RUTGERS
Center for Advanced Infrastructure and Transportation

QUARTERLY PROGRESS REPORT

Project Title:	Evaluation of Warm Asphalt Technology
RFP NUMBER: 2008-01	NJDOT RESEARCH PROJECT MANAGER: Lad Szalaj
TASK ORDER NUMBER: TO 218 / RU Acct 4-27212	PRINCIPAL INVESTIGATOR: Thomas Bennert
Project Starting Date: 01/01/2008 **Original** Project Ending Date: 12/31/2009 **Anticipated No-Cost Extension to 6/30/10**	Period Covered: 4th Quarter 2009

Rutgers Center for Advanced Infrastructure and Transportation

Task #	Task	% of Total	Fixed Budget	% of Task this quarter	Cost this quarter	% of Task to date	Total cost to date
1	Mobilization	10.52%	$ 30,000	0.0%	$ -	100.0%	$ 30,000
2	Literature Search	2.88%	$ 8,200	0.0%	$ -	100.0%	$ 8,200
3	Influence of Aggregate Blend Moisture Content	6.96%	$ 19,840	0.0%	$ -	100.0%	$ 19,840
4	Assessment of Compactibility of Different WMA's	6.75%	$ 19,238	0.0%	$ -	100.0%	$ 19,238
5	Laboratory Sensitivity on the Gyratory Compaction of WMA's	13.11%	$ 37,360	0.0%	$ -	100.0%	$ 37,360
6	Laboratory Specimen Conditioning for Performance Testing	10.33%	$ 29,436	25.0%	$ 7,359	75.0%	$ 22,077
7	Asphalt Binder Grade Selection	16.08%	$ 45,835	0.0%	$ -	100.0%	$ 45,835
8	Use of RAP	12.37%	$ 35,250	25.0%	$ 8,813	75.0%	$ 26,438
9	In-Project Implementation - Field Trials	13.82%	$ 39,390	0.0%	$ -	100.0%	$ 39,390
10	Final Report and Quarterly Reporting	7.20%	$ 20,522	50.0%	$ 10,261	50.0%	$ 10,261
11		0.00%	$ -	0.0%	$ -	0.0%	$ -
12		0.00%	$ -	0.0%	$ -	0.0%	$ -
13		0.00%	$ -	0.0%	$ -	0.0%	$ -
14		0.00%	$ -	0.0%	$ -	0.0%	$ -
15		0.00%	$ -	0.0%	$ -	0.0%	$ -
16		0.00%	$ -	0.0%	$ -	0.0%	$ -
17		0.00%	$ -	0.0%	$ -	0.0%	$ -
18		0.00%	$ -	0.0%	$ -	0.0%	$ -
19		0.00%	$ -	0.0%	$ -	0.0%	$ -
20		0.00%	$ -	0.0%	$ -	0.0%	$ -
	TOTAL	100.00%	$ 285,071		$ 26,433		$ 258,639

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Green text is updated ever quarter

Black text is automatically updated or static

Project Objectives:

The objective of NJDOT 2008-01, *Warm Pavement Technology*, is to evaluate the different facets of warm mix asphalt production and performance for future use by the New Jersey Department of Transportation (NJDOT). An assessment of available warm mix additives/technologies will be conducted to provide NJDOT with preliminary recommendations for future use. The assessment will be based on Literature Reviews/Interviews, as well as a detailed laboratory and field research program detailed in this research proposal. This includes critical factors during the laboratory mixture design, as well as critical factors during the production and placement of warm mix asphalt. The research project will also evaluate the potential end uses of warm mix asphalt. This includes the typical use in structural pavements, as well as the potential use for pothole/maintenance mixes that could be used for long haul/long dwell time projects.

Project Abstract:
The research proposal is broken down into a Literature Search and nine major tasks. The research team will evaluate possible modifications to mixture design and analysis procedures for warm mix asphalt. This will be conducted through a literature search and interview process and then using laboratory experiments that address critical areas where hot and warm mix asphalt differ significantly. This includes limits to aggregate moisture, procedure for the selection of WMA and dosage rate, specimen fabrication, binder grade selection, and recycled asphalt materials (RAP). A sensitivity study to provide recommendations as to which WMA's are preferred, as well as to assess the affects of mixture volumetrics after compaction in the gyratory compactor will provide guidance to warm mix additive selection and expected issues with the Superpave volumetric design when using these additives. It is also proposed that a warm mix test trial, designed based on recommendations from the research study, be included as a validation/verification task. It is important to include the field study so a proper comparison can be verified between laboratory and field produced materials. An Implementation Plan at the conclusion of the study will provide a 1-Day Workshop regarding the use of Warm Mix Additives. The workshop will provide procedures and recommendations for warm mix additive selection, mixture design, and quality control procedures. The workshop will be conducted in the state or the art lecture hall facility at CAIT.

