RUTGERS

Center for Advanced Infrastructure and Transportation

QUARTERLY PROGRESS REPORT

Project Title:	Performance Testing for HMA Quality Assurance
RFP NUMBER: 2011-012	NJDOT RESEARCH PROJECT MANAGER: Daniel LiSanti
TASK ORDER NUMBER: TO 273 / RU Acct 4-33842	PRINCIPAL INVESTIGATOR: Thomas Bennert, Ph.D.
Project Starting Date: 08/01/2011 **Original** Project Ending Date: 08/01/2013 **Modified Completion Date:** 7/01/2014	Period Covered: 3rd Quarter 2014 Final

Task #	Task	% of Total	Fixed Budget	% of Task this quarter	Cost this quarter	% of Task to date	Total cost to date
0	Mobilization	31.47%	$ 85,000	0.00%	$ -	100.00%	$ 85,000
1	Literature Search	1.85%	$ 5,000	0.00%	$ -	100.00%	$ 5,000
2	Performance of "Typical" NJDOT HMA	31.05%	$ 83,853	0.00%	$ -	100.00%	$ 83,853
3	Balanced Mixture Design	21.14%	$ 57,100	0.00%	$ -	100.00%	$ 57,100
4	Install & Train NJDOT	11.52%	$ 31,121	5.00%	$ 1,556	100.00%	$ 31,121
5	Quarterly & Final Reports	2.97%	$ 8,000	25.00%	$ 2,000	100.00%	$ 8,000
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	TOTAL	100.00%	$ 270,074		$ 3,556		$ 270,074

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Green text is updated ever quarter

Black text is automatically updated or static

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Project Objectives:

The objective of NJDOT 2012-12, *Performance Testing for HMA Quality Assurance*, is to evaluate various HMA performance tests for potential implementation as an end result Quality Assurance test for hot mix asphalt and provide recommendations upon its potential use for NJDOT. The scope of the project would also include the procurement, set-up and training of the performance test equipment, as well as a round robin study to compare test results between the NJDOT and Rutgers University.

Project Abstract:

The Superpave asphalt mixture design system is based on evaluating the performance of each constituent of the asphalt mixture; asphalt binder, aggregate/sand, and the mixture as a whole. In its development and initial release, a suite of performance tests were developed to accompany the new volumetric design system to verify asphalt mixtures would not prematurely rut or crack. Unfortunately, the cost of the test equipment, as well as the time it took to test the mixture design specimens, was impractical. This resulted in the Superpave design system to simply be a volumetric based asphalt mixture design system with only moisture damage being evaluated using AASHTO T283, *Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage*.

During its initial implementation with the New Jersey Department of Transportation (NJDOT), the initial Superpave mixtures were found to be coarser, had less asphalt binder, and harder to place and compact than the previous Marshal asphalt mixtures designed for the identical traffic level. What resulted were asphalt mixtures that were prone to poor longitudinal joint construction and asphalt pavements failing quicker due to fatigue cracking related distress.

To combat the fatigue-prone Superpave mixtures, the NJDOT began making slight modifications to the Superpave procedure. For example, the NJDOT immediately eliminated the "V" Superpave mixtures, which were recommended for "very heavy" traffic volumes of 30 million ESAL's or greater, and began using "H" Superpave mixtures in their place. This resulted in a slight increase in asphalt content in the mixtures, although it did not resolve the fatigue cracking and longitudinal joint issue. NJDOT is currently evaluating the drop of another gyratory level, from "H" to "M", to once again attempt to increase the asphalt content in their asphalt mixtures.

Adding to the already fatigue prone asphalt mixtures, the asphalt industry in New Jersey has been pressuring the NJDOT to utilize more recycled asphalt pavement (RAP) in their mixtures. Historically, due to the oxidized and stiff asphalt binder associated with RAP, higher percentages of RAP have been associated with an increase in fatigue and low temperature cracking potential when compared to virgin or low RAP content asphalt mixtures. Rutgers University completed a pilot study for the NJDOT Materials Bureau evaluating fatigue resistance of virgin and RAP asphalt mixtures in the Overlay Tester (Zhou and Scullion, 2005). On average, the virgin asphalt mixtures were able to obtain a fatigue life of 150 cycles or greater, while the RAP mixtures were not able to reach 50 cycles (Figure 1). Unfortunately, the NJDOT does not have a test/design procedure in place to evaluate the

performance of their asphalt mixtures during design and actual plant production to ensure premature fatigue cracking is not an issue.

1. Progress this quarter by task:
The equipment for the project has been ordered. This is under the mobilization portion of the project.

Task 1 – Literature Review (100% Completed)

A Literature Review has been initiated pertaining to the various performance tests used to evaluate HMA mixture performance. In particular, the use of mixture tests for mixture design acceptance and quality control practices.

Recently, TxDOT has developed performance-based specifications for their asphalt mixtures and will be letting out projects in 2013 that must meet these specifications. TxDOT will be using the Hamburg Wheel Tracking test for the rutting criteria and will be using the Overlay Tester for the fatigue cracking performance. Rutgers is currently proposing to utilize the Asphalt Pavement Analyzer (APA) as the rutting criteria due to Rutgers University and NJDOT's experience with the device. However, the TxDOT Overlay Tester requirements provide a good comparison to what may be proposed by the NJDOT. These minimum requirements for different mixtures are shown below:

- Dense Graded Mixes
    - Surface Course: > 150 cycles
    - Intermediate Course: > 100 cycles
    - Base Course: > 30 cycles
- Stone Matrix Asphalt (SMA): > 200 cycles
- Open Graded Friction Course (called PFC by TxDOT): > 300 cycles

In another recent event, the Rutgers helped the NJDOT develop a performance-based specification for High RAP mixtures. The performance criteria were established using a database of performance history for Virgin mixtures. The thinking was that if the asphalt supplier could produce a High RAP mixture that performed as well as virgin mixture, than it would be acceptable by the NJDOT. The performance requirements are shown in the following table (Table 1). It is interesting to note how similar the Overlay Tester results are in Table 1 for the surface and intermediate course mixtures to those proposed by TxDOT.

