TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): New Hampshire DOT

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(230)	**Transportation Pooled Fund Program - Report Period:** ■ Quarter 1 (January 1 – March 31) ☐ Quarter 2 (April 1 – June 30) ☐ Quarter 3 (July 1 – September 30) ☐ Quarter 4 (October 1 – December 31)
Project Title: **Evaluation of Plant-Produced High-Percentage RAP Mixtures in the Northeast**	

Name of Project Manager(s): **Jo Sias Daniel**	**Phone Number:** **603-862-3277**	**E-Mail** jo.daniel@unh.edu
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:** **8/11/2010**
Original Project End Date: **12/31/2013**	**Current Project End Date:** **12/31/2013**	**Number of Extensions:** **0**

Project schedule status:

☐ On schedule ☐ On revised schedule ☐ Ahead of schedule ■ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
781,706	417,705	47%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	84,841	

Project Description:

Research Objectives

The objectives of this research project are to:

1. Evaluation the performance in terms of low temperature cracking, fatigue cracking, and moisture sensitivity of plant produced RAP mixtures in the laboratory and field.
2. Establish guidelines on when it is necessary to bump binder grades with RAP mixtures.
3. Provides further understanding of the blending that occurs between RAO and virgin binder in plant-produced mixtures.
4. Refine fatigue failure criteria for RAP mixtures that can be used in the simplified Viscoelastic Continuum Damage (S-VECD) model.

Research Plan

The research plan is broken down into two phases. Phase I will focus on evaluating the effects of binder grade and plant type on the properties of mixtures with various percentages of RAP. Phase II of the study will be geared towards evaluating the fatigue failure criteria in the S-VECD model.

The following tasks will be required to achieve the research objectives for both phases of this project:

1. Producing Plant Mixtures.
2. Testing and Analysis of Asphalt Binders and Mixtures.
3. Construction and Evaluation of Field Test Sections.
4. Reporting.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

The structure of the database for the project has been finalized.

Five tables showing the up-to-date status of all the binder, mixture and field cores testing is presented in Appendix A

In this quarter, four controlled crosshead (CX) fatigue tests were done on the primary mixture of the project (VTe30LC-Core Core Mix). Gauge length of 70 mm was used for two of them, while the other two had a gauge length of 100 mm. Testing was conducted with two different inputs (aiming 1000 and 10000 cycles of failure) at 20°C and C versus S characteristic curves were compared. All four curves collapsed well among each other and also collapsed reasonably with other CX fatigue tests that had been done on this mixture using AMPT, so a gauge length of 100 mm was selected for continuing the CX fatigue testing on the MTS.

During this quarter, all CX fatigue testing for two of the mixtures (VTe00LC-Core Mix and VTe40LC-Core Mix) were completed. The CX fatigue testing for the other mixtures will be continued in the next quarter using the MTS.

Anticipated work next quarter:

The database will be populated with the Phase I testing data.

A. Binder Testing

All the binder testing relative to the Phase I binders will be completed

The testing data will be accordingly reduced and analyzed

B. Mixture Testing

Continued testing and analysis of Phase II mixtures.

Conclusion of the silo storage testing program

Additional mixtures from 2012 construction season will be gathered

Significant Results:

Results from Dynamic Modulus testing of the New York plant-compacted silo storage mixtures are presented in Appendix B

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

In the previous quarter, the unexpected behavior of the loading waveforms prevented NCSU from using the AMPT for controlled crosshead (CX) fatigue testing and the testing had to be switched to the MTS machine, but before this change could happen, a proper LVDT gauge length had to be determined. For having consistency between all projects that are using the MTS, using a gauge length of 100 mm was preferable, which was different from the gauge length of 70 mm that had been used for AMPT specimens in the beginning of the project. A gauge length study on |E*| testing previously had been done in the research group and the results showed no obvious difference between 70 and 100 mm gauge lengths, but a similar study on controlled crosshead (CX) fatigue testing was needed.

The pooled fund contributions are $150,000 below the original budgeted amount due to issues with FHWA procuring funds for this project. FHWA will be requesting funds for the upcoming FY to contribute to the project. UNH is working with NHDOT to develop an alternate budget and scope for the project in the event the funds are not secured.

Potential Implementation:

APPENDIX A

Phase I and Phase II Current Testing Status

(Binder, Mixtures and Field Cores)

