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Evaluation of a Rutting/Fatigue Cracking Device

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16. Abstract

Rutting is one of the most critical failure mechanisms in New Jersey's flexible pavement roadways. A current technology in the asphalt pavement testing industry involves the use of a loaded wheel-tracking device as a tool for predicting a pavement's tendency for rutting. However, an industry-wide standardized set of testing criteria does not exist. Consequently, the state agencies and universities have experienced an array of conflicting results. Currently, the New Jersey Department of Transportation (NJDOT) is developing pass/fail criteria for asphalt samples tested in a loaded wheel-tracking device. Results from this study will be used to assist in the NJDOT project.

The objective of the study was to evaluate the effect of mix gradations, compaction methods, sample geometries, and testing configurations on rutting potential of hot mix asphalt (HMA) mixtures. The asphalt binder used in this study was PG 64-22. The testing matrix consisted of 143 samples with air voids of 7% (±1%). Four aggregate gradations were studied: 12.5 mm TRZ (through Superpave restricted zone), 12.5 mm BRZ (below Superpave restricted zone), 19 mm ARZ (above Superpave restricted zone), and 19 mm BRZ (below Superpave restricted zone). For each aggregate blend, two compaction methods were used: vibratory (bricks and pills), and Superpave gyratory (pills). The pill samples were tested both in traditional two-sample molds, as well as in center-cut one-sample molds built specifically for this research project. Rut tests were conducted at both 64^{o}C and 60^{o}C with the Asphalt Pavement Analyzer (APA) under 689 kPa (100 psi) contact pressure and 45.4 kg (100 lb.) wheel load. Rut depths were measured at the end of 8,000 cycles.

Analysis of the test results indicates that mix gradation, compaction method, testing configuration, and temperature all have reasonably significant impacts on rutting in the Asphalt Pavement Analyzer. An asphalt pavement mix that violated the Superpave restricted zone showed slightly improved rutting resistance over a coarse (below the restricted zone) mix. Specimens compacted by the Superpave Gyratory Compactor showed less rutting than samples compacted in the Asphalt Vibratory Compactor. Further, there seems to be some accelerated loading effects near the end of the APA wheel path. Lastly, the increase of 4^{o}C in testing temperature allowed a significant increase in APA sample rutting.

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ABSTRACT

Rutting is one of the most critical failure mechanisms in New Jersey's flexible pavement roadways. A current technology in the asphalt pavement testing industry involves the use of a loaded wheel-tracking device as a tool for predicting a pavement's tendency for rutting. However, an industry-wide standardized set of testing criteria does not exist. Consequently, the state agencies and universities have experienced an array of conflicting results. Currently, the New Jersey Department of Transportation (NJDOT) is developing pass/fail criteria for asphalt samples tested in a loaded wheel-tracking device. Results from this study will be used to assist in the NJDOT project.

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INTRODUCTION

Statement of the Problem

One of the major pavement distresses of New Jersey highways is the rutting of the hot-mix asphalt layer. The state's high volume of heavy truck traffic leads toward premature failure of many road sections. Traditionally, rutting is measured periodically in the field. However, a new tool for predicting an asphalt pavement mix's susceptibility to rutting, called the Asphalt Pavement Analyzer, has been developed. However, at this time, a complete set of standardized testing specifications relevant to the APA has not been agreed upon. As a result, various agencies use differing sets of testing parameters (Table 1), resulting in data that may not be suitable for comparison.

Table 1: APA Testing Criteria Used by Various State Agencies

State	Test Temp. (°C)	Voids (Target / Range)	Compactor Type(s)	Seating Cycles	Cycles
AL	67	4/1	SGC	25	8000
AR	64	4/1	SGC	25	8000
CN	PG	7/1	SGC/AVC	25	8000
DE	67	7/0.5	AVC	25	8000
FL	64	7/0.5	AVC	25	8000
GA	49	6/1	SGC	50	8000
IL	64	7/1	SGC	25	8000
KS	(<PG)	7/1	SGC	25	8000
KY	64	7/1	SGC	25	8000
LA	64	7/1	AVC	25	8000
MI	PG	4 to 7	SGC/LKC	25	8000
MS	64	7/1	SGC	50	8000
MO	64	7/1	SGC	25	8000
NJ	60	4&7/1	SGC	25	8000
NC	64	7/1	SGC/AVC	25	8000
OK	64	7/1	SGC	25	8000
SC	64	7/1	AVC	25	8000
TN	64	7/1	SGC	----	8000
TX	64	7/1	SGC	50 (25)	8000
UT	64	7/1	LKC	50	8000
WV	60	7/1	SGC	----	8000
WY	52	6/1	AVC	25	8000

SGC = Superpave Gyratory Compactor
AVC = Asphalt Vibratory Compactor
LKN = Linear Kneading Compactor

For many years, very successful hot mix asphalt mixes were designed using the Marshal design program. However, with the search for better performing, less expensive technologies, the inception of Superpave design began. Through Superpave, aggregate structures developed for heavy traffic volumes and similar to those used in the Marshal Method need less asphalt binder, yet the mixes are experiencing similar or improved service life of the pavement. This reduction in asphalt binder creates a reduction in the unit cost of the HMA material. However, a design criterion in the Superpave design program called the "Superpave restricted zone" has resulted in much controversy. This zone is the boundary for fine and coarse mixes. Gradations that pass above the zone are 'fine' mixes, and those that pass below the zone are 'coarse' mixes. It is thought that HMA mixes whose aggregate gradations passed through this zone would be tender mixes, and prone to a reduction in service life of the pavement. Many agencies have evaluated this parameter, but with mixed results.

Objectives of the Study

The purpose of this project is twofold. The first objective is to evaluate the effect of varying sample production and/or testing parameters on APA rutting results. Among these will be: aggregate gradation, compaction type, sample geometry, APA testing mold type, and testing temperature. The second objective is to show performance comparisons of mixes with New Jersey aggregates with gradations above, through and below the Superpave restricted zone.

LITERATURE SEARCH

Background of the Asphalt Pavement Analyzer (APA)

The first loaded wheel tester was the Georgia Loaded Wheel Tester. This device was developed by the Georgia Department of Transportation and the Georgia Institute of Technology (Georgia Tech University) in 1985. It was developed in response to a belief in the industry that Marshal stability tests were inadequate to accurately predict rutting potential in asphalt pavement mixes (Collins, 1996). Since then, several loaded wheel-testing devices have been developed, including the Hamburg Wheel Tracking Device and Purdue University's PURwheel device.

The APA is a second-generation loaded wheel tester (Figure 1). It has the capability of testing compacted brick or pill samples under various environmental conditions in both rutting (high temperature permanent deformation) and fatigue (low temperature cracking). This project utilized the rutting feature of the APA. Basically, a moving wheel load is applied at a rate of about one cycle per second to a ¾ inch pressurized hose that rests atop the HMA samples (Figure 2). This simulates (on a small scale) the loading of the standard 80 kN (18 kip) wheel loads on actual road sections.

Figure 1: Asphalt Pavement Analyzer at RAPL

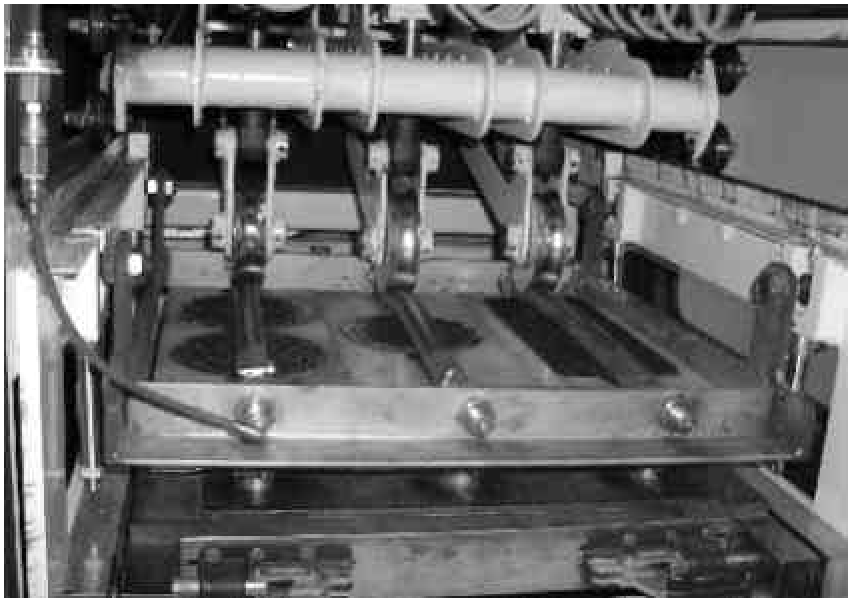

Figure 2: APA Testing Set Up

Recent Events Regarding APA Testing

Recently there was a meeting of the APA User's Group in Jackson, Mississippi (September 26-27, 2000). On the First APA Rut Test Ballot was the issue of standardizing the testing temperature. Until this meeting, a majority of the agencies tested their samples at 60^{o}C. However, testing samples at the performance grade (ie. PG 64-22) temperature would be more appropriate for modeling rutting of HMA in different climatic regions. For this reason, the APA User's Group voted to standardize the testing temperatures to the performance grade temperature of the asphalt to be used. Thus, the testing temperature for New Jersey HMA samples would be increased from 60^{o}C to 64^{o}C. This increase could have drastic affect on APA rutting results.

Another issue on the ballot was the proposal to standardize the compaction method for HMA samples. With a 2/3 (67%) majority required to pass an individual vote item, the vote was 13 (56%) for the Superpave Gyratory Compactor (SGC) and 6 for the Automated Vibratory Compactor (AVC) with three undecided votes and one vote for the Linear Kneading Compactor (LKC). The matter went unresolved, and there remains no standardized compaction type. Chairman Randy West (APAC, Inc.) recommended "caution when comparing labs with different compaction methods". In addition, Jim Brumfield (Mississippi DOT) commented that "ASTM precision/bias will require such data regarding compactors – this will be difficult to gather" (APA User's Group Meeting, 2000). However, the Department of Civil & Environmental Engineering at Rutgers University is fortunate enough to own both an AVC and a SGC compactor for comparative purposes.

Recent Research on the Validity of the Superpave Restricted Zone

Another area of debate in HMA technology has been that of the Superpave Restricted Zone. This "restricted zone" is an area superimposed along the maximum density line of the 0.45 power gradation chart (see Appendix A.1.4-5). For 12.5 mm and 19 mm maximum nominal size aggregate blends the restricted zone resides between the 2.36 mm and 0.3 mm sieve sizes (the maximum nominal size is defined as one sieve size higher than the largest sieve to retain more than 10 percent). HMA mixes with aggregate structures passing through this zone "…often result in a tender mix, which is a mixture that is difficult to compact and has a reduced resistance to rutting during its performance life. Gradations that violate the restricted zone possess weak aggregate skeletons that depend too much on asphalt binder stiffness to achieve mixture strength" (Construction of Hot Mix Asphalt Pavements, 1998).

A paper by Hand and Epps (2000) investigated the background of the Superpave Restricted Zone. Although this paper was more of a literature search and summary, it sites three major references to the restricted zone: First, that SHRP Reports A-407 (Cominski et al., 1994) and A-408 (Cominski, Leahy, and Harrigan, 1994) define the restricted zone as a zone "through which it is undesirable for the gradation to pass."; second, that AASHTO Provision Standard MP2-99 (1999), Section 6.1.3 states, "it is recommended that the select combined aggregate gradation does not pass through the restricted zones…". third, the Asphalt Institute (Superpave Mix Design, 1996) and Federal Highway Administration (Background of Superpave Asphalt Mixture Design and Analysis, 1995) publications that state, "The restricted zone forms a band through which the gradation cannot pass". After reviewing several research projects, Hand & Epps conclude, "no relationship exists between the Superpave restricted zone and HMA rutting".

There has been significant research on the validity of the restricted zone. In a paper by Kandhal and Mallick (2000), an evaluation was made of 12.5 mm and 19 mm mixes (Ndes = 76) passing above the Superpave restricted zone (ARZ), below the restricted zone (BRZ), and through the restricted zone (TRZ). In no case was the deepest rutting observed in the mix that passed through the restricted zone. In addition, the granite and limestone mixes showed that the TRZ mixes performed best. Another paper by Chowdhury et al. (2000), on 19 mm mixes (Ndes = 96) indicated that in general, BRZ gradations had the deepest rutting, again with a TRZ granite mix showing the highest resistance to rutting.

In a paper entitled "The Superpave Restricted Zone and Performance Testing With the Georgia Loaded Wheel Tester", the authors caution "although the gradations of certain mixes may enter the Superpave restricted zone, these mixes perform acceptably and therefore should not be categorically rejected for entering the zone." The use of 'proof-testing equipment' (i.e., the APA) can screen mixes so that acceptable mixes are not rejected. However, since some studies have shown that mixes that violate the restricted zone may be susceptible to permanent deformation (rutting), the authors urge, "In the event that such proof-testing equipment is unavailable, adherence to the Superpave gradations requirements is recommended" (Watson et al., 1997).

EXPERIMENTAL PROGRAM

Mix Design

Mixture designs were in accordance with AASHTO MP2, Specification for Superpave Volumetric Mix Design (AASHTO Provisional Standards, 1997). The testing matrix includes two 12.5 mm (riding surface) HMA mixes and two 19 mm (base / riding) HMA mixes. These aggregate gradations are a result of blending in-house stockpiles of various sized crushed stone. Trap Rock Industries-Kingston supplied the stone aggregates and Clayton Block and Sand supplied the natural sands. Appendix A.1 shows the aggregate stockpile gradations (A.1.1), the percentages of each stockpile used in each blend (A.1.2), and the resulting blend gradations (A.1.3). For the 12.5 mm mixes, both a through the Superpave restricted zone (TRZ) and a below the restricted zone (BRZ) aggregate gradation were evaluated (A.1.4). The 19 mm mixes included an above the restricted zone (ARZ) and a BRZ aggregate gradation (A.1.5).

Once aggregate structures had been developed, the corresponding optimum asphalt contents (AC%) were determined. The first step in determining the AC% for each mix involved varying the amount of asphalt binder in three 115 mm (± 5 mm) tall gyratory specimens at each of four asphalt contents. Compaction data was entered into an HMA design program (Pine Pave 5.0-a2). After providing the program with the design ESAL's (3-30 million) and information regarding the asphalt binder and aggregates, the program determines the 'optimum' asphalt content. The ESAL loading corresponds to the following N-values: Nini=8, Ndes=100, Nmax=160. This is the asphalt content where the 115 mm sample would have exactly 4.0 % air voids at 100 gyrations (Ndes), while satisfying other parameters including, but not limited to: voids in the mineral aggregate (VMA), voids filled with asphalt (VFA), and dust to binder ratio. The optimum AC% and related parameters for each test mix are shown in Appendix A.2.

Sample Preparation

Samples were produced in lots of 6 to 12. The aggregates were blended based on the percentages in appendix A.1.3. The sample preparation followed the guidelines set forth at the Asphalt Pavement Analyzer User Group Meeting on September 27-28, 1999 in Auburn, Alabama. The aggregates were heated to 148 ^{o}C and the appropriate amount of PG64-22 asphalt binder at 148 ^{o}C was added. The batch was then mixed using a rotating 5-gallon stainless steel mixing bucket for 5 minutes (Figure 3). Immediately after mixing, the batch was transferred to a pan and cured for 2 hours at the compaction temperature of 144 ^{o}C. This was done to model the aging of the mix that occurs at the mixing plant and in the truck in route from the asphalt plant to the construction site. After the samples had been 'aged', the mix was transferred to the corresponding compaction mold and compacted.

Figure 3: Rotating 5-gallon Stainless Steel Mixing Bucket

Sample Compaction Type

Three compaction types were studied for each asphalt mix. The first type was a gyratory pill, 150 mm in diameter and 77 mm in height, compacted in the Superpave Gyratory Compactor (Figure 4). The gyratory compactor applies a constant stress of 600 kPa (87 psi) while the mold is gyrated at a contact angle of 1.25o at a rate of 30 gyrations per minute. The gyratory compactor automatically stops compacting when the sample reaches its design height of 77 mm.

Figure 4: Superpave Gyratory Compactor at RAPL

The other two sample types were compacted using the Vibratory Compactor (Figure 5). The vibratory pill has the same geometry as the gyratory pill, and the vibratory brick is 125 mm wide, 300 mm long, and 77 mm high. The vibratory compactor applies a 793 kPa vibrating stress, for a duration specified by the user. This duration is determined through experience in the lab and varies from mix to mix. The different compaction molds are pictured in Figure 6.

Figure 5: Asphalt Vibratory Compactor at RAPL

Figure 6: Compaction Molds.

(From left to right: Gyratory Pill, Vibratory Pill, and Vibratory Brick)

After compaction, the samples were cooled completely before determining the individual sample's percent air voids. Using the saturated surface-dry (SSD) method (AASHTO 166-93: Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens), the bulk specific gravity of each specimen was determined. The values for the maximum specific gravity of the mixes had previously been determined using the 'Rice Test' (AASHT0 T209-93: Maximum Specific Gravity of Bituminous Paving Mixtures). Using these values, the air voids of the compacted samples were calculated. The target air voids for the project, as recommended at the APA User's Meeting, were 7% (± 1%), thus any samples that fell outside the acceptable range were discarded.