Table 1 – Performance Requirements for NJDOT High RAP Study

Table 902.11.03-2 Performance Testing Requirements for HMA HIGH RAP Design				
Test	Requirement			
	Surface Course		Intermediate Course	
	PG 64-22	PG 76-22	PG 64-22	PG 76-22
APA @ 8,000 loading cycles (AASHTO T 340)	< 7 mm	< 4 mm	< 7 mm	< 4 mm
Overlay Tester (NJDOT B-10)	> 150 cycles	> 175 cycles	> 100 cycles	> 125 cycles

Task 2 – Initial Performance of "Typical" NJ HMA (100% Completed)

Rutgers procured a variety of cores from the NJDOT to conduct initial mixture characterization. In particular, three tests are proposed to be conducted that have shown to be able to be utilized during mixture design acceptance on gyratory compacted specimens, as well as for quality control practices using field cores:

1. Overlay Tester for fatigue cracking resistance
2. Asphalt Pavement Analyzer for rutting resistance
3. High Temperature IDT testing for rutting resistance

These tests were initially selected as they can be conducted both on laboratory gyratory specimens as well as field cores.

Core from the following pavement locations, all produced during the 2011 paving season, were procured and are being prepared for testing:

1. Rt 73 (12.5M64)
2. Rt 79 (25M64)
3. Rt 70 (SMA)
4. Rt 68 (9.5M64)
5. Rt 18 (12.5M76)
6. Rt 78 (12.5M76; 19H76; 25M76)
7. Rt 88 (12.5M64)
8. Rt 202 (12.5M76; 12.5M64)
9. Rt 34 (9.5H76)

Preliminary testing is shown in Figures 1 and 2. Figure 1 shows the fatigue cracking of the Overlay Tester and Figure 2 shows the rutting performance in the Asphalt Pavement Analyzer. The Overlay Tester results in Figure 1 compare well with the minimum values shown earlier in Table 1 with the base mixture not able to meet the minimum requirement of 100 cycles. However, both the

intermediate course (19H76) and surface course (12.5M76) mixes met the requirements by 30 to 50 cycles.

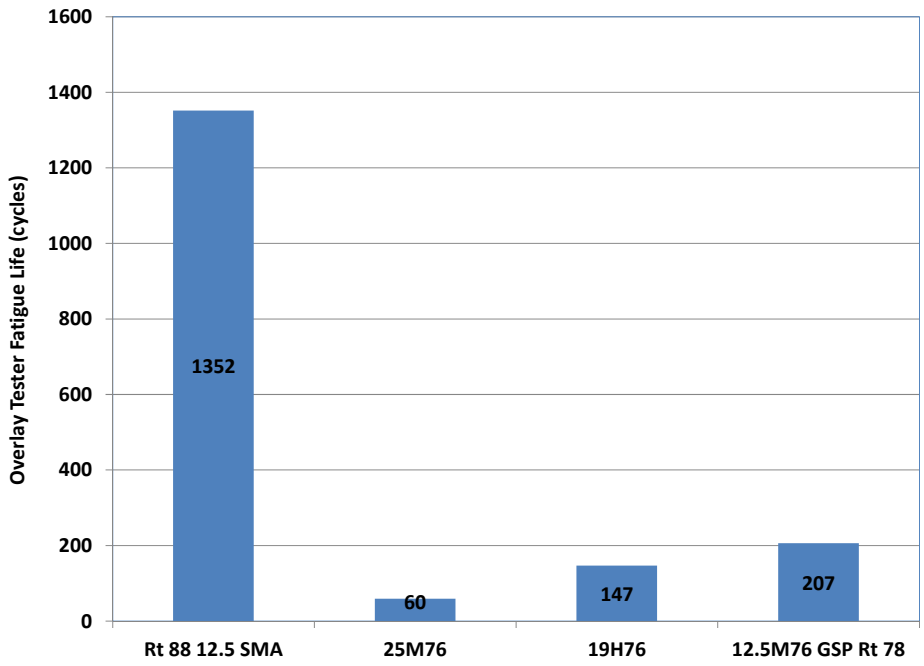

Figure 1 – Overlay Tester Results

The results in Figure 1 trend as to what would be expected with the SMA mixture achieving a greater resistance to fatigue cracking in the Overlay Tester. Meanwhile, the 25mm mixture resulted in the lowest fatigue life with the fatigue life increasing as nominal aggregate size decreases (resulting in higher effective asphalt contents). The higher SMA Overlay Tester fatigue life is also expected within the TxDOT as shown via the minimum requirement of 200 cycles.

Meanwhile, in Figure 2, the APA results do not show a large difference among the different asphalt mixtures. The 12.5mm SMA resulted in the lowest rutting while the 12.5M76 mixture resulted in the highest rutting. It is anticipated that larger differences will be found when testing non-polymer modified asphalt mixtures.

