COMPARATIVE ANALYSIS OF SUPERPAVE GYRATORY COMPACTED SPECIMENS WITH LINEAR KNEADING COMPACTED SLABS USING THE HAMBURG WHEEL-TRACKING DEVICE

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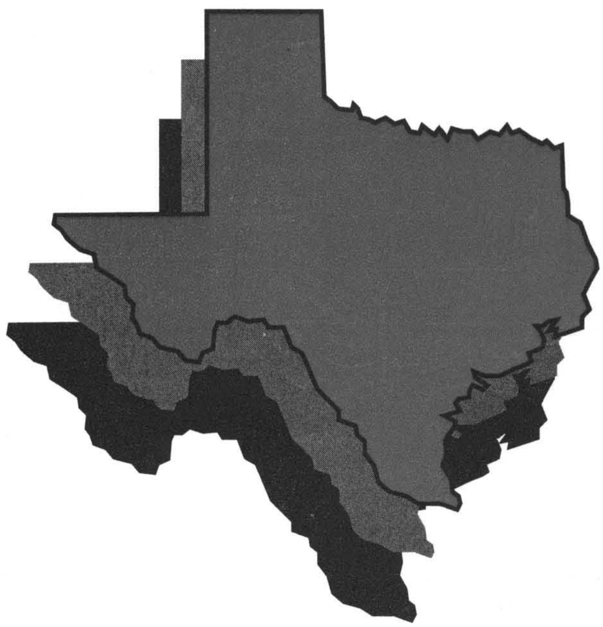

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16. Abstract

In September 1990, individuals representing the American Association of State Highway Transportation Officials (AASHTO), Federal Highway Administration (FHWA), National Asphalt Pavement Association (NAPA), Strategic Highway Research Program (SHRP), Asphalt Institute (AI), and Transportation Research Board (TRB) were introduced to performance-related testing equipment used in several European countries. This introduction was part of a two-week tour of six European countries. Among the testing devices was the Hamburg Wheel-Tracking device (HWTD). This device was designed in Germany and used to evaluate HMA mixtures potential for rutting and stripping.

Several agencies purchased HWTDs to evaluate HMA mixtures susceptibility to moisture damage. There are no standard specifications for the test on a nationwide basis. However, CDOT has established a standardized testing procedure for their use. Testing is ongoing and evaluation of the testing apparatus is not complete. There are several factors to be addressed, i.e., repeatability, compaction of test specimens, and test temperature. This paper addresses the type of compaction utilized to fabricate test specimens for the HWTD, as well as repeatability of the test results.

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Hamburg Wheel-Tracking device, moisture susceptibility, asphalt mixtures, asphalt pavement, performance-related testing, rutting, stripping. specimen preparation, specimen compaction, Superpave, gyratory compactor, kneading linear compactor, hot mixed asphalt, HMAC	No restrictions. This document is available to the public through the Texas Department of Transportation Research Library, P.O. Box 5080, Austin, TX, 78763-5080.

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by

Richard P. Izzo, M.S., E.I.T.

Maghsoud Tahmoressi, P.E.

Bituminous Section
Materials and Tests Division
Texas Department of Transportation

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INTRODUCTION

Moisture damage of hot mix asphalt (HMA) has been plaguing the pavement industry throughout the United States for many years. Moisture damage or sensitivity, commonly referred to as stripping, is the separation of asphalt from the surface of aggregate. HMA becomes susceptible to permanent deformation (rutting), cracking, and bleeding (or flushing) as a consequence of stripping.

Laboratory testing capabilities for prediction of moisture damage have been vastly improved. However, there are a limited number of basic tests with many variations of each test. It has been shown that these different tests and test variations do not yield the same results and thus vary in the prediction of moisture susceptibility *(1)*.

In September 1990, individuals representing the American Association of State Highway Transportation Officials (AASHTO), Federal Highway Administration (FHWA), National Asphalt Pavement Association (NAPA), Strategic Highway Research Program (SHRP), Asphalt Institute (AI), and Transportation Research Board (TRB) were introduced to performance-related testing equipment used in several European countries. This introduction was part of a two-week tour of six European countries. Among the testing devices was the Hamburg Wheel-Tracking device (HWTD). This device was designed in Germany and used to evaluate HMA mixtures potential for rutting and stripping *(2)*.

The Colorado Department of Transportation (CDOT) and FHWA have performed extensive amounts of research with the HWTD since 1990. The HWTD measures the combined effects of rutting and moisture damage by rolling a steel wheel across the surface of a rectangular slab that is submerged in water at 50°C. The device tests two rectangular slabs simultaneously with two reciprocating solid steel wheels that each have a diameter of 203.5 mm and a width of 47 mm. The load applied on each specimen is 703 N where each wheel rolls 230 mm before reversing in direction. A standard test applies a maximum number of 20,000 passes. The data produced by the device are customarily reported versus passes rather than cycles. A cycle is two passes. A linear variable differential transducer measures the rut depth in each slab automatically and continuously with an accuracy of 0.01 mm. The maximum allowable rut depth of 4 mm at 20,000 passes is specified in Hamburg, Germany (*3*).

CDOT has developed Colorado Procedure CP-L 5112, Hamburg Wheel Track Testing of Compacted Bituminous Mixtures to assess the potential of moisture damage to HMA in Colorado. This specification adopted by CDOT utilizes the HWTD and is unique such that it specifies testing temperatures according to site location and asphalt binder type. A maximum impression of 10 mm at 20,000 passes is specified (*2*).

Several agencies purchased HWTDs to evaluate HMA mixtures susceptibility to moisture damage. There are no standard specifications for the test on a nationwide basis. However, CDOT has established a standardized testing procedure for their use. Testing is ongoing and evaluation of the testing apparatus is not complete. There are several factors to be addressed, i.e., repeatability, compaction of test specimens, and test temperature. This paper addresses the type of compaction utilized to fabricate test specimens for the HWTD, as well as repeatability of the test results.

EXPERIMENTAL DESIGN

The objective of the experimental design is to assess the use of the Superpave Gyratory Compaction (SGC) device for the fabrication of specimens tested with the HWTD. The HWTD performs testing on compacted rectangular HMA slabs. The SGC produces significantly smaller cylindrical specimens.

A standard procedure has not been developed in Germany with regards to specimen fabrication. CDOT have been utilizing a linear kneading compaction device to fabricate test specimens. Colorado specifications also allow specimens to be compacted with the Laboratoire

Central des Ponts et Chaussees (LCPC) Compactor de Plaques. This machine employs a reciprocating, pneumatic rubber tire to produce slabs for testing with the French Pavement Rutting Tester. Originally, the FHWA compacted test specimens with a vibratory hammer and a steel wheel roller; however, they are presently using a linear kneading compactor.

Materials Selection and Specimen Fabrication

Laboratory testing consisted of the evaluation of two types of HMA mixtures. The mixtures were composed of a limestone and gravel aggregate. The asphalt used for both mixtures was a Coastal AC-20. The HMA was produced at asphalt batch plants following Texas Department of Transportation (TxDOT) specifications for a Type-D mixture. Limestone and gravel mixture components are listed in tables 1a and 1b. The optimum asphalt content and aggregate gradation for each mixture are listed in table 1c. The limestone mixture was procured from Austin Bridge & Road located in Austin, TX. The gravel mixture was obtained from Balenger located in Pharr, TX. The material was delivered in burlap sacks.

The intent of this research was to conduct testing with rectangular slabs and SGC specimens. The loose mixtures in burlap sacks were mailed to CDOT and compacted into slabs with their linear kneading compactor. The SGC specimens were fabricated with a Pine SGC at TxDOT. It was intended to compact all the test specimens to a density of 94 ±1%. However, the slabs with the gravel mixture were compacted to a density of 96 ±1%, thus the SGC specimens composed of the same mixture were compacted to that level as well. SGC specimens of 94 ±1% density were also tested. The heights of the test specimens were approximately 62 mm.

Laboratory Testing

The HWTD was used to evaluate the use of SGC test specimens, in lieu of rectangular compacted slabs, to assess moisture damage. The tests were performed according to German specifications with the addition of SGC test specimens and a molding configuration designed by TxDOT. Testing was conducted at 50°C with no specified maximum allowable rut depth. However, the software requires the input of a maximum impression or rut depth as a test parameter, thus 20 mm was selected.