Rutting Evaluation

Samples were tested in rutting using the Asphalt Pavement Analyzer (APA). Testing conditions and procedures follow the guidelines set forth at the September 2000 APA User's Group Meeting in Jackson, Mississippi. Samples were preheated for four hours to the binder's performance grade temperature (64 ^{o}C) to ensure uniform testing temperature throughout the sample. To evaluate temperature effects, some samples were tested at 60^{o}C. Initial and final rutting measurements were taken with the aid of a digital gauge with an accuracy of 0.01 mm, and the standard aluminum template (Figure 7). Allowing the APA to run for 25 cycles before taking the initial rutting measurements provided an initial 'seating' of the hoses. The APA was then reactivated and allowed to continue to 8000 cycles (16,000 passes). Final rutting measurements were taken and the sample's average rut depth was determined. The wheel load was calibrated bi-weekly to 45 kg (100 lb.) and the hose pressures set to 689 kPa (100 psi).

Figure 7: Standard APA Measuring Devices

Three different test molds were utilized (Figure 8). For the vibratory bricks, the standard mold was used. Rut depths are recorded at 5 locations along the sample, as allowed by the measurement template. However, only the middle three rut depths are used in the calculation of the sample's average rut depth. For the vibratory and gyratory pills, two test molds were utilized. The first was the standard double sample mold. With this mold, two measurements are taken at approximately 50 mm and 100 mm along the 150 mm diameter of the specimen. These values are averaged to calculate average rutting for the sample. Lastly, a custom-fabricated center-cut pill mold built by Pavement Technologies was utilized. In this mold, one sample is centered in the middle of the mold allowing measurements to be taken at the same three locations that are used to determine the average rutting in a brick sample. All three measurements are used to calculate the sample's rut depth. This was designed to evaluate what effect, if any, the speed of the wheel load has on rutting depths. The hypothesis is that there may be some accelerated rutting effects near the front and rear of the wheel path due to longer loading durations, as the wheel must slow to a stop before reversing its direction.

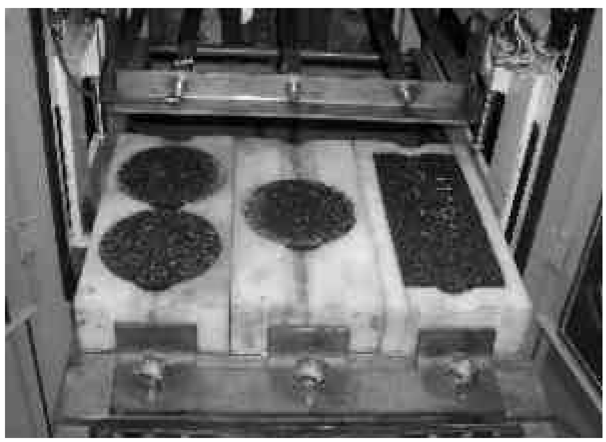

Figure 8: APA Test Molds

TEST RESULTS

Testing Matrix

A testing matrix was developed to evaluate four different mix gradations. Each of these mixes would be compacted by three different compaction methods, including the vibratory pill, the vibratory brick, and the gyratory pill. This allows for a comparison between both compaction methods and sample geometry. Pill samples would be tested in both the traditional double molds and the custom center-cut molds. This would allow for an evaluation of any exaggerated rutting near the ends of the APA wheel path. In addition, the 12.5 mm and 19 mm below the restricted zone (BRZ) coarse mixes would be tested at both 60°C and 64°C, to allow for analysis of the effect of temperature on rutting. This testing schedule is shown graphically in Table 2. Table 3 shows average rutting values and standard deviations for each combination tested.

Table 2: Testing Matrix

Mix Gradation	Testing Mold	Testing Temperature (°C)	Vibratory Bricks	Vibratory Pills	Gyratory Pills
12.5 mm fine (TRZ)	Standard Brick	64	6		
	Traditional Double	64		6	6
	Center-Cut	64		6	6
12.5 mm coarse (BRZ)	Standard Brick	60	4		
		64	6		
	Traditional Double	60			4
		64		6	6
	Center-Cut	64		6	6
19 mm fine (ARZ)	Standard Brick	64	6		
	Traditional Double	64		6	6
	Center-Cut	64		6	6
19 mm coarse (BRZ)	Standard Brick	60	3		
		64	6		
	Traditional Double	60			10
		64		6	6
	Center-Cut	64		6	6

Table 3: Rutting Results

Mix Gradation	Compaction Method	Testing Temperature (°C)	APA Test Mold Type	Average Rut Depth (mm)	Standard Deviation	Average Voids (%)
12.5 mm fine (TRZ)	Gyratory	64	Center-Cut	4.46	0.745	7.0
			Traditional Double	3.74	0.493	7.0
	Vibratory Pill	64	Center-Cut	4.97	0.742	6.9
			Traditional Double	5.49	0.693	6.8
	Vibratory Brick	64	Standard	4.56	0.717	6.7
12.5 mm coarse (BRZ)	Gyratory	60	Traditional Double	3.90	1.001	7.0
		64	Center-Cut	4.62	0.284	6.8
			Traditional Double	5.12	0.237	6.8
	Vibratory Pill	64	Center-Cut	5.20	0.976	7.3
			Traditional Double	5.22	1.108	7.2
	Vibratory Brick	60	Standard	4.28	1.114	7.3
		64	Standard	4.82	0.933	6.8
19 mm fine (ARZ)	Gyratory	64	Center-Cut	5.32	1.141	7.0
			Traditional Double	6.51	1.051	6.9
	Vibratory Pill	64	Center-Cut	6.02	0.817	7.4
			Traditional Double	7.20	1.411	7.1
	Vibratory Brick	64	Standard	6.31	1.363	7.2
19 mm coarse (BRZ)	Gyratory	60	Traditional Double	1.65	0.637	6.5
		64	Center-Cut	3.86	0.627	7.0
			Traditional Double	4.96	0.393	6.8
	Vibratory Pill	64	Center-Cut	3.46	0.625	7.8
			Traditional Double	4.45	0.771	7.8
	Vibratory Brick	60	Standard	5.06	1.068	6.9
		64	Standard	5.29	1.075	7.3

Sample Geometry

When comparing the gyratory pills tested in traditional double molds to the vibratory bricks, the results were, in most cases, very similar. The 12.5 mm through the restricted zone (TRZ) was the exception, as the gyratory pills rutted 0.9 mm (19%) less than the bricks. However, the 12.5 mm below the restricted zone (BRZ) gyratory pills rutted only 0.3 mm (6%) more (Figure 9). Also, the 19 mm above the restricted zone (ARZ) gyratory pills tested in the traditional molds rutted 0.2 mm (3%) more, while the BRZ gyratory pills rutted 0.3 mm (6%) less than the respective bricks (Figure 10).

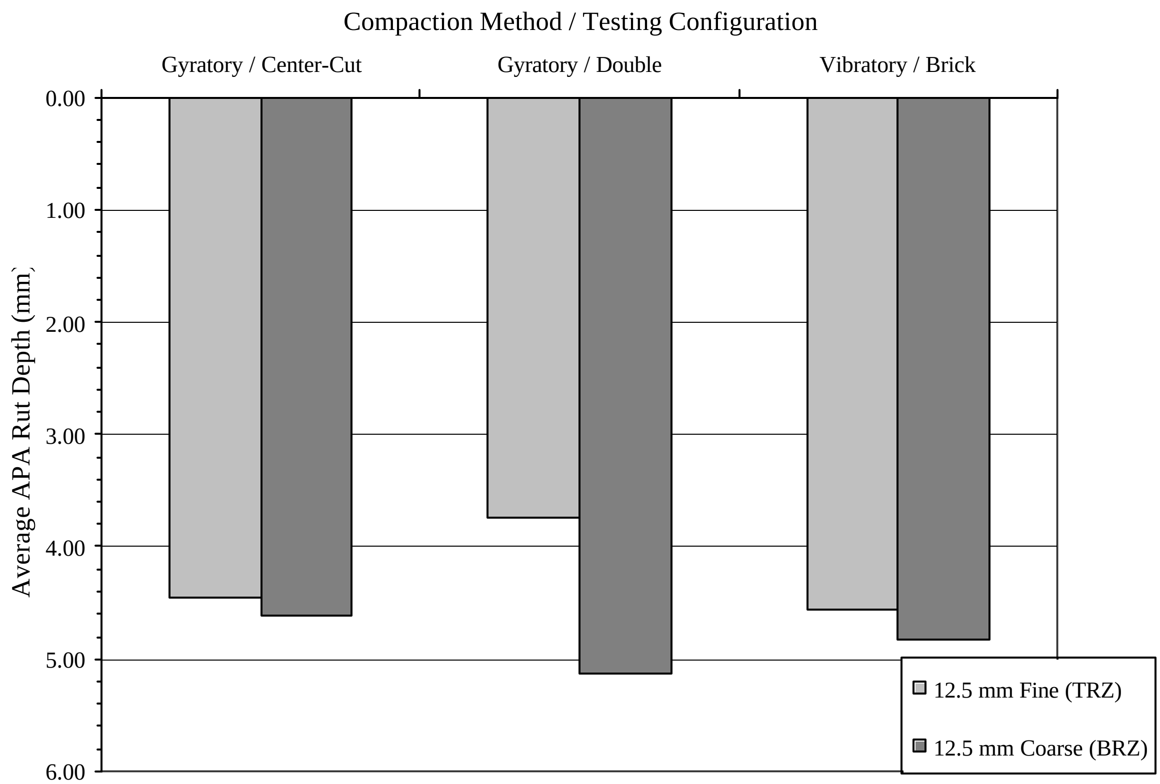

Figure 9: Average Rutting of 12.5 mm Gyratory Pills and Vibratory Bricks

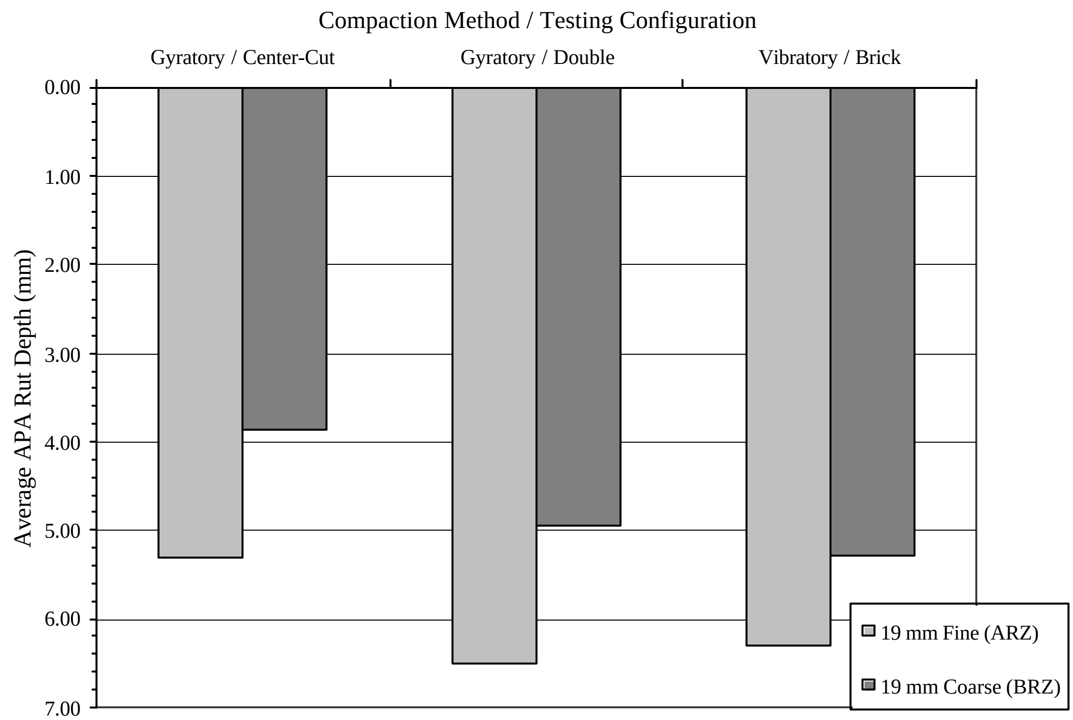

Figure 10: Average Rutting of 19 mm Gyratory Pills and Vibratory Bricks

A comparison between the vibratory pills tested in traditional double molds and the vibratory bricks generally show that the vibratory bricks are more resistant to rutting. This is true in both 12.5 mm mixes, as the 12.5 mm TRZ vibratory pills demonstrated 0.9 mm (16%) more rutting, and the 12.5 BRZ vibratory pills had 0.4 mm (8%) more rutting than the respective bricks (Figure 11). In the 19 mm vibratory pills tested in the traditional double molds, the ARZ pills showed 0.9 mm (12%) more rutting than the bricks. The 19 mm BRZ vibratory pills contradict the trend, as they averaged 0.8 mm (15%) less rutting than the bricks (Figure 12).

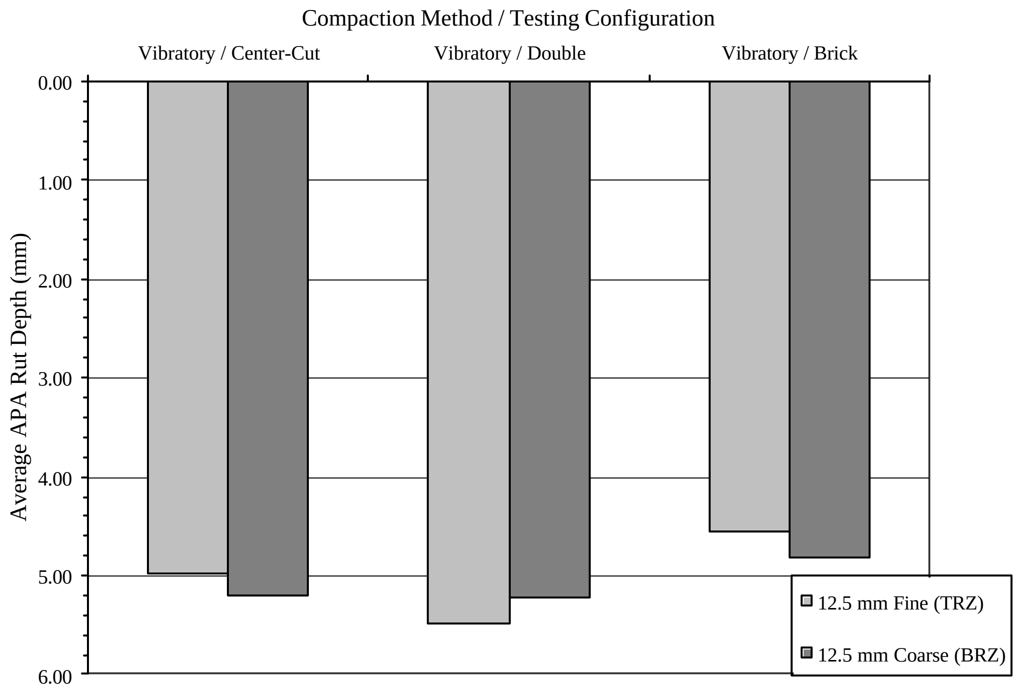

Figure 11: Average Rutting of 12.5 mm Vibratory Pills and Bricks

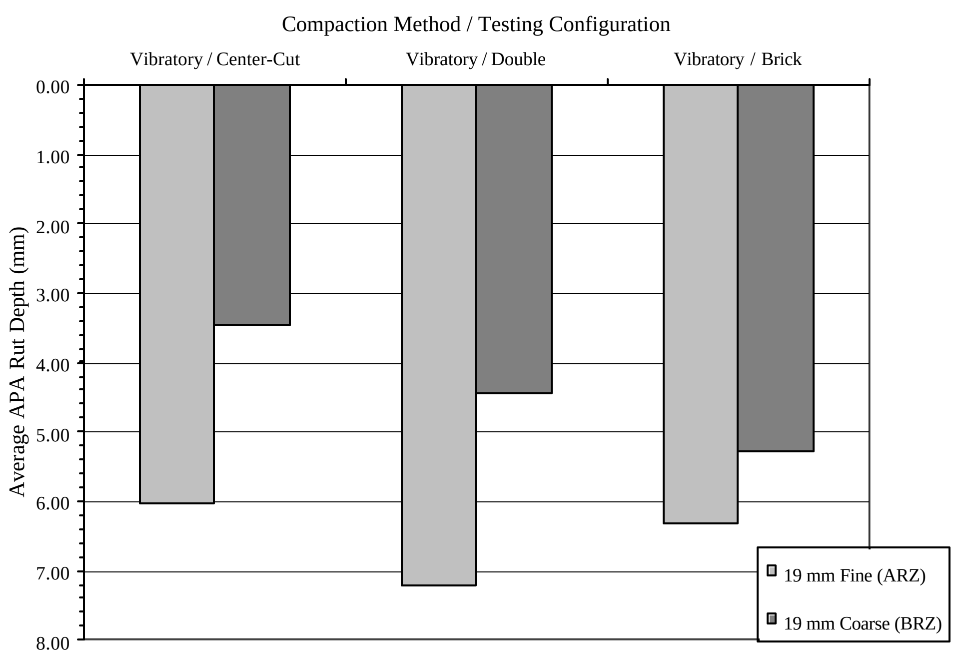

Figure 12: Average Rutting of 19 mm Vibratory Pills and Bricks

All gyratory pills tested in center-cut molds revealed less rutting than the vibratory bricks. In the 12.5 mm gyratory pills, the TRZ samples averaged 0.1 mm (2%) less rutting, while the BRZ samples averaged 0.2 mm (4%) less rutting than the respective 12.5 mm bricks (Figure 9). The 19 mm ARZ pills showed 1 mm (16%) less rutting and the 19 mm BRZ pills had 1.4 mm (26%) less rutting than the respective bricks (Figure 10). Comparisons of the vibratory pills tested in center-cut molds and the vibratory bricks showed different results for the 12.5 and 19 mm mixes. In the 12.5 mm mixes, both the TRZ and BRZ pills rutted 0.4 mm (8%) more than the respective bricks (Figure 11). In the 19 mm mixes, the ARZ pills rutted 0.3 mm (5%) less, and the BRZ pills rutted 1.8 mm (35%) less than the respective bricks (Figure 12).