1. Progress this quarter by task:

Task 1 – Mobilization (100% Completed)

Mobilization for the project has been completed.

Task 2 – Literature Review (100% Completed)

The Feasibility/Literature Review was submitted to the NJDOT for view and comments and was eventually accepted. The technical working group (TWG) then gave the official OK to continue with the testing program.

Task 3 – Influence of Aggregate Moisture Content (100% Completed)

Task 3 was completed this Quarter and the analysis is being finalized. In summary, the test results indicate that moisture sensitivity (stripping potential) may be an issue when production temperatures are reduced to approximately 270F. This is due to residual moisture remaining in the aggregates from lack of drying. The test results showed:

Hamburg Wheel Track Testing

- Greater levels of stripping potential were found for the higher absorptive aggregates (1.47%) than in the lower absorptive aggregates (0.61%). The worst performing mix, which showed stripping almost immediately, was the higher absorptive aggregate mix at the 270F temperature. This occurred at both the 3% and 6% aggregate blend moisture level.

Tensile Strength Ratio (TSR)

- TSR showed an immediate decrease unless the samples were dry and mixing at a temperature at 315F. A reduction in mixing temperature or the inclusion of moisture reduced the TSR value by over 25%. This data has only been analyzed to date using the lower absorptive aggregates. Analysis is on-going for the higher absorptive aggregates and should be available for presentation.

Task 4 – Compactibility of Different WMA's (100% Completed)

Based on the Feasibility Study and new technologies introduced to New Jersey (REVIX), the Compactibility Study has been slightly modified. The study will mainly focus on preblended warm mix additives (Rediset, Sasobit, and REVIX) at different percentages. A number of factors will be evaluated to measure workability/compactibility;

- Casola Method (NCHRP Project 9-39, *Procedures for Determining Mixing and Compaction Temperatures of Asphalt Binders in Hot Mix Asphalt*) for determining mixing and compaction temperatures of binder modified with the warm mix additives;
- Rotational Viscosity (current standard for Superpave) for determining mixing and compaction temperatures of the binder modified with the warm mix additives;
- Thin-film rheology – recently introduced to asphalt with the work by Gerry Reinke at Mathy Construction, Thin-Film Rheology gives an indication of the lubrication that occurs between aggregates (i.e. – higher the lubrication, the better compaction).
- University of Massachusetts Workability Device – the workability is measured as a function of temperature and torque resistance during mixing. Unlike the previous two tests, this test is conducted on the mixture itself.
- Marshall Compaction Hammer – constant energy is applied to the mix through a constant weight falling at a constant height to a known number of blows. Previous work by Rutgers University has shown the Marshall Hammer to be sensitive enough to temperature/workability to pick up the influence of warm mix additives.
- Gyratory Compaction – used as a baseline for comparison.

Testing has been completed for the Massachusetts Workability Device, Marshall and Gyratory compaction. The test results are shown below.

At the moment, the Casola Method for mixing and compaction temperatures, is not applicable to warm mix asphalt. Simply, this is due to the equations developed for the analysis. Each equation, mixing or compaction temperature, incorporates a minimum production or compaction temperature that increases as the phase angle of the asphalt binder increases. Unfortunately, the minimum temperatures set in the equations are higher than typical warm mix production temperatures. Therefore, it is recommended that the Casola Method from NCHRP Project 9-39 not be used for asphalt binders containing warm mix additives (i.e. – Rediset, Sasobit, Evotherm 3G).