The rectangular slabs were mounted in the center of the sample trays with the use of plaster of Paris. The plaster was mixed with water until fluid enough to pour in between the test specimen and mounting tray. The plaster was allowed to set overnight prior to testing.

TxDOT modified the test specimen configuration such that one test specimen for the HWTD consists of two SGC specimens. The specimens are secured in the mounting tray with two molds and two spacer plates fabricated with an acrylic material. Figure 1 illustrates a top view of the set up. This figure is not drawn to scale and all dimensions are in mm. The spacer plates, which aid in securing the configuration, are placed behind each mold at opposite ends. The molds are shaped as rectangles with semicircles cut out approximately 25 mm from the back edge. However, with the spacer plates the semicircles are approximately 40 mm from the back edge of the mounting tray. The specimens are sawed such that they fit into the molds. The specimens are tightly fastened in the mounting tray by tightening nuts that adjoin a front plate to the mounting tray. Overall, the whole specimen resembles a snowman figure with a contact area among the SGC specimens approximately 51 cm^2 (8.3 cm * 6.2 cm) and is adequately secured such that movement during testing does not occur other than any degradation resulting from the test. The sawed portion is approximately 5% of the total volume of a single SGC specimen. This configuration with the SGC specimens can be seen in figure 2. The mounting trays in this figure are 40 mm in height. Testing is performed with the mounting tray 60 mm in height, which was not available at the time this picture was taken.

TABLE 1a: Limestone Mixture Components

Aggregate	Percent
Alamo Type D Rock	35.0
Alamo Type F Rock	22.6
Alamo Screenings	29.6
Southern Field Sand	12.8
Anti-Stripping Additive	None

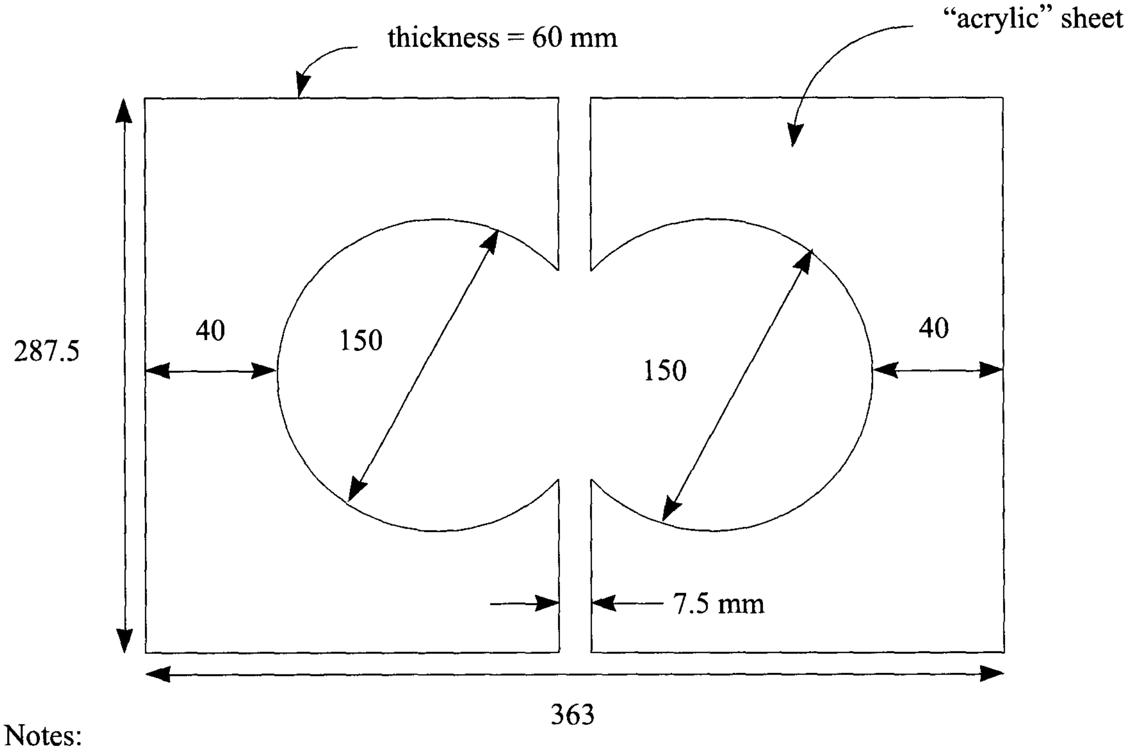
TABLE 1b: Gravel Mixture Components

Aggregate	Percent
Fordyce Grade 4	32.0
Fordyce Grade 6	30.0
Border Pacific Limestone Screenings	23.0
Fordyce Field Sand	15.0
Anti-Stripping Additive	1 - Hydrated Lime

TABLE 1c: Aggregate Gradation in Percent Passing for Limestone and Gravel Mixtures

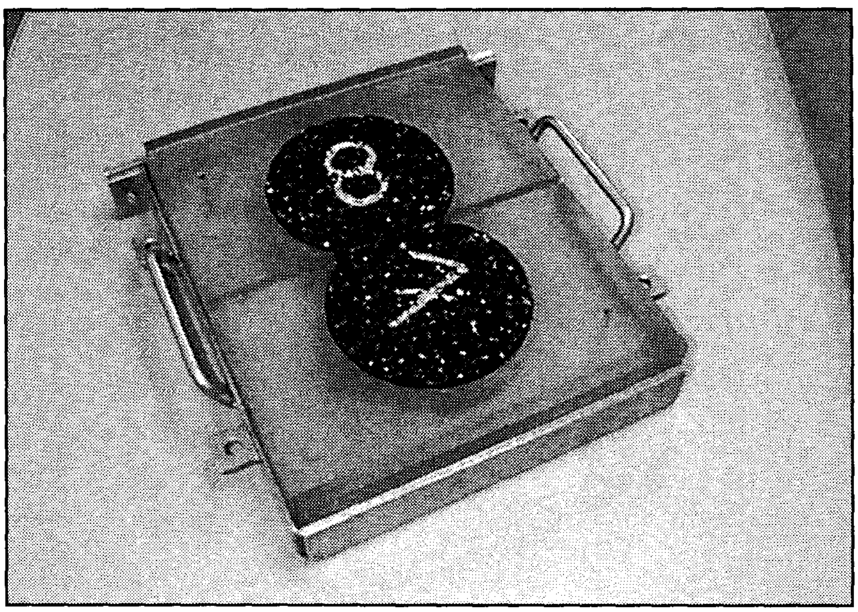
Sieve Size, mm	Limestone Mixture	Gravel Mixture
12.7	100.0	100.0
9.5	93.6	94.3
4.75	64.8	67.1
2.00	40.6	39.6
0.425	19.8	19.4
0.180	6.9	10.4
0.075	2.0	6.6
Asphalt Content	5.8%	5.3%

FIGURE 1: Top view of Superpave gyratory specimen configuration for the Hamburg Wheel-Tracking device