Mix Design

Comparison of the 12.5 mm rutting results with respect to mixture gradation reveals that the 12.5 mm TRZ mix showed slightly better resistance to rutting than did the 12.5 mm BRZ mix (~ 0.2 mm). Two exceptions to this trend occurred in the gyratory and vibratory pill samples tested in the traditional double molds. In the 12.5 mm gyratory pills, the TRZ mix rutted approximately 1.4 mm (27%) less than the BRZ mix. Also, in the 12.5 mm vibratory pills, the BRZ mix showed slightly better rutting resistance (~ 0.2 mm) than the TRZ mix (Figure 13).

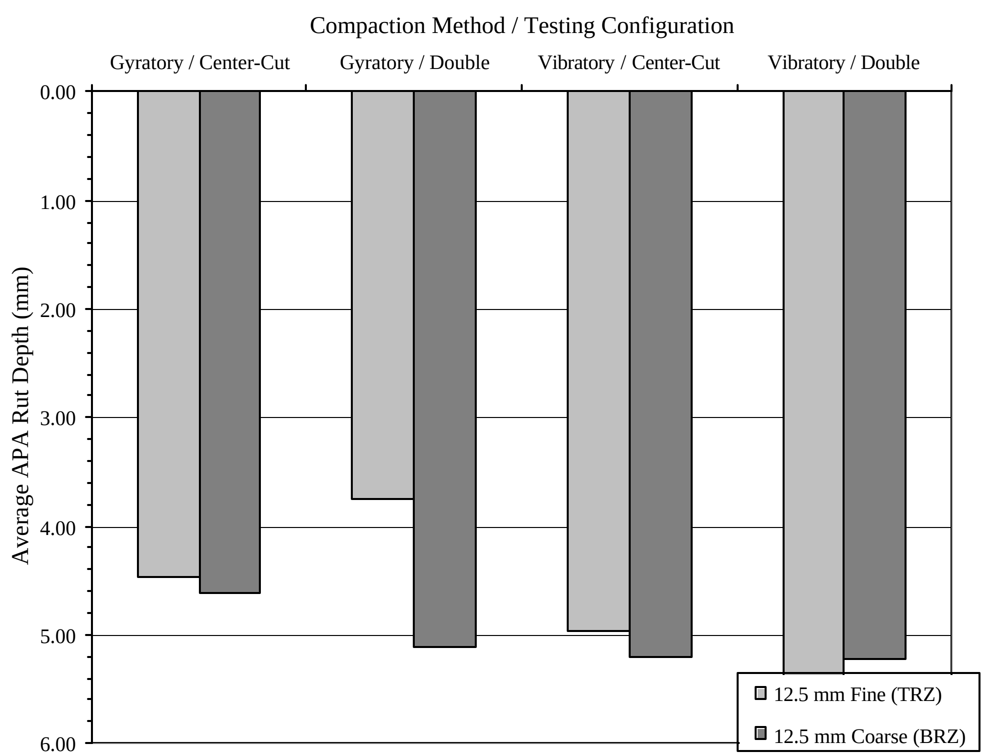

Figure 13: Average Rutting of 12.5 mm Mixes with Varied Compaction Type / Testing Configuration

Examining the 19 mm rutting results, again with respect to mix gradation, showed that the 19 mm BRZ mix had a much greater resistance to rutting than did the 19 mm ARZ mix. The 19 mm vibratory bricks had the closest results, with 1 mm (16%) less rutting in the BRZ mix. The BRZ gyratory pills rutted about 1.5 mm (23-28%) less than the ARZ gyratory pills. The greatest difference occurred in the vibratory pills, where the BRZ pills rutted in excess of 2.5 mm (35-41%) less than the ARZ pills (Figure 14).

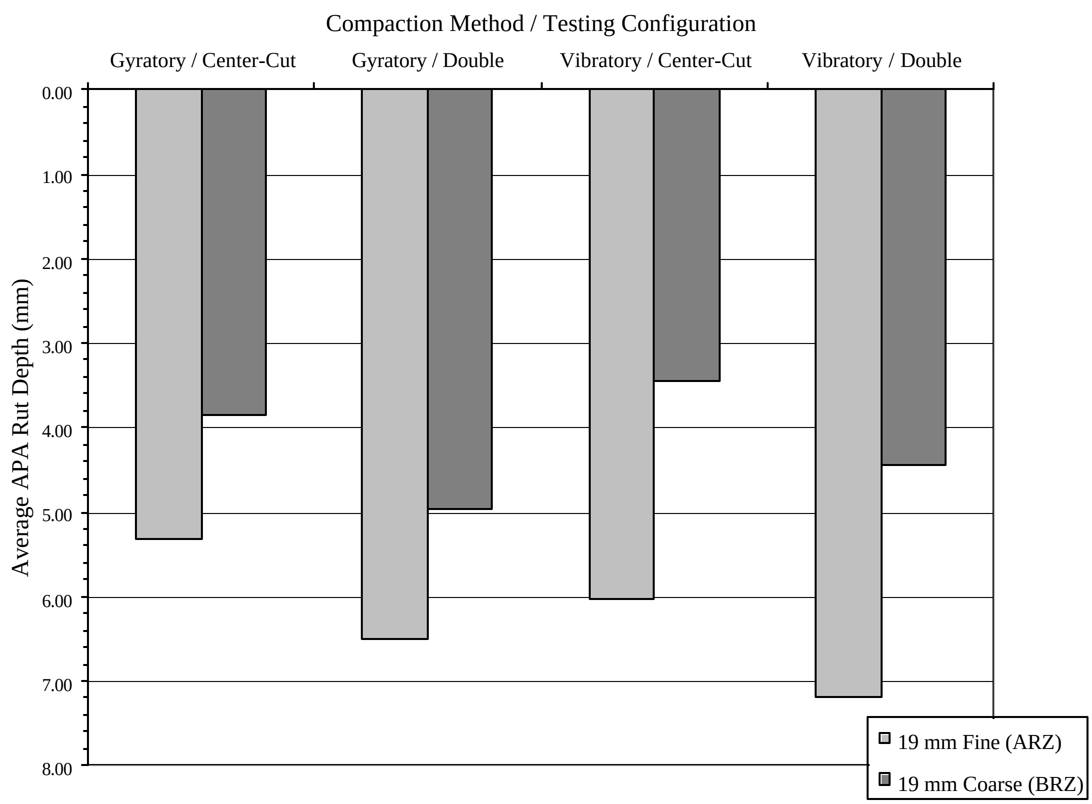

Figure14: Average Rutting of 19 mm Mixes with Varied Compaction Type / Testing Configuration

As expected, the 19 mm BRZ mix (typical base coarse) performed significantly better than the 12.5 mm BRZ mix (typical wearing surface). Figure 15 shows performance trend for gyratory samples, and Figure 16 shows the vibratory brick performance trend. For both sample types, and both testing temperatures, the 19 mm BRZ mix always demonstrated much more resistance to rutting.

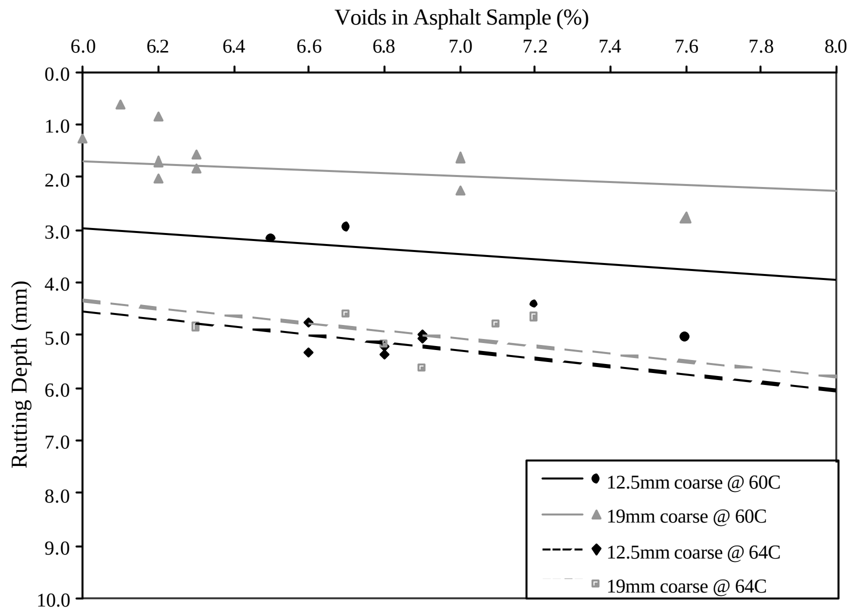

Figure 15: Effect of Temperature on Rutting of Gyratory Pills Tested in Traditional Molds

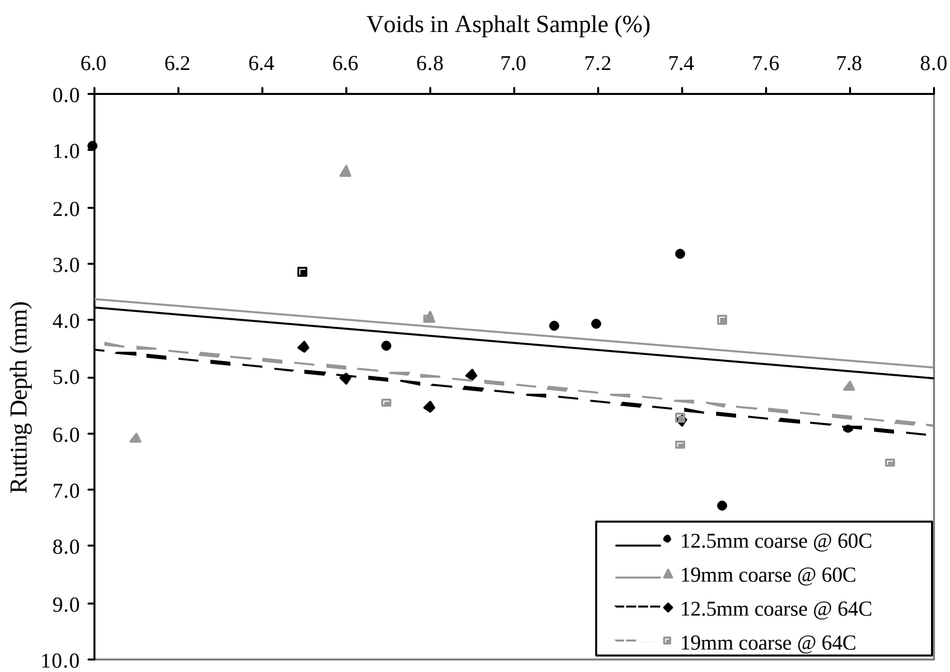

Figure 16: Effect of Temperature on Rutting of Vibratory Bricks

Compaction Method

Comparison of the 12.5 mm rutting results with regards to compaction method shows that the gyratory pills were more resistant to rutting than the vibratory pills. Of the 12.5 mm pills tested in the center-cut molds, the gyratory pills rutted approximately 0.5 mm (10%) less than the vibratory pills. The 12.5 mm pills tested in the traditional double molds showed about 1.8 mm (32%) less rutting in the TRZ mix and 0.1 mm (< 2%) less rutting in the BRZ mix (Figure 13).

The 19 mm ARZ gyratory pills showed 0.7 mm (10%) less rutting than the vibratory counterparts, in both the center-cut and traditional double test molds. An irregularity to the trend of gyratory compacted pills being more resistant to rutting than vibratory compacted pills occurs in the 19 mm BRZ pills. In both the center-cut and traditional double molds, the gyratory pills showed approximately 0.5 mm (10-13%) more rutting than did the vibratory pills (Figure 14).

APA Test Mold Type

In the 12.5 mm vibratory pills, the BRZ pills tested in the center-cut molds showed slightly more resistance to rutting than the pills tested in the traditional double molds. The 12.5 mm TRZ vibratory pills tested in the center-cut molds rutted 0.5 mm (9%) less than those tested in the traditional double molds. The 12.5 mm gyratory pills showed mixed results. The 12.5 mm BRZ gyratory pills tested in the center-cut mold displayed 0.5 mm (10%) less rutting than the pills tested in the traditional double molds. However, the 12.5 mm TRZ gyratory pills tested in the center-cut molds rutted nearly 0.8 mm (18%) more than those tested in the traditional double molds (Figure 13).

In all the 19 mm pills tested, those tested in the center-cut molds showed significantly greater resistance to rutting than did the pills tested in the traditional double molds. On average, there was 1.1 mm less rutting observed in the center-cut mold tested samples. For the 19 mm ARZ gyratory samples, this corresponds to 18% less rutting. In the 19 mm BRZ gyratory pills, the difference is 27%. Of the vibratory pills tested, the ARZ pills showed 16% less rutting, while the BRZ pills exhibited 22% reduced rutting (Figure 14).

Testing Temperature

Increasing the testing temperature from 60oC to the performance grade temperature of the asphalt (64oC) had significant effects on the rutting of the HMA samples. To analyze the affect of temperature, samples of 12.5 mm BRZ and 19 mm BRZ HMA mixes were prepared as gyratory pills and vibratory bricks, and tested at 60oC and 64oC.

The gyratory samples were tested in traditional double pill molds. Referring to Table 3, the 12.5 mm BRZ mix experienced an average rutting increase of over 1.2 mm (30%) when tested at the higher temperature. Even more drastically, the 19 mm BRZ mix experienced an increase of over 3.3 mm (200%). A plot of rutting vs. air voids (Figure 15) shows the performance of the 12.5 mm and 19 mm BRZ mixes for the two testing temperatures.

Vibratory bricks displayed a similar, but not as pronounced trend. Again referring to Table 3, the 12.5 mm BRZ mix had an average rutting increase of 0.5 mm (12%), while the 19 mm BRZ mix had an average increase of 0.2 mm (5%). The corresponding plot of rutting vs. air voids (Figure 16) shows the performance trend of the 12.5 mm and 19 mm BRZ bricks.

DISCUSSION OF RESULTS

Sample Geometry

Analysis of the APA rutting data indicates that sample geometry has no influence on APA results. There were 16 different pill combinations of mix type, compaction type, and APA mold type. Of these pills, nine (56%) displayed more resistance to rutting than did the vibratory bricks of the same mix. This indicates that the pill (round) geometry provides slightly better rutting resistance than does the brick geometry. However, six (67%) of the more rut resistant pill types were gyratory samples, while only three (33%) were vibratory samples. In addition, of the seven pill combinations that performed worse than the bricks, five (71%) were tested in the traditional double molds. Thus, the increased rutting resistance is attributed to effects of compaction type and APA test mold type. These will be discussed later.

Mix Design

Experience has shown that 19 mm BRZ mixes demonstrate greater resistance to rutting than do 12.5 mm BRZ mixes. In many flexible pavement systems, the 19 mm BRZ mix is used as a base course for the 12.5 mm BRZ mix, providing structural stability to the system. The reduction in structural value of the 12.5 mm BRZ mix is a trade-off, as its smaller maximum nominal aggregate size provides a smoother ride quality. The 19 mm BRZ samples tested in this project showed approximately 0.2 mm less rutting at 64^{o}C, and significantly increased performance for the gyratory samples tested at 60^{o}C (Figures 15, 16).

The comparison between 12.5 mm TRZ and BRZ mixes revealed that the TRZ mix was slightly more resistant to rutting. However, these gradations are fairly similar, with the maximum percent passing difference of 4.6% occurring on the #4 sieve (4.75 mm). The initial test matrix was to include only ARZ and BRZ mixes, for both the 12.5 mm and 19 mm maximum aggregate sizes. However, to balance stockpile supplies of all aggregates (while limiting the amount of natural sands) it was necessary to adjust the 12.5 mm fine mix to be a TRZ mix. This method of balancing stockpile amounts is commonly used at asphalt plants. The increased resistance to rutting for the 12.5 mm TRZ mix comes from its dense gradation. The 0.45 power chart for the 12.5 mm mixes (Appendix A.1.4) reveals that the gradation follows fairly closely to the maximum density line for all sieve sizes smaller than 4.75 mm, and violates the Superpave restricted zone. While this mix had a greater performance with respect to rutting, its dense gradation may cause a reduced resistance to fatigue and cracking, as there is little room for expansion of moisture in the void spaces.