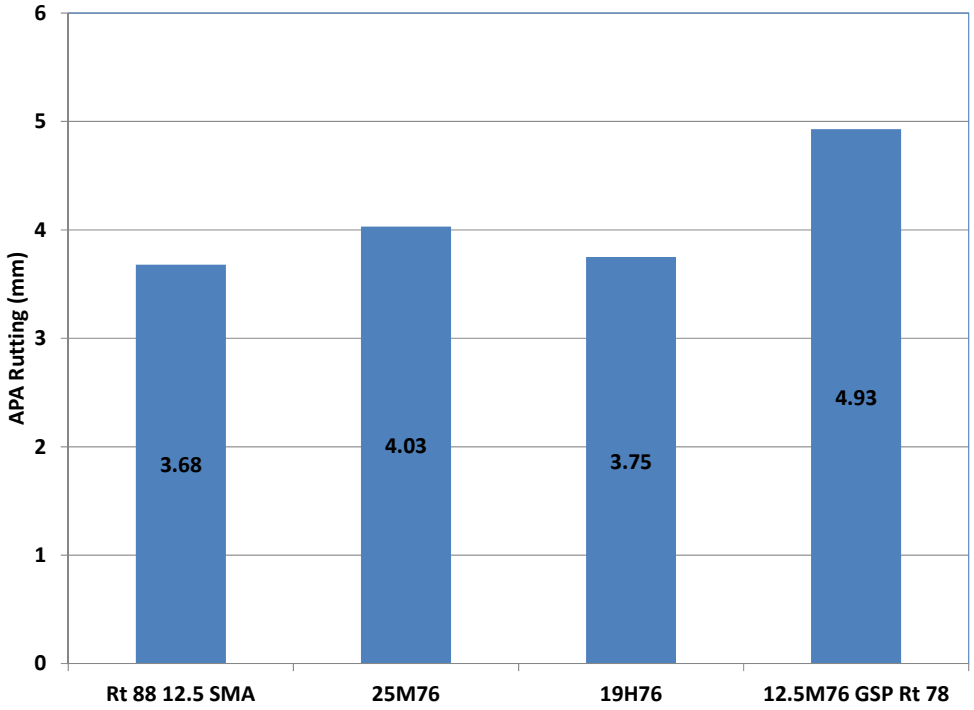

Figure 2 – APA Rutting

After meeting with the NJDOT at the previous Quarterly Meeting, it was decided that the following criteria would be established as the first trial performance criteria for Superpave mixture design:

Overlay Tester Fatigue Requirement

- Surface Course Mixes with PG76-22: > 175 cycles
- Surface Course Mixes with PG64-22: > 125 cycles
- Intermediate Course with PG76-22: > 100 cycles
- Intermediate Course with PG64-22: > 75 cycles
- Base Course Mixes: > 50 cycles
- SMA Mixtures: > 300 cycles

APA Rutting Criteria

- Mixes with PG76-22: < 4.0 mm rutting
- Mixes with PG4-22: < 6.0 mm rutting
- SMA Mixtures: < 4.0 mm rutting

The above criteria will be used as the initial performance criteria to evaluate the Balanced Mixture Design procedure.

Task 3 – Balanced Mixture Design (100% Completed)

The concept of the Balanced Mixture Design is that there is an area where rutting performance and fatigue cracking performance are "balanced". Generally, asphalt mixtures that are highly rut resistant are prone to fatigue cracking and vice versa (i.e. - highly fatigue resistant mixtures are rutting prone). Therefore, the Asphalt Pavement Analyzer (APA) and the Overlay Tester were used with the criteria established in Task 2 of the study to re-evaluate NJDOT pre-approved mixtures. All mixtures were evaluated with 15% RAP. It should be noted the NJDOT asphalt mixture designs are conducted without RAP and the asphalt plants are allowed to make gradation and asphalt content adjustments during production to account for RAP.

For each mixture, the compacted air voids were determined, along with the performance results, for the mixtures containing 15% RAP. Tables 1 and 2 below summarize the "optimum asphalt content" determined through the different conditions. Tables 1and 2 clearly indicate that the addition of 15% RAP requires additional virgin asphalt content to achieve 4% air voids. On average, it was determined that 0.58% additional asphalt binder is required for the Tilcon Mt. Hope mixtures, while an additional 0.60% of asphalt binder is required for the Trap Rock Industries mixtures when designing with RAP.

Table 1 – Summary of Mt Hope Determined Optimum Asphalt Contents

Mix Type	Optimum AC% (%)		Balanced Mix Design Optimum AC% (%)
	Virgin	15% RAP	
MH 9.5M64	5.0	5.5	5.2 - 5.9 (5.6)
MH 9.5M76	5.0	5.7	5.1 - 5.6 (5.4)
MH 12.5M64	5.1	5.5	5.2 - 5.8 (5.5)
MH 12.5M76	5.1	5.8	5.5 - 6.0 (5.8)

Table 2 – Summary of Trap Rock Industries Determined Optimum Asphalt Contents

Mix Type	Optimum AC% (%)		Balanced Mix Design Optimum AC% (%)
	Virgin	15% RAP	
TRI 9.5M64	5.4	5.5	5.2 - 5.9 (5.5)
TRI 9.5M76	5.4	5.7	5.8 - 6.0 (5.9)
TRI 12.5M64	4.9	5.7	5.1 - 6.0 (5.6)
TRI 12.5M76	4.9	6.1	5.5 - 6.0 (5.7)

When comparing the Balanced Performance Design optimum asphalt content to the original (virgin) optimum asphalt content, the Balanced Performance again indicates that a higher asphalt content is required to achieve balanced performance. For the Tilcon Mt. Hope mixtures, on average, 0.53% additional asphalt binder is required when using the middle of the Balanced Mix Design Optimum AC% range shown in Table 1. For the Trap Rock Industries mixtures, an additional 0.4% of asphalt binder was required. It should be noted that the middle of the range should be utilized as this would take into consideration production tolerances allowed at the asphalt plant and still meet the minimum performance requirements.