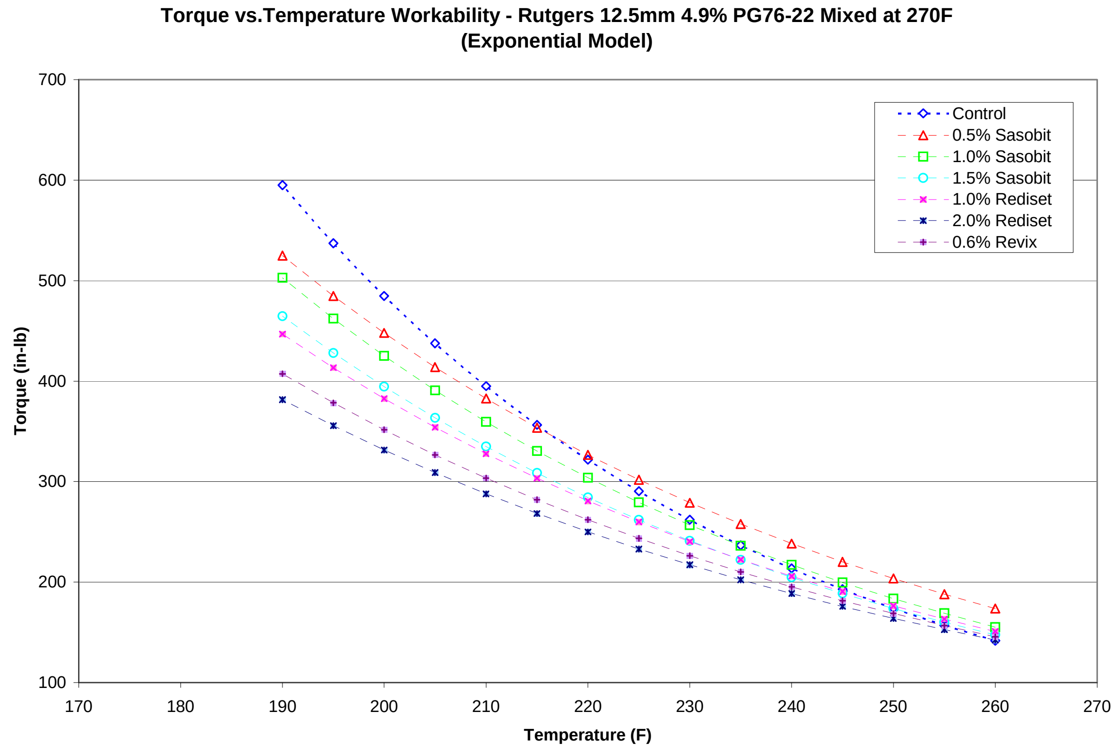

Figure 3 – University of Massachusetts Workability Device Results

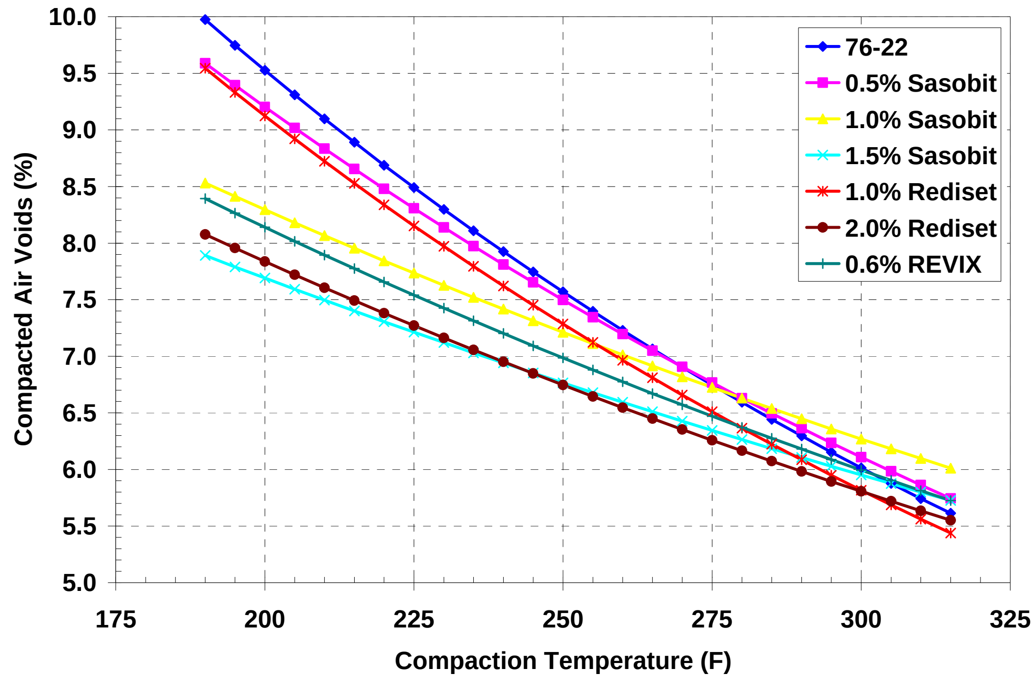

Figure 4 – Compacted Air Voids vs Compaction Temperature – Marshall Compaction

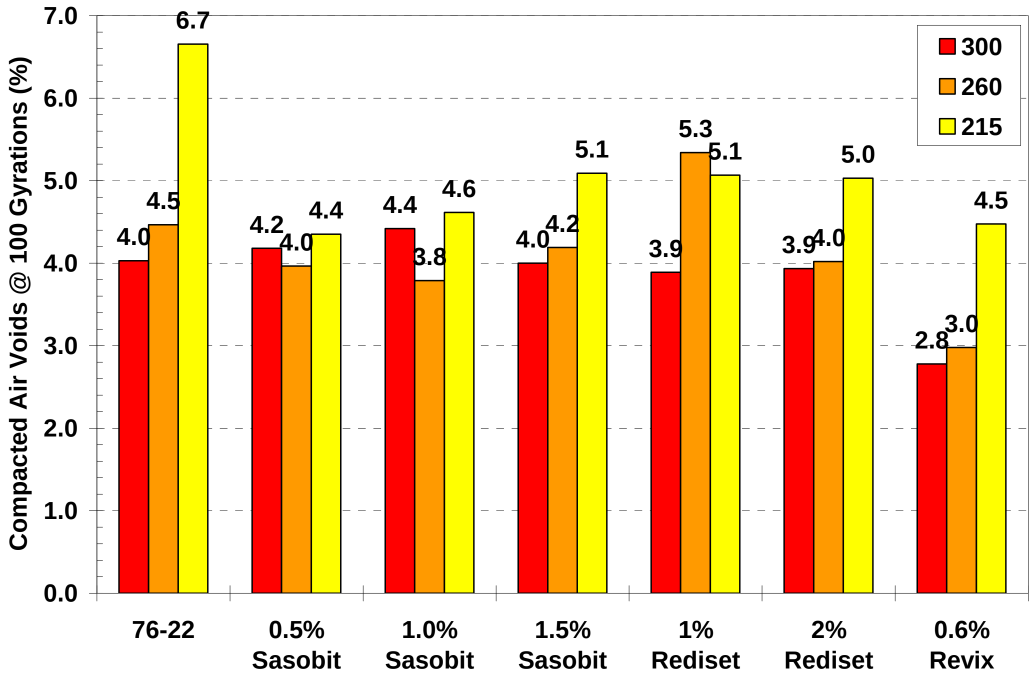

Figure 5 – Compacted Air Voids at Different Compaction Temperatures

The compactibility of the mixture results appears to show differences in ranking depending on the method. Both the UMass Workability Device and the Marshall Compactor show reasonable and logical rankings of the workability/compactibility of the different warm mix additives. A general ranking of the results is shown in Table 1.

Table 1 – Ranking of Warm Mix Additives

	UMass Workability Device		
Best	270F Mixing Temp	320F Mixing Temp	Marshall Compactor
↑	0.6% REVIX	2% Rediset	1.5% Sasobit
	2% Rediset	0.6% REVIX	2% Rediset
	1% Rediset	1% Rediset	0.6% REVIX
	1.5% Sasobit	1.5% Sasobit	1.0% Sasobit
	1.0% Sasobit	1.0% Sasobit	1.0% Rediset
	0.5% Sasobit	0.5% Sasobit	0.5% Sasobit
↓	PG76-22	PG76-22	PG76-22
Worst			

The test results from Table 1 indicate that using the Marshall Compactor at different compaction temperatures provides similar rankings to the UMass Workability Device.

Data analysis from the Thin-Film Rheology is being completed and Rutgers is awaiting the test results. Specialized testing conducted by Gerry Reinke at Mathy Construction in Wisconsin.

Task 5 – Laboratory Specimen Preparation Procedure (50% Completed)

Laboratory testing for the specimen preparation has completed, however, asphalt binder testing required for verification has yet to be finished. It is anticipated that the subcontractor for the asphalt binder testing should have the testing completed by the end of December/beginning of January.