Table A1. Phase I Binder and Aggregate Testing Status

Binder and Aggregate Testing																							
Test Description		Responsible Lab.	New York Mixtures							New Hampshire Mixtures					Vermont Mixtures								
			NYd00	NYd20	NYd30	NYd40	NYb30	NYb40	RAP	NHe00	NHe20	NHe30	NHe40	RAP	VTe00	VTe20	VTe30	VTe40	VTa00	VTa20	VTa30	VTa40	RAP
Binder Extraction and Recovery from Mixtures		Pike Ind.	Done	Done	Done	Done	Done	Done	In Progress	Done	Done	Done	Done	In Progress	Done	Done	Done	Done	Done	Done	Done	Done	In Progress
PG - grading (Including Critical Cracking Temp.)	Virgin Binders (Tank Supplied)	Rutgers	Done				Done		N/A	Done				N/A	Done				Done				N/A
	Ext.&Rec. Binders		Done	Done	Done	Done	Done	Done	In Progress	Done	Done	Done	Done	Not Started	Done	Done	Done	Done	Done	Done	Done	Done	In Progress
(ABCD) Asphalt Binder Cracking Device	Virgin Binders (Tank Supplied)	U-Mass	Done				Done		N/A	Done				N/A	Done				Done				N/A
	Ext.&Rec. Binders		Done	Done	Done	Done	Done	Done	Not Started	Done	Done	Done	Done	Not Started	Done	Done	Done	Done	Done	Done	Done	Done	Not Started
Binder Modulus (G*) & Binder Master Curve	Virgin Binders (Tank Supplied)	U-Mass	Done				Done		N/A	Done				N/A	Done				Done				N/A
	Ext.&Rec. Binders		Done	Done	Done	Done	Done	Done	In Progress	Done	Done	Done	Done	Not Started	Done	Done	Done	Done	Done	Done	Done	Done	In Progress
AASHTO T53 (Softening Point)	Virgin Binders (Tank Supplied)	Rutgers	N/A				N/A		N/A	N/A				N/A	N/A				N/A				N/A
	Ext.&Rec. Binders		N/A	N/A	N/A	N/A	N/A	N/A	In Progress	N/A	N/A	N/A	N/A	Not Started	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	In Progress

Table A2. Phase I Mixture Testing Status

Mixture Testing																				
Test Description		Responsible Lab.	New York Mixtures						New Hampshire Mixtures				Vermont Mixtures							
			NYd00	NYd20	NYd30	NYd40	NYb30	NYb40	NHe00	NHe20	NHe30	NHe40	VTe00	VTe20	VTe30	VTe40	VTa00	VTa20	VTa30	VTa40
Dynamic Modulus (AMPT)	Lab Fabricated	Rutgers	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done
	Plant Compacted		Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done
Push-Pull Fatigue Test (S-VECD)	Lab Fabricated	UNH	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done
	Plant Compacted	UNH	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done
Low Temp. Creep Compliance and Strength	Lab Fabricated	UNH	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done
AASHTO T283 (Moisture Damage)	Lab Fabricated	UNH	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done
HWTD (Hamburg Wheel Tracking Device)	Lab Fabricated	U-Mass	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done
Overlay tester	Lab Fabricated	Rutgers	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done
TSRST	Lab Fabricated	U-Mass	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done
Flexural Beam Fatigue	Lab Fabricated	Rutgers	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done
U-Mass Dartmouth Workability		U-Mass	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done

Table A3. Phase II Binder and Aggregate Testing Status

	Binder and Aggregate Testing																								
	Test Description		Responsible Lab.	New Hampshire Mixtures							Virginia Mixtures					New York Mixtures									
				NHb00	NHb15	NHb25	NHa25	NHa30	NHa40	RAP	VAf00	VAf20	VAd30	VAd40	RAP	NYd00,0.0	NYd00,2.5	NYd00,5.0	NYd00,7.5	NYd25,0.0	NYd25,2.5	NYd25,5.0	NYd25,7.5	NYd25,10.0	RAP
Binder and Aggregate Testing	Binder Extraction and Recovery from Mixtures		Pike Ind.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started
	Binder Extraction and Recovery from Mixtures		FHWA	Done	Done	Done	Done	Done	Done	Done	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	PG - grading (Including Critical Cracking Temp.)	Virgin Binders (Tank Supplied)	Rutgers	N/A							In Progress				N/A	Not Started				Not Started					N/A
		Ext.&Rec. Binders		N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started
	PG - grading (Including Critical Cracking Temp.)	Virgin Binders (Tank Supplied)	FHWA	Done							In Progress				N/A	N/A				N/A					N/A
		Ext.&Rec. Binders		Done	Done	Done	Done	Done	Done	Done	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	(ABCD) Asphalt Binder Cracking Device	Virgin Binders (Tank Supplied)	U-Mass	N/A							Not Started				N/A	Not Started				Not Started					N/A
		Ext.&Rec. Binders		N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started
	Binder Modulus (G*) & Binder Master Curve	Virgin Binders (Tank Supplied)	U-Mass	N/A							Not Started				N/A	Not Started				Not Started					N/A
		Ext.&Rec. Binders		N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started
	Binder Modulus (G*) & Binder Master Curve	Virgin Binders (Tank Supplied)	FHWA	Done							N/A				N/A	N/A				N/A					N/A
		Ext.&Rec. Binders		Done	Done	Done	Done	Done	Done	Done	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	AASHTO T53 (Softening Point)	Virgin Binders (Tank Supplied)	Rutgers	N/A							N/A				N/A	N/A				N/A					N/A
		Ext.&Rec. Binders		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Started	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Started