Notes:
1. not to scale
2. dimensions in millimeters

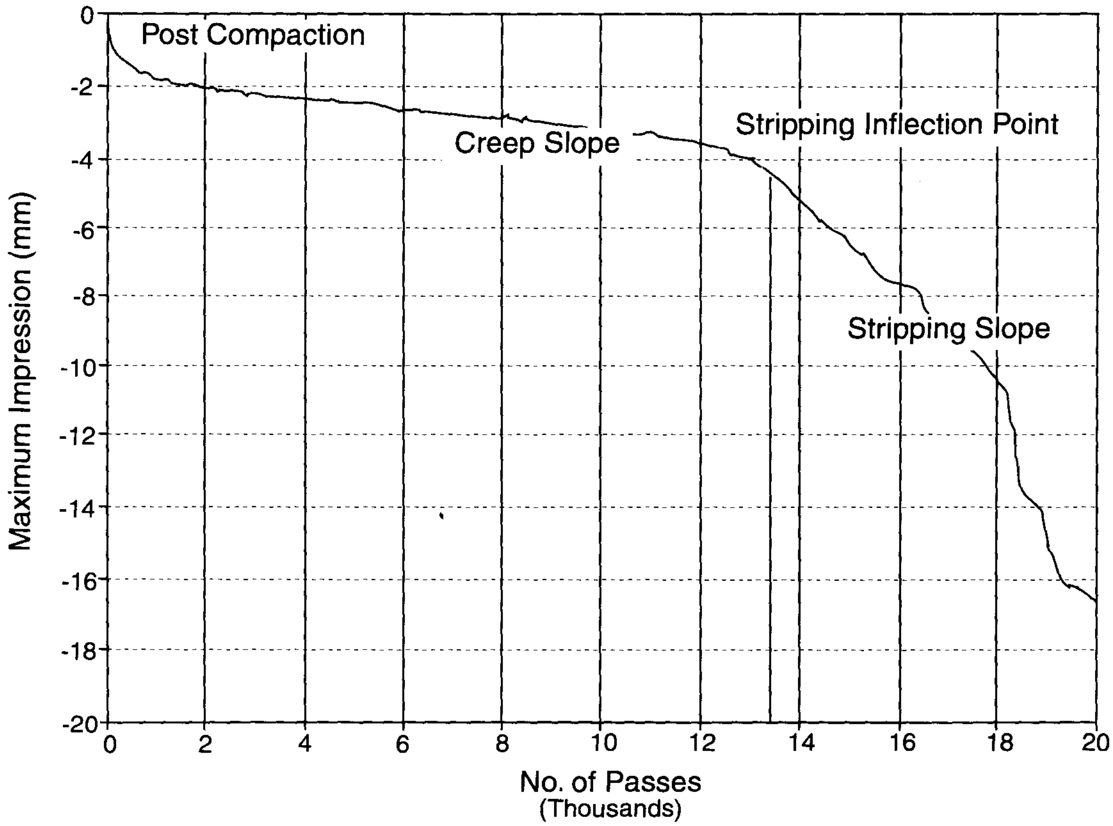
FIGURE 2: Test specimen configuration for the Hamburg Wheel-Tracking device with Superpave gyratory-compacted specimens



RESULTS AND DISCUSSION

Data analyses included the evaluation of rut depth (in mm) at 5000, 10000, 15000, and 20000 cycles where applicable and at the stripping inflection point. The analysis also included the creep and stripping slopes and stripping inflection point. The creep slope relates to rutting primarily from plastic flow. It is the number of passes required to create a 1-mm rut depth. The stripping inflection point is the number of passes at the intersection of the creep slope and stripping slope. It is the number of passes at which stripping starts to dominate performance. The stripping slope is a measure of the accumulation of rutting primarily from moisture damage. It is the number of passes required to create a 1-mm rut depth after the stripping inflection point (*3*). Figure 3 is an illustration of a plot of the typical output produced from the test with test parameters.

FIGURE 3: Definition of the Hamburg Wheel-Tracking device test results



The data were analyzed according to comparisons of test parameters found for slab compacted specimens versus SGC specimens, as well as for the effect of aggregate type upon performance. Comparisons were made with average test values of three replicates, as well as with statistical results from F-tests testing for the equality of two variances at α=0.05 and T-tests testing for the equality of means at α=0.05. A summary of F- and T-test results are shown in Table 2.

TABLE 2a: Summary of F- and T-Test Results for Limestone Mixtures @ α=0.05.

Test Parameter	F-Test	T-Test
Rut Depth @ 5,000	Not Equal	Equal
Rut Depth @ 10,000	Equal	Equal
Rut Depth @ 15,000	Equal	Equal
Rut Depth @ S I P	Not Equal	Not Equal
Creep Slope	Equal	Equal
Stripping Slope	Equal	Equal
No. of Passes @ S I P	Equal	Not Equal

Note — S I P is the abbreviation for "stripping inflection point."

TABLE 2b: Summary of F and T Test Results for Limestone Mixtures @ α=0.05.

Slab versus SGC @ 96 % Density		
	F-Test	T-Test
Rut Depth @ 5,000	Not Equal	Not Equal
Rut Depth @ 10,000	Not Equal	Not Equal
Rut Depth @ S I P	Not Equal	Not Equal
Creep Slope	Equal	Equal
Stripping Slope	Not Equal	Equal
No. of Passes @ S I P	Not Equal	Not Equal
Slab @ 96 % Density versus SGC @ 94 % Density		
	F-Test	T-Test
Rut Depth @ 5,000	Not Equal	Equal
Rut Depth @ 10,000	Not Equal	Not Equal
Rut Depth @ S I P	Equal	Not Equal
Creep Slope	Equal	Equal
Stripping Slope	Equal	Not Equal
No. of Passes @ S I P	Equal	Not Equal
SGC @ 94 % Density versus SGC @ 96 % Density		
	F-Test	T-Test
Rut Depth @ 5,000	Equal	Not Equal
Rut Depth @ 10,000	Equal	Equal
Rut Depth @ S I P	Not Equal	Not Equal
Creep Slope	Not Equal	Equal
Stripping Slope	Not Equal	Not Equal
No. of Passes @ S I P	Equal	Equal

Note — S I P is the abbreviation for "stripping inflection point."

Slab versus SGC Specimens

Limestone Mixtures

SGC specimens composed of limestone failed in less cycles than the rectangular slabs fabricated with the linear kneading compactor by CDOT. Table 3 lists the rut depths after 5,000, 10,000, 15,000, and 20,000 cycles where applicable, as well as at the stripping inflection point. The rut depths after 5,000 cycles were greater in the slabs than the SGC specimens. However, the rut depths in the SGC specimens after 10,000, 15,000, and 20,000 cycles were greater. Figure 4 is a plot of the rut depth for the slab versus SGC. A line has been drawn at 45° to evaluate the equality of the rut depths for the slab and SGC specimens. It can be seen that the rut depths after 5,000 and 10,000 cycles are fairly similar, whereas the rut depths after 15,000 cycles are somewhat different. The rut depth at the stripping inflection point were lower in the slabs in comparison to that found for the SGC specimens.

The variance for the rut depth at 10,000 and 15,000 cycles were found to be unequal for the slab and SGC specimens. However, the variance for the rut depth at 5,000 cycles and at the stripping inflection point were found to be equal. The T-test indicated that the mean for the rut depth after 5,000, 10,000, and 15,000 cycles were statistically equal for the slab and SGC specimens. However, the mean for the rut depth at the stripping inflection point were found to be unequal.

The creep slope, stripping slope, and number of passes at the stripping inflection point for the slab and SGC specimens are listed in table 3. It has been found that the creep and stripping slope for the slabs were greater overall. The slabs have shown better performance relative to rutting and stripping. Figure 9 depicts the number of passes at the stripping inflection point, which is less for the compacted slabs.

The variances of the creep slope for the slab and SGC specimens were found to be statistically equal. However, the variance for the stripping slope values and number of passes at the stripping inflection point for the slab and SGC specimens were found to be unequal. The T-test indicated that the mean of the creep slope and stripping slope for the slab and SGC specimens were equal. The number of passes at the stripping inflection point were found to be unequal.

Figure 4 displays the impression measured at each pass of the steel wheel and is indicative of better repeatability among the slab test replicates. Table 4 lists the average and standard deviation determined from the test replicates for the slab and SGC specimens. The standard deviation found for the rut depth at 5,000 cycles and creep slope were greater for the slab specimens. The standard deviation computed for the number of passes at the stripping inflection point were similar. The test data for the slab replicates indicated a smaller standard deviation for the rut depth at 10,000 and 15,000 cycles and at the inflection point, as well as for the stripping slope. Table 5 lists the air void content for each test specimen.

The slab and SGC specimens performed reasonably alike according to the comparative analyses performed. However, it is speculated that the confinement from the acrylic molds in the SGC configuration may be too great, thus yielding significantly different creep slope values and the number of passes at the stripping inflection point.