Task 6 – Asphalt Binder Selection (100% Completed)

Information was provided to Rutgers regarding a proposed compaction temperature limit that is based on the Aging Ratio of the asphalt binder, where the aging ratio is defined at G^*_{RTFO}/G^*_{Orig}. After receiving this information, Rutgers contacted both SemMaterials and NuStar, the two most prominent asphalt binder manufacturers in New Jersey, to obtain the general Aging Ratio information for various asphalt binder grades produced by the refineries. A table of the recommended lower limit for compaction temperature without the need to bump the binder grade has been generated and will be presented at the Quarter Meeting. This proposed table will be evaluated in the laboratory using the Asphalt Pavement Analyzer and Flow Number.

Dynamic Modulus testing showed that on average (i.e. – average for all materials and loading frequencies per temperature):

- 4^{o}C Test Temperature
  - No stiffness reduction found at 270F mixing temp
  - 14% reduction in stiffness at 230F mixing temp
- 20^{o}C Test Temperature
  - 5% reduction found at 270F mixing temp
  - 23% reduction found at 230F mixing temp
- 45^{o}C Test Temperature (Rutting Conditions)
  - 16% reduction found at 270F mixing temp
  - 42% reduction found at 230F mixing temp
- Testing softer binders (PG70-22 and PG64-22) indicated that:
  - 30 to 35% reduction in dynamic modulus at 45^{o}C equivalent to dropping from PG76 to PG70-22
  - 45 to 50% reduction in dynamic modulus at 45^{o}C equivalent to dropping from PG76 to PG64-22