Table A4. Phase II Mixture Testing Status

Mixture Testing																					
Test Description		Responsible Lab.	New Hampshire Mixtures						Virginia Mixtures				New York Mixtures								
			NHb00	NHb15	NHb25	NHa25	NHa30	NHa40	VAf00	VAf20	VAd30	VAd40	NYd00,0.0	NYd00,2.5	NYd00,5.0	NYd00,7.5	NYd25,0.0	NYd25,2.5	NYd25,5.0	NYd25,7.5	NYd25,10.0
Dynamic Modulus (AMPT)	Lab Fabricated	Rutgers/UNH	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	In Progress	In Progress	In Progress	In Progress	Done	Done	Done	Done	In Progress	In Progress	In Progress	In Progress	In Progress
	Plant Compacted		Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Done	Done	Done	Done	Done	Done	Done	Done	Done
Dynamic Modulus (AMPT)	Plant Compacted	FHWA	Done	Done	Done	Done	Done	Done	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dynamic Modulus (IDT)	Lab Fabricated	UNH	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started
	Plant Compacted		Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started
Push-Pull Fatigue Test (S-VECD)	Lab Fabricated	UNH	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started
	Plant Compacted		Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started
Low Temp. Creep Compliance and Strength	Lab Fabricated	UNH	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started
	Plant Compacted		Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started
Overlay tester	Lab Fabricated	Rutgers	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress
TSRST	Lab Fabricated	U-Mass	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started
Flexural Beam Fatigue	Lab Fabricated	Rutgers	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress	In Progress
HWTD (Hamburg Wheel Tracking Device)	Lab Fabricated	U-Mass	Done	Done	Done	Done	Done	Done	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started
	Plant Compacted		Done	Done	Done	Done	Done	Done	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table A5. Phase II Field Cores Testing Status

Field Cores Testing																				
Test Description	Responsible Lab.	New Hampshire Mixtures						Virginia Mixtures				New York Mixtures								
		NHb00	NHb15	NHb25	NHa25	NHa30	NHa40	VAf00	VAf20	VAd30	VAd40	NYd00,0.0	NYd00,2.5	NYd00,5.0	NYd00,7.5	NYd25,0.0	NYd25,2.5	NYd25,5.0	NYd25,7.5	NYd25,10.0
Dynamic Modulus (IDT)	UNH	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Low Temp. Creep Compliance and Strength	UNH	Not Started	Not Started	Not Started	Not Started	Not Started	Not Started	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

APPENDIX B

Silo Storage Dynamic Modulus and Phase Angle Results

(NY Mixtures – 0, 2.5, 5, 7.5 and 10hrs)

Results from dynamic modulus testing on plant-compacted mixtures as part of the New York silo storage study (Phase II) are presented in this section. Nine mixtures were tested using the Asphalt Mixture Performance Tester (AMPT) at temperatures of 4.4°C, 21.1°C, and 37.8°C and frequencies of 25 Hz, 10 Hz, 5 Hz, 1 Hz, 0.5 Hz, and 0.1 Hz. Three replicate specimens were tested for each mixture, individual specimen master curves were constructed, and an overall average master curve fit for each mixture. Tables 1 and 2 show the measured air void contents for each test specimen.

Table 1 NY silo storage air voids for virgin plant-compacted dynamic modulus specimens

Specimen	Air Void	Average Air Void
0RAP, 0 hr		
NYd00PH02-00	6.6	6.8
NYd00PH06-00	6.7	
NYd00PH08-00	7.0	
0RAP, 2.5 hr		
NYd00PH02-2.5	6.2	6.1
NYd00PH03-2.5	6.5	
NYd00PH06-2.5	5.6	
0RAP, 5 hr		
NYd00PH03-5.0	6.6	6.7
NYd00PH04-5.0	6.8	
NYd00PH07-5.0	6.7	
0RAP, 7.5 hr		
NYd00PH02-7.5	7.1	7.4
NYd00PH07-7.5	7.6	
NYd00PH08-7.5	7.4	

Table 2 NY silo storage air voids for RAP plant-compacted dynamic modulus specimens

Specimen	Air Void	Average Air Void
25RAP, 0 hr		
NYd25PH01-00	6.7	6.6
NYd25PH05-00	6.6	
NYd25PH10-00	6.6	
25RAP, 2.5 hr		
NYd25PH05-2.5	6.8	6.5
NYd25PH07-2.5	6.3	
NYd25PH11-2.5	6.5	
25RAP, 5 hr		
NYd25PH04-5.0	6.4	6.0
NYd25PH08-5.0	6.0	
NYd25PH09-5.0	5.6	
25RAP, 7.5 hr		

NYd25PH02-7.5	5.6	5.8
NYd25PH05-7.5	6.0	
NYd25PH10-7.5	5.8	
25RAP, 10 hr		
NYd25PH03-10	5.3	5.5
NYd25PH07-10	5.7	
NYd25PH09-10	5.5	

Several observations can be made from the average dynamic modulus and phase angle master curves. Figure 1 shows that the dynamic modulus of the virgin mixture does not follow any trend with respect to silo storage time. At low frequencies (high temperatures), the 0 hour virgin mixture exhibits the highest dynamic modulus values, while specimens in the silo for 5.0 and 7.5 hours are the least stiff at this frequency range. At higher frequencies (low temperatures), the 2.5 hour and 0 hour mixtures display the highest dynamic modulus values. The curves also show the 2.5 hour mixture becoming stiffer than the unconditioned at a reduced frequency of about 0.1 Hz. Some of the observed differences may be explained by the differences in air void content; the 2.5 hour specimens have the lowest air void content and therefore a stiffer response is expected whereas the 7.5 hour specimens have the highest air void content and therefore a softer response is expected.