Based on the asphalt mixtures evaluated in this study, it appears that additional asphalt binder is required to not only achieve balanced rutting and fatigue cracking performance, but also when simply conducting volumetric designs with recycled asphalt pavement (RAP). In the case of this study, mixtures only utilizing 15% RAP were evaluated.

If the NJDOT was to require additional asphalt binder in their mixtures, the major question would be how this would be specified during Quality Control (QC). Currently, although the asphalt plants are conducting the asphalt mixture designs with no RAP, they routinely use 15% to 25% RAP and are able to achieve 43 to 5% air void allowable range. During production, the additional 0.5% asphalt binder, which was determined to be required through the RAP volumetric and balanced performance work, would close up the compacted air voids of the QC gyratory samples, most likely resulting in a failure under current specifications. Future consideration towards how QC acceptance testing and its respective criteria are enforced would be required for implementation.

Further volumetric analysis was conducted on the Balanced Mixture Design data to determine how the durability/fatigue resistance of NJ's asphalt mixtures could be improved. Figures 3 and 4 show the overall results for the Tilcon Mt Hope (Figure 3) and Trap Rock Industries (Figure 4) mixtures evaluated in the study. However, instead of showing design asphalt content on the x-axis, the figures show the volumetric parameter "Effective Asphalt Content by Volume (EACV)". This value is easily calculated by subtracting compacted air voids from the Voids in Mineral Aggregate (VMA – AV%). The advantage of using EACV over VMA as a durability index is that EACV should remain constant

in the mixture while VMA and air voids can change depending on the level of compaction. EAVC is only dependent on the effective asphalt binder content (i.e. – asphalt binder on the outside of the aggregate) of the mixture. Although there is some scatter in the data, the trend is clear that as the EAVC increases, the fatigue resistance increases while the rutting resistance decreases.

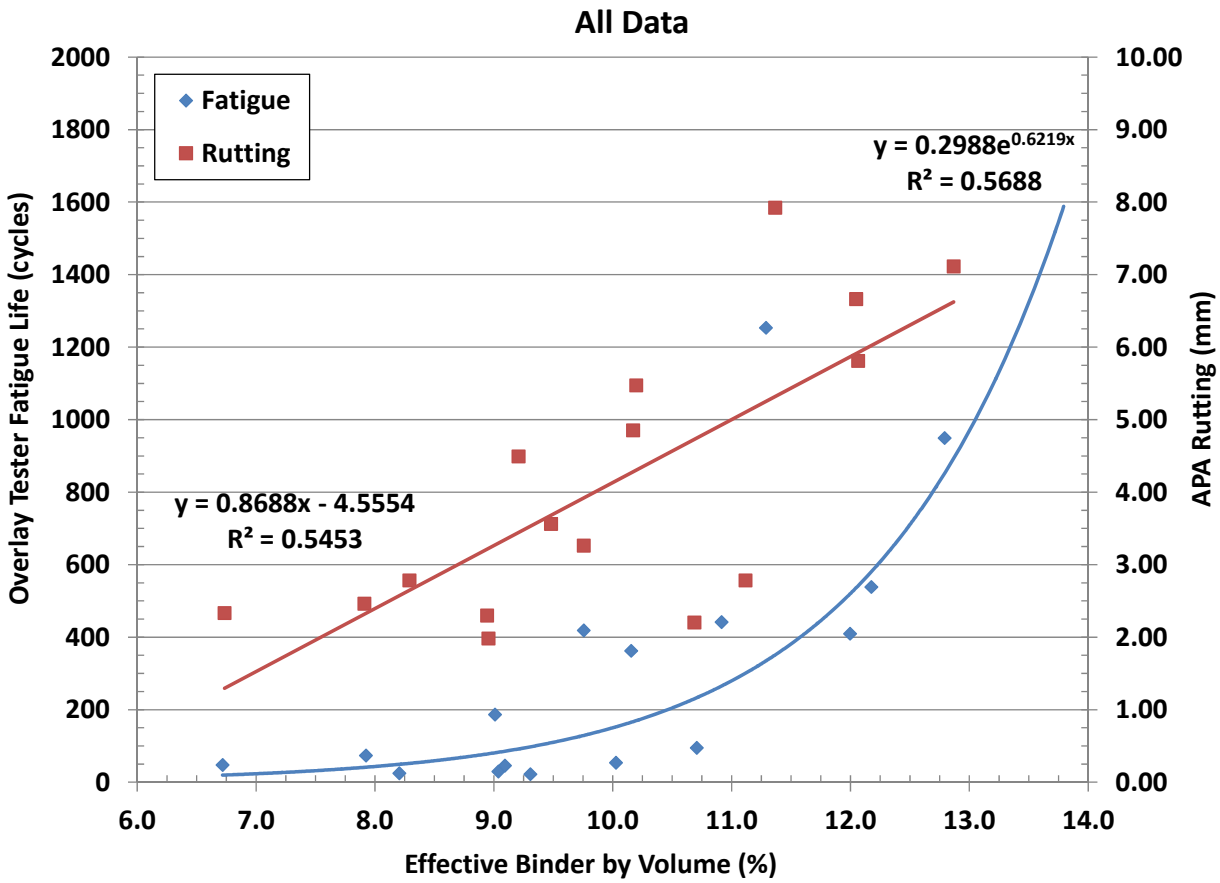

Figure 3 – Effective Asphalt Content by Volume vs Performance (Tilcon Mt. Hope)

A more detailed analysis of the data indicates that for the mixtures evaluated, the APA rutting was more a function of the high temperature PG grade of the asphalt binder, while the fatigue resistance trends vs EACV were stronger when separating out the nominal aggregate size of the mixtures (NMAS). This would be expected as smaller NMAS require more effective asphalt to ensure proper coating and good film thickness.