The dynamic modulus testing clearly showed that as production temperature decreases, the overall stiffness of the asphalt mixture decreases due to the general aging that occurs in the asphalt binder. At test temperatures of 4 and 20°C, the amount of stiffness reduction was found to be minimal. However, reduction in mixture stiffness at intermediate and low temperatures commonly results in greater fatigue resistance, which is obviously not detrimental to the asphalt mixture. At 45oC, which would be the test temperature more critical for rutting resistance, the reduction in production temperature has a dramatic affect on stiffness. Although their exists only a 16% stiffness reduction when reducing production temperatures from 315 to 270F, at production temperatures of 230F, an average of 42% stiffness reduction was measured. When comparing this to the softer asphalt binders tested (i.e. – PG70-22 and PG64-22), a 42% reduction is equivalent to dropping the PG binder by almost 2 grades (i.e. – dropping from PG76-22 to PG64-22).

Flow Number measurements, as determined during the Repeated Load test, indicated that on average:

- A 30% decrease in the Flow Number was found when decreasing the mixing/compaction temperature from 315F to 270F
- A 60% decrease in the Flow Number was found when decreasing the mixing/compaction temperature from 315F to 230F
- Testing softer binders (PG70-22 and PG64-22) indicated that:
  - 60% reduction in Flow Number equates to 1 drop in PG grade (from 76-22 to 70-22)
  - 80% reduction equates to a 76-22 dropping to a 64-22

Similar to the Dynamic Modulus testing, the Repeated Load results showed the influence of production temperature reduction to permanent deformation.

The laboratory results were then compared to plant produced materials that were collected and tested. To compare equally across the board, the reduction in performance (dynamic modulus or Flow Number) was compared to the reduction in production temperature (normal production temperature to warm mix production temperature). The results are shown in Figures 1 and 2. It should also be noted that all plant produced projects had RAP included, with the I78 project actually containing 25% RAP. The plant produced mixes are in line with the laboratory produced mixes, confirming that regardless of mixture type, it is the change in production temperature that influences the mixture stiffening. Based on this concept, it was recommended to NJDOT to limit the "reduction of production temperature" to 55oF in order to maintain the specified PG grade performance. In most cases, this results in limiting the production temperature to a minimum of 260°F.

