"Evaluation of Plant-Produced High-Percentage RAP Mixtures in the Northeast"
Transportation Pooled Fund Project TPF-5(230)

Quarterly Report #1
August-December 2010

Research Team:

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Work Completed This Quarter:

Phase I of the project started in August. The following sections summarize the work that has been completed to date.

<u>Technical Committee</u>
The technical committee for this project was formed and is comprised of at least one representative from each agency that has contributed funds to the project. The technical committee members are listed below in Table 1.

Table 1. Technical Committee Members

Name	**Agency**	**Email**
Audrey Copeland	FHWA	audrey.copeland@dot.gov
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<u>Production of Mixtures</u>
Table 2 shows a summary of the Phase I mixtures and date when each was produced. All Phase I mixtures have been producedand sampled for testing. Virgin asphalt and loose mix were collected and shipped to the research team for laboratory testing. Additionally, gyratory specimens were fabricated at the plant during production for testing to evaluate the impact of reheating the mixtures.

Table 2. Phase I Mixtures

Plant	NMAS (mm)	PG Grade	% RAP			
			0	20	30	40
Callanan NY (drum)	12.5	64-22	9/1/10	8/19/10	9/7/10	7/30/10
		58-28	n/a	n/a	9/7/10	7/30/10
Pike VT (batch)	12.5	58-28	11/15/10	11/15/10	11/16/10	11/16/10
		52-34	11/15/10	11/15/10	11/16/10	11/16/10
Pike NH (drum)	9.5	64-28	10/28/10	10/29/10	11/01/10	10/28/10

<u>Binder Testing</u>

PG grading of the virgin binder used in the NY mixtures has been completed and is summarized in Table 3 below.

Table 3. Virgin Binder PG Grades

Plant	Date Sampled	Designated PG grade	Measured Continuous PG grade
Callanan NY	7/30/10	58-28	60.3-30.8
	9/07/10	58-28	61.0-34.6
	7/30/10	64-22	67.3-26.0
	9/07/10	64-22	67.0-25.5

<u>Mixture Testing</u>

A reheating and specimen fabrication protocol (TPF-5 (230) reheating test procedure, *Procedure for Reheating Plant Produced Mixtures for Specimen Fabrication in the Lab*dated October 18th, 2010) for the plant produced loose mixture was developed to ensure consistent procedures among the different research team members. All research team members have been actively fabricating specimens this quarter. A labeling system for specimens was developed using the following notation:

1- The State where the mix is produced.
2- Binder performance grade.
   - PG 52-34 (a)
   - PG 58-28 (b)
   - PG 58-34 (c)
   - PG 64-22 (d)
   - PG 64-28 (e)
3- RAP percentage. (2 digits)
4- Whether the sample is fabricated in the lab, the plant, or cored from field.
   - Field Extracted (F)
   - Lab Fabricated (L)
   - Plant Gyratory (P)
5- Name of the university conducting the test.
   - North Carolina State University (C)
   - University of New Hampshire (H)
   - University of Massachusetts (M)
   - Rutgers University (R)

6- Sample Number. (2 digits)

For Example (NHa30LH01) means:

1- Mix produced in New Hampshire
2- Binder PG grade is PG 52-34
3- RAP percentage is 30%
4- Lab fabricated
5- This sample is tested by University of New Hampshire
6- First specimen of its type

Testing that has been completed this quarter includes:

- Dynamic modulus testing of NY Callanan plant produced gyratory specimens
- Dynamic modulus testing of NY Callanan laboratory fabricated (reheated) specimens
- Moisture sensitivity testing of the NY Callanan and 0% & 20% RAP NH Pike laboratory fabricated (reheated) specimens using the Hamburg Wheel Tracking Device

Test specimens were fabricated to 7±1% air voids using the TPF-5 (230) reheating test procedure. Dynamic modulus was measured in accordance with AASHTO TP79, *Determining the Dynamic Modulus and Flow Number for Hot Mix Asphalt (HMA) Using the Asphalt Mixture Performance Tester* and dynamic modulus master curves were constructed in accordance to AASHTO PP61, *Developing dynamic Modulus Master Curves for Hot Mix Asphalt (HMA) Using the Asphalt Mixture Performance Tester (AMPT).*Moisture sensitivity tests were conducted using the Hamburg Wheel Tracking Device in accordance with AASHTO T-324, *Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Hot-Mix Asphalt (HMA).*