TABLE 3: Summary of Test Results for Mixtures Composed of Limestone

Sample ID	Rut Depth, mm @ 5,000 Cycles	10,000 Cycles	15,000 Cycles	20,000 Cycles	Inflection Point	Creep Slope	Stripping Slope	N @ S I P
Slab-1a	3.88	8.77	13.35	17.80	1.70	3614	746	3251
Slab-1b	2.33	8.02	14.81	19.11	2.48	4227	822	5278
Average	***3.11***	***8.40***	***14.08***	***18.46***	***2.09***	***3921***	***784***	***4265***
Slab-2a	4.27	9.07	12.75	17.34	1.69	2671	949	2481
Slab-2b	2.58	8.91	14.07	19.18	3.62	4808	788	4343
Average	***3.43***	***8.99***	***13.41***	***18.26***	***2.66***	***3740***	***869***	***3412***
Slab-3a	1.77	6.42	10.96	15.31	1.90	5336	1013	5246
Slab-3b	3.22	8.18	11.20	15.11	1.39	5484	727	3661
Average	***2.50***	***7.30***	***11.08***	***15.21***	***1.65***	***5410***	***870***	***4453***
Total Avg	***3.01***	***8.23***	***12.86***	***17.31***	***2.13***	***4357***	***841***	***4043***
SGC-1a	2.10	4.71	9.77	failed	2.95	3932	1230	7657
SGC-1b	2.22	7.12	15.08	failed	2.76	4008	681	7013
Average	***2.16***	***5.92***	***12.43***	***failed***	***2.86***	***3970***	***956***	***7335***
SGC-2a	2.82	8.75	17.78	failed	3.12	2898	760	5391
SGC-2b	2.68	9.18	18.87	failed	2.91	3166	680	5100
Average	***2.75***	***8.97***	***18.33***	***failed***	***3.02***	***3032***	***720***	***5245***
SGC-3a	3.03	12.73	19.79	failed	3.01	2670	589	4965
SGC-3b	2.29	9.92	18.89	failed	5.14	3789	503	6392
Average	***2.66***	***11.33***	***19.34***	***failed***	***4.08***	***3230***	***546***	***5679***
Total Avg	***2.52***	***8.74***	***16.70***	***failed***	***3.32***	***3411***	***741***	***6086***

TABLE 4: Mean and Standard Deviation of Test Parameters Determined for Limestone and Gravel Mixtures

Statistical Parameter	Rut Depth, mm @ 5,000 Cycles	10,000 Cycles	15,000 Cycles	20,000 Cycles	Inflect. Point	Creep Slope	Stripping Slope	N @ S I P
			Slab Test Specimens — Limestone Mixtures					
Average	3.01	8.23	12.86	17.31	2.13	4357	841	4043
Std. Dev.	0.96	0.98	1.54	1.78	0.82	1081	115	1120
			Superpave Gyratory Compacted Specimens — Limestone Mixtures					
Average	2.52	8.74	16.70	failed	3.32	3411	741	6086
Std. Dev.	0.37	2.70	3.76	failed	0.90	573	256	1108
			Slab Test Specimens — Gravel Mixtures					
Average	5.40	17.44	failed	failed	4.23	2418	330	4725
Std. Dev.	1.43	1.71	failed	failed	0.77	417	70	347
			Superpave Gyratory Compacted Specimens — Gravel Mixtures at 96% Density					
Average	3.12	7.89	13.12	failed	5.51	3121	302	9718
Std. Dev.	0.39	3.64	6.40	failed	0.33	1125	31	2412
			Superpave Gyratory Compacted Specimens — Gravel Mixtures at 94% Density					
Average	4.16	7.15	18.17	failed	7.48	2548	223	10564
Std. Dev.	0.32	2.38	1.51	failed	0.50	385	31	1612

FIGURE 4: Rut depth of slab and SGC specimens for limestone mixtures

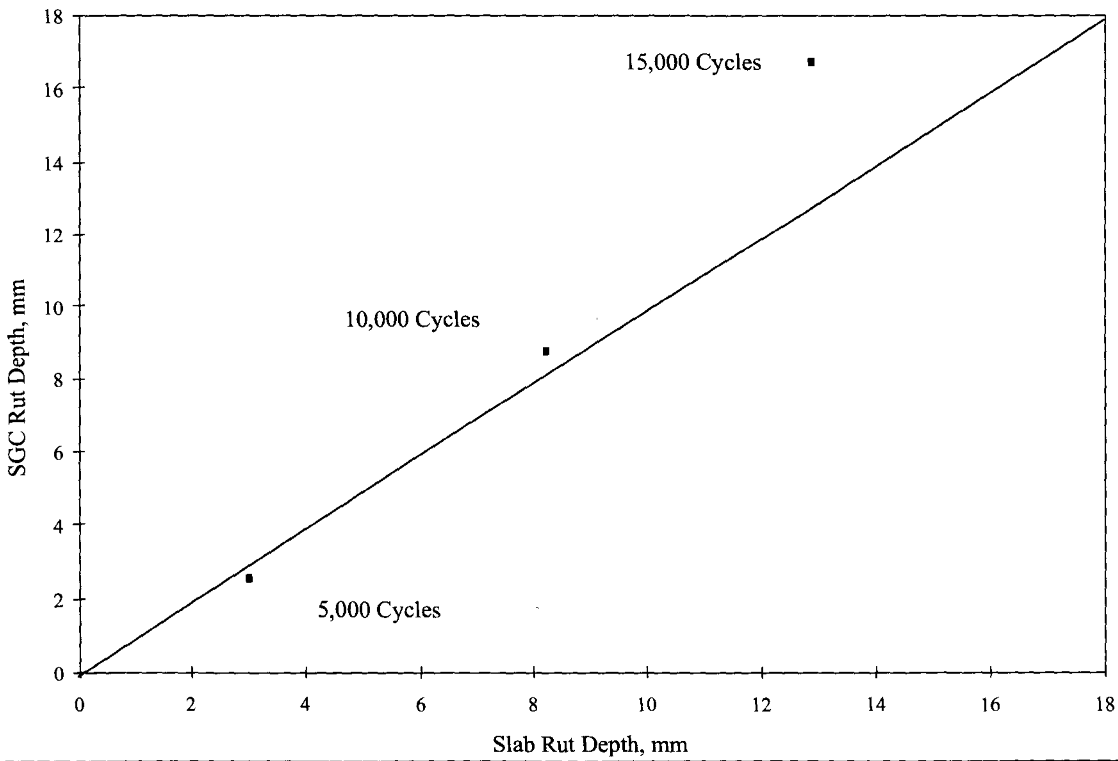


FIGURE 5: Average impression for mixtures composed of limestone @ 94% density

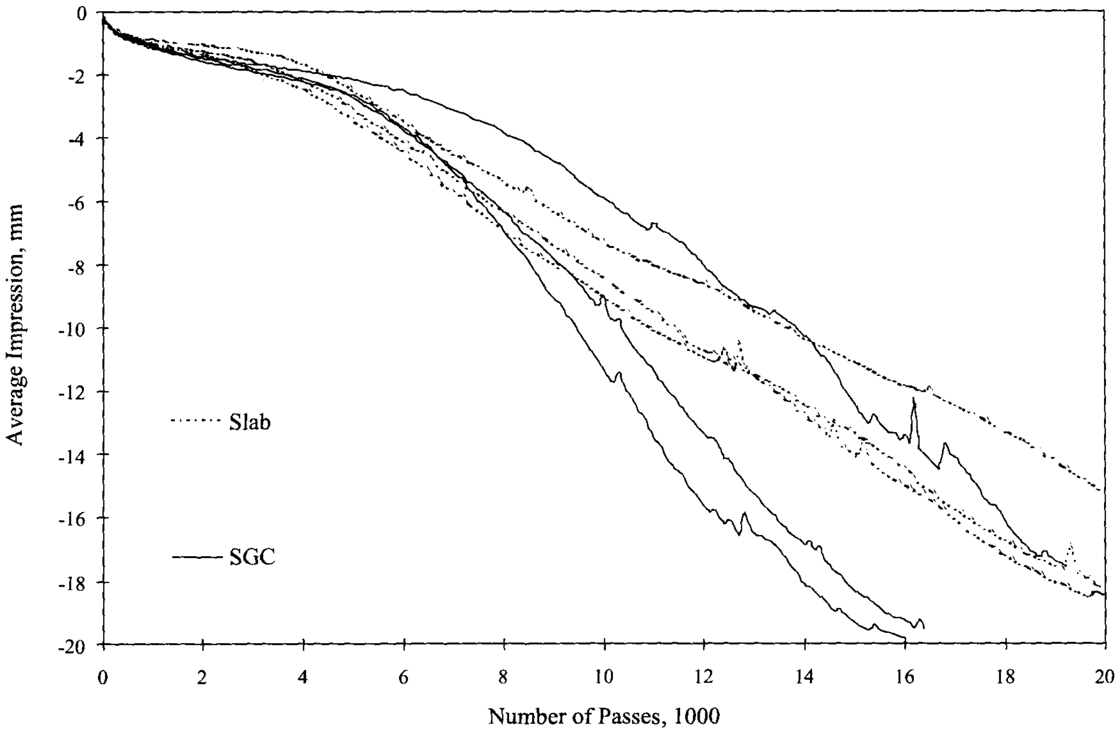


TABLE 5: Air Void Contents for Slab and SGC Test Specimens

Limestone Mixtures				
Test No.	Slab Left	Slab Right	SGC Left	SGC Right
1	5.9	5.9	6.0	6.1
2	5.9	5.8	6.0	6.1
3	5.9	5.8	5.9	6.1