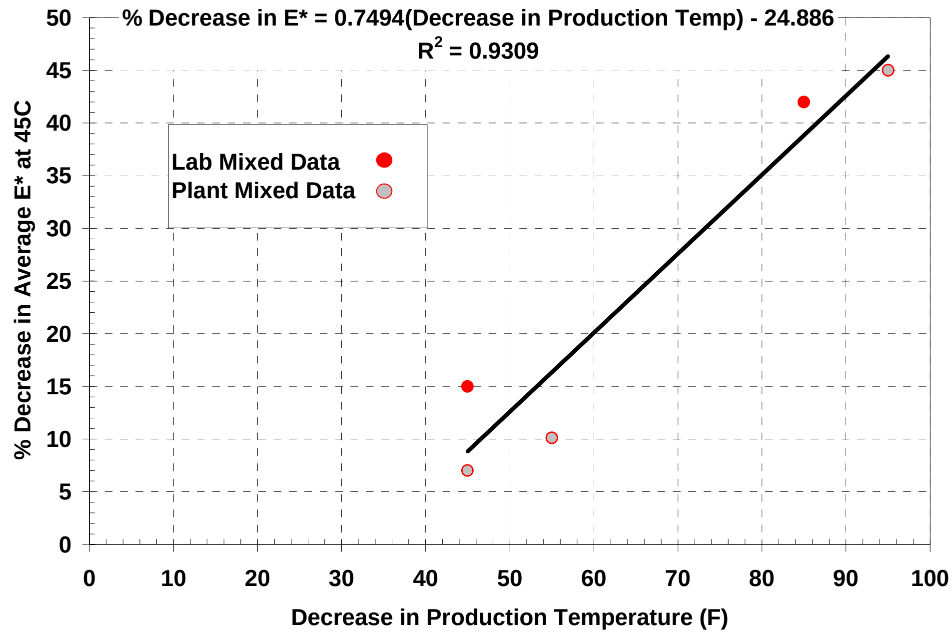

Figure 1 – Decrease in Dynamic Modulus vs Decrease in Production Temperature

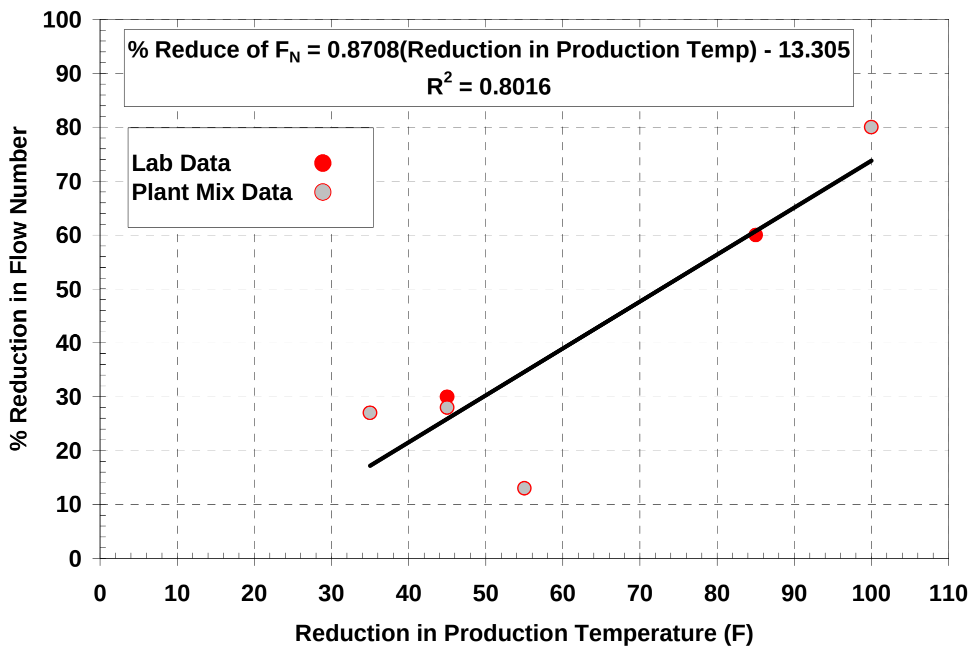

Figure 2 – Decrease in Flow Number vs Decrease in Production Temperature

Task 7 – Use of Higher RAP Percentages (50% Completed)

Preliminary testing had been recommended to NJDOT to evaluate how RAP in WMA will affect the final properties. Dynamic modulus testing of compacted asphalt samples were used to construct master stiffness curves, as well as used to "backcalculate" the asphalt binder stiffness. Asphalt binder was also extracted and recovered and tested under a frequency sweep at different test temperatures to create a master stiffness curve. The idea behind this testing is that the closer the predicted curve is to the actual, the more blending between the RAP and the virgin asphalt binder is occurring. The further apart the curves are, the less blending that is taking place.

Figure 3 shows developed asphalt binder master stiffness curves a PG76-22 with 0.8% Sasobit that was placed on Rt 38 and produced at 315°F. The mix was a 9.5H76 with 15% RAP. Figure 3 indicates that the predicted and measured curves are close, although they do not necessarily match. This would indicate that some blending occurs between the virgin and RAP binder, but not 100%. Figure 4 shows the same mix, but produced at 270°F. The curves are much farther apart in Figure 4 than in Figure 3, where the production temperature was 45°F higher. This is an indication that there was even less blending between the virgin and RAP binders. Although at the moment it is not understood exactly why, but it is hypothesized that the lower productions attributed to lower amount of RAP binder being mobilized and blended.

