million equivalent single axle loads (ESALs). As indicated in Table 1, all of the verified aggregate properties were acceptable for this blend. Since the coarse aggregate fraction was produced from quarried limestone, all of the coarse aggregate was considered angular.

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TABLE 1 - Trial Mixture: Combined Aggregate Properties

Property	AI Result	Agency Result	Criteria
Angularity:			
Coarse	n/a	n/a	85% one or more 80% two or more
Fine	46.0	n/a	45 minimum
Flat and Elongated Particles	3.8%	n/a	10% maximum
Sand Equivalent	75	n/a	45 minimum
Specific Gravity:			
Coarse	2.670	2.654	n/a
Fine	2.661	2.573	n/a
Combined	2.667	2.623	

The asphalt binder selected for the project met the requirements of a PG 64-28 asphalt binder in accordance with AASHTO MP1 (2). The asphalt binder grade was tested by the supplier, so no further testing was performed. To obtain mixing and compaction temperatures, a temperature-viscosity profile was determined using the rotational viscometer. The asphalt binder had

viscosities of 0.850 Pascal-seconds at 135°C and 0.295 Pascal-seconds at 165°C. The equiviscous mixing and compaction temperatures for this asphalt binder were estimated to be 180-188°C for mixing, and 164-170°C for compaction. Since the asphalt binder was produced using an elastomeric modifier, the manufacturer was contacted to discuss these temperatures for laboratory testing. These temperatures, based on viscosity, were believed to be unrealistically high. Based on discussions with the asphalt supplier, temperatures of approximately 163°C for mixing and 150°C for compaction were used.

After verifying the component material properties, the aggregate blend was prepared to verify the design asphalt binder content. Two trial mixture specimens were prepared at each of four asphalt binder contents to verify the design asphalt binder content. All specimens were subjected to four hours of short term aging. The specimens were aged at 135°C for three hours and forty minutes before being transferred to an oven operating at 163°C for twenty minutes. At the end of the four hour conditioning period the mix sample was at the appropriate compaction temperature. The design number of gyrations (Nd) for the asphalt mixture was 106, and the maximum (Nm) was 169 gyrations. Specimens were then compacted to Nm using the Superpave gyratory compactor (SGC). This is appropriate for a road with a traffic level of three to ten million ESALs with a design high air temperature of 39-40°C (1). Densification curves were generated after determining the maximum theoretical specific gravity (Gmm) and bulk specific gravity (Gmb) at Nm for each specimen. Volumetric and densification properties were determined for the mixture as shown in Table 2.

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TABLE 2 - Mixture Volumetric and Densification Properties: AI Results

	@Nd					
Asphalt Content, %	Air Voids, %	VMA, %	VFA, %	Dust Prop.	%G _{mm} @N _i	%G _{mm} @N _m
5.0	7.5	15.9	52	1.3	81.3	93.9
5.5	6.3	15.9	60	1.2	82.4	95.2
6.0	5.1	15.9	68	1.0	83.1	96.4
6.5	4.0	15.9	75	0.9	84.0	97.5
Criteria	4.0	14.0	65-75	0.6-1.2	<89	<98

Note: % VMA calculated using Agency's combined aggregate specific gravity.

Table 3 indicates the mixture properties at the design asphalt binder content. The testing verified the agency selection of the design asphalt binder content. The main difference between the two testing labs was in the percentage of voids in the mineral aggregate (%VMA). The percentage of voids filled with asphalt (%VFA) was verified within the allowable range.

TABLE 3- Comparison of Design Mixture Properties

		@Nd					
	% AC	Air Voids, %	% VMA	% VFA	Dust Prop.	%G _{mm} @N _i	%G _{mm} @N _m
AI Result	6.5	4.0	15.9	74.9	0.9	84.0	97.5
Agency Result	6.3	4.0	15.3	73.9	1.0	n/a	n/a
Criteria		4.0	14.0	65-75	0.6-1.2	<89	<98