The dynamic modulus master curves for the NY CallananPG 58-28 plant compacted and laboratory compacted mixtures are shown in Figures 1 and 2, respectively. The virgin PG 64-22 mixture dynamic modulus is shown in both graphs for comparison. The dynamic modulus master curves for both the plant and laboratory compacted specimens indicates that by using a softer PG graded asphalt binder (PG58-28) with 30% RAP provides stiffness characteristics lower than the virgin PG64-22 mixture. However, once the RAP content was increased to 40%, the stiffness of the mixture becomes greater than the virgin PG64-22 mixture. It should also be noted that there are differences in the silo storage time and mixture discharge temperature that may influencing the general stiffness parameters. For example, the PG58-28 (40% RAP) mixture had the highest aggregate heating and mix discharge temperatures and was also stored at the elevated temperatures longer than both the PG64-22 virgin mixture and the PG58-28 (30% RAP) mixture.

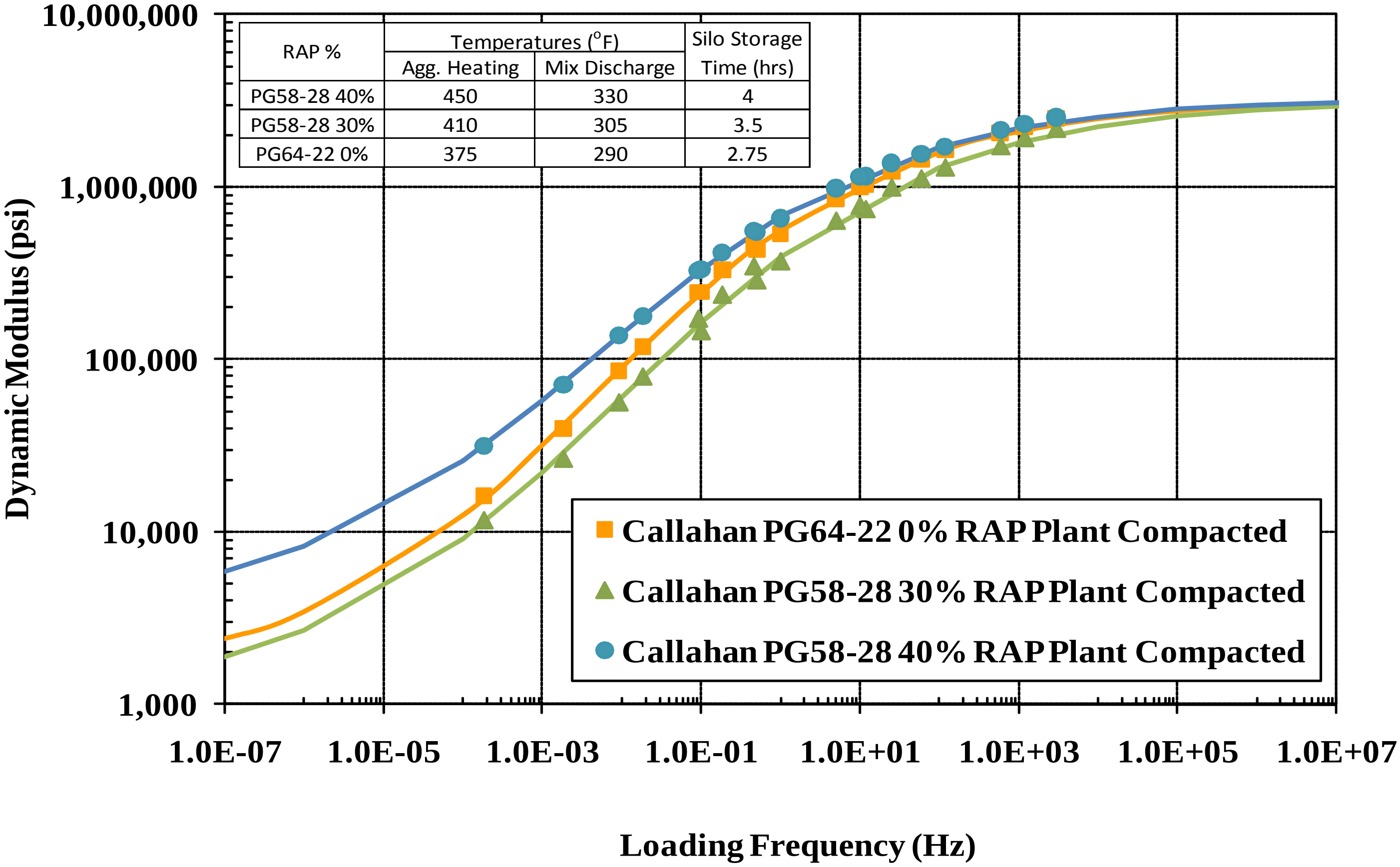

Figure 1. Dynamic Modulus Master Curves for NY Callanan PG 58-28 and Virgin PG 64-22 Plant Compacted Mixtures