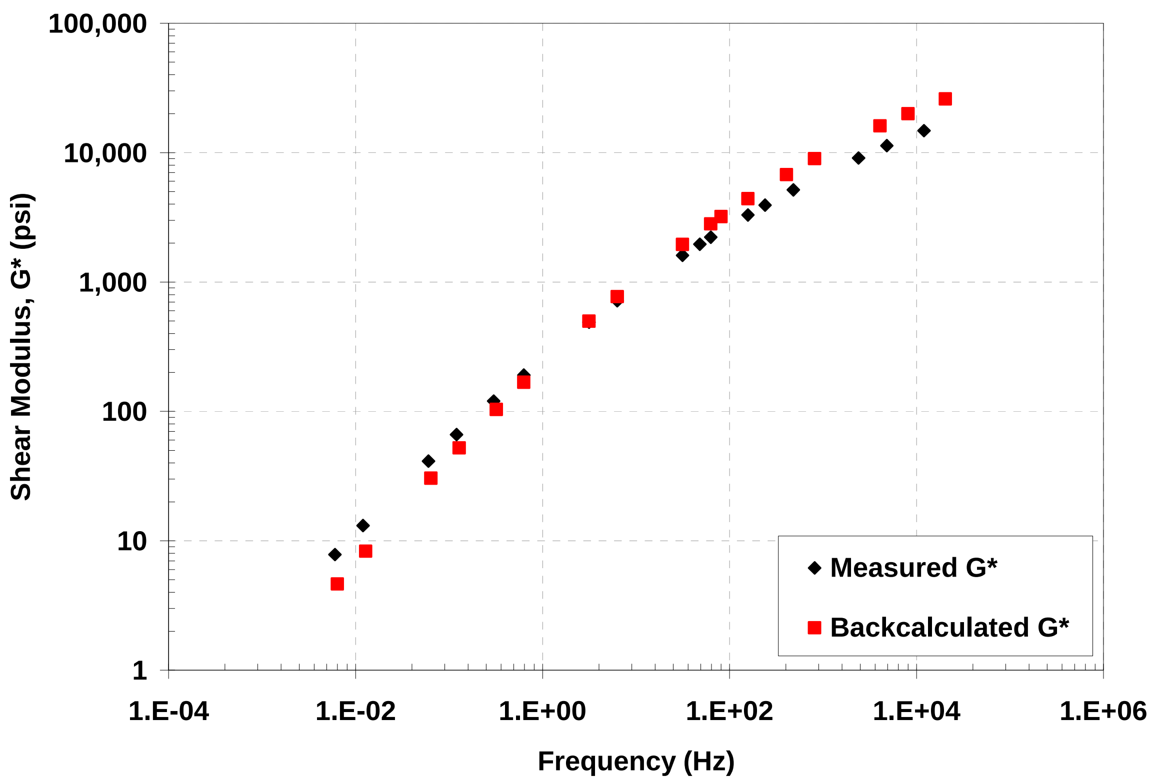

Figure 3 – Predicted and Measured G* for Rt 38 9.5H76 – 315°F Production Temperature

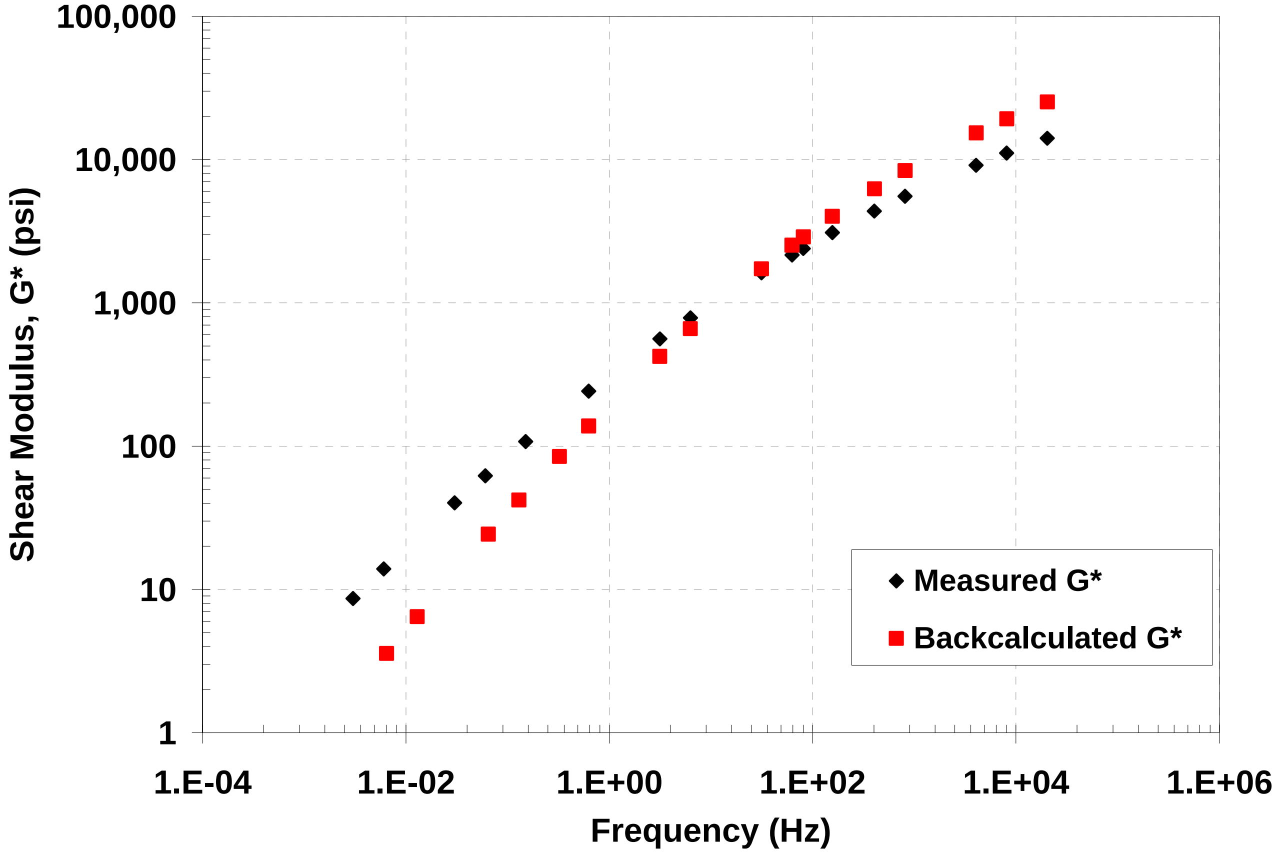

Figure 4 – Predicted and Measured G* for Rt 38 9.5H76 – 270°F Production Temperature

Similar to Task 5, the asphalt binder testing required to complete this phase has yet to be completed. It is anticipated that the binder testing should be completed by the end of December/beginning of January.