The final step in the verification of the Superpave mix design was the determination of the moisture sensitivity of the mixture. Currently in the Superpave system, moisture sensitivity is determined using a modified version of AASHTO T-283, Resistance of Compacted Bituminous Mixture to Moisture Induced Damage (3). In Superpave, specimens are prepared using the SGC with dimensions of 150 millimeters diameter and 95 millimeters height to approximately 7% air voids. The asphalt mixture specimens were aged using the procedure listed in AASHTO T-283 rather than the short term oven aging normally used for SGC specimens. The T-283 procedure requires that the mix specimens be aged 16 hours at 60°C followed by 2 hours at 135°C prior to compaction. Unconditioned and moisture conditioned specimens are tested in indirect tension and the ratio of the conditioned to unconditioned indirect tensile strength is reported. Superpave mixes must have a minimum tensile strength ratio of 0.80, or 80%. The tensile strength ratio of the design mix was 0.90, or 90%.

The design mixture was verified to meet all Superpave Volumetric Mix Design criteria. The next phase of testing would evaluate the susceptibility of the mixture to permanent deformation.

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Phase 2: Permanent Deformation Testing

The principal concern of user agencies regarding asphalt mixtures is the potential of premature failure as permanent deformation (rutting), fatigue cracking, and thermal cracking. Moisture susceptibility was not considered a distress form, but rather a contributing factor to the main distresses. It is addressed through the use of AASHTO T-283.

These distress mechanisms are considered in a Superpave Mix Analysis directly through performance tests. They are only indirectly considered in the Superpave Volumetric Mix Design through other, performance-related parameters. For instance, thermal cracking is addressed through the selection of the proper asphalt binder grade for the climate in accordance with AASHTO MP1. Fatigue cracking is partially examined through the use of the intermediate temperature complex shear modulus and phase angle of the asphalt binder, and through the use of minimum %VMA criterion to ensure the presence of adequate asphalt binder in the mixture.

However, rutting is possibly the most complicated, and least directly considered distress in the Superpave Volumetric Mix Design. Several binder, aggregate, and mix properties have some relation to the permanent deformation performance of a mixture, but there is no single property that can be directly associated with rutting susceptibility. For these reasons, most Superpave users are considering the addition of a test to measure the rutting potential of an asphalt mixture.

The focus of Phase 2 of this case study was to evaluate several existing tests to compare the rutting potential of the design asphalt mixture. As a case study, the design mixture was evaluated to determine its relative rutting potential. Tests that were performed included:

- Repeated Shear Test at Constant Height (RSST-CH)
- Repeated Shear Test at Constant Stress Ratio (RSST-CS)
- Simple Shear and Frequency Sweep at Constant Height (SS-CH and FS-CH)
- Georgia Loaded Wheel Test

Each test and the test results are discussed in the following sections.

Repeated Shear Test at Constant Height

The repeated shear test at constant height (RSST-CH) is an optional mixture test that is included in AASHTO TP7, Standard Test Method for Determining the Permanent Deformation and Fatigue Cracking Characteristics of Hot Mix Asphalt (HMA) Using the Simple Shear Test (SST) Device (7), as a test to evaluate the rutting potential of asphalt mixtures. While this test is not part of the Superpave Mix Analysis system, protocols for performing the testing and analysis were developed during SHRP.

To execute the RSST-CH, cylindrical specimens, utilizing the design asphalt mixture from Phase 1 (150 millimeters diameter and 50 millimeters height), were first prepared to a nominal air voids content of three percent. The test specimen was then allowed to condition to the test temperature. This temperature is dependent on the maximum pavement temperature for a given project location, based on the weather station data collected in the Superpave weather database (8). Other factors such as temperature reliability and depth can affect the test temperature.

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The test specimen is instrumented and loaded into the testing chamber. After temperature equilibration, the specimen is tested by applying a haversine shear stress of 68 kiloPascals for 0.1 seconds with a 0.6 second rest period. During this loading cycle, the height of the specimen is maintained constant within ± 0.0013 mm. The test is executed for 5000 cycles, or until the specimen reaches five percent permanent shear strain. The output of the test is a set of shear strain data that can be plotted as a function of the number of loading cycles. The test procedure and analysis are described in detail in SHRP Report A-698 (9). Specimens that reach five percent shear strain before 5000 cycles of loading may be susceptible to rutting. Test data can also be evaluated by determining the number of cycles a mixture will require to achieve a fixed shear strain, such as five percent. In many cases, this value will be determined by extrapolation from the linear regression of shear strain and number of cycles (between 1000 and 5000 cycles) plotted on a log-log scale.