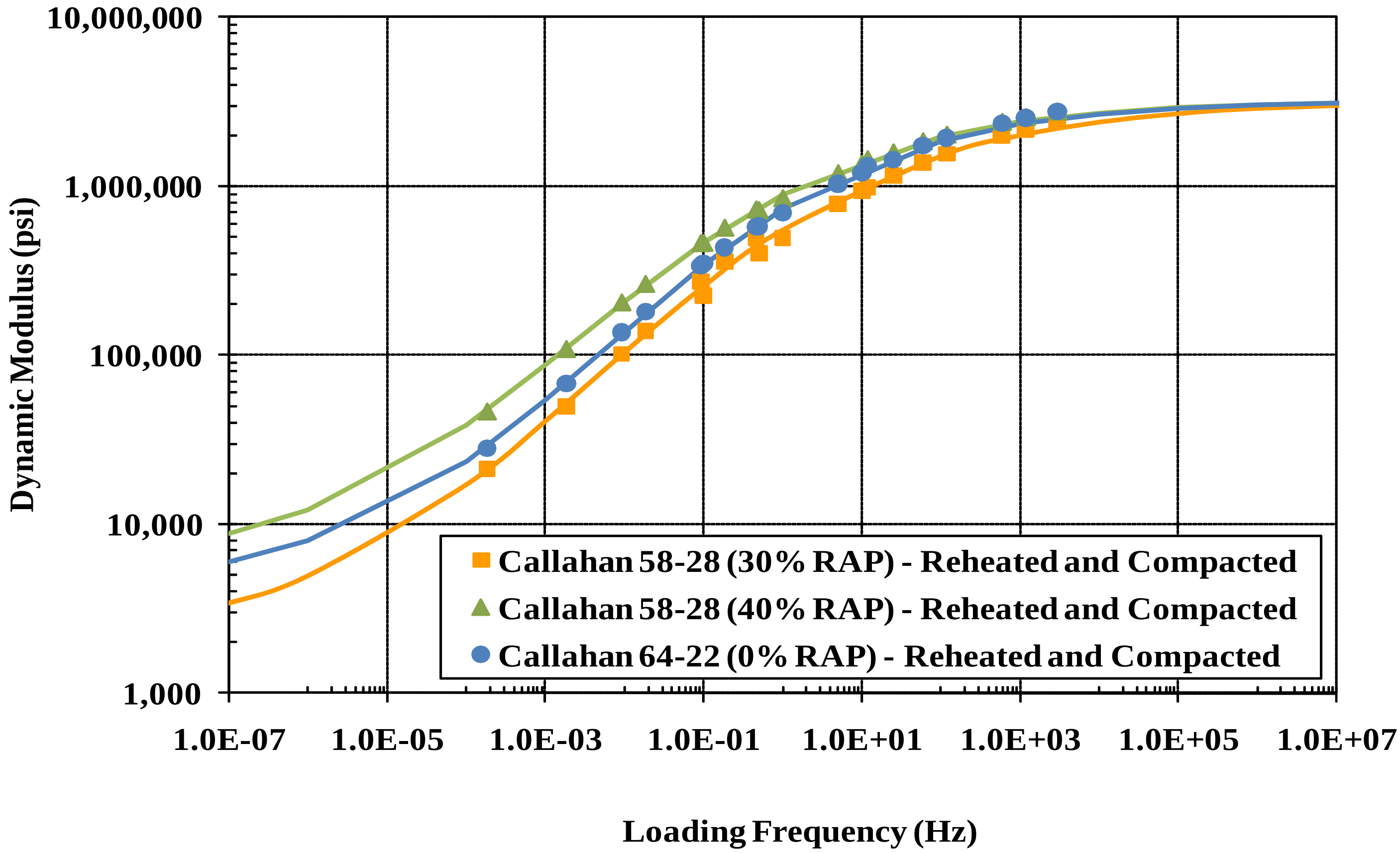

Figure 2. Dynamic Modulus Master Curves for NY Callanan PG 58-28 and Virgin PG 64-22 Laboratory Compacted (Reheated) Mixtures

Figure 3 shows the mastercurves for the lab compacted PG 64-22 NY Callanan mixtures. The master curves show that there is a general trend for the mixture stiffness to increase as RAP content increases, except for the PG64-22 (20% RAP) material, as this mixture appeared to be softer than even the PG64-22 virgin (0% RAP) mixture. Similar trends are observed with the plant compacted mixtures. Further examination shows that the PG64-22 (20% RAP) material was only stored for 0.75 hours prior to discharge – 2 to 2.5 hours less than the other mixtures. Based on this information and the master curves, it appears that the storage time had an impact on the stiffness characteristics of the PG64-22 asphalt mixtures.