In the 19 mm mixes, the BRZ samples were much more resistant to rutting than the ARZ samples. The difference in average rutting of the individual sample type / testing configuration combinations ranged from 16% to 41 %. The weakness in the 19 mm ARZ mix is a result of the high percentage of aggregate smaller than 4.75 mm (Appendix A.1.5). This is because a 19 mm mix derives its strength from stone to stone contact within the pavement structure. Since this is significantly reduced in the 19 mm ARZ mix, the mix is prone to flow under high temperature loading conditions.

Compaction Method

In general, samples compacted by both the gyratory and vibratory compactor provided sample sets well inside the acceptable range of ± 1% average air voids (Table 3). With one exception, average air voids remained inside the range of ± 0.5%. The outlier was the set of 19 mm BRZ vibratory compacted pills with average air voids of 7.8%. These 19 mm BRZ vibratory pills were very difficult to compact due to the elevated percent of coarse aggregate.

The difficulty in compaction may be due to the aggregate orientation within the compaction mold. As the vibratory load is applied, it pushes straight down onto the mix. Consequently, the aggregates tend to remain in their original orientation. Increased resistance of the compaction load may also develop due to a combination of confinement provided by the compaction mold and stone-to-stone contact found in coarser mixes. However, during gyratory compaction, the load is applied with both vertical and horizontal direction. This causes the aggregates to develop a slightly more horizontal orientation, as the horizontal force pushes (rotates) the aggregates. In addition, aggregates in stacked formations would tend to be pushed off into more horizontal formations, thus reducing the vertical stresses that would resist compaction.

To evaluate the affect of compaction method on APA rutting results, the both gyratory and vibratory pill samples were compared. In nearly all cases, the gyratory pills performed better than the vibratory pills. This was true for both the 12.5 mm ARZ and BRZ mixes, and the 19 mm ARZ mix. However, the 19 mm BRZ gyratory pills rutted an average of 10%-13% more than the 19 mm BRZ vibratory pills. This was unexpected, as the voids of the vibratory pills were 0.8 to 1.0 % higher. Conceivably, the same theoretical resisting stresses that perhaps develop during compaction may also have developed during the rut testing.

APA Test Mold Type

The concept of the center-cut mold arose from the hypothesis that there may be some accelerated rutting near the ends of the APA wheel path. The theory is that slower moving loads could cause increased rutting as the wheel slows to a stop and then reverses direction and accelerates. With vibratory bricks, the center three rutting measurements are averaged (where the wheel load has a constant velocity) and the end measurements are discarded. In the traditional double pill molds, these end values are used in the calculation of average rutting of the samples. The center-cut mold would allow rutting measurements to be taken at the same locations used for vibratory bricks. The measurement locations for all three APA test mold types are shown in Figure 17. The same locations are also used in the new automated data recovery system that can be used with the APA (Wallace, 2001).

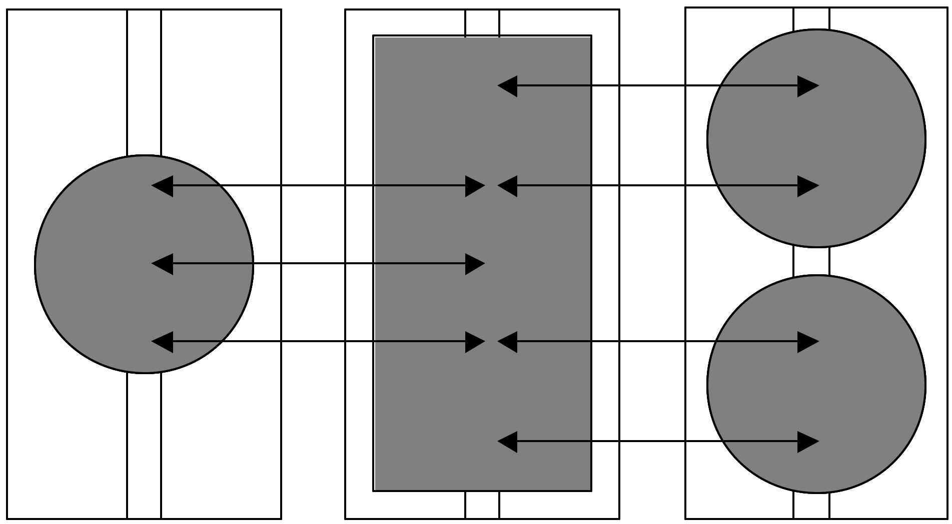

Figure 17: Location of Rutting Measurements on the Three APA Mold Types (plan view)
(left to right: center-cut, brick, traditional double)

Before testing began, concerns of possible confinement issues of the center-cut tested samples arose due to the hose channel incorporated in each APA rutting mold. This channel serves to prevent the APA hose from resting on the mold and in effect, interfering with the rutting of the sample. Thus, a small portion of the pill sample is left exposed. At these locations there is a lower lateral confinement provided by the polystyrene mold for the upper 10 millimeters of the pill sample. Due to reduced confinement at these locations, which were in close proximity to the locations of the outer measurements of the center-cut pill specimen, exaggerated rutting results may be observed (Figure 18). However, this was not observed as the deepest rut depth occurred equally as often at each of the three measurement locations (Figure 19).

In seven of eight pill sample types, the center cut tested samples showed more resistance to rutting. This corresponds to 16% to 27% less rutting in the 19 mm, and 9% to 10% in the 12.5 mm center-cut samples, with the exception of the 12.5 TRZ gyratory pills. In these, the center cut tested samples rutted 18% more than the traditional double mold tested samples.

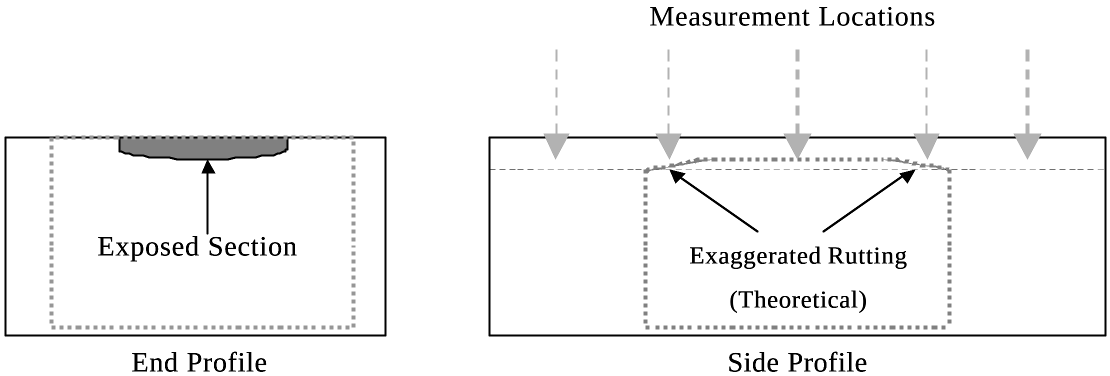

Figure 18: Schematic of Center-Cut APA Test Molds

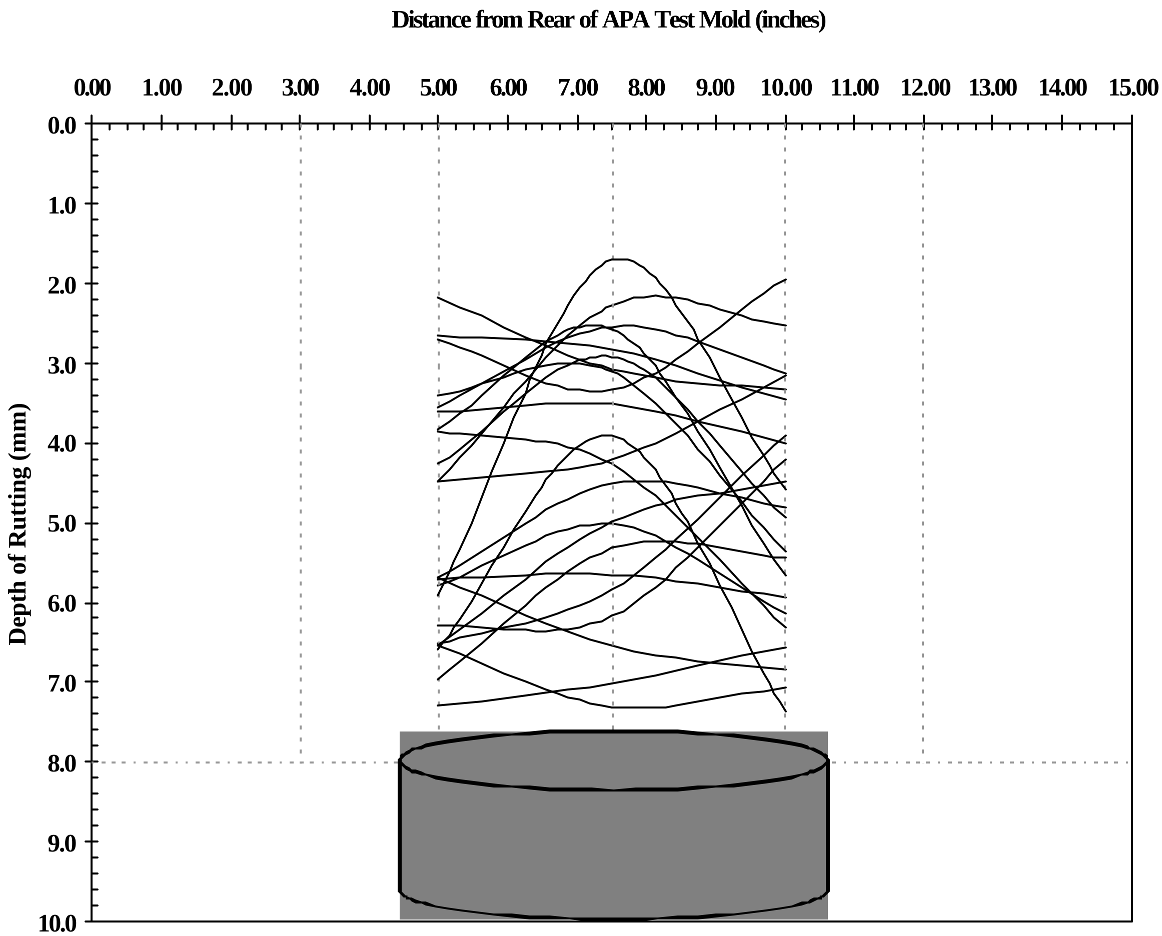

Figure 19: Local Rutting of 19 mm Pill Samples Tested at 64 ^{o}C in Center-Cut Molds

When comparing the center-cut tested specimens to the corresponding vibratory bricks, it is clear that the 12.5 mm TRZ and BRZ gyratory samples show very similar results to the bricks. These results differed by only 0.1 mm and 0.2 mm, respectively. In addition, the vibratory center-cut tested 12.5 mm TRZ and BRZ mixes showed a 0.4 mm difference from the bricks. The 19 mm ARZ and BRZ center-cut specimens did not show good correlation with the vibratory bricks. The 19 mm ARZ gyratory and vibratory pills differed from the bricks by 1.0 mm and 0.3 mm, respectively. The worst correlation occurred with the 19 mm BRZ bricks and center-cut pills. The 19 mm BRZ gyratory pills displayed 1.4 mm less and the vibratory pills 1.8 mm less rutting than observed in the bricks.

The large difference between observed rutting in the 19 mm BRZ coarse samples is due to the differences in confinement between the pills and bricks. During the rut testing, the samples are maintained at a temperature of $64^{o}C$ ($147^{o}F$). As the load is applied, the hot-mix asphalt flows as it deforms. There is much less confinement in the brick samples than in the pill samples to restrict this flowing motion, thus deeper rutting occurs.

Testing Temperature

As expected, increasing the testing temperature from $60^{o}C$ to $64^{o}C$ had a significant affect on the rutting susceptibility of an asphalt pavement mix. Rutting of the gyratory samples showed a 30% increase in the 12.5 mm BRZ samples and a 200% increase in the 19 mm BRZ samples. The vibratory bricks tested at both temperatures showed a 12% rutting increase in the 12.5 mm BRZ samples and only a 5% increase in the 19 mm BRZ samples.

Traditional Sample Type / Testing Configuration

The most traditional of APA sample types includes the vibratory brick and the gyratory pill tested in the double pill mold. Testing of 24 gyratory pills in double molds and 24 vibratory bricks indicated that these two sample type / testing configuration combinations yield extremely similar results. Average rutting values for these samples varied by only 3% to 6% for the 12.5 mm BRZ and both 19 mm mixes. The largest difference occurred in the 12.5 mm TRZ mix, as the bricks rutted 19% more than the gyratory pills.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Asphalt Pavement Analyzer rutting results were determined with respect to changes in sample characteristics and/or testing configurations that most influence rutting characteristics of the pavement samples, i.e., aggregate gradation, compaction method, and testing temperature. The following conclusions can be made based on the project results:

1. Gyratory compaction produced specimens of better rutting resistance than did the vibratory compaction. This is due to the manner in which the compaction stresses are applied to the hot asphalt mix.
    - The gyratory compaction effort is a multi-directional applied stress that encourages the hot mix asphalt to seek a uniform and slightly horizontal aggregate structure. This uniformity provides the correct balance of structural support from the aggregate and void spaces to allow for shrinking and swelling of the mix.
    - The vibratory compaction effort is a one-dimensional stress that leaves the aggregates in the same orientation and simply forces the mix to compact. This sometimes results in a segregated aggregate structure within the sample. In addition, the vibratory compactor has difficulty compacting 19 mm coarse pills due to the confinement of larger aggregates within the small mold. The vertical application of compaction effort provides no means for these aggregates to re-align and reduce the compaction-resisting stresses.

    Thus, comparing pill samples that were compacted in different manners is not appropriate.

2. Center-cut tested pill samples rutted less than samples tested in traditional double molds. This was shown in all the vibratory and gyratory pills tested, with the exception of the 12.5 mm TRZ gyratory pills. This supports the hypothesis that there exists some accelerated rutting near the ends of the APA wheel path, due to the slower moving loading application at these locations.

3. Traditionally tested gyratory pills and vibratory bricks showed extremely similar rutting results for the 12.5 mm mixes. However, due to differences in boundary constraints, the gyratory pills and vibratory bricks may not be suitable for comparison of coarser mixes, as observed in the 19 mm mixes.

4. Changing the testing temperature from the 1999 APA User Group recommendation of 60^{o}C to the Group's year 2000 recommendation of 64^{o}C had a significant affect on APA rutting results. Average rutting was increased by 5 to 200 percent.

5. The geometry of a sample appears to have no bearing on the rutting observed in a particular mix type. Pills and bricks outperformed one another at a fairly even rate. In the 12.5 mm TRZ and BRZ mixes, the gyratory pills displayed better rutting resistance than the bricks, but the vibratory pills displayed less resistance to rutting than the bricks. In the 19 mm ARZ mix, the center-cut tested pills outperformed the bricks, while the samples tested in the double molds rutted more than the bricks. In the 19 mm BRZ mix, all pill samples showed much better resistance to rutting than the bricks.

6. Aggregate gradation is a key component in the performance of a hot-mix asphalt mix. Asphalt pavement mixes that have high percentages of aggregate smaller than 4.75 mm have low resistance to rutting due to lower amounts of stone-to-stone contact. In addition, mixes with gradations that pass through the Superpave restricted zone exhibit marginally higher resistance to rutting as compared to mixes passing below the zone. Increasing the maximum nominal aggregate size of an asphalt pavement mix causes significantly improved resistance to rutting.

7. Caution should be observed whenever comparing any testing results. As demonstrated in the project, variations in sample characteristics and/or testing conditions can have significant results on observed results. Comparisons between agencies in different geographical locations are even more susceptible to misinterpretation due to such factors as varied climatic conditions and variations in local aggregate composition and quality.

Recommendations

1. In order to develop a set of failure criteria for New Jersey's hot-mix asphalt pavements tested in the Asphalt Pavement Analyzer (APA), an in-depth study should be performed to correlate laboratory results to actual field measurements. Although the APA can effectively show that certain hot-mix asphalt pavements (HMA) may be more susceptible to rutting deformation than other mixes, there is no correlation to actual in-service pavement performance.

2. When developed, the failure criteria should consider the roadway's anticipated traffic loading. This can be accomplished in one of two ways. First, the criteria could have a tiered structure, where each level of ESAL loading has a unique failure limit. Second, that the criteria is fixed at some value, but APA testing conditions are adjusted to correlate to the planned traffic loading (i.e. hose pressure, wheel load, number of cycles, etc.). A study using Weigh-In-Motion (WIM) sensors both in the field and in the APA could lead to a set of correlated testing conditions. Although this will require additional research, there is no other means of accurately setting APA failure criteria for local conditions.

3. There are two major failure mechanisms in hot-mix asphalt pavements: rutting and fatigue. Although many agencies have published research that seems to indicate that the Superpave restricted zone should be removed from mix design specifications, their conclusions are based mainly on results from rutting results. An in-depth study should be performed, utilizing the Asphalt Pavement Analyzer's fatigue testing capabilities (requires vibratory bricks). This testing would serve to evaluate mixes with regards to cold temperature cracking that have already exhibited good high temperature resistance to deformation (rutting).