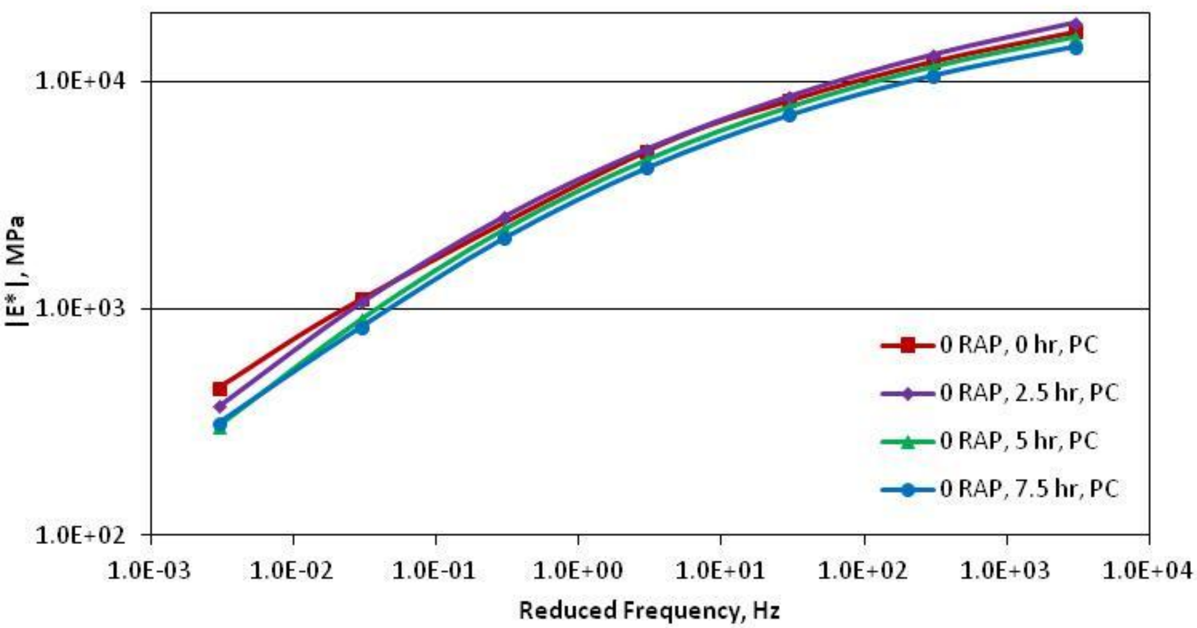

Figure 1(a) NY Silo Storage Dynamic Modulus (0RAP) : log-log scale

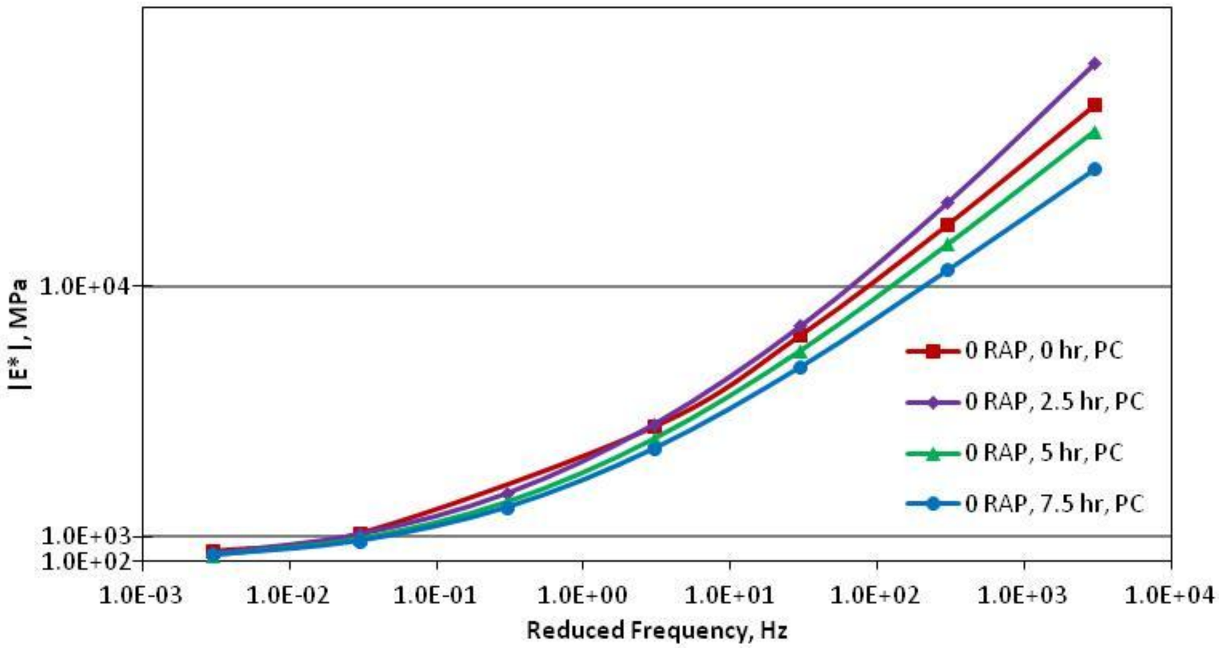

Figure 1(b) NY Silo Storage Dynamic Modulus (0RAP) : semi-log scale

Statistical analysis on the master curves was performed using a t-test (with 95% confidence interval) at a range of reduced frequencies. Table 3 shows the p-values from this analysis with significant differences highlighted. There are significant differences between the 0 hour mixture and the 5 and 7.5 hour mixtures at all frequencies. The 2.5 hour mixture is also significantly different than the 5 and 7.5 hour mixtures at all frequencies.