Since the EACV was found to have a strong correlation to mixture performance, a closer look at the NJDOT's specifications was done to see what level NJDOT is currently specifying EACV. Table 3 contains the NJDOT's volumetric design requirements for dense-graded asphalt mixtures. Since this mixtures are designed at 4% air voids, the EACV can easily be determined by taking the VMA –

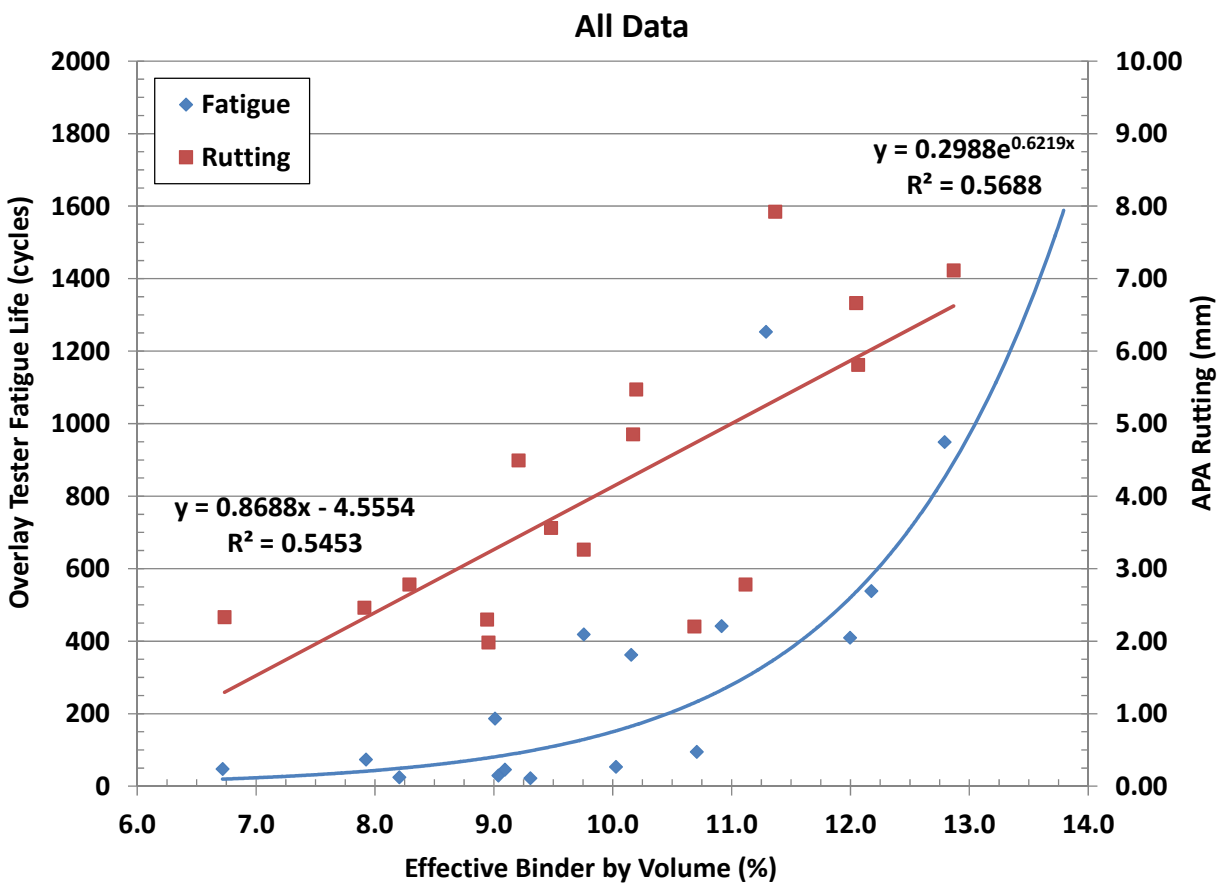

Figure 4 – Effective Asphalt Content by Volume vs Performance (Trap Rock Industries)

Design Air Voids. Therefore, for a 12.5mm NMAS mixture, a minimum EACV of 10% is required. For a 9.5mm NMAS, a minimum EACV of 11% is required. These values are transposed on Figures 4 and 5 for the 9.5mm NMAS and 12.5mm NMAS mixtures evaluated, respectively.

Table 3 – NJDOT HMA Volumetric Requirements for Dense Graded Asphalt Mixtures

Table 902.02.03-3 HMA Requirements for Design

Compaction Levels	Required Density(% of Theoretical Max. Specific Gravity)		Voids in Mineral Aggregate (VMA),% (minimum) Nominal Max. Aggregate Size, mm						Voids Filled With Asphalt (VFA)[1] %	Dust-to-Binder Ratio
	@N_{des}[2]	@N_{max}	37.5	25.0	19.0	12.5	9.5	4.75		
L	96.0	≤ 98.0	11.0	12.0	13.0	14.0	15.0	16.0	70 - 80	0.6 - 1.2
M	96.0	≤ 98.0	11.0	12.0	13.0	14.0	15.0	16.0	65 - 78	0.6 - 1.2
H	96.0	≤ 98.0	11.0	12.0	13.0	14.0	15.0	16.0	65 - 75	0.6 - 1.2

As shown in Figures 5 and 6, at an EACV level under the current NJDOT specifications, APA rutting is clearly met for the PG64-22 mixes (< 7mm rutting) and for the PG76-22 mixes (< 4mm rutting) with the Overlay Tester results between 250 and 300 cycles, respectively. However, since the APA rutting is met without issue, the EACV was increased 1% for each NMAS to determine its impact on the mixture performance. Figures 7 and 8 show these results.