SHRP A-698 provides a procedure to correlate the number of loading cycles to a desired shear strain with traffic to a maximum rut depth. Of concern, this procedure was based on testing using specimens that were not prepared using the SGC. Consequently, the procedure for estimating rut depth is likely invalid for SGC prepared specimens. However, it is proposed that relative comparisons can still be made between rutting resistant and rutting susceptible mixtures.

The design asphalt mixture specimens were prepared to approximately three percent air voids. Duplicate specimens were prepared and tested using the RSST-CH procedure described in AASHTO TP7 at a test temperature of 56°C. The data is illustrated in Figure 2. A summary of test results is shown in Table 4.

TABLE 4 -Design Mixture: RSST-CH Results

	$g_{100}, \%$	$g_{1000}, \%$	$g_{5000}, \%$	Slope
Replicate 1	1.22	2.14	2.80	0.165
Replicate 2	0.37	0.71	1.05	0.245
Average			1.92	0.205

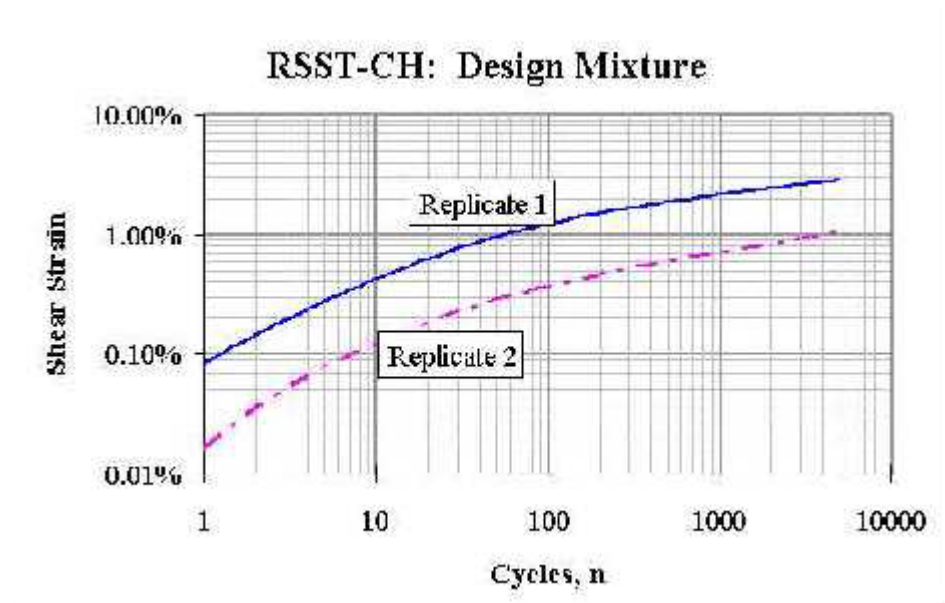


Figure 2

The final shear strain at 5000 cycles (g5000) for the duplicate specimens was 2.80 and 1.05 percent. These test values are not very repeatable, but still indicate that the mixture did not, in either test, exceed five percent shear strain. Based on the Asphalt Institute's experience with the RSST-CH using SGC specimens, the average shear strain (1.92%) is an above average value that should indicate adequate resistance to rutting.

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Repeated Shear Test at Constant Stress Ratio

The repeated shear test at constant stress ratio (RSST-CS) is a required Superpave mixture test that is included in AASHTO TP7. The RSST-CS is a screening test used to evaluate the potential of an asphalt mixture to exhibit gross instability. Mixtures that exhibit instability in this test cannot be accurately modeled in Superpave.

Current research by organizations involved in examining Superpave modeling indicates that the RSST-CS offers promise for use in calculating tertiary rutting, and determining the slope of the curve of the log shear strain versus log loading cycles used as an input to the Superpave Mix Analysis system. This research is being coordinated at the University of Maryland.

Specimen preparation and temperature conditioning are the same in the RSST-CS as the RSST-CH procedure. Test temperature is based on the critical pavement temperature, which is a function of the maximum pavement temperature, reliability, and traffic.