Table 3 NY silo storage dynamic modulus master curve statistical results for virgin, plant-compacted mixtures

Mixture	Frequency (Hz)	p-value for comparison of mixtures			
		0RAP, 0 hr	0RAP, 2.5 hr	0RAP, 5 hr	0RAP, 7.5 hr
0RAP, 0 hr	300	N/A	0.001	0.007	0.000
	30	N/A	0.062	0.026	0.000
	3	N/A	0.388	0.036	0.000
	0.3	N/A	0.802	0.027	0.000
	0.03	N/A	0.898	0.011	0.000
	0.003	N/A	0.371	0.001	0.000
0RAP, 2.5 hr	300	0.001	N/A	0.000	0.000
	30	0.062	N/A	0.000	0.000
	3	0.388	N/A	0.005	0.000
	0.3	0.802	N/A	0.016	0.000
	0.03	0.898	N/A	0.017	0.000
	0.003	0.371	N/A	0.011	0.001

0RAP, 5 hr	300	0.007	0.000	N/A	0.000
	30	0.026	0.000	N/A	0.006
	3	0.036	0.005	N/A	0.042
	0.3	0.027	0.016	N/A	0.104
	0.03	0.011	0.017	N/A	0.175
	0.003	0.001	0.011	N/A	0.446
0RAP, 7.5 hr	300	0.000	0.000	0.000	N/A
	30	0.000	0.000	0.006	N/A
	3	0.000	0.000	0.042	N/A
	0.3	0.000	0.000	0.104	N/A
	0.03	0.000	0.000	0.175	N/A
	0.003	0.000	0.001	0.446	N/A

Figure 2 shows the dynamic modulus master curves for the 25% RAP mixture. These mixtures show increasing stiffness with silo storage time at all reduced frequencies. The air void contents of the RAP mixtures will not have a significant impact on stiffness variation because they are all within about 1%. The 0 hour and 10 hour specimens have the highest and lowest air void contents respectively, which may contribute to the difference between these two mixtures.