Gravel Mixtures				
Test No.	Slab Left	Slab Right	SGC Left	SGC Right
1	3.4	3.3	4.6	4.2
2	3.4	3.2	4.3	4.3
3	3.5	3.7	4.3	4.2

Gravel Mixtures				
Test No.	Slab Left	Slab Right	SGC Left	SGC Right
1	Not Tested		6.0	6.1
2	Not Tested		6.0	6.1
3	Not Tested		5.9	6.1

Gravel Mixtures

Unlike the limestone aggregate specimens, the slabs composed of gravel aggregate failed in less cycles than those fabricated with the SGC. Tables 6 and 7 list the rut depths after 5,000, 10,000, 15,000, and 20,000 cycles where applicable, as well as at the stripping inflection point. The rut depths after 5,000 and 10,000 cycles were greater in the slabs than the SGC specimens. Slabs and all but one SGC specimen failed before 15,000 passes, therefore no comparisons of rut depth could be made at these number of passes. Figure 6 is a plot of the rut depth for the slab versus SGC. A line has been drawn at 45° to evaluate the equality of the rut depths for the slab and SGC specimens. It can be seen that the rut depths after 5,000 cycles are fairly similar, whereas the rut depth after 10,000 were different. However, the rut depths at the stripping inflection point were found to be lower for the slabs.

The variance of the rut depth at 5,000, 10,000 cycles, and stripping inflection point were statistically unequal between the slab and SGC specimens at 94% and 96% density at $\alpha=0.05$. The different air void contents of the SGC specimens, which are listed in table 5, did not significantly affect the test results relative to the slab specimens. The variance of the rut depth at 5,000 and 10,000 cycles for the SGC specimens at 94% and 96% density were found to be equal. The rut depth at the stripping inflection point for the SGC specimens at 94% and 96% density were not equal. The mean of the rut depth at 5,000, 10,000 cycles, and stripping inflection point were predominately statistically different between the slab and SGC specimens at 94% and 96% density.

The creep slope found for the slabs were less, while the stripping slopes were greater. This can be seen in figures 7 and 8 as well. Susceptibility to rutting is greater for the gravel slabs, whereas the susceptibility to stripping is greater for the SGC specimens.

The variance and mean of the creep slope data for the slab and SGC specimens are statistically equal (figure 9). However, the variance of the stripping slope values and number of passes at the stripping inflection point for the slab and SGC specimens @ 96 % density were found to be unequal. It was determined that the variance for the creep slope and stripping slope data were not equal for the SGC specimens at 94% and 96% density. It was statistically equal for the number of passes at the stripping inflection point for the SGC specimens. The mean for the creep and stripping slope values, and number of passes at the stripping inflection point were predominately equal.

Figure 10 is an illustration of a plot of the impression measured at each pass of the steel wheel for the slab and SGC gravel mixtures. It can be seen that there is better repeatability among the slab test replicates. The standard deviation determined for the rut depth at 5,000 cycles and inflection point, as well as the stripping slope were greater for the slab specimens. The standard deviation found for the rut depth at 10,000 cycles, creep slope, and the number of passes at the stripping inflection point are greater for the SGC specimens.

The slab and SGC specimens did not perform reasonably alike according to the comparative analyses performed. However, it is speculated that the confinement from the acrylic molds in the SGC configuration may be too great, thus producing significantly different test results.

TABLE 6: Summary of Test Results for Mixtures Composed of Gravel @ 96% Density.

Sample ID	Rut Depth, mm @ 5,000 Cycles	10,000 Cycles	15,000 Cycles	20,000 Cycles	Inflection Point	Creep Slope	Stripping Slope	N@ S I P
Slab-1a	5.47	failed	failed	failed	5.19	2422	333	4747
Slab-1b	5.92	failed	failed	failed	5.20	1917	381	4784
Average	***5.70***	***failed***	***failed***	***failed***	***5.19***	***2170***	***357***	***4766***
Slab-2a	3.92	15.59	failed	failed	4.01	2488	420	5120
Slab-2b	6.86	18.79	failed	failed	3.57	2112	342	4351
Average	***5.39***	***17.19***	***failed***	***failed***	***3.79***	***2300***	***381***	***4735***
Slab-3a	6.76	18.99	failed	failed	3.88	2426	224	4289
Slab-3b	3.46	16.38	failed	failed	3.51	3140	282	5059
Average	***5.11***	***17.69***	***failed***	***failed***	***3.70***	***2783***	***253***	***4674***
Total Avg	***5.40***	***17.44***	***failed***	***failed***	***4.23***	***2418***	***330***	***4725***
SGC-1a	3.52	6.90	failed	failed	5.47	2945	303	9436
SGC-1b	3.00	8.68	failed	failed	5.22	2887	293	8934
Average	***3.26***	***7.79***	***failed***	***failed***	***5.35***	***2916***	***298***	***9185***
SGC-2a	3.40	13.26	failed	failed	5.63	2085	295	7607
SGC-2b	3.46	10.38	failed	failed	6.06	1901	282	7831
Average	***3.43***	***11.82***	***failed***	***failed***	***5.85***	***1993***	***289***	***7719***
SGC-3a	2.73	4.47	19.51	failed	5.31	4201	279	10302
SGC-3b	2.63	3.66	6.72*	failed	5.55	4708	362	14196
Average	***2.68***	***4.07***	***13.12***	***failed***	***5.34***	***4455***	***321***	***12249***
Total Avg	***3.12***	***7.89***	***13.12***	***failed***	***5.51***	***3121***	***302***	***9718***

* Test result appears to be an outlier.

TABLE 7: Summary of Test Results for Mixtures Composed of Gravel @ 94% Density

Sample ID	Rut Depth, mm @ 5,000 Cycles	10,000 Cycles	15,000 Cycles	20,000 Cycles	Inflection Point	Creep Slope	Stripping Slope	N@ S I P
Slab-1a	4.15	5.97	failed	failed	7.14	2826	192	10815
Slab-1b	4.64	11.76	failed	failed	7.98	2152	211	8777
Average	***4.40***	***8.87***	***failed***	***failed***	***7.56***	***2489***	***202***	***9796***
Slab-2a	4.34	7.73	failed	failed	7.14	1980	205	9042
Slab-2b	4.15	5.82	failed	failed	None	2895	None	None
Average	***4.25***	***6.78***	***failed***	***failed***	***7.14***	***2438***	***205***	***9042***
Slab-3a	3.73	5.62	19.68	failed	7.09	2772	228	11818
Slab-3b	3.93	5.99	16.66	failed	8.07	2662	281	12366
Average	***3.83***	***5.81***	***18.17***	***failed***	***7.58***	***2717***	***255***	***12092***
Total Avg	***4.16***	***7.15***	***18.17***	***failed***	***7.48***	***2548***	***223***	***10564***