After temperature equilibration, the specimen is tested by applying synchronized haversine axial and shear stresses for 0.1 seconds with a 0.6 second rest period. The ratio of axial to shear stress is maintained constant during the loading. The magnitudes of the applied stresses are a function of the asphalt binder content and existing base condition. According to AASHTO TP7, the test is executed for 5000 cycles, or until the specimen reaches five percent permanent shear strain. Like the RSST-CH, the output of the RSST-CS is a set of shear strain data that can be plotted as a function of the number of loading cycles. When plotting shear strain versus loading cycles on a log-log graph, the resulting curve should be mostly linear after an initial number of loading cycles. Mixtures that have a high potential for gross instability will have curves that are

linear at first, but then exhibit rapidly increasing shear strain with a relatively low number of additional loading cycles.

The design asphalt mixture specimens were prepared to approximately three percent air voids. Duplicate specimens were prepared and tested using the RSST-CS procedure described in AASHTO TP7 at a test temperature of 60°C. Specimens were tested for 20,000 cycles using an applied shear stress of 66 kiloPascals and an applied axial stress of 82 kiloPascals. The data is illustrated in Figure 3.

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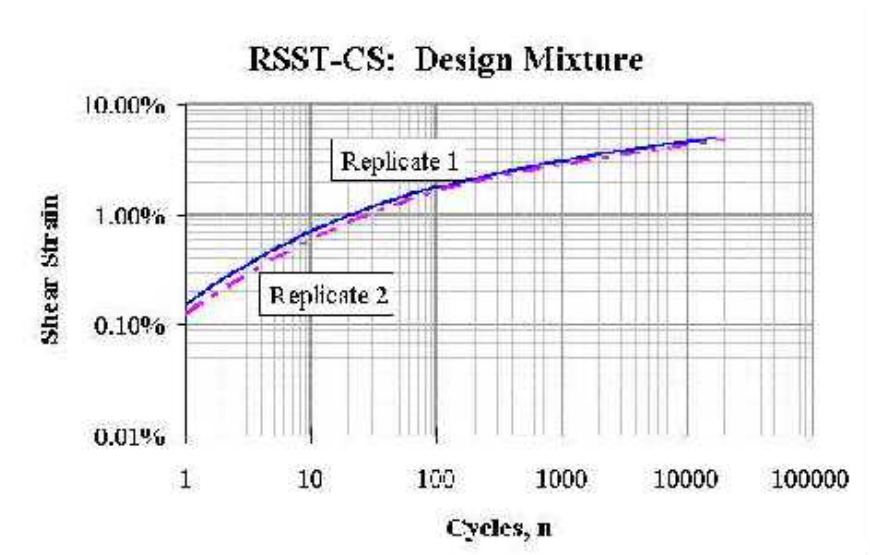


Figure 3

The final shear strain at 20,000 cycles ($g_{20,000}$) for the duplicate specimens was 4.91 and 4.75 percent. Unlike the RSST-CH, the permanent shear strain was much higher at 5000 cycles. Despite the higher shear strains, the curve of shear strain versus loading cycles, on a log-log graph, did not indicate the rapid increase in shear strain associated with mix instability. As indicated Figure 3, the curves remained linear after the initial loading phase. This is an indication that the design mix would be considered stable, and could be tested further, if desired, using Superpave Mix Analysis.

It should be expected that the permanent shear strain would be higher for the RSST-CS specimens than the RSST-CH specimens, even though the magnitudes of the applied shear stresses were equivalent. This is due to two main factors: the higher test temperature, and the difference in confinement during the application of the shear stress. In the RSST-CH, the specimen is restrained from dilation by the constant height requirement. Therefore the axial stress required to maintain the constant height varies during the test. The confinement in the RSST-CS is applied as a constant axial stress synchronized with the applied shear stress.

Simple Shear and Frequency Sweep at Constant Height

The Simple Shear (SS-CH) and Frequency Sweep (FS-CH) tests at constant height form part of the Superpave Mix Analysis system. These tests were performed at two test temperatures for the design asphalt mixture to characterize rutting. The SS-CH and FS-CH were performed at effective temperatures for permanent deformation, T_{eff} (PD), and fatigue cracking, T_{eff} (FC), that are representative of the temperatures that could be used to characterize the distresses on a year-round basis. Only these two tests are required in Superpave to model permanent deformation.