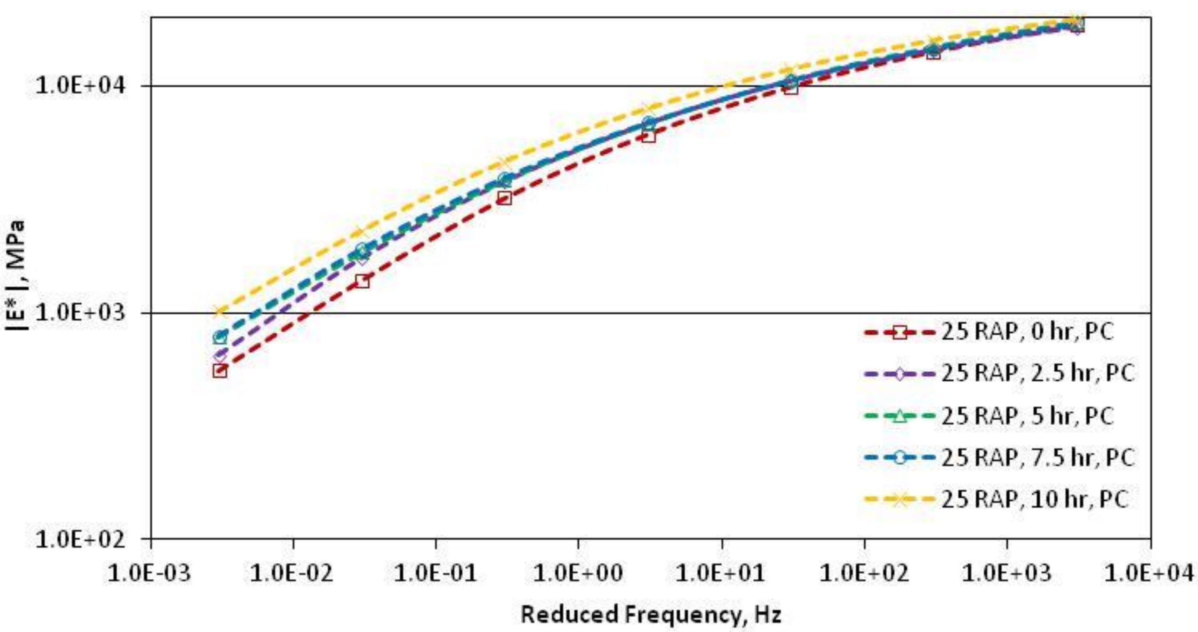

Figure 2(a) NY Silo Storage Dynamic Modulus (25RAP) : log-log scale

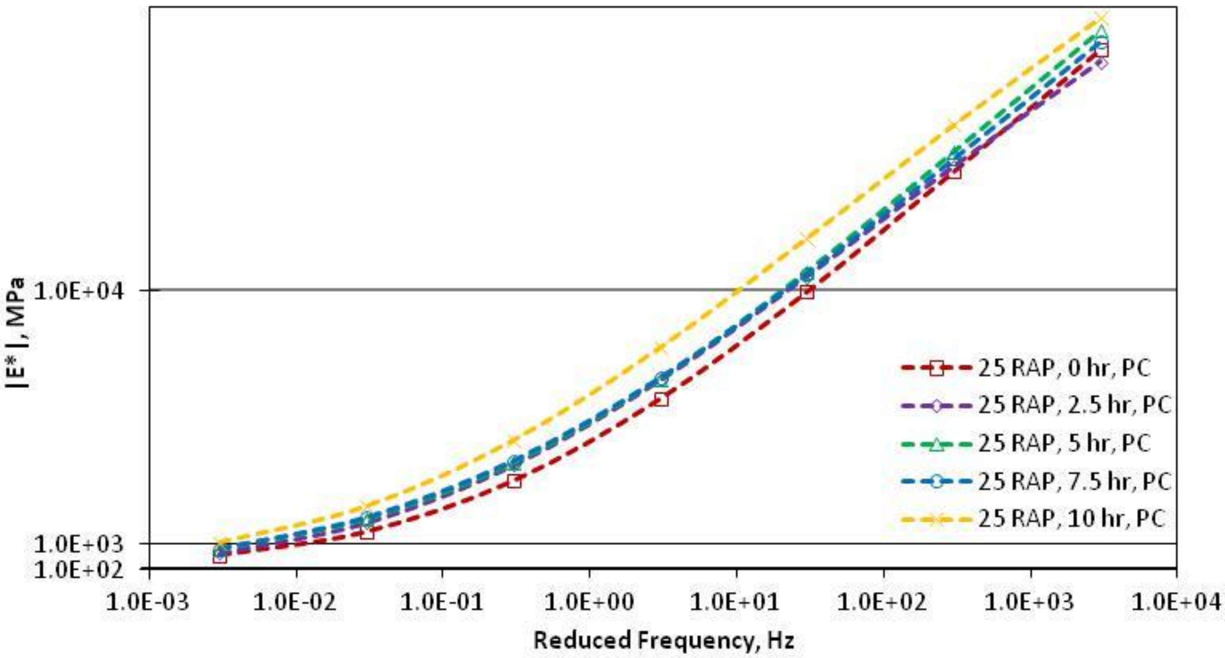

Figure 2(b) NY Silo Storage Dynamic Modulus (25RAP) : semi-log scale

The results of the statistical analysis on the RAP mixtures are shown in Table 3. Statistical significances exist between the 10 hour mixture and all others at all tested frequencies. The 0 hour mixture is significantly different than the 5 hour mixture over the whole frequency range and different from the 2.5 hour and 7.5 hour mixtures at the low frequencies (high temperatures).

Table 3 NY silo storage dynamic modulus master curve statistical results for RAP, plant-compacted mixtures

Mixture	Frequency (Hz)	p-value for comparison of mixtures				
		25RAP, 0 hr	25RAP, 2.5 hr	25RAP, 5 hr	25RAP, 7.5 hr	25RAP, 10 hr
25RAP, 0 hr	300	N/A	0.488	0.034	0.298	0.000
	30	N/A	0.281	0.029	0.109	0.000
	3	N/A	0.032	0.014	0.019	0.000
	0.3	N/A	0.006	0.003	0.001	0.000
	0.03	N/A	0.002	0.000	0.000	0.000
	0.003	N/A	0.002	0.000	0.000	0.000
25RAP, 2.5 hr	300	0.488	N/A	0.004	0.070	0.000
	30	0.281	N/A	0.213	0.555	0.000
	3	0.032	N/A	0.690	0.822	0.000
	0.3	0.006	N/A	0.847	0.651	0.000
	0.03	0.002	N/A	0.598	0.286	0.000
	0.003	0.002	N/A	0.141	0.051	0.000

25RAP, 5 hr	300	0.034	0.004	N/A	0.250	0.043
	30	0.029	0.213	N/A	0.510	0.001
	3	0.014	0.690	N/A	0.859	0.000
	0.3	0.003	0.847	N/A	0.796	0.000
	0.03	0.000	0.598	N/A	0.579	0.000
	0.003	0.000	0.141	N/A	0.588	0.000
25RAP, 7.5 hr	300	0.298	0.070	0.250	N/A	0.001
	30	0.109	0.555	0.510	N/A	0.000
	3	0.019	0.822	0.859	N/A	0.000
	0.3	0.001	0.651	0.796	N/A	0.000
	0.03	0.000	0.286	0.579	N/A	0.001
	0.003	0.000	0.051	0.588	N/A	0.001
25RAP, 10 hr	300	0.000	0.000	0.043	0.001	N/A
	30	0.000	0.000	0.001	0.000	N/A
	3	0.000	0.000	0.000	0.000	N/A
	0.3	0.000	0.000	0.000	0.000	N/A
	0.03	0.000	0.000	0.000	0.001	N/A
	0.003	0.000	0.000	0.000	0.001	N/A

The phase angle master curve for the virgin mixtures (Figure 3) shows that with increased silo storage time, the peak phase angle increases and shifts towards the higher frequencies, indicating that with storage the maximum phase angle will occur at lower temperatures. The phase angle master curves for the 25% RAP mixtures show the opposite trend, as displayed in Figure 4. The slope of the phase angle master curves decrease with increased silo storage time for the RAP mixture, while the virgin mixture does not show a trend. These results indicate that the RAP mixture response becomes more elastic with increased storage time.