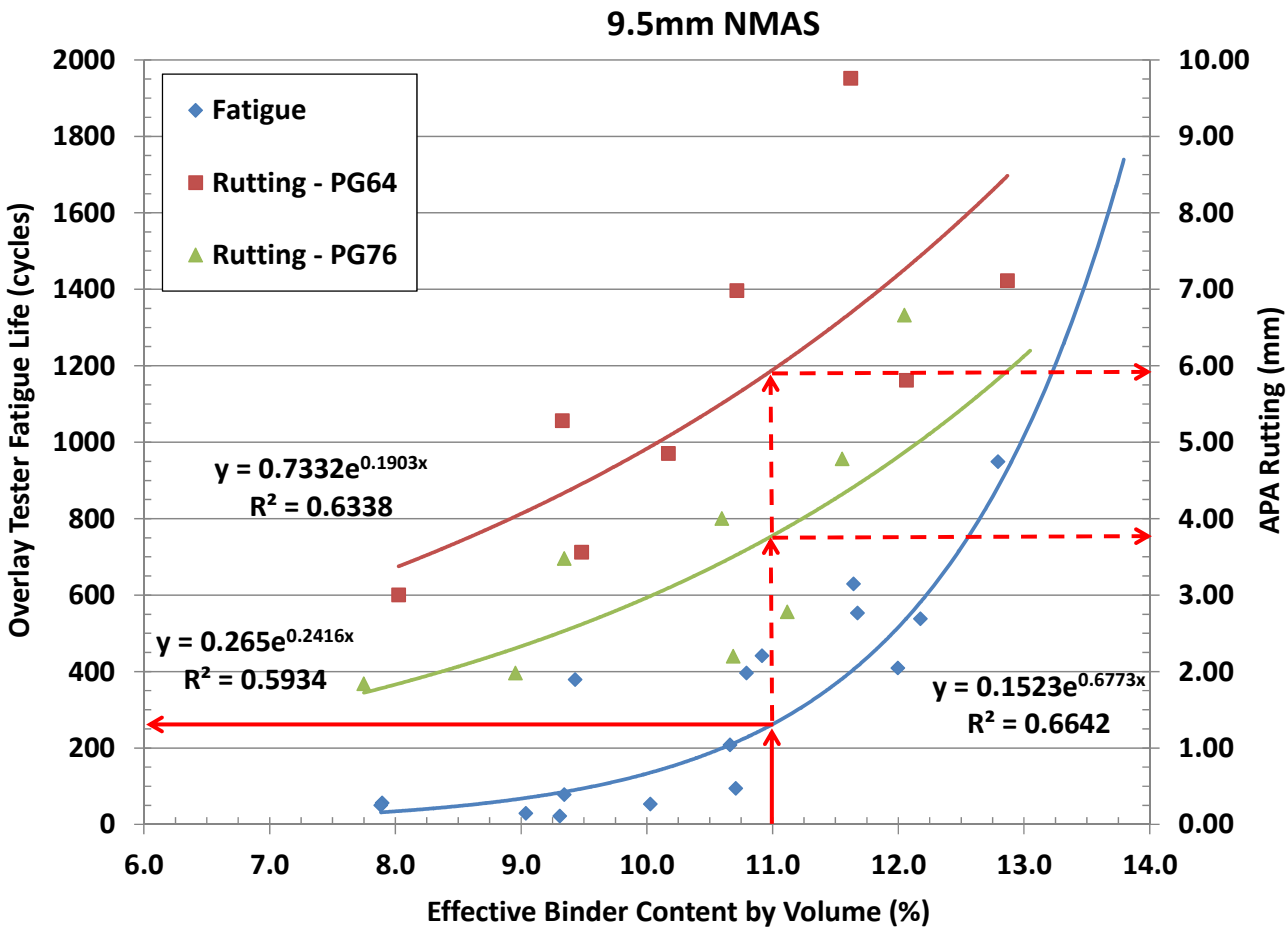

Figure 5 – Effective Asphalt Content by Volume for 9.5mm NMAS – Current NJDOT Specs