Specimen preparation is similar to the specimen preparation described in the RSST-CH procedure, except SGC specimens were prepared to a nominal air voids content of seven percent.

In the FS-CH test, the specimen is tested in controlled strain mode by applying a sinusoidal shear stress corresponding to a shear strain of 0.01 percent for a variety of loading frequencies. The height of the specimen is maintained constant during the loading cycle. The output of the test is a set of shear stress and strain data that can be used to calculate complex shear modulus and phase angle. The slope of the complex shear modulus versus frequency curve on a log-log graph is calculated and used as an input to the Superpave models for estimating rut depth.

In the SS-CH test, the specimen is tested using a single shear loading and unloading cycle. A shear stress is applied and shear strains are measured. The shear stress is applied by ramping the stress quickly to the maximum level, holding that level for a period of time, and releasing the shear stress at a controlled rate. The magnitude of the shear stress is dependent on the test temperature. The output of the test is a set of shear stress and strain data that are used to calculate some of the non-linear elastic and Vermeer properties needed by Superpave models to estimate rut depth.

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For the project conditions, Teff (FC) was 27°C and Teff (PD) was 42°C. The data was analyzed through the Superpave models using the following assumed pavement structure:

- 50 millimeters design asphalt mixture
- 200 millimeters existing asphalt concrete, slight ruts
- 300 millimeters average granular base
- Subgrade A-5

As indicated by the data in Figure 4, the Superpave models estimated that the design asphalt mixture will exhibit 4.8 millimeters of rutting after eight million ESALs for the given project-specific conditions. Using the Superpave Mix Analysis system, the user agency will determine if this amount of permanent deformation is acceptable for the project.

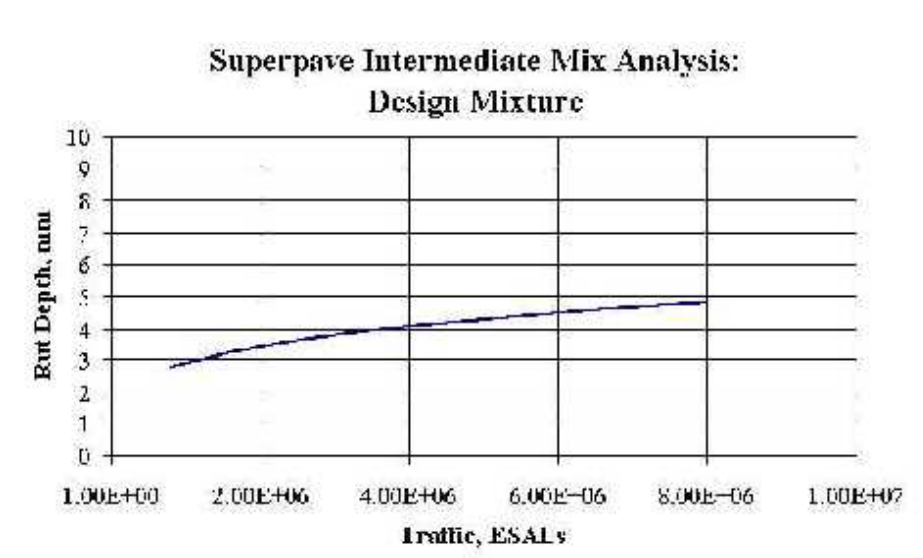


Figure 4

Unfortunately, minimal validation work has been performed to inform the user if 4.8 millimeters is a true estimation of the expected rutting. As such, the results reported from a Superpave Mix Analysis are useful only in relative comparisons.

The principal value in performing the SS-CH and FS-CH tests is in determining the material properties necessary for the Superpave models. The FS-CH test provides a determination of the complex shear modulus (G^*) and phase angle (δ) for a variety of loading frequencies. Results from the FS-CH test for the design mixture can be compared directly with results from other mixtures to form a basis of comparison for performance. Table 5 indicates a relative comparison of G^* , and the slope of the G^* versus frequency curve (m_{FS}) for some typical Superpave mixtures.