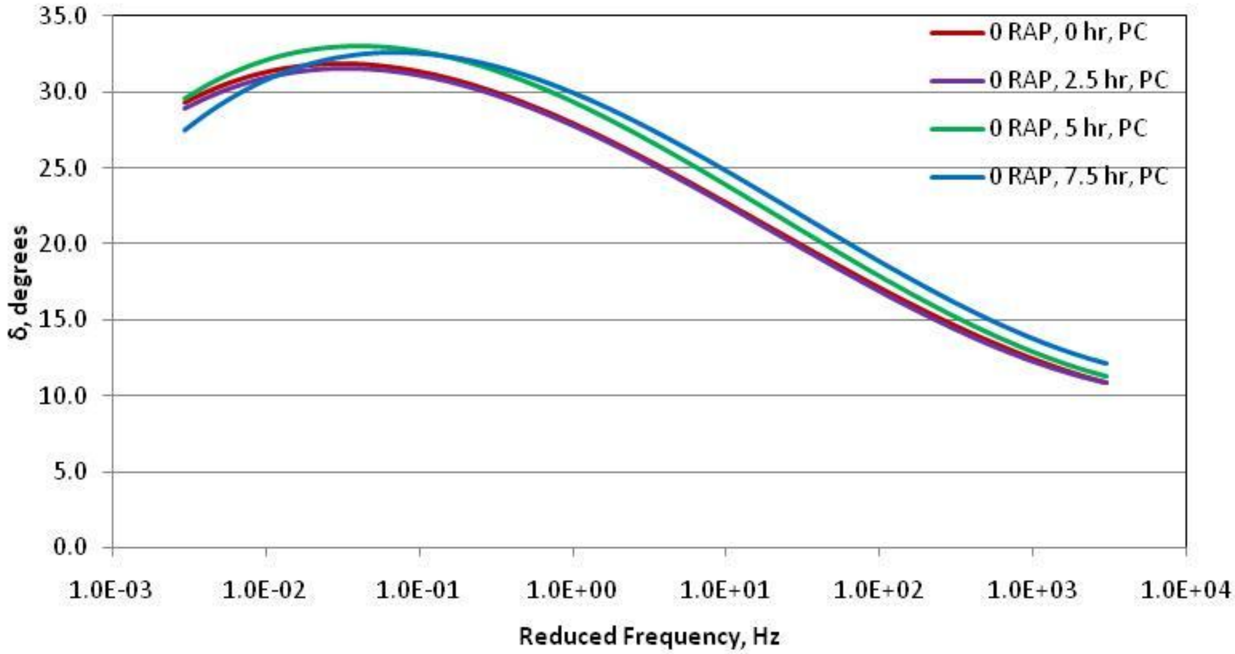

Figure 3 NY Silo Storage Phase Angle (0RAP)