4. Gyratory pills tested in double molds should be used for rut testing in the APA, for several reasons. First, pill samples use less than half the material required in brick samples, and showed fairly similar testing results. Second, the double molds allow twice as many samples to be tested at one time. Finally, correlation to actual field results can be made for any sample type and testing configuration.

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APPENDIX A: SAMPLE PREPARATION DATA

APPENDIX A.1: Mix Gradations

APPENDIX A.1.1: Aggregate Stockpile Gradations

	Percent Passing				
Sieve No.	**#57 Stone**	**#67 Stone**	**#8 Stone**	**#10 Stone**	**Natural Sand**
1.0"	100.0	100.0	100.0	100.0	100.0
3/4"	94.8	100.0	100.0	100.0	100.0
1/2"	13.1	77.9	100.0	100.0	100.0
3/8"	1.6	55.7	84.0	100.0	100.0
# 4	0.4	8.1	9.8	100.0	100.0
# 8	0.4	0.7	1.5	74.1	98.4
# 16	0.4	0.7	1.5	51.9	93.2
# 30	0.4	0.7	1.5	38.0	75.4
# 50	0.4	0.7	1.5	28.3	41.2
# 100	0.4	0.7	1.4	20.0	8.8
# 200	0.4	0.7	1.1	13.6	0.5

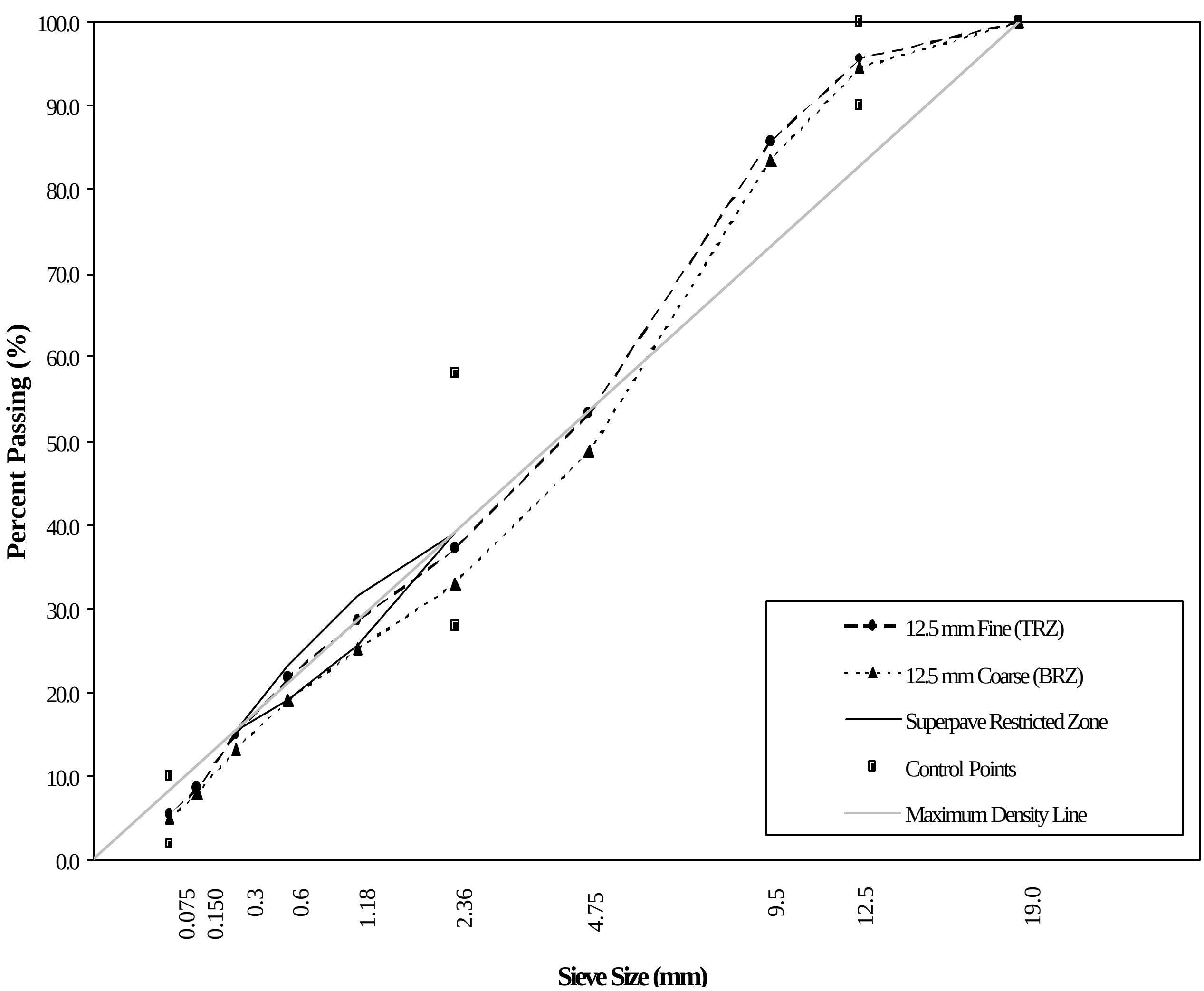
APPENDIX A.1.2: Aggregate Batching from Stockpiles

	Percent of Stockpile Aggregate in Blend			
	12.5 mm Fine	**12.5 mm Coarse**	**19 mm Fine**	**19 mm Coarse**
#57 Stone	0.0	0.0	16.0	17.0
#67 Stone	20.0	25.0	0.0	0.0
#8 Stone	34.0	34.0	38.0	47.0
#10 Stone	36.0	33.0	36.0	32.0
Natural Sand	10.0	8.0	10.0	5.0

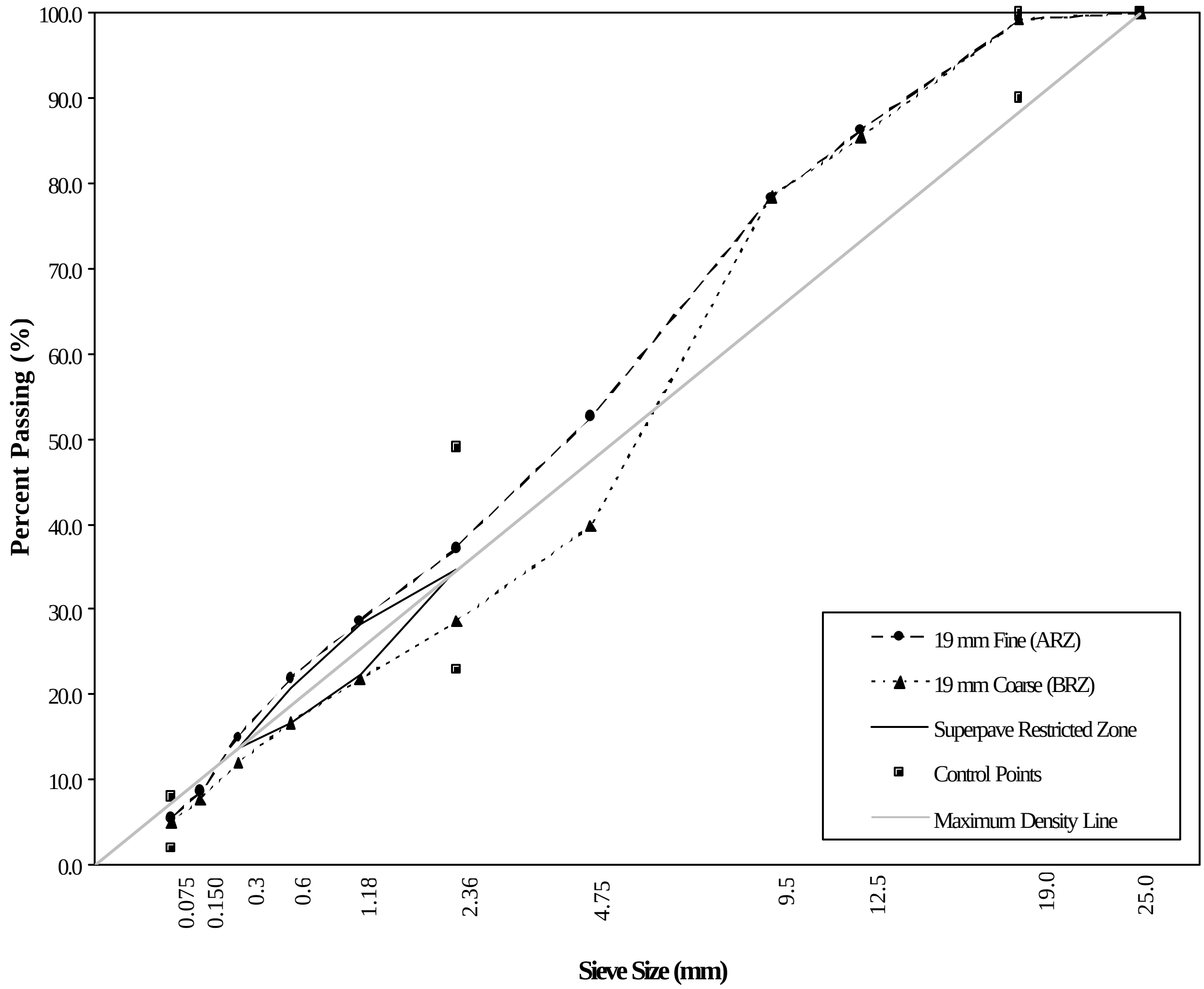
APPENDIX A.1.3: Resulting Aggregate Blend Gradations

	Percent Passing			
Sieve No.	**12.5 mm Fine**	**12.5 mm Coarse**	**19 mm Fine**	**19 mm Coarse**
1.0"			100	100
3/4"	100	100	99.2	99.2
1/2"	95.6	94.5	86.2	85.4
3/8"	85.7	83.5	78.2	78.4
# 4	53.4	48.8	52.6	39.8
# 8	37.2	33	37.2	28.6
# 16	28.6	25.2	28.7	21.8
# 30	21.8	19.2	21.9	16.8
# 50	14.9	13.3	15	12
# 100	8.7	8	8.7	7.7
# 200	5.5	5.1	5.5	5.1

APPENDIX A.1.4: Superpave 0.45 Power Curve for 12.5 mm Mixes



APPENDIX A.1.5: Superpave 0.45 Power Curve for 19 mm Mixes



APPENDIX A.2: Optimum Asphalt Content Determination
APPENDIX A.2.1: Optimum Asphalt Content Determination

Asphalt Grade:	**PG 64-22**	**Design ESAL's (millions)**	**3-30**	
Compaction Temp. (°F)	**142**	**Gyrations:** N_{ini}	**8**	
Mixing Temp. (°F)	**148**	N_{des}	**100**	
		N_{max}	**160**	
	12.5 mm Fine	**12.5 mm Coarse**	**19 mm Fine**	**19 mm Coarse**
% Air Voids (V_a)	4.0	4.0	4.0	4.0
% Voids in the Mineral Aggregate (VMA)	15.2	14.9	14.6	14.9
% Voids Filled with Asphalt (VFA)	72.7	73.1	72.5	73.1
Dust / Asphalt Ratio	1.2	1.1	1.2	1.1
Max. Specific Gravity (G_{mm})	2.693	2.731	2.731	2.741
Bulk Specific Gravity (G_{mb})	2.615	2.653	2.654	2.663
% G_{mm} @ N_{ini}	87.3	87.3	87.2	87.3
% G_{mm} @ N_{des}	96.0	96.0	96.0	96.0
% G_{mm} @ N_{max}	97.3	97.1	97.2	97.1
Specific Gravity of the Binder (G_b)	1.03	1.03	1.03	1.03
Effective Specific Gravity of the Blend (G_{se})	2.951	2.974	2.973	2.985
Specific Gravity of the Aggregate Blend (G_{sb})	2.925	2.936	2.926	2.940
Optimum Asphalt Content (%AC)	4.7	4.9	4.7	4.7

APPENDIX A.3: Sample Characteristics

Mix Type:	12.5mm fine, PG 64-22, with target 7% voids	
Mix Properties:	G_{sb} = 2.925	AC% = 4.7
	G_{mm} = 2.693	Agg. % = 95.3

A	B	D	G	H	I	J	K	M	N	O	P	Q	R
Specimen ID	Sample Type	Thickness (mm)	Weight of Specimen in Grams			Volume of Specimen	Sp. Gravity of Spec.	Unit Wt. (pcf)	% Air Voids	VMA %	VFA %	Number of Gyrations (if applicable)	Temp. of Mix at Compaction (°F)
			In Air	S.S.D.	In Water (@ 4 min.)	(H - I)	(G / J)	(K * 62.4)	[100 * ((G$_{mm}$ - K) / G$_{mm}$)]	[100 - (K * Agg. % / G$_{sb}$)]	[(O - N) / O] * 100		
12.5FG1	gyratory	77	3305.6	3331.5	2001.0	1330.5	2.484	155.0	7.7	19.1	59.4	29	295
12.5FG2	gyratory	77	3307.1	3335.5	2009.7	1325.8	2.494	155.7	7.4	18.7	60.6	29	295
12.5FG3	gyratory	77	3316.3	3345.8	2026.0	1319.8	2.513	156.8	6.7	18.1	63.1	49	295
12.5FG4	gyratory	77	3316.7	3335.2	2013.4	1321.8	2.509	156.6	6.8	18.2	62.6	28	295
12.5FG5	gyratory	77	3304.0	3330.5	2010.3	1320.2	2.503	156.2	7.1	18.5	61.7	28	295
12.5FG6	gyratory	77	3310.9	3321.9	1995.8	1326.1	2.497	155.8	7.3	18.7	60.9	20	295
12.5FG7	gyratory	77	3309.3	3339.2	2021.7	1317.5	2.512	156.7	6.7	18.2	63.0	45	295
12.5FG8	gyratory	77	3308.5	3335.8	2009.9	1325.9	2.495	155.7	7.3	18.7	60.7	22	295
12.5FG9	gyratory	77	3311.9	3338.4	2022.8	1315.6	2.517	157.1	6.5	18.0	63.7	36	295
12.5FG10	gyratory	77	3318.1	3341.5	2028.7	1312.8	2.527	157.7	6.1	17.7	65.2	25	295
12.5FG11	gyratory	77	3321.7	3346.8	2024.3	1322.5	2.512	156.7	6.7	18.2	62.9	34	295
12.5FG12	gyratory	77	3314.5	3341.9	2016.2	1325.7	2.500	156.0	7.2	18.5	61.4	31	295
12.5FB1	vibratory brick	77.3	7183.8	7204.3	4332.1	2872.2	2.501	156.1	7.1	18.5	61.5		295
12.5FB2	vibratory brick	76.7	7171.3	7193.7	4362.2	2831.5	2.533	158.0	6.0	17.5	65.9		295
12.5FB3	vibratory brick	77.2	7244.2	7259.6	4387.9	2871.7	2.523	157.4	6.3	17.8	64.5		295
12.5FB4	vibratory brick	77.4	7224.7	7240.3	4365.3	2875.0	2.513	156.8	6.7	18.1	63.1		295
12.5FB5	vibratory brick	78.0	7238.5	7257.6	4356.1	2901.5	2.495	155.7	7.4	18.7	60.7		295
12.5FB6	vibratory brick	77.0	7204.2	7214.8	4351.2	2863.6	2.516	157.0	6.6	18.0	63.5		295
12.5FV1	vibratory pill	77	3309.8	3334.5	2012.6	1321.9	2.504	156.2	7.0	18.4	61.9		295
12.5FV2	vibratory pill	77	3309.2	3335.6	2020.9	1314.7	2.517	157.1	6.5	18.0	63.7		295
12.5FV3	vibratory pill	77	3301.7	3322.0	2008.4	1313.6	2.513	156.8	6.7	18.1	63.2		295
12.5FV4	vibratory pill	77	3309.9	3328.4	2012.8	1315.6	2.516	157.0	6.6	18.0	63.5		295
12.5FV5	vibratory pill	77	3306.7	3333.5	2008.8	1324.7	2.496	155.8	7.3	18.7	60.9		295
12.5FV6	vibratory pill	77	3316.9	3335.8	2017.1	1318.7	2.515	157.0	6.6	18.0	63.4		295
12.5FV7	vibratory pill	77	3314.2	3336.0	2018.5	1317.5	2.516	157.0	6.6	18.0	63.5		295
12.5FV8	vibratory pill	77	3305.9	3330.1	2011.7	1318.4	2.508	156.5	6.9	18.3	62.4		295
12.5FV9	vibratory pill	77	3311.2	3328.3	2013.0	1315.3	2.517	157.1	6.5	18.0	63.7		295
12.5FV10	vibratory pill	77	3308.5	3334.3	2007.5	1326.8	2.494	155.6	7.4	18.8	60.5		295
12.5FV11	vibratory pill	77	3315.8	3340.5	2021.6	1318.9	2.514	156.9	6.6	18.1	63.3		295
12.5FV12	vibratory pill	77	3308.5	3331.6	2007.7	1323.9	2.499	155.9	7.2	18.6	61.2		295