TABLE 5- Design Mixture: FS-CH Results

Mix 3				
G^* @10Hz, kPa	239,706	549,450	470,212	316,910
m_{FS}	0.300	0.352	0.372	0.425
Temp, C	42	40	40	40

Georgia Loaded Wheel Test

The Georgia Loaded Wheel Test (GLWT) has been used by the Georgia DOT for nearly a decade to supplement their mix design process for high traffic volume roads. The test is executed by applying multiple cycles of a loaded wheel to a pressured hose resting on an asphalt mixture specimen. The amount of rutting is measured after the completion of the test and is used as a relative indication of the rutting potential of an asphalt mixture. Georgia DOT uses a maximum allowable rut depth of 7.5 millimeters based on their experience with the GLWT and asphalt mixture performance in the State.

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Beam specimens, having dimensions of 75 millimeters height by 125 millimeters width by 300 millimeters length, are produced at seven percent air voids using rolling wheel compaction. Triplicate beam specimens are produced. After temperature conditioning, the specimens are loaded in the testing device. A steel wheel with a load of 448 Newtons oscillates across a rubber hose pressurized to 690 kiloPascals. The test is executed at 40°C for 8000 cycles. At the end of the test, rut depth measurements are taken at three locations on the beam. The average of the three measurements is reported as the rut depth for the asphalt mixture specimen. The average rut depth of three beams is reported and compared to the criteria. Table 6 indicates the test results for the design asphalt mixture.

As shown in Table 6, the average rut depth for the three beams was 4.0 millimeters with a range of 2.8 to 4.7 millimeters. The average air voids of the specimens was 8.1 percent. The design asphalt mixture would be acceptable using Georgia DOT criteria.

TABLE 6- Design Mixture: GLWT Results

	Specimen 1	Specimen 2	Specimen 3	Average	Criteria
Air Voids, %	9.1	7.7	7.4	8.1	7±1
Rut Depth, mm	4.6	4.7	2.8	4.0	7.5 max.

SUMMARY

The purpose of the applied research effort was to determine if additional tests are necessary to supplement the Superpave Volumetric Mix Design system, and to evaluate some of those potential tests. In its current form, Superpave Volumetric Mix Design does not have any torture or fundamental materials characterization tests required to ensure that a design asphalt mixture will not exhibit premature failure, particularly rutting failure. The plan was to study a particular asphalt mixture that was of concern to the user agency. The testing plan included two phases: verification of the design Superpave mix, and evaluation of the permanent deformation potential of the design asphalt mixture.

The design asphalt mixture was verified through materials testing, determination of volumetric and densification properties, and evaluation of moisture sensitivity. All required elements of a Superpave Volumetric Mix Design were satisfied by the design asphalt mixture. However, the user agency had concerns based on poor past performance history with the aggregates used in the design asphalt mixture. The design asphalt content was also higher than what would normally be used by the user agency in an asphalt mixture being placed on an Interstate highway. As a consequence, permanent deformation evaluation was desired.

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To determine the permanent deformation potential, four analyses were performed using different tests:

1. Repeated Shear Test at Constant Height -- permanent shear strain as a result of shear stress applications in a constant volume state.
2. Repeated Shear Test at Constant Stress Ratio -- development of gross mix instability as a result of synchronized shear and axial stress applications.
3. Simple Shear and Frequency Sweep Tests at Constant Height -- necessary part of Superpave Intermediate Mix Analysis. Output is prediction of rut depth for a given set of project conditions using non-linear elastic, plastic, and viscoelastic properties.
4. Georgia Loaded Wheel Test -- rut depth estimation after loaded wheel testing.

None of the four analyses indicated that the design asphalt mixture would be expected to exhibit early permanent deformation. For this asphalt mixture and project conditions, no additional testing would be needed to ensure that the asphalt mixture, as designed by Superpave Volumetric Mix Design, had adequate resistance to premature permanent deformation.

Despite the results of this testing program, additional experience is needed with the Superpave Volumetric Mix Design System and potential torture tests before discarding the hypothesis that Superpave Volumetric Mix Design, by itself, is sufficient. The disadvantages of the tests used in this project for evaluating permanent deformation potential is the additional cost of the equipment and the additional effort in preparation and testing of the asphalt mixture specimens. Further research is necessary before recommending additional testing. The increased cost of such testing may be unnecessary when all the criteria are met in the Superpave Volumetric Mix Design system.

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