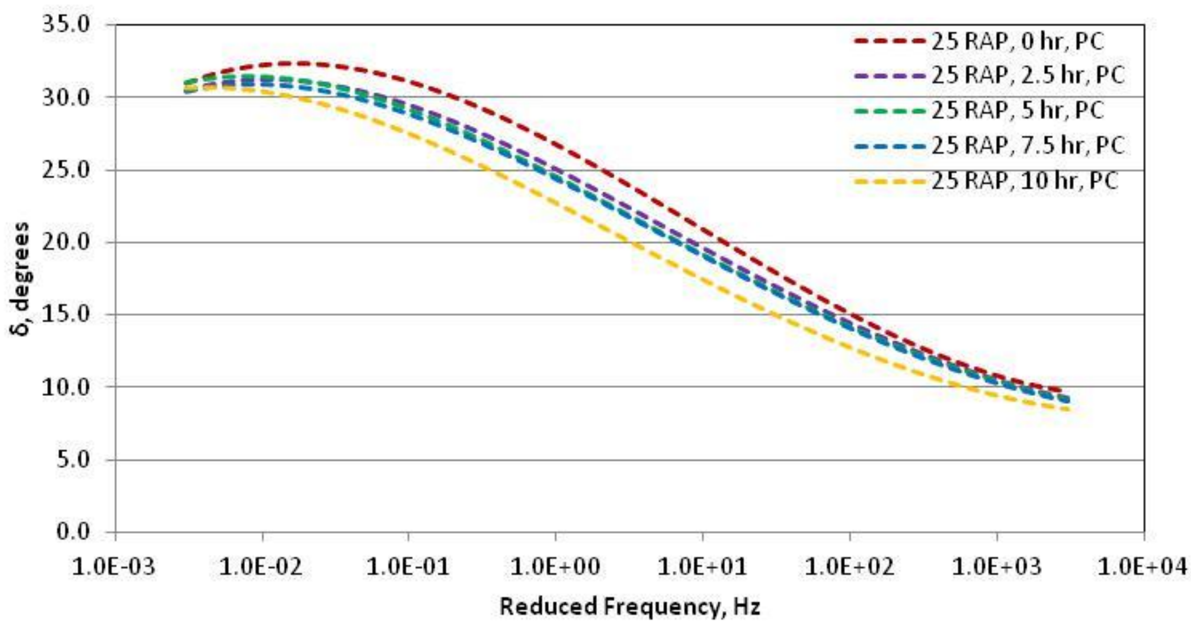

Figure 4 NY Silo Storage Phase Angle (25RAP)

The statistical analyses for the virgin and 25% RAP phase angle master curves are shown in Tables 4 and 5, respectively. The 0 hour virgin mixture is significantly different from the 7.5 hour mixture at most reduced frequencies, and from the 5 hour mixture at frequencies up to 3 Hz. Table 5 shows that the 0 hour and 10 hour RAP mixtures are statistically different from other mixtures along most of the master curve. The 2.5 hour, 5 hour, and 7.5 hour mixtures are similar over most of the reduced frequency range.

Table 4 NY silo storage phase angle master curve statistical results for virgin, plant-compacted mixtures

Mixture	Frequency (Hz)	p-value for comparison of mixtures			
		0RAP, 0 hr	0RAP, 2.5 hr	0RAP, 5 hr	0RAP, 7.5 hr
0RAP, 0 hr	300	N/A	0.551	0.159	0.000
	30	N/A	0.504	0.104	0.000
	3	N/A	0.653	0.016	0.000
	0.3	N/A	0.651	0.000	0.000
	0.03	N/A	0.122	0.000	0.000
	0.003	N/A	0.052	0.000	0.277
0RAP, 2.5 hr	300	0.551	N/A	0.044	0.000
	30	0.504	N/A	0.026	0.000
	3	0.653	N/A	0.005	0.000
	0.3	0.651	N/A	0.000	0.000
	0.03	0.122	N/A	0.000	0.000
	0.003	0.052	N/A	0.000	0.822
0RAP, 5 hr	300	0.159	0.044	N/A	0.004
	30	0.104	0.026	N/A	0.028
	3	0.016	0.005	N/A	0.038
	0.3	0.000	0.000	N/A	0.060
	0.03	0.000	0.000	N/A	0.671
	0.003	0.000	0.000	N/A	0.000
0RAP, 7.5 hr	300	0.000	0.000	0.004	N/A
	30	0.000	0.000	0.028	N/A
	3	0.000	0.000	0.038	N/A
	0.3	0.000	0.000	0.060	N/A
	0.03	0.000	0.000	0.671	N/A
	0.003	0.277	0.822	0.000	N/A

Table 5 NY silo storage phase angle master curve statistical results for RAP, plant-compacted mixtures

Mixture	Frequency (Hz)	p-value for comparison of mixtures				
		25RAP, 0 hr	25RAP, 2.5 hr	25RAP, 5 hr	25RAP, 7.5 hr	25RAP, 10 hr
25RAP, 0 hr	300	N/A	0.122	0.046	0.009	0.000
	30	N/A	0.120	0.033	0.012	0.000
	3	N/A	0.007	0.000	0.000	0.000
	0.3	N/A	0.000	0.000	0.000	0.000
	0.03	N/A	0.000	0.000	0.000	0.000
	0.003	N/A	0.000	0.000	0.000	0.000
25RAP, 2.5 hr	300	0.122	N/A	0.647	0.271	0.000
	30	0.120	N/A	0.544	0.297	0.000
	3	0.007	N/A	0.322	0.181	0.000
	0.3	0.000	N/A	0.239	0.082	0.000
	0.03	0.000	N/A	0.329	0.016	0.000
	0.003	0.000	N/A	0.000	0.000	0.000
25RAP, 5 hr	300	0.046	0.647	N/A	0.519	0.000
	30	0.033	0.544	N/A	0.651	0.000
	3	0.000	0.322	N/A	0.720	0.000
	0.3	0.000	0.239	N/A	0.578	0.000
	0.03	0.000	0.329	N/A	0.579	0.000
	0.003	0.000	0.000	N/A	0.168	0.000
25RAP, 7.5 hr	300	0.009	0.271	0.519	N/A	0.001
	30	0.012	0.297	0.651	N/A	0.000
	3	0.000	0.181	0.720	N/A	0.000
	0.3	0.000	0.082	0.578	N/A	0.000
	0.03	0.000	0.016	0.579	N/A	0.000
	0.003	0.000	0.000	0.168	N/A	0.000
25RAP, 10 hr	300	0.000	0.000	0.000	0.001	N/A
	30	0.000	0.000	0.000	0.000	N/A
	3	0.000	0.000	0.000	0.000	N/A
	0.3	0.000	0.000	0.000	0.000	N/A
	0.03	0.000	0.000	0.000	0.000	N/A
	0.003	0.000	0.000	0.000	0.000	N/A