Mix Type:	12.5mm coarse, PG 64-22, with target 7% voids	
Mix Properties:	G_{sb} = 2.932	AC% = 4.9
	G_{mm} = 2.731	Agg. % = 95.1

A	B	D	G	H	I	J	K	M	N	O	P	Q	R
Specimen ID	Sample Type	Thickness (mm)	Weight of Specimen in Grams			Volume of Specimen	Sp. Gravity of Spec.	Unit Wt. (pcf)	% Air Voids	VMA %	VFA %	Number of Gyrations (if applicable)	Temp. of Mix at Compaction (°F)
			In Air	S.S.D.	In Water (@ 4 min.)	(H - I)	(G / J)	(K * 62.4)	[100 * {(G_{mm} - K) / G_{mm}}]	[100- (K * Agg. % / G_{sb})]	[(O - N) / O] * 100		
12.5CG1	gyratory	77.0	3358.9	3380.2	2060.2	1320.0	2.545	158.8	6.8	17.5	60.9	49	295
12.5CG2	gyratory	77.0	3356.0	3375.9	2055.6	1320.3	2.542	158.6	6.9	17.6	60.5	39	295
12.5CG3	gyratory	77.0	3361.4	3378.9	2059.3	1319.6	2.547	159.0	6.7	17.4	61.3	64	290
12.5CG4	gyratory	77.0	3360.1	3380.8	2065.2	1315.6	2.554	159.4	6.5	17.2	62.2	60	290
12.5CG5	gyratory	77.0	3360.2	3374.0	2053.9	1320.1	2.545	158.8	6.8	17.4	61.0	60	290
12.5CG6	gyratory	77.0	3362.3	3380.1	2062.4	1317.7	2.552	159.2	6.6	17.2	61.9	44	295
12.5CG7	gyratory	77.0	3350.7	3372.3	2051.4	1320.9	2.537	158.3	7.1	17.7	59.9	74	290
12.5CG8	gyratory	77.0	3347.7	3364.5	2049.5	1315.0	2.546	158.9	6.8	17.4	61.1	49	295
12.5CG9	gyratory	77.0	3354.3	3369.2	2053.7	1315.5	2.550	159.1	6.6	17.3	61.6	44	295
12.5CG10	gyratory	77.0	3351.5	3366.5	2052.9	1313.6	2.551	159.2	6.6	17.2	61.9	57	295
12.5CG11	gyratory	77.0	3352.7	3368.8	2050.3	1318.5	2.543	158.7	6.9	17.5	60.7	46	295
12.5CG12	gyratory	77.0	3354.5	3373.3	2054.8	1318.5	2.544	158.8	6.8	17.5	60.9	47	295
12G7	gyratory	77.0	3340.4	3361.8	2043.1	1318.7	2.533	158.1	7.2	17.8	59.4	34	295
13G7	gyratory	77.0	3344.5	3365.4	2055.4	1310.0	2.553	159.3	6.5	17.2	62.1	53	295
14G7	gyratory	77.0	3370.6	3384.7	2062.2	1322.5	2.549	159.0	6.7	17.3	61.5	48	295
15G7	gyratory	77.0	3338.2	3359.0	2036.1	1322.9	2.523	157.5	7.6	18.2	58.1	44	295
12.5CB1	vibratory brick	77.1	7324.3	7342.7	4461.4	2881.3	2.542	158.6	6.9	17.5	60.6		295
12.5CB2	vibratory brick	77.3	7321.0	7340.7	4470.8	2869.9	2.551	159.2	6.6	17.3	61.8		295
12.5CB3	vibratory brick	77.8	7331.5	7353.0	4472.3	2880.7	2.545	158.8	6.8	17.5	61.0		295
12.5CB4	vibratory brick	77.4	7327.3	7346.9	4478.5	2868.4	2.554	159.4	6.5	17.1	62.3		295
12.5CB5	vibratory brick	77.6	7334.0	7360.2	4487.0	2873.2	2.553	159.3	6.5	17.2	62.0		295
12.5CB6	vibratory brick	77.5	7337.3	7357.1	4456.6	2900.5	2.530	157.9	7.4	17.9	58.9		295
9B5	vibratory brick	78.0	7321.4	7349.5	4476.4	2873.1	2.548	159.0	6.7	17.3	61.4		295
5B7	vibratory brick	77.4	7408.2	7441.6	4508.1	2933.5	2.525	157.6	7.5	18.1	58.4		295
8B7	vibratory brick	79.0	7306.5	7347.8	4457.3	2890.5	2.528	157.7	7.4	18.0	58.7		295
9B7	vibratory brick	77.0	7206.7	7229.7	4389.3	2840.4	2.537	158.3	7.1	17.7	59.9		295
10B7	vibratory brick	77.0	7201.3	7228.8	4387.1	2841.7	2.534	158.1	7.2	17.8	59.5		295
14B7	vibratory brick	80.0	7243.4	7285.2	4408.1	2877.1	2.518	157.1	7.8	18.3	57.4		295
12.5CV1	vibratory pill	77.0	3371.7	3386.1	2054.2	1331.9	2.531	158.0	7.3	17.9	59.2		295
12.5CV2	vibratory pill	77.0	3353.0	3366.8	2038.4	1328.4	2.524	157.5	7.6	18.1	58.2		295
12.5CV3	vibratory pill	77.0	3352.0	3367.7	2035.5	1332.2	2.516	157.0	7.9	18.4	57.2		295
12.5CV4	vibratory pill	77.0	3353.0	3366.6	2043.8	1322.8	2.535	158.2	7.2	17.8	59.6		295
12.5CV5	vibratory pill	77.0	3393.4	3409.6	2078.5	1331.1	2.549	159.1	6.7	17.3	61.6		295
12.5CV6	vibratory pill	77.0	3374.1	3391.3	2053.4	1337.9	2.522	157.4	7.7	18.2	57.9		295
12.5CV7	vibratory pill	77.0	3382.9	3395.8	2061.5	1334.3	2.535	158.2	7.2	17.8	59.7		295
12.5CV8	vibratory pill	77.0	3377.9	3392.4	2064.5	1327.9	2.544	158.7	6.9	17.5	60.8		295
12.5CV9	vibratory pill	77.0	3345.3	3359.0	2038.7	1320.3	2.534	158.1	7.2	17.8	59.5		295
12.5CV10	vibratory pill	77.0	3362.2	3371.0	2049.0	1322.0	2.543	158.7	6.9	17.5	60.7		295
12.5CV11	vibratory pill	77.0	3356.9	3373.2	2045.8	1327.4	2.529	157.8	7.4	18.0	58.8		295
12.5CV12	vibratory pill	77.0	3364.8	3379.4	2060.0	1319.4	2.550	159.1	6.6	17.3	61.7		295

Mix Type:	19mm fine, PG 64-22, with target 7% voids	
Mix Properties:	G_{sb} = 2.926	AC% = 4.7
	G_{mm} = 2.693	Agg. % = 95.3

A	B	D	G	H	I	J	K	M	N	O	P	Q	R
Specimen ID	Sample Type	Thickness (mm)	Weight of Specimen in Grams			Volume of Specimen	Sp. Gravity of Spec.	Unit Wt. (pcf)	% Air Voids	VMA %	VFA %	Number of Gyrations (if applicable)	Temp. of Mix at Compaction (°F)
			In Air	S.S.D.	In Water (@ 4 min.)	(H - I)	(G / J)	(K * 62.4)	[100 * {(G_{mm} - K) / G_{mm}}]	[100- (K * Agg. % / G_{sb})]	[(O - N) / O] * 100		
19FG1	gyratory	77.0	3289.2	3306.6	1989.3	1317.3	2.497	155.8	7.3	18.7	61.0	19	295
19FG2	gyratory	77.0	3307.4	3329.6	2013.2	1316.4	2.512	156.8	6.7	18.2	63.1	27	295
19FG3	gyratory	77.0	3303.2	3326.1	2008.1	1318.0	2.506	156.4	6.9	18.4	62.2	22	295
19FG4	gyratory	77.0	3310.4	3326.3	2005.5	1320.8	2.506	156.4	6.9	18.4	62.3	21	295
19FG5	gyratory	77.0	3308.9	3325.3	2004.3	1321.0	2.505	156.3	7.0	18.4	62.1	20	295
19FG6	gyratory	77.0	3318.0	3329.0	2010.2	1318.8	2.516	157.0	6.6	18.1	63.6	24	295
19FG7	gyratory	77.0	3315.6	3328.4	2009.2	1319.2	2.513	156.8	6.7	18.1	63.2	17	295
19FG8	gyratory	77.0	3299.7	3316.7	1998.2	1318.5	2.503	156.2	7.1	18.5	61.8	19	295
19FG9	gyratory	77.0	3328.3	3343.1	2019.2	1323.9	2.514	156.9	6.6	18.1	63.3	30	295
19FG10	gyratory	77.0	3300.1	3312.6	1985.9	1326.7	2.487	155.2	7.6	19.0	59.8	22	295
19FG11	gyratory	77.0	3301.8	3320.4	1996.7	1323.7	2.494	155.6	7.4	18.8	60.7	24	295
19FG12	gyratory	77.0	3313.9	3328.3	2009.7	1318.6	2.513	156.8	6.7	18.1	63.2	23	295
19FB1	vibratory brick	77.0	7209.3	7254.3	4370.6	2883.7	2.500	156.0	7.2	18.6	61.4		295
19FB2	vibratory brick	77.0	7196.9	7233.2	4356.9	2876.3	2.502	156.1	7.1	18.5	61.7		295
19FB3	vibratory brick	77.0	7208.7	7247.4	4383.8	2863.6	2.517	157.1	6.5	18.0	63.8		295
19FB4	vibratory brick	77.0	7196.5	7248.1	4359.5	2888.6	2.491	155.5	7.5	18.9	60.3		295
19FB5	vibratory brick	77.0	7162.8	7201.6	4326.5	2875.1	2.491	155.5	7.5	18.9	60.3		295
19FB6	vibratory brick	77.0	7196.5	7227.9	4343.3	2884.6	2.495	155.7	7.4	18.7	60.7		295
19FV1	vibratory pill	77.0	3293.8	3306.1	1989.2	1316.9	2.501	156.1	7.1	18.5	61.6		295
19FV2	vibratory pill	77.0	3293.2	3311.1	1988.0	1323.1	2.489	155.3	7.6	18.9	60.0		295
19FV3	vibratory pill	77.0	3332.1	3345.1	2021.2	1323.9	2.517	157.1	6.5	18.0	63.7		295
19FV4	vibratory pill	77.0	3334.6	3349.1	2032.4	1316.7	2.533	158.0	6.0	17.5	66.0		295
19FV5	vibratory pill	77.0	3317.1	3329.8	2006.1	1323.7	2.506	156.4	6.9	18.4	62.2		295
19FV6	vibratory pill	77.0	3326.5	3341.6	2015.7	1325.9	2.509	156.6	6.8	18.3	62.6		295
19FV7	vibratory pill	77.0	3281.5	3306.6	1984.1	1322.5	2.481	154.8	7.9	19.2	59.0		295
19FV8	vibratory pill	77.0	3299.0	3315.5	1994.6	1320.9	2.498	155.8	7.3	18.7	61.1		295
19FV9	vibratory pill	77.0	3268.5	3282.5	1963.3	1319.2	2.478	154.6	8.0	19.3	58.6		295
19FV10	vibratory pill	77.0	3294.7	3313.2	1989.0	1324.2	2.488	155.3	7.6	19.0	59.9		295
19FV11	vibratory pill	77.0	3302.3	3318.1	1993.8	1324.3	2.494	155.6	7.4	18.8	60.6		295
19FV12	vibratory pill	77.0	3271.8	3294.6	1976.7	1317.9	2.483	154.9	7.8	19.1	59.2		295

Mix Type:	19mm coarse, PG 64-22, with target 7% voids	
Mix Properties:	G_{sb} = 2.936	AC% = 4.7
	G_{mm} = 2.741	Agg. % = 95.3

A	B	D	G	H	I	J	K	M	N	O	P	Q	R
Specimen ID	Sample Type	Thickness (mm)	Weight of Specimen in Grams			Volume of Specimen	Sp. Gravity of Spec.	Unit Wt. (pcf)	% Air Voids	VMA %	VFA %	Number of Gyrations (if applicable)	Temp. of Mix at Compaction (°F)
			In Air	S.S.D.	In Water (@ 4 min.)	(H - I)	(G / J)	(K * 62.4)	[100 * [(G_{mm} - K) / G_{mm}]]	[100- (K * Agg. % / G_{sb})]	[(O - N) / O] * 100		
19CG1	gyratory	77.0	3334.6	3353.2	2045.9	1307.3	2.551	159.2	6.9	17.2	59.7	76	295
19CG2	gyratory	77.0	3365.2	3383.3	2068.0	1315.3	2.559	159.7	6.7	17.0	60.7	92	290
19CG3	gyratory	77.0	3352.1	3370.5	2057.0	1313.5	2.552	159.2	6.9	17.2	59.8	62	295
19CG4	gyratory	77.0	3363.0	3377.4	2062.0	1315.4	2.557	159.5	6.7	17.0	60.5	78	295
19CG5	gyratory	77.0	3334.2	3349.1	2032.1	1317.0	2.532	158.0	7.6	17.8	57.2	51	295
19CG6	gyratory	77.0	3338.4	3354.6	2042.1	1312.5	2.544	158.7	7.2	17.4	58.7	66	295
19CG7	gyratory	77.0	3356.1	3369.4	2051.5	1317.9	2.547	158.9	7.1	17.3	59.1	62	295
19CG8	gyratory	77.0	3368.0	3380.8	2063.8	1317.0	2.557	159.6	6.7	17.0	60.6	87	295
19CG9	gyratory	77.0	3360.7	3374.8	2058.6	1316.2	2.553	159.3	6.8	17.1	60.0	73	295
19CG10	gyratory	77.0	3368.5	3382.5	2070.4	1312.1	2.567	160.2	6.3	16.7	62.0	69	295
19CG11	gyratory	77.0	3352.9	3364.0	2047.0	1317.0	2.546	158.9	7.1	17.4	59.0	68	295
19CG12	gyratory	77.0	3339.6	3354.5	2044.7	1309.8	2.550	159.1	7.0	17.2	59.5	83	290
3G5	gyratory	77.0	3386.1	3398.0	2080.4	1317.6	2.570	160.4	6.2	16.6	62.4	70	295
4G5	gyratory	77.0	3387.8	3400.0	2081.4	1318.6	2.569	160.3	6.3	16.6	62.3	91	290
6G5	gyratory	77.0	3388.8	3406.0	2089.5	1316.5	2.574	160.6	6.1	16.4	63.0	122	290
7G5	gyratory	77.0	3382.4	3404.1	2088.5	1315.6	2.571	160.4	6.2	16.5	62.5	107	290
8G5	gyratory	77.0	3381.3	3405.2	2092.5	1312.7	2.576	160.7	6.0	16.4	63.2	99	290
3G7	gyratory	77.0	3329.7	3347.1	2050.0	1297.1	2.567	160.2	6.3	16.7	61.9	36	295
5G7	gyratory	77.0	3325.3	3349.3	2045.2	1304.1	2.550	159.1	7.0	17.2	59.5	65	295
7G7	gyratory	77.0	3312.5	3331.6	2024.2	1307.4	2.534	158.1	7.6	17.8	57.4	34	295
10G7	gyratory	77.0	3370.1	3385.8	2075.5	1310.3	2.572	160.5	6.2	16.5	62.7	66	295
24G7	gyratory	77.0	3308.4	3329.3	2031.5	1297.8	2.549	159.1	7.0	17.3	59.5	54	295
19CB1	vibratory brick	77.0	7273.0	7299.5	4434.3	2865.2	2.538	158.4	7.4	17.6	58.0		295
19CB2	vibratory brick	77.0	7269.5	7295.7	4453.6	2842.1	2.558	159.6	6.7	17.0	60.6		295
19CB3	vibratory brick	77.0	7230.9	7262.5	4399.5	2863.0	2.526	157.6	7.9	18.0	56.4		295
19CB4	vibratory brick	77.0	7293.0	7318.0	4445.9	2872.1	2.539	158.4	7.4	17.6	58.1		295
19CB5	vibratory brick	77.0	7283.4	7307.1	4455.9	2851.2	2.555	159.4	6.8	17.1	60.2		295
19CB6	vibratory brick	77.0	7282.8	7310.0	4437.6	2872.4	2.535	158.2	7.5	17.7	57.6		295
6B5	vibratory brick	80.1	7589.5	7597.7	4635.0	2962.7	2.562	159.8	6.5	16.8	61.2		295
11B7	vibratory brick	78.0	7218.2	7244.8	4389.6	2855.2	2.528	157.8	7.8	17.9	56.7		295
16B7	vibratory brick	77.0	7160.8	7189.1	4387.4	2801.7	2.556	159.5	6.8	17.0	60.4		295
19CV1	vibratory pill	77.0	3324.9	3340.6	2022.8	1317.8	2.523	157.4	8.0	18.1	56.1		295
19CV2	vibratory pill	77.0	3339.3	3355.6	2031.3	1324.3	2.522	157.3	8.0	18.2	55.9		295
19CV3	vibratory pill	77.0	3348.9	3369.7	2050.3	1319.4	2.538	158.4	7.4	17.6	58.0		295
19CV4	vibratory pill	77.0	3336.5	3353.2	2037.0	1316.2	2.535	158.2	7.5	17.7	57.6		295
19CV5	vibratory pill	77.0	3322.4	3342.2	2026.3	1315.9	2.525	157.5	7.9	18.0	56.3		295
19CV6	vibratory pill	77.0	3337.1	3353.3	2031.2	1322.1	2.524	157.5	7.9	18.1	56.2		295
19CV7	vibratory pill	77.0	3331.8	3352.4	2031.8	1320.6	2.523	157.4	8.0	18.1	56.1		295
19CV8	vibratory pill	77.0	3337.2	3359.9	2037.5	1322.4	2.524	157.5	7.9	18.1	56.1		295
19CV9	vibratory pill	77.0	3350.4	3368.0	2043.5	1324.5	2.530	157.8	7.7	17.9	56.9		295
19CV10	vibratory pill	77.0	3313.5	3334.3	2020.9	1313.4	2.523	157.4	8.0	18.1	56.1		295
19CV11	vibratory pill	77.0	3338.0	3355.1	2039.1	1316.0	2.536	158.3	7.5	17.7	57.8		295
19CV12	vibratory pill	77.0	3344.8	3361.4	2043.4	1318.0	2.538	158.4	7.4	17.6	57.9		295