FIGURE 6: Rut depth of slab and SGC specimens for gravel mixtures

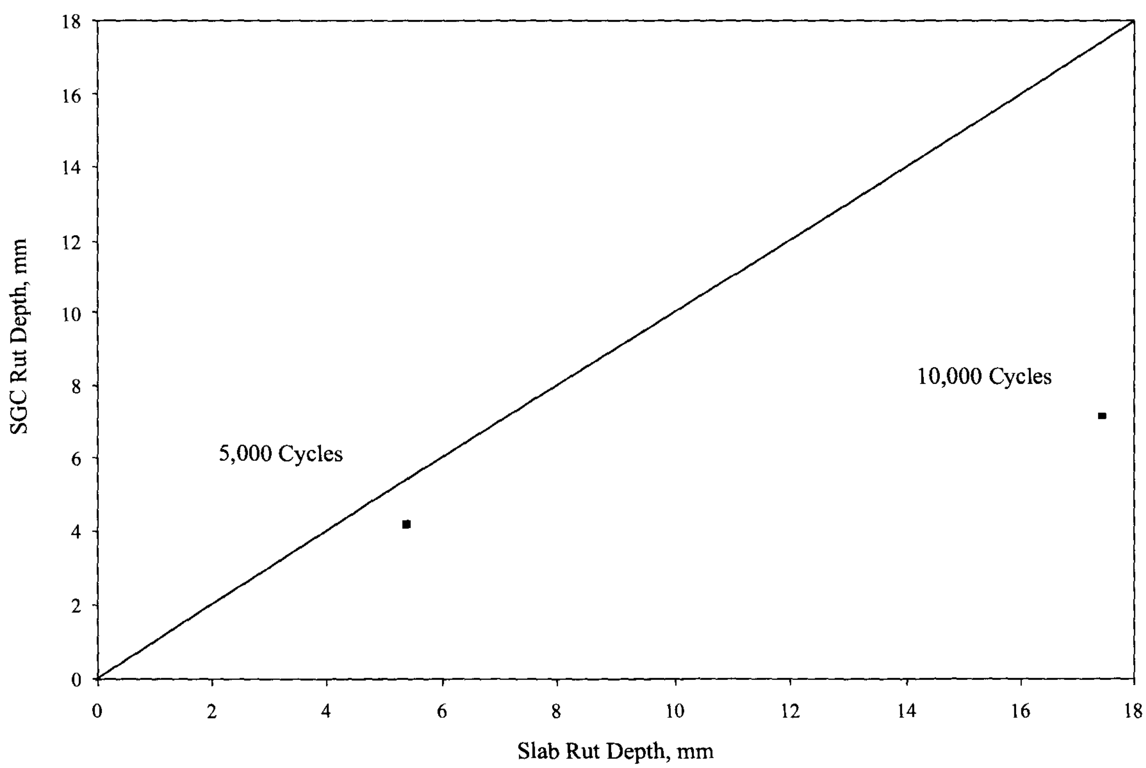


FIGURE 7: Creep slope values for slab and SGC specimens composed of limestone and gravel aggregate

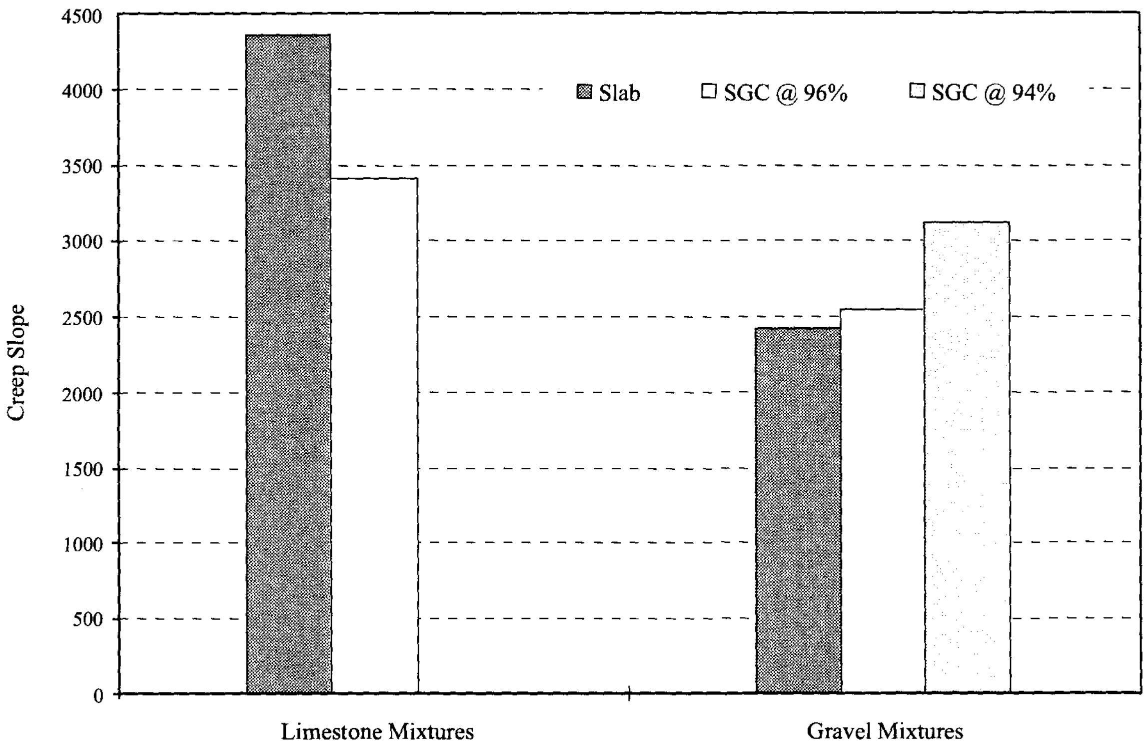


FIGURE 8: Stripping slope values for slab and SGC specimens composed of limestone and gravel aggregate

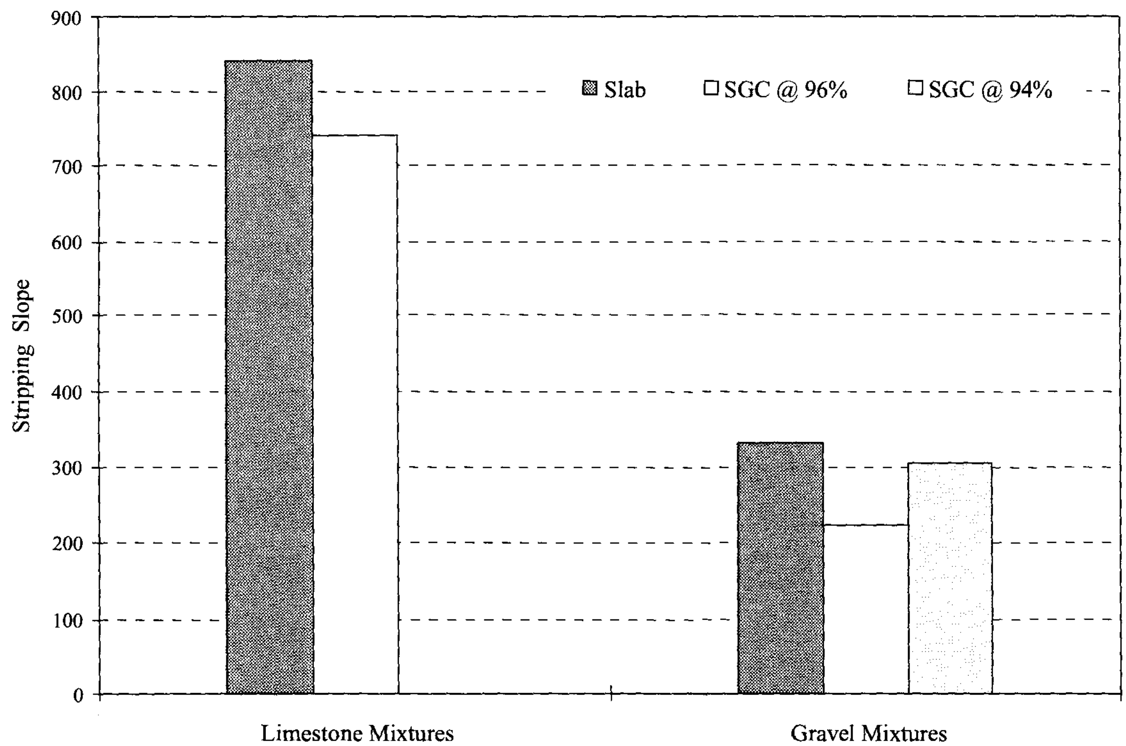


FIGURE 9: Number of passes at the stripping inflection point for slab and SGC specimens composed of limestone and gravel aggregate