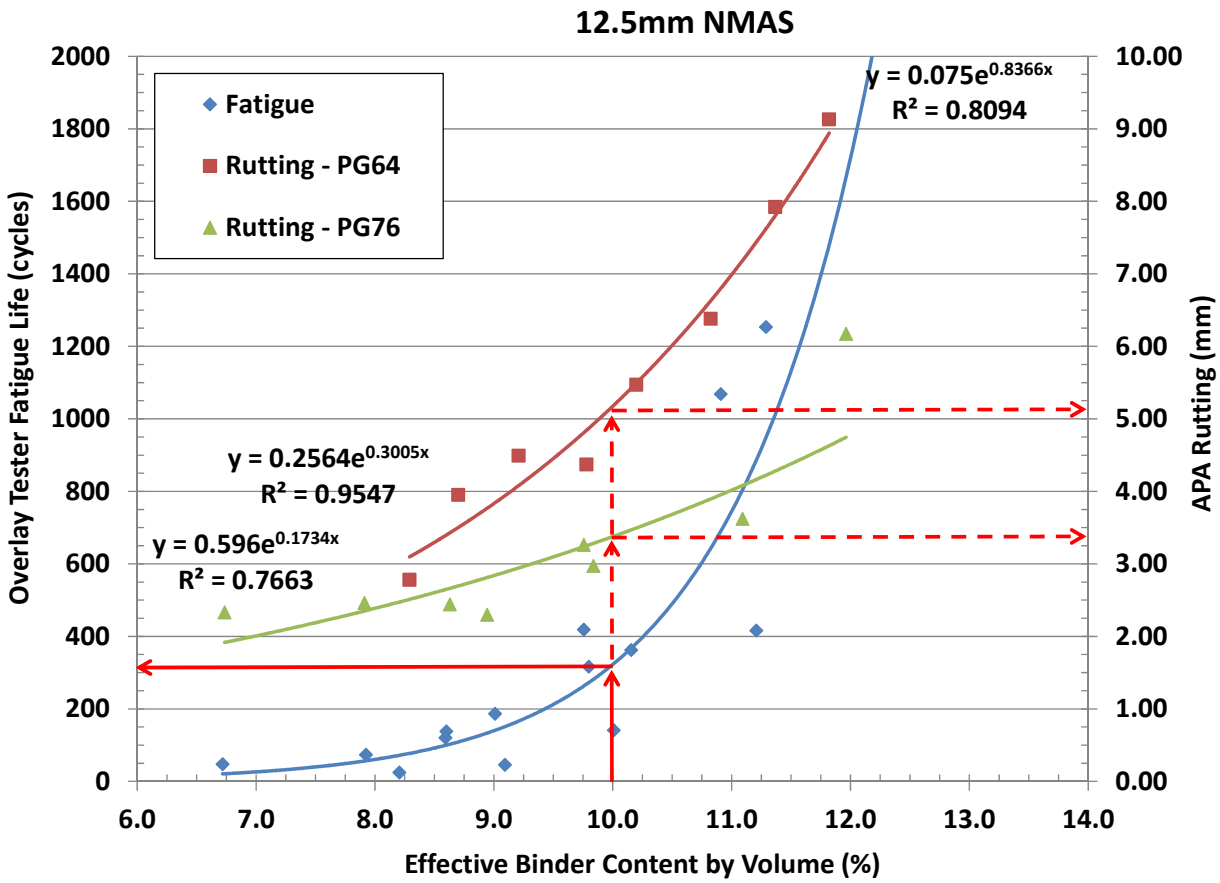

Figure 6 – Effective Asphalt Content by Volume for 12.5mm NMAS – Current NJDOT Specs