Task 8 – Field Trials (100% Completed)

An additional field trial was conducted using the Evotherm 3G product with an asphalt rubber open-graded friction course (AR-OGFC) mix. Although performance testing has yet to be completed, emission testing was conducted using a portable emissions tester mounted onto the paver. The location of the emissions tester was placed in an area that would represent the general area where personnel are during a paving operation (Figure 5). Emissions data is still being reduced, but Figure 6 shows a plot of measured Hydrocarbons vs Time and Temperature. The test results clearly indicate a reduction in Hydrocarbons as production temperatures decrease. This is consistent with the general findings and visual observations to date.

Figure 5 – Emissions Tester Mounted on Paver

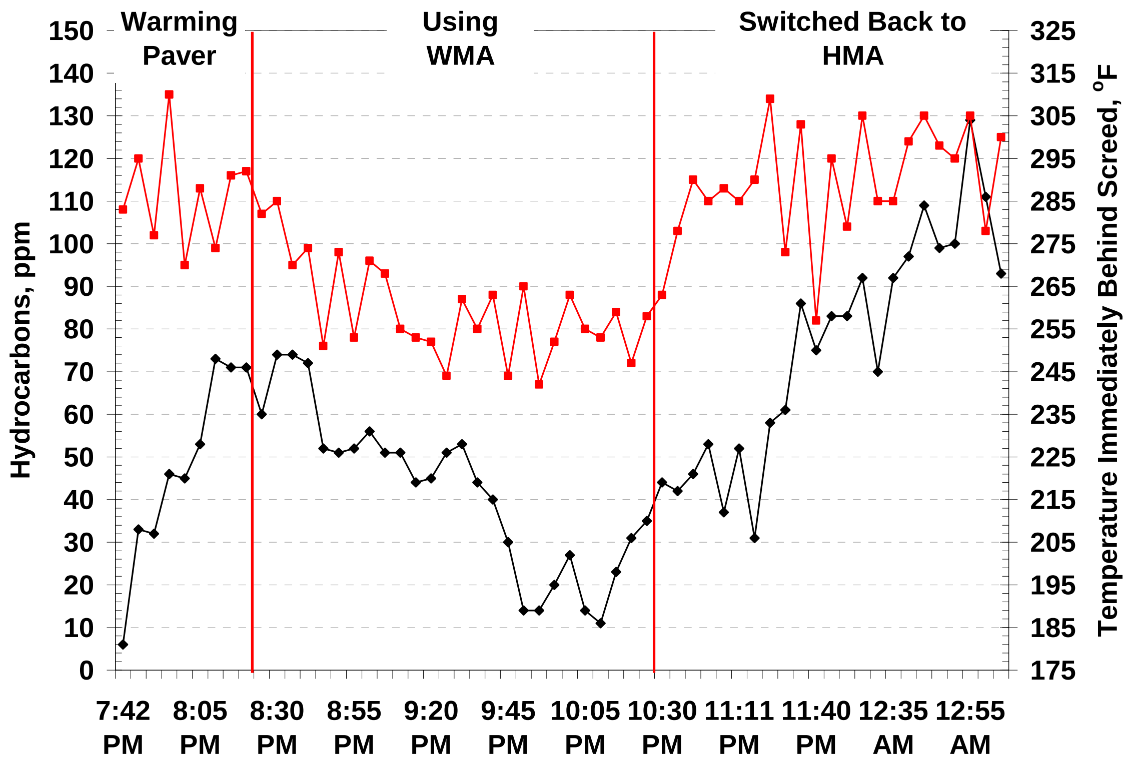

Figure 6 – Measured Hydrocarbon vs Time and Temperature

2. Proposed activities for next quarter by task:

Asphalt binder testing required to complete the analysis in Tasks 5 and 7 will be conducted and should be completed. However, this will not allow for the submission of a final report at the scheduled due date of December 31st, 2009. Therefore, CAIT will be requesting a 6 month No Cost Extension so the remaining asphalt binder testing can be completed, as well as the necessary analysis and report writing.

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

4. Progress on Implementation and Training Activities:

5. Problems/Proposed Solutions:

Year 1 Budget	$166,385
Years 1 & 2 Cumulative Budget	$285,071
Years 1, 2 & 3 Cumulative Budget	
Total Project Budget	$ 285,071
Modified Contract Amount:	
Total Project Expenditure to date	$ 258,639
% of Total Project Budget Expended	90.73%

NJDOT Research Project Manager Concurrence: ___________________________ Date: ________