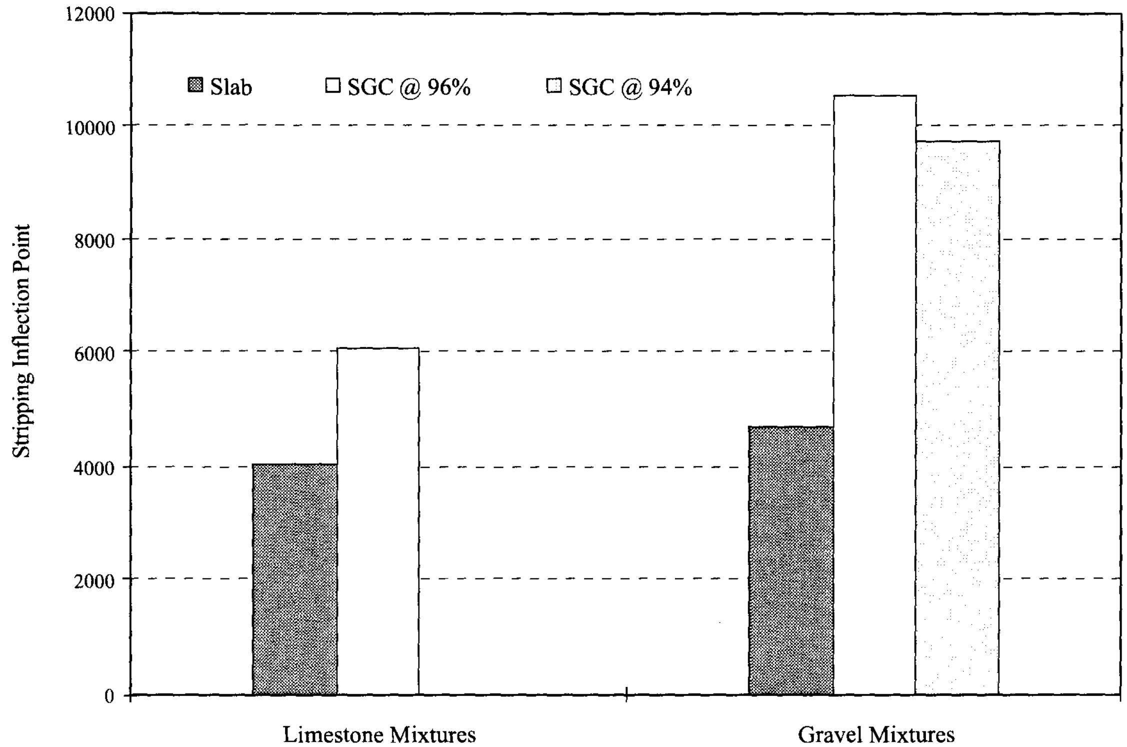
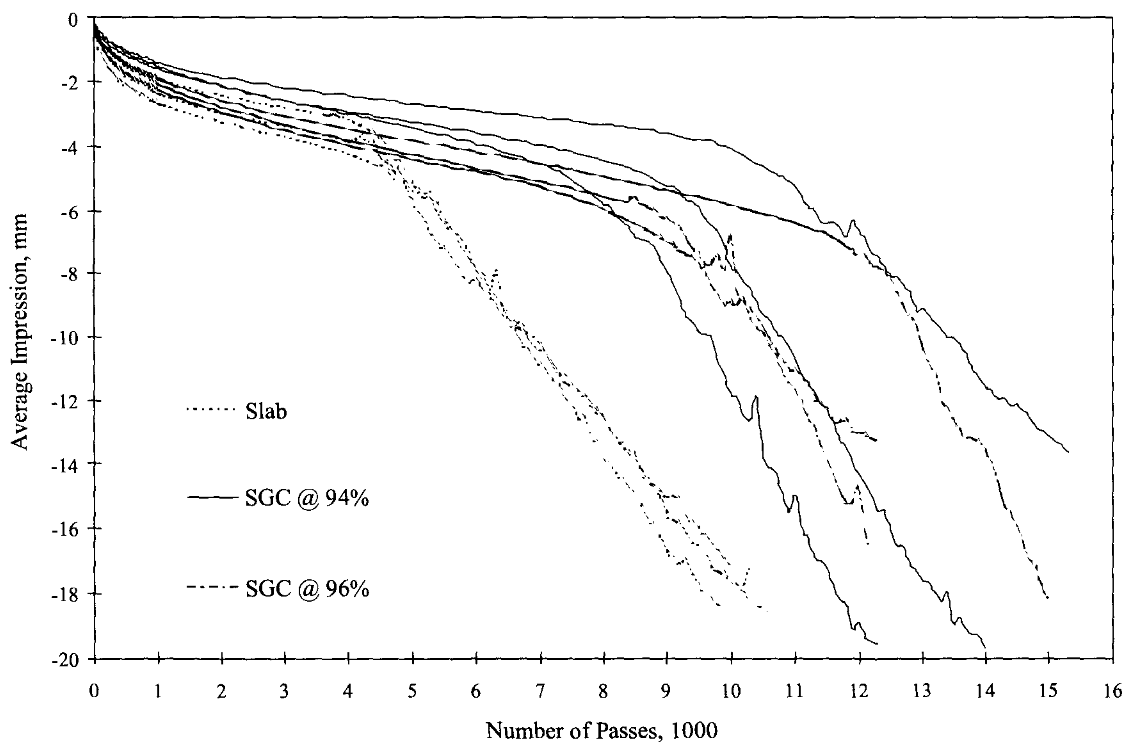


FIGURE 10: Average impression for mixtures composed of gravel at 94% and 96% density



Limestone Versus Gravel Mixtures

The mixtures composed of limestone aggregate were less susceptible to moisture damage than the mixtures with gravel aggregate. This trend occurred among the slab compacted specimens, as well as the SGC specimens. The gravel mixtures failed the test at a lesser number of passes than the limestone mixtures, where the failure criterion was established as a maximum impression of 20mm.

Figure 11 shows the rut depth after 5,000 and 10,000 cycles, as well as at the stripping inflection point for limestone and gravel mixtures compacted with the linear kneading compactor by CDOT. Gravel mixtures failed before 15,000 cycles, therefore there is no information plotted for 15,000 and 20,000 cycles. Figure 12 displays the rut depth for the SGC specimens after 5,000, 10,000, and 15,000 cycles, as well as at the stripping inflection point. The SGC gravel mixtures failed before 20,000 cycles. The rut depths at 5,000, 10,000, 15,000, and 20,000 cycles where applicable, as well as at the stripping inflection point were greater for the gravel mixtures.

Figures 7 to 9 depict the results of creep slope, stripping slope, and number of passes at the stripping inflection point for limestone and gravel mixtures. It can be seen that the creep and stripping slopes were greater for the limestone mixtures, indicating a greater number of passes required to create a 1-mm rut depth due to plastic flow and moisture damage. This can be seen in figures 7 and 8. The stripping inflection point occurred at a greater number of passes for the gravel mixtures, which is shown in figure 9. The limestone mixtures performed better in comparison to the gravel mixtures according to the comparative analyses performed.