APPENDIX B: TEST DATA

Vibratory Brick Specimen Rutting Data Worksheet			
Date of Testing	1/22/01		
Number of Cycles	8000		
Testing Temperature (°C)	64		
Mix Type (Target Voids)	12.5 mm Fine (7%)		
Position in Chamber	Left	Center	Right
Sample Number	12.5FB1	12.5FB2	12.5FB3
Avg. Sample Height (mm)	77.3	76.7	77.2
Actual Voids (%)	7.1	6.0	6.3
Avg. Rut Depth (mm)	4.21	4.02	5.44
APA RUTTING DATA (mm)			
back (initial)	12.66	11.73	11.68
back (final)	7.00	7.60	4.99
mid-back (initial)	12.60	11.78	11.36
mid-back (final)	7.92	7.43	5.96
middle (initial)	12.42	11.43	10.64
middle (final)	7.95	7.65	5.03
mid-front (initial)	11.56	11.38	10.98
mid-front (final)	8.09	7.46	5.68
front (initial)	11.77	11.47	10.58
front (final)	7.05	7.54	5.34

Vibratory Brick Specimen Rutting Data Worksheet			
Date of Testing	1/23/01		
Number of Cycles	8000		
Testing Temperature (°C)	64		
Mix Type (Target Voids)	12.5 mm Fine (7%)		
Position in Chamber	Left	Center	Right
Sample Number	12.5FB4	12.5FB5	12.5FB6
Avg. Sample Height (mm)	77.4	78.0	77.0
Actual Voids (%)	6.7	7.4	6.6
Avg. Rut Depth (mm)	4.93	3.62	5.16
APA RUTTING DATA (mm)			
back (initial)	10.14	10.87	9.18
back (final)	4.40	5.21	3.78
mid-back (initial)	9.90	10.06	9.04
mid-back (final)	4.72	7.02	4.33
middle (initial)	9.30	10.20	8.30
middle (final)	3.94	6.00	2.84
mid-front (initial)	8.75	10.35	8.67
mid-front (final)	4.51	6.72	3.37
front (initial)	8.76	9.65	7.87
front (final)	3.55	5.63	2.92

Vibratory Brick Specimen Rutting Data Worksheet			
Date of Testing	1/24/01		
Number of Cycles	8000		
Testing Temperature (°C)	64		
Mix Type (Target Voids)	12.5 mm Coarse (7%)		
Position in Chamber	Left	Center	Right
Sample Number	12.5CB1	12.5CB2	12.5CB3
Avg. Sample Height (mm)	77.1	77.3	77.8
Actual Voids (%)	6.9	6.6	6.8
Avg. Rut Depth (mm)	4.97	5.03	5.53
APA RUTTING DATA (mm)			
back (initial)	11.24	12.66	11.99
back (final)	4.84	7.08	6.48
mid-back (initial)	11.31	12.88	11.93
mid-back (final)	7.12	7.43	6.03
middle (initial)	12.10	12.69	11.29
middle (final)	6.07	7.32	5.92
mid-front (initial)	11.66	12.12	11.78
mid-front (final)	6.96	7.86	6.47
front (initial)	11.53	12.10	10.56
front (final)	6.51	7.55	5.99

Vibratory Brick Specimen Rutting Data Worksheet			
Date of Testing	1/24/01		
Number of Cycles	8000		
Testing Temperature (°C)	64		
Mix Type (Target Voids)	12.5 mm Coarse (7%)		
Position in Chamber	Left	Center	Right
Sample Number	12.5CB4	12.5CB5	12.5CB6
Avg. Sample Height (mm)	77.4	77.6	77.5
Actual Voids (%)	6.5	6.5	7.4
Avg. Rut Depth (mm)	4.47	3.16	5.77
APA RUTTING DATA (mm)			
back (initial)	10.63	10.39	10.25
back (final)	4.69	6.60	3.05
mid-back (initial)	10.17	10.71	9.87
mid-back (final)	6.60	6.95	4.32
middle (initial)	9.95	10.05	8.89
middle (final)	4.55	6.78	3.30
mid-front (initial)	9.40	10.43	9.80
mid-front (final)	4.97	7.98	3.63
front (initial)	8.91	9.64	9.58
front (final)	4.21	6.84	3.20

Vibratory Brick Specimen Rutting Data Worksheet			
Date of Testing	7/13/00		
Number of Cycles	8000		
Testing Temperature (°C)	60		
Mix Type (Target Voids)	12.5 mm Coarse (7%)		
Position in Chamber	Left	Center	Right
Sample Number	9B7	10B7	8B7
Avg. Sample Height (mm)	77.0	77.0	79.0
Actual Voids (%)	7.1	7.2	7.4
Avg. Rut Depth (mm)	4.11	4.07	2.83
APA RUTTING DATA (mm)			
back (initial)	10.12	9.67	10.30
back (final)	5.87	6.22	7.01
mid-back (initial)	10.68	10.19	10.85
mid-back (final)	6.07	6.01	7.38
middle (initial)	10.41	10.30	10.98
middle (final)	6.06	6.61	8.50
mid-front (initial)	10.58	10.03	11.34
mid-front (final)	7.22	5.69	8.80
front (initial)	9.96	9.60	9.81
front (final)	7.02	5.76	6.80

Vibratory Brick Specimen Rutting Data Worksheet			
Date of Testing	7/20/00		
Number of Cycles	8000		
Testing Temperature (°C)	60		
Mix Type (Target Voids)	12.5 mm Coarse (7%)		
Position in Chamber	Left	Center	Right
Sample Number	5B7	14B7	9B5
Avg. Sample Height (mm)	77.4	80.0	78.0
Actual Voids (%)	7.5	7.8	6.7
Avg. Rut Depth (mm)	7.30	5.94	4.47
APA RUTTING DATA (mm)			
back (initial)	12.26	10.04	10.88
back (final)	5.98	4.63	5.44
mid-back (initial)	12.33	10.21	10.60
mid-back (final)	5.70	4.37	6.42
middle (initial)	12.50	10.75	10.55
middle (final)	4.45	4.71	6.08
mid-front (initial)	12.05	10.78	10.20
mid-front (final)	4.84	4.83	5.44
front (initial)	10.73	10.24	9.28
front (final)	4.98	3.54	5.60

Vibratory Brick Specimen Rutting Data Worksheet			
Date of Testing	4/3/01		
Number of Cycles	8000		
Mix Type (Target Voids)	19 mm Fine (7%)		
Position in Chamber	Left	Center	Right
Sample Number	19FB1	19FB2	19FB3
Avg. Sample Height (mm)	77.0	77.0	77.0
Actual Voids (%)	7.2	7.1	6.5
Avg. Rut Depth (mm)	6.66	4.82	6.25
APA RUTTING DATA (mm)			
back (initial)	11.76	11.75	12.59
back (final)	5.04	5.24	6.30
mid-back (initial)	11.74	12.00	12.28
mid-back (final)	4.86	7.08	6.39
middle (initial)	12.44	12.16	12.92
middle (final)	5.36	7.64	6.60
mid-front (initial)	12.46	12.05	13.04
mid-front (final)	6.43	7.03	6.50
front (initial)	12.40	12.11	12.96
front (final)	6.47	6.60	6.34

Vibratory Brick Specimen Rutting Data Worksheet			
Date of Testing	4/4/01		
Number of Cycles	8000		
Testing Temperature (°C)	64		
Mix Type (Target Voids)	19 mm Fine (7%)		
Position in Chamber	Left	Center	Right
Sample Number	19FB4	19FB5	19FB6
Avg. Sample Height (mm)	77.0	77.0	77.0
Actual Voids (%)	7.5	7.5	7.4
Avg. Rut Depth (mm)	6.57	5.00	8.58
APA RUTTING DATA (mm)			
back (initial)	11.97	10.47	12.74
back (final)	5.69	4.67	3.59
mid-back (initial)	11.89	11.66	12.69
mid-back (final)	5.44	6.23	3.31
middle (initial)	12.19	11.90	12.78
middle (final)	5.26	6.92	4.66
mid-front (initial)	12.13	10.93	12.80
mid-front (final)	5.80	6.34	4.56
front (initial)	12.39	11.40	12.86
front (final)	6.12	5.38	5.63

Vibratory Brick Specimen Rutting Data Worksheet			
Date of Testing	4/5/01		
Number of Cycles	8000		
Mix Type (Target Voids)	19 mm Coarse (7%)		
Position in Chamber	Left	Center	Right
Sample Number	19CB2	19CB5	19CB1
Avg. Sample Height (mm)	77.0	77.0	77.0
Actual Voids (%)	6.7	6.8	7.4
Avg. Rut Depth (mm)	5.48	3.99	5.47
APA RUTTING DATA (mm)			
back (initial)	11.48	11.81	13.22
back (final)	7.04	6.87	8.17
mid-back (initial)	12.12	11.67	13.21
mid-back (final)	5.94	8.16	7.56
middle (initial)	12.75	12.06	13.43
middle (final)	7.38	7.96	8.33
mid-front (initial)	12.78	12.28	13.58
mid-front (final)	7.88	7.91	7.91
front (initial)	12.97	12.01	13.52
front (final)	8.50	7.20	9.40

Vibratory Brick Specimen Rutting Data Worksheet			
Date of Testing	4/6/01		
Number of Cycles	8000		
Testing Temperature (°C)	64		
Mix Type (Target Voids)	19 mm Coarse (7%)		
Position in Chamber	Left	Center	Right
Sample Number	19CB4	19CB6	19CB3
Avg. Sample Height (mm)	77.0	77.0	77.0
Actual Voids (%)	7.4	7.5	7.9
Avg. Rut Depth (mm)	6.22	4.02	6.53
APA RUTTING DATA (mm)			
back (initial)	12.23	12.49	13.21
back (final)	6.27	9.54	6.34
mid-back (initial)	12.92	12.65	13.49
mid-back (final)	6.05	8.47	5.63
middle (initial)	13.38	13.27	13.26
middle (final)	6.80	9.71	7.48
mid-front (initial)	12.95	12.91	13.30
mid-front (final)	7.75	8.60	7.35
front (initial)	13.57	11.96	13.20
front (final)	8.79	8.65	8.46

Vibratory Brick Specimen Rutting Data Worksheet			
Date of Testing	7/24/00		
Number of Cycles	8000		
Testing Temperature (°C)	60		
Mix Type (Target Voids)	19 mm Coarse (7%)		
Position in Chamber	Left	Center	Right
Sample Number	11B7	6B5	16B7
Avg. Sample Height (mm)	78.0	80.1	77.0
Actual Voids (%)	7.8	6.1	6.8
Avg. Rut Depth (mm)	5.16	6.08	3.95
APA RUTTING DATA (mm)			
back (initial)	10.10	6.24	9.56
back (final)	5.02	0.07	5.34
mid-back (initial)	10.15	6.37	9.17
mid-back (final)	4.52	0.01	5.48
middle (initial)	9.58	6.08	9.10
middle (final)	4.88	0.12	4.67
mid-front (initial)	9.58	5.92	8.55
mid-front (final)	4.44	0.01	4.83
front (initial)	8.97	5.17	8.10
front (final)	4.12	0.02	3.86

Gyratory Specimen Rutting Data Worksheet				
Date of Testing	11/29/00	Mix Type (Target Voids)		12.5 mm Fine (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center	Right Rear	Right Front
Sample Number	12.5FG3	12.5FG9	12.5FG10	12.5FG11
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	6.7	6.5	6.1	6.7
Avg. Rut Depth (mm)	3.63	4.54	3.61	2.98
APA RUTTING DATA (mm)				
back (initial)			7.43	
back (final)			3.85	
mid-back (initial)	9.64	11.54	7.54	
mid-back (final)	5.46	6.18	3.90	
middle (initial)	12.18	11.28		
middle (final)	9.80	7.50		
mid-front (initial)	11.61	11.63		8.18
mid-front (final)	7.28	7.16		4.83
front (initial)				7.22
front (final)				4.61

Gyratory Specimen Rutting Data Worksheet				
Date of Testing	11/30/00	Mix Type (Target Voids)		12.5 mm Fine (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center	Right Rear	Right Front
Sample Number	12.5FG7	12.5FG12	12.5FG4	12.5FG5
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	6.7	7.2	6.8	7.1
Avg. Rut Depth (mm)	3.47	4.84	4.01	3.10
APA RUTTING DATA (mm)				
back (initial)			6.77	
back (final)			2.73	
mid-back (initial)	10.62	10.92	6.86	
mid-back (final)	5.71	5.01	2.88	
middle (initial)	11.54	11.37		
middle (final)	8.00	6.87		
mid-front (initial)	10.02	10.41		7.19
mid-front (final)	8.06	6.31		3.91
front (initial)				6.96
front (final)				4.04

Gyratory Specimen Rutting Data Worksheet				
Date of Testing	12/1/00	Mix Type (Target Voids)		12.5 mm Fine (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center	Right Rear	Right Front
Sample Number	12.5FG8	12.5FG2	12.5FG6	12.5FG1
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	7.3	7.4	7.3	7.7
Avg. Rut Depth (mm)	5.11	5.19	4.22	2.89
APA RUTTING DATA (mm)				
back (initial)			6.76	
back (final)			2.33	
mid-back (initial)	9.08	11.14	7.06	
mid-back (final)	4.29	4.66	3.05	
middle (initial)	10.66	11.97		
middle (final)	5.51	7.98		
mid-front (initial)	10.89	11.11		8.14
mid-front (final)	5.50	6.01		5.07
front (initial)				7.53
front (final)				4.82

Gyratory Specimen Rutting Data Worksheet				
Date of Testing	1/17/01	Mix Type (Target Voids)		12.5 mm Coarse (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center Rear	Center Front	Right
Sample Number	12.5CG4	12.5CG6	12.5CG10	12.5CG9
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	6.5	6.6	6.6	6.6
Avg. Rut Depth (mm)	4.74	4.75	5.33	4.82
APA RUTTING DATA (mm)				
back (initial)		11.29		
back (final)		5.73		
mid-back (initial)	10.69	11.24		10.41
mid-back (final)	6.24	7.30		5.22
middle (initial)	11.36			9.86
middle (final)	6.55			4.87
mid-front (initial)	11.46		11.26	10.01
mid-front (final)	6.49		6.38	5.74
front (initial)			11.10	
front (final)			5.33	

Gyratory Specimen Rutting Data Worksheet				
Date of Testing	1/18/01	Mix Type (Target Voids)		12.5 mm Coarse (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center	Right Rear	Right Front
Sample Number	12.5CG3	12.5CG5	12.5CG12	12.5CG8
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	6.7	6.8	6.8	6.8
Avg. Rut Depth (mm)	4.89	5.22	5.38	4.75
APA RUTTING DATA (mm)				
back (initial)		11.54		
back (final)		5.76		
mid-back (initial)	11.01	11.15		10.01
mid-back (final)	6.57	6.49		4.96
middle (initial)	11.46			11.00
middle (final)	6.43			5.78
mid-front (initial)	10.86		11.45	9.28
mid-front (final)	5.67		6.87	5.30
front (initial)			11.74	
front (final)			5.56	

Gyratory Specimen Rutting Data Worksheet				
Date of Testing	1/19/01	**Mix Type (Target Voids)**		12.5 mm Coarse (7%)
Number of Cycles	8000	**Testing Temperature (°C)**		64
Position in Chamber	**Left**	**Center Rear**	**Center Front**	**Right**
Sample Number	12.5CG1	12.5CG2	12.5CG11	12.5CG7
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	6.8	6.9	6.9	7.1
Avg. Rut Depth (mm)	4.35	5.07	4.98	4.19
APA RUTTING DATA (mm)				
back (initial)		11.85		
back (final)		6.57		
mid-back (initial)	11.38	11.87		10.94
mid-back (final)	6.38	7.02		6.41
middle (initial)	11.69			10.87
middle (final)	7.21			7.51
mid-front (initial)	10.97		11.64	10.41
mid-front (final)	7.41		6.49	5.72
front (initial)			11.33	
front (final)			6.53	