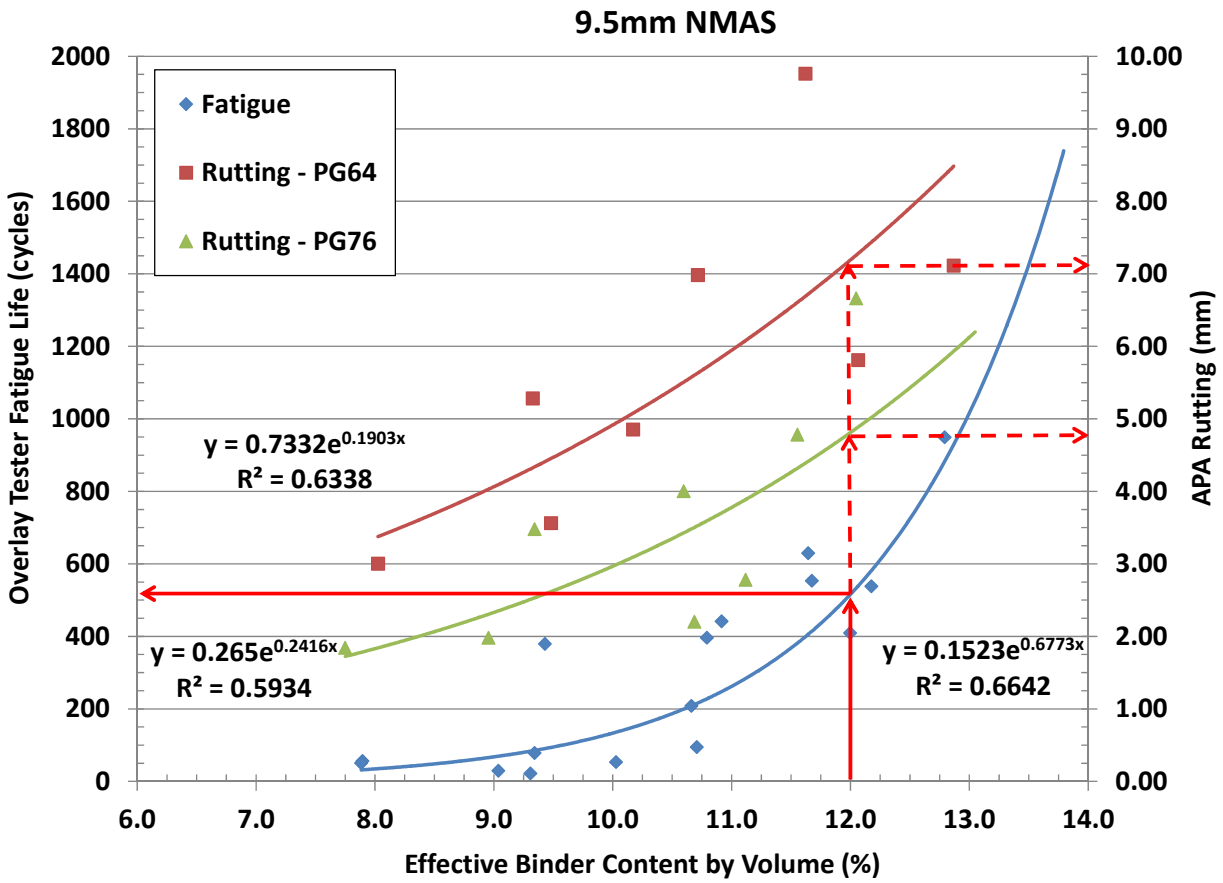

Figure 7 – Effective Asphalt Content by Volume for 9.5mm NMAS – Proposed Specs

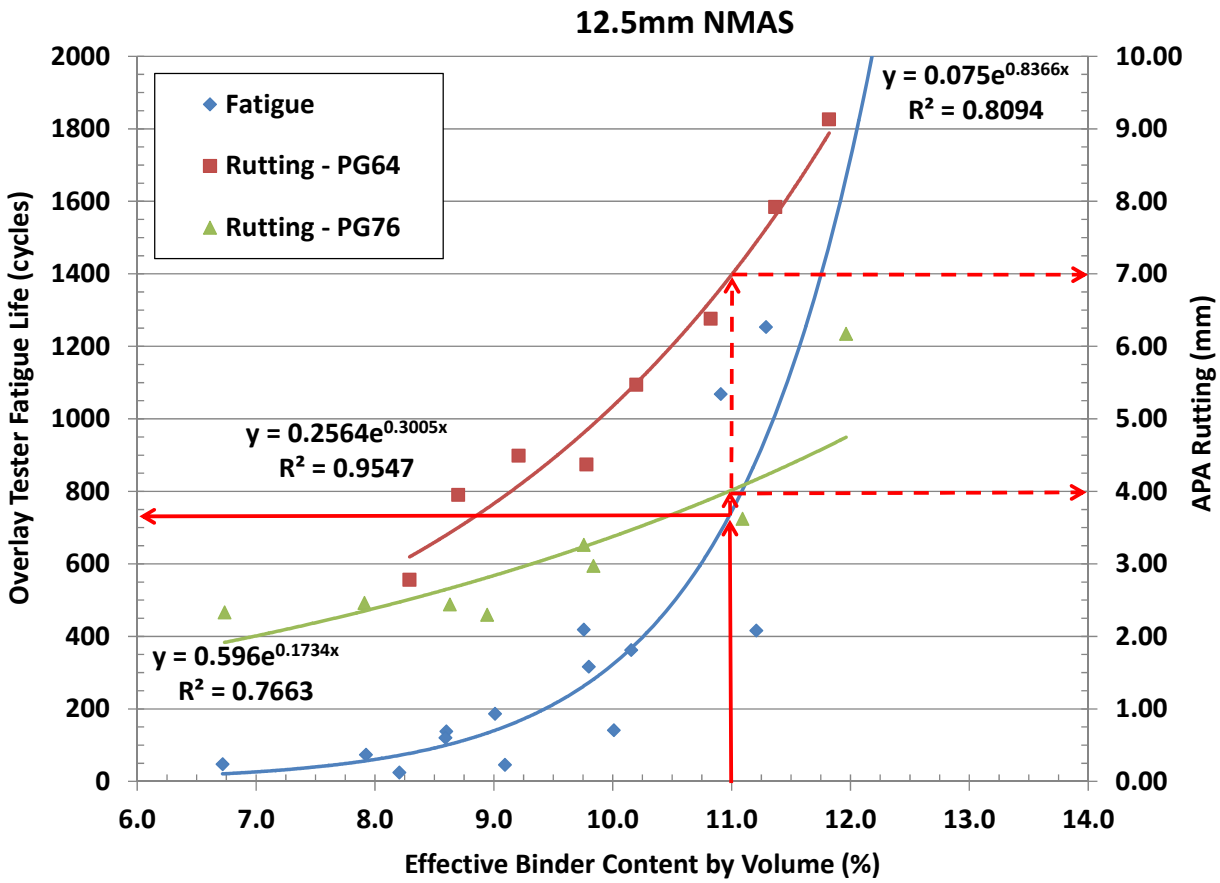

Figure 8 – Effective Asphalt Content by Volume for 12.5mm NMAS – Proposed Specs

As shown in Figures 7 and 8, a 1% increase in the EACV results in a slight increase in the APA rutting – 22% increase for the PG64-22 mixtures and 17% increase for the PG76-22 mixtures. Meanwhile, the 1% increase in EACV resulted in a 59% and 52% increase in Overlay Fatigue life for the 9.5mm and 12.5mm mixes, respectively. The 1% increase in EACV would result in a 1% increase in VMA at design.

Therefore, it is clear from the test data generated that to help improve the durability of NJ's dense graded mixtures, NJDOT should look to increase the design VMA by 1% over the current specifications, especially for the PG76-22 asphalt mixtures which are placed on the surface of NJ's heavier trafficked roadways.

Task 4 – Install and Train NJDOT on the Overlay Tester (100% Completed)

Testing and analysis is in progress (delayed due to a malfunction of a cooling fan) and results should be available for close out presentation and final report.

2. Proposed activities for next quarter by task:

Draft final report should be generated and submitted at the October 1st quarterly meeting.

3. List of deliverables provided in this quarter by task (product date):
N.A.

4. Progress on Implementation and Training Activities:

N.A.

Problems/Proposed Solutions:

N/A

Total Project Budget	$270,074
Year 1 funding	$188,642
Modified Contract Amount:	
Total Project Expenditure to date	$266,517
% of Total Project Budget Expended	100%

NJDOT Research Project Manager Concurrence: _____ Date: _____