FIGURE 11: Rut depth for limestone and gravel mixtures compacted with the linear kneading compactor by CDOT

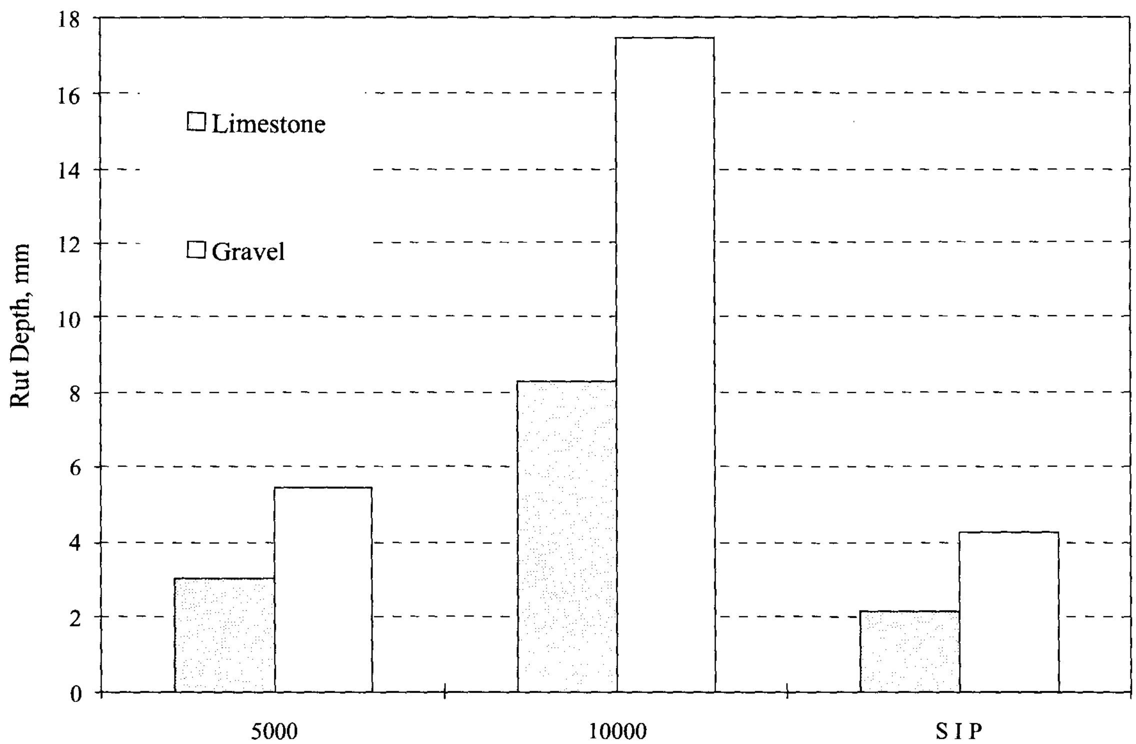
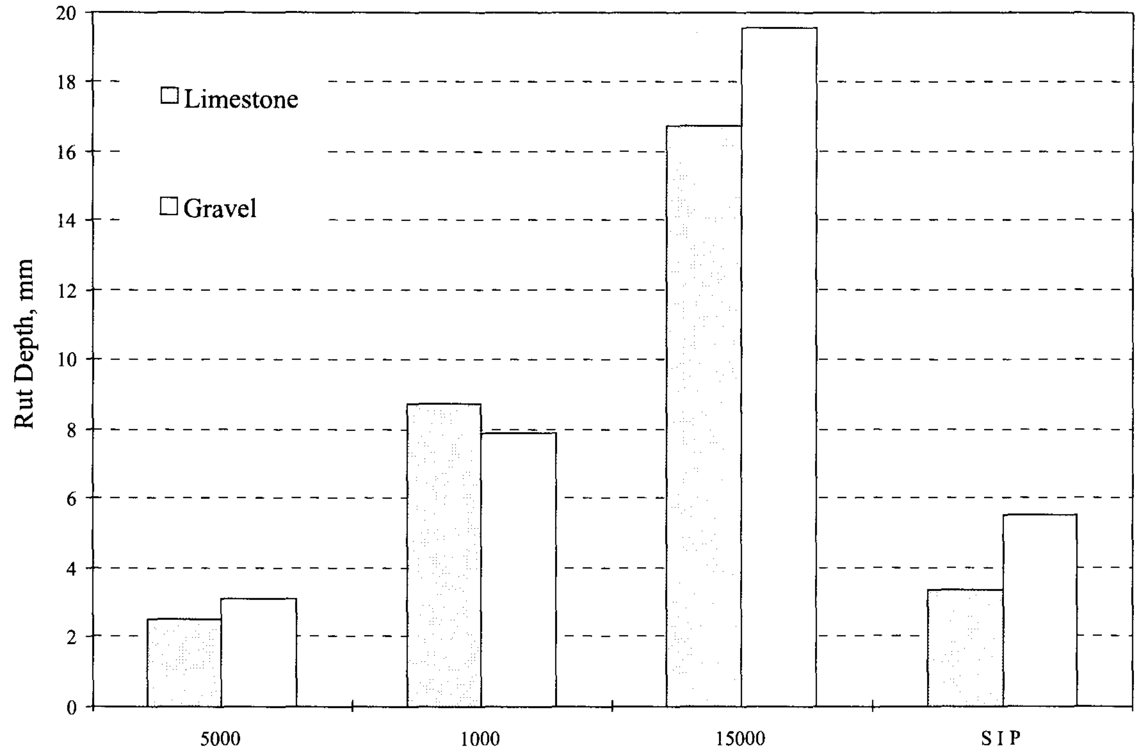


FIGURE 12: Rut depth for limestone and gravel mixtures compacted with the Superpave gyratory compactor



CONCLUSIONS

Evaluation of moisture susceptibility of rectangular slabs compacted with a linear kneading compactor and specimens compacted with a Superpave Gyratory Compactor (SGC) composed of limestone and gravel aggregate was performed utilizing the Hamburg Wheel-Tracking Device (HWTD). It has been shown that mixtures with limestone aggregate are less susceptible to moisture damage than those composed of gravel aggregate. This trend occurred among the slab compacted specimens, as well as SGC specimens. The gravel mixtures failed the test at a lesser number of passes than the limestone mixtures, where the failure criterion was established as a maximum impression of 20 mm. The creep and stripping slopes were found to be greater for the limestone mixtures, indicating a greater number of passes required to create a 1-mm rut depth due to plastic flow and moisture damage. The rut depths at 5,000, 10,000, 15,000, and 20,000 cycles, as well as at the stripping inflection point were greater for the gravel mixtures. However, the stripping inflection point occurred at a greater number of passes for the gravel mixtures.

The use of SGC specimens for testing in comparison to rectangular slabs was evaluated with the HWTD as well. SGC specimens were tested utilizing a molding configuration developed at the Texas Department of Transportation. The configuration represents a snowman or a figure eight where two SGC specimens are adjoined and tested as one sample. A total of four specimens are required for one test.

F- and T-tests have shown that the variance and mean of the rut depth after 5,000, 10,000, 15,000 cycles, and at the stripping inflection point, as well as creep slope, stripping slope, and number of passes at the stripping inflection point were predominately statistically equal at α=0.05 for the slab and SGC limestone mixtures. Based upon visual inspection the day after testing, the limestone aggregate was not stripped of asphalt but was degraded.

F- and T-tests have shown that the variance and mean for the test parameters mentioned in the previous paragraph for slab and SGC (94% and 96% density) gravel mixtures were mostly statistically different at α=0.05.

The difference found in performance of the limestone mixtures cannot be attributed to air void content. The air void content for the slabs and SGC specimens were similar. The air void content of the slabs composed of gravel were less than the SGC specimens. The difference was as great as 1.2%. However, it is not likely that this would yield significantly different test results. SGC specimens were tested at 94% and 96% density. This difference in air void content did not significantly effect the test results among the test replicates. There was also no substantial difference relative to the slab specimens.

There were no consistent trends found in the difference of repeatability for the test results from the slab versus SGC test specimens.

Tests conducted with the HWTD on rectangular slabs and SGC specimens have shown significant differences for creep slope values and the number of passes at the stripping inflection point. However, the stripping slope and all the rut depths were statistically equal. SGC specimens can be used for the evaluation of moisture susceptibility utilizing the HWTD. Additional testing is desired to evaluate the material type of the molds in the molding configuration. Material with a lower modulus to provide less confinement is desirable, however the material must be wear resistant to water. The use of pneumatic tires should be investigated as well. It is possible that the SGC configuration may work well with pneumatic tires provided with the HWTD. However, the pneumatic tires weigh much less than the steel wheels and additional weight may need to be added.

In summary, it can be concluded that SGC molded test specimens can be used for moisture evaluation in the HWTD for comparative evaluation of one material to another. The test results from SGC molded specimens cannot be directly compared to slab molded specimens.

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Texas
Department
of Transportation

CONSTRUCTION DIVISION,
RESEARCH AND TECHNOLOGY TRANSFER SECTION
P.O. Box 5080 Austin, Texas 78763-5080
Phone: 512-465-7403, FAX 512-465-7486