Gyratory Specimen Rutting Data Worksheet				
Date of Testing	7/6/00	Mix Type (Target Voids)		12.5 mm Coarse (7%)
Number of Cycles	8000	Testing Temperature (°C)		60
Position in Chamber	Left Rear	Left Front	Right Rear	Right Front
Sample Number	12G7	15G7	13G7	14G7
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	7.2	7.6	6.5	6.7
Avg. Rut Depth (mm)	4.42	5.04	3.17	2.95
APA RUTTING DATA (mm)				
back (initial)	9.46		8.39	
back (final)	5.19		5.30	
mid-back (initial)	9.14		7.91	
mid-back (final)	4.57		4.66	
mid-front (initial)		9.40		7.90
mid-front (final)		4.23		5.30
front (initial)		9.44		8.20
front (final)		4.54		4.90

Gyratory Specimen Rutting Data Worksheet				
Date of Testing	2/1/01	Mix Type (Target Voids)		19 mm Fine (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center	Right Rear	Right Front
Sample Number	19FG2	19FG9	19FG6	19FG7
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	6.7	6.6	6.6	6.7
Avg. Rut Depth (mm)	5.76	3.09	5.76	6.57
APA RUTTING DATA (mm)				
back (initial)			9.27	
back (final)			3.59	
mid-back (initial)	10.11	10.75	10.37	
mid-back (final)	4.41	6.26	4.53	
middle (initial)	10.06	10.94		
middle (final)	4.41	8.67		
mid-front (initial)	10.34	10.17		9.78
mid-front (final)	4.41	7.65		3.56
front (initial)				10.41
front (final)				3.50

Gyratory Specimen Rutting Data Worksheet				
Date of Testing	2/2/01	Mix Type (Target Voids)		19 mm Fine (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left Rear	Left Front	Center	Right
Sample Number	19FG12	19FG3	19FG4	19FG5
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	6.7	6.9	6.9	7.0
Avg. Rut Depth (mm)	8.25	7.07	5.65	5.42
APA RUTTING DATA (mm)				
back (initial)	11.22			
back (final)	2.51			
mid-back (initial)	11.10		10.57	10.47
mid-back (final)	3.32		4.78	3.95
middle (initial)			11.30	10.20
middle (final)			6.28	4.36
mid-front (initial)		10.22	11.10	9.62
mid-front (final)		3.71	4.96	5.72
front (initial)		11.23		
front (final)		3.61		

Gyratory Specimen Rutting Data Worksheet				
Date of Testing	2/3/01	Mix Type (Target Voids)		19 mm Fine (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center Rear	Center Front	Right
Sample Number	19FG1	19FG11	19FG8	19FG10
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	7.3	7.4	7.1	7.6
Avg. Rut Depth (mm)	6.36	6.06	5.32	5.56
APA RUTTING DATA (mm)				
back (initial)		10.85		
back (final)		4.31		
mid-back (initial)	8.91	10.70		9.97
mid-back (final)	3.22	5.13		3.67
middle (initial)	9.94			10.34
middle (final)	3.39			4.17
mid-front (initial)	10.51		10.67	8.81
mid-front (final)	3.67		5.86	4.59
front (initial)			11.33	
front (final)			5.50	

Gyratory Specimen Rutting Data Worksheet				
Date of Testing	3/12/01	Mix Type (Target Voids)		19 mm Coarse (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center	Right Rear	Right Front
Sample Number	19CG4	19CG2	19CG10	19CG8
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	6.7	6.7	6.3	6.7
Avg. Rut Depth (mm)	3.71	2.86	4.85	4.60
APA RUTTING DATA (mm)				
back (initial)			9.63	
back (final)			3.30	
mid-back (initial)	9.73	10.32	10.75	
mid-back (final)	6.12	8.15	7.39	
middle (initial)	10.12	10.25		
middle (final)	6.61	7.17		
mid-front (initial)	10.85	10.66		10.49
mid-front (final)	6.85	7.33		6.98
front (initial)				11.07
front (final)				5.39

Gyratory Specimen Rutting Data Worksheet				
Date of Testing	3/13/00	Mix Type (Target Voids)		19 mm Coarse (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left Rear	Left Front	Center	Right
Sample Number	19CG9	19CG1	19CG3	19CG12
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	6.8	6.9	6.9	7.0
Avg. Rut Depth (mm)	5.19	5.64	3.83	4.81
APA RUTTING DATA (mm)				
back (initial)	10.57			
back (final)	4.53			
mid-back (initial)	10.05		10.55	9.84
mid-back (final)	5.72		4.89	5.99
middle (initial)			11.25	10.56
middle (final)			8.31	6.29
mid-front (initial)		11.22	10.44	10.86
mid-front (final)		6.01	7.54	4.55
front (initial)		11.78		
front (final)		5.72		

Gyratory Specimen Rutting Data Worksheet				
Date of Testing	3/14/01	**Mix Type (Target Voids)**		19 mm Coarse (7%)
Number of Cycles	8000	**Testing Temperature (°C)**		64
Position in Chamber	**Left**	**Center Rear**	**Center Front**	**Right**
Sample Number	19CG11	19CG6	19CG7	19CG5
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	7.1	7.2	7.1	7.6
Avg. Rut Depth (mm)	3.95	4.66	4.80	4.02
APA RUTTING DATA (mm)				
back (initial)		10.91		
back (final)		5.34		
mid-back (initial)	10.60	11.01		10.40
mid-back (final)	6.13	7.27		6.57
middle (initial)	10.08			9.80
middle (final)	5.87			7.23
mid-front (initial)	9.73		11.08	10.70
mid-front (final)	6.57		6.71	5.03
front (initial)			11.30	
front (final)			6.07	

Gyratory Specimen Rutting Data Worksheet				
Date of Testing	6/20/00	Mix Type (Target Voids)		19 mm Coarse (7%)
Number of Cycles	8000	Testing Temperature (°C)		60
Position in Chamber	Left Rear	Left Front	Right Rear	Right Front
Sample Number	6G5	7G7	5G7	3G5
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	6.1	7.6	7.0	6.2
Avg. Rut Depth (mm)	0.63	2.77	1.62	1.70
APA RUTTING DATA (mm)				
back (initial)	9.19		8.60	
back (final)	8.29		6.86	
mid-back (initial)	7.55		8.41	
mid-back (final)	7.20		6.91	
mid-front (initial)		8.51		8.13
mid-front (final)		5.68		6.41
front (initial)		9.04		8.35
front (final)		6.34		6.68

Gyratory Specimen Rutting Data Worksheet						
Date of Testing	7/6/00		Mix Type (Target Voids)		19 mm Coarse (7%)	
Number of Cycles	8000		Testing Temperature (°C)		60	
Position in Chamber	Left Rear	Left Front	Center Rear	Center Front	Right Rear	Right Front
Sample Number	7G5	10G7	4G5	3G7	8G5	24G7
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0	77.0	77.0
Actual Voids (%)	6.2	6.2	6.3	6.3	6.0	7.0
Avg. Rut Depth (mm)	0.85	2.03	1.57	1.84	1.26	2.26
APA RUTTING DATA (mm)						
back (initial)	8.63		8.21		9.16	
back (final)	7.72		6.37		7.93	
mid-back (initial)	9.12		7.40		9.28	
mid-back (final)	8.33		6.11		8.00	
mid-front (initial)		9.71		7.45		8.90
mid-front (final)		7.60		5.61		7.35
front (initial)		10.40		7.83		9.47
front (final)		8.45		5.99		6.50

Vibratory Pill Rutting Data Worksheet				
Date of Testing	2/6/01	Mix Type (Target Voids)		12.5 mm Fine (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center	Right Rear	Right Front
Sample Number	12.5FV2	12.5FV6	12.5FV4	12.5FV9
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	6.5	6.6	6.6	6.5
Avg. Rut Depth (mm)	4.37	4.65	5.47	5.05
APA RUTTING DATA (mm)				
back (initial)			10.93	
back (final)			5.08	
mid-back (initial)	10.82	11.21	11.43	
mid-back (final)	6.31	5.95	6.35	
middle (initial)	11.43	11.18		
middle (final)	4.91	7.69		
mid-front (initial)	9.27	10.84		11.26
mid-front (final)	7.18	5.64		6.42
front (initial)				11.38
front (final)				6.13

Vibratory Pill Rutting Data Worksheet				
Date of Testing	2/7/01	Mix Type (Target Voids)		12.5 mm Fine (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left Rear	Left Front	Center	Right
Sample Number	12.5FV11	12.5FV3	12.5FV7	12.5FV8
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	6.6	6.7	6.6	6.9
Avg. Rut Depth (mm)	6.15	6.42	4.54	4.67
APA RUTTING DATA (mm)				
back (initial)	10.50			
back (final)	4.36			
mid-back (initial)	11.21		11.64	9.55
mid-back (final)	5.06		5.01	3.77
middle (initial)			11.38	10.51
middle (final)			7.51	5.49
mid-front (initial)		11.93	10.69	8.88
mid-front (final)		6.27	7.56	5.68
front (initial)		11.52		
front (final)		4.34		

Vibratory Pill Rutting Data Worksheet				
Date of Testing	2/7/01	Mix Type (Target Voids)		12.5 mm Fine (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center Rear	Center Front	Right
Sample Number	12.5FV12	12.5FV1	12.5FV5	12.5FV10
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	7.2	7.0	7.3	7.4
Avg. Rut Depth (mm)	6.37	4.56	5.29	5.21
APA RUTTING DATA (mm)				
back (initial)		11.90		
back (final)		7.26		
mid-back (initial)	10.47	11.60		11.31
mid-back (final)	4.04	7.13		5.08
middle (initial)	10.79			9.65
middle (final)	4.21			5.94
mid-front (initial)	10.96		11.88	10.85
mid-front (final)	4.86		5.80	5.15
front (initial)			11.70	
front (final)			7.21	

Vibratory Pill Rutting Data Worksheet				
Date of Testing	2/8/01	Mix Type (Target Voids)		12.5 mm Coarse (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center	Right Rear	Right Front
Sample Number	12.5CV12	12.5CV10	12.5CV5	12.5CV8
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	6.6	6.9	6.7	6.9
Avg. Rut Depth (mm)	4.97	3.67	4.10	4.56
APA RUTTING DATA (mm)				
back (initial)			11.78	
back (final)			6.83	
mid-back (initial)	10.71	11.63	11.81	
mid-back (final)	5.91	7.38	8.57	
middle (initial)	12.24	12.08		
middle (final)	7.53	9.01		
mid-front (initial)	12.23	11.39		11.84
mid-front (final)	6.84	7.69		7.54
front (initial)				12.18
front (final)				7.37

Vibratory Pill Rutting Data Worksheet				
Date of Testing	2/10/01	Mix Type (Target Voids)		12.5 mm Coarse (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left Rear	Left Front	Center	Right
Sample Number	12.5CV7	12.5CV4	12.5CV9	12.5CV1
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	7.2	7.2	7.2	7.3
Avg. Rut Depth (mm)	6.92	6.25	4.70	5.73
APA RUTTING DATA (mm)				
back (initial)	12.30			
back (final)	4.51			
mid-back (initial)	12.42		11.34	11.62
mid-back (final)	6.37		5.09	5.31
middle (initial)			10.99	11.65
middle (final)			7.56	6.41
mid-front (initial)		11.58	10.93	11.41
mid-front (final)		6.04	6.52	5.77
front (initial)		11.57		
front (final)		4.61		

Vibratory Pill Rutting Data Worksheet				
Date of Testing	2/12/01	Mix Type (Target Voids)		12.5 mm Coarse (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center Rear	Center Front	Right
Sample Number	12.5CV2	12.5CV6	12.5CV11	12.5CV3
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	7.6	7.7	7.4	7.9
Avg. Rut Depth (mm)	6.48	4.64	4.82	5.65
APA RUTTING DATA (mm)				
back (initial)		12.81		
back (final)		6.86		
mid-back (initial)	12.08	12.05		12.00
mid-back (final)	5.21	8.73		5.43
middle (initial)	11.82			11.51
middle (final)	4.63			6.75
mid-front (initial)	11.18		12.91	10.99
mid-front (final)	5.80		8.26	5.38
front (initial)			12.57	
front (final)			7.59	

Vibratory Pill Rutting Data Worksheet				
Date of Testing	3/19/01	Mix Type (Target Voids)		19 mm Fine (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center	Right Rear	Right Front
Sample Number	19FV6	19FV3	19FV4	19FV5
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	6.8	6.5	6.0	6.9
Avg. Rut Depth (mm)	6.96	5.33	6.90	5.25
APA RUTTING DATA (mm)				
back (initial)			10.63	
back (final)			4.07	
mid-back (initial)	10.02	11.10	11.59	
mid-back (final)	2.72	4.56	4.35	
middle (initial)	10.16	11.32		
middle (final)	3.14	6.33		
mid-front (initial)	10.18	11.15		11.37
mid-front (final)	3.62	6.68		5.70
front (initial)				10.00
front (final)				5.18

Vibratory Pill Rutting Data Worksheet				
Date of Testing	3/20/01	Mix Type (Target Voids)		19 mm Fine (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left Rear	Left Front	Center	Right
Sample Number	19FV1	19FV8	19FV11	19FV2
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	7.1	7.3	7.4	7.6
Avg. Rut Depth (mm)	8 70	8 91	5 00	5 95
APA RUTTING DATA (mm)				
back (initial)	11.30			
back (final)	1.61			
mid-back (initial)	10.89		10.72	9.63
mid-back (final)	3.18		5.03	3.05
middle (initial)			11.13	10.22
middle (final)			6.62	6.31
mid-front (initial)		11.08	10.96	9.58
mid-front (final)		2.88	6.16	2.22
front (initial)		11.44		
front (final)		1.82		

Vibratory Pill Rutting Data Worksheet				
Date of Testing	3/21/01	Mix Type (Target Voids)		19 mm Fine (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center Rear	Center Front	Right
Sample Number	19FV12	19FV7	19FV10	19FV9
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	7.8	7.9	7.6	8.0
Avg. Rut Depth (mm)	5.91	7.17	6.26	6.98
APA RUTTING DATA (mm)				
back (initial)		11.48		
back (final)		4.43		
mid-back (initial)	10.09	12.66		8.36
mid-back (final)	3.13	5.37		1.81
middle (initial)	8.23			9.63
middle (final)	2.91			2.32
mid-front (initial)	8.31		11.69	9.33
mid-front (final)	2.87		5.37	2.26
front (initial)			10.35	
front (final)			4.15	

Vibratory Pill Rutting Data Worksheet				
Date of Testing	3/23/01	Mix Type (Target Voids)		19 mm Coarse (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left Rear	Left Front	Center	Right
Sample Number	19CV9	19CV5	19CV6	19CV8
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	7.7	7.9	7.9	7.9
Avg. Rut Depth (mm)	5.61	4.65	2.98	3.95
APA RUTTING DATA (mm)				
back (initial)	12.39			
back (final)	6.33			
mid-back (initial)	12.49		12.54	11.51
mid-back (final)	7.34		9.89	8.12
middle (initial)			11.44	12.50
middle (final)			8.61	9.39
mid-front (initial)		12.81	11.91	12.91
mid-front (final)		8.43	8.45	7.55
front (initial)		12.36		
front (final)		7.44		

Vibratory Pill Rutting Data Worksheet				
Date of Testing	3/24/01	Mix Type (Target Voids)		19 mm Coarse (7%)
Number of Cycles	8000	Testing Temperature (°C)		64
Position in Chamber	Left	Center Rear	Center Front	Right
Sample Number	19CV2	19CV7	19CV1	19CV10
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	8.0	8.0	8.0	8.0
Avg. Rut Depth (mm)	3 08	4 17	3 74	2 66
APA RUTTING DATA (mm)				
back (initial)		12.43		
back (final)		7.85		
mid-back (initial)	10.44	11.52		12.17
mid-back (final)	6.89	7.77		9.46
middle (initial)	11.44			11.71
middle (final)	8.90			8.38
mid-front (initial)	11.46		11.55	11.83
mid-front (final)	8.32		7.84	9.89
front (initial)			12.21	
front (final)			8.45	

Vibratory Pill Rutting Data Worksheet				
Date of Testing	3/26/01	Mix Type (Target Voids)		19 mm Coarse (7%)
Number of Cycles	8000	Testing Temperature (^oC)		64
Position in Chamber	Left	Center	Right Rear	Right Front
Sample Number	19CV4	19CV12	19CV3	19CV11
Avg. Sample Height (mm)	77.0	77.0	77.0	77.0
Actual Voids (%)	7.5	7.4	7.4	7.5
Avg. Rut Depth (mm)	4.04	4.06	4.93	3.57
APA RUTTING DATA (mm)				
back (initial)			11.66	
back (final)			6.54	
mid-back (initial)	11.53	12.07	12.34	
mid-back (final)	7.26	6.17	7.60	
middle (initial)	11.27	10.70		
middle (final)	8.35	8.99		
mid-front (initial)	10.64	12.36		11.71
mid-front (final)	5.70	7.79		8.98
front (initial)				11.94
front (final)				7.53