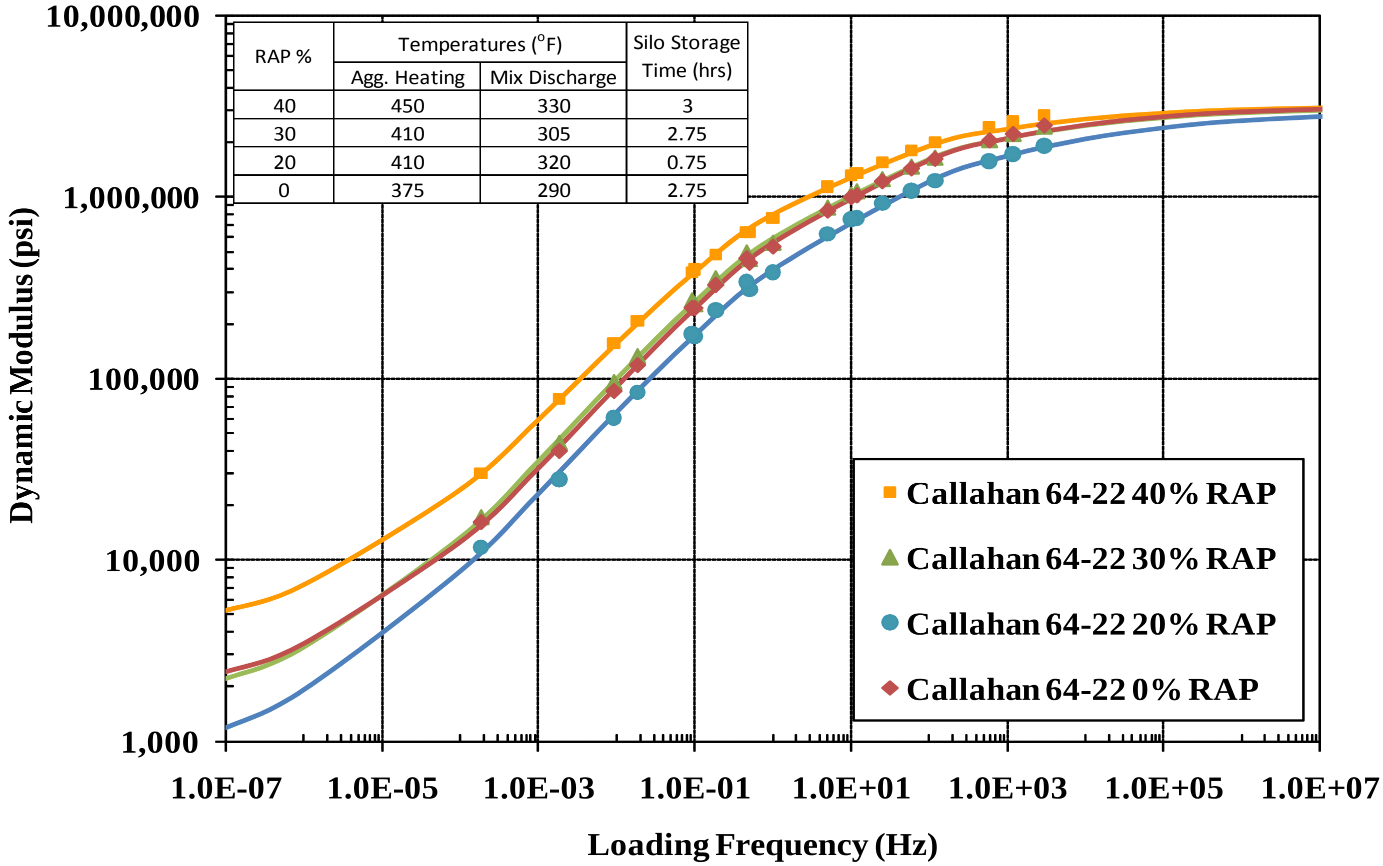

Figure 3. Dynamic Modulus Master Curves for NY Callanan PG 64-22 Lab Compacted Mixtures

Figures 4 and 5 show comparisons between the different binder grades for the 30% and 40% RAP mixtures, respectively. There is a greater difference between the two binder grades for the 30% RAP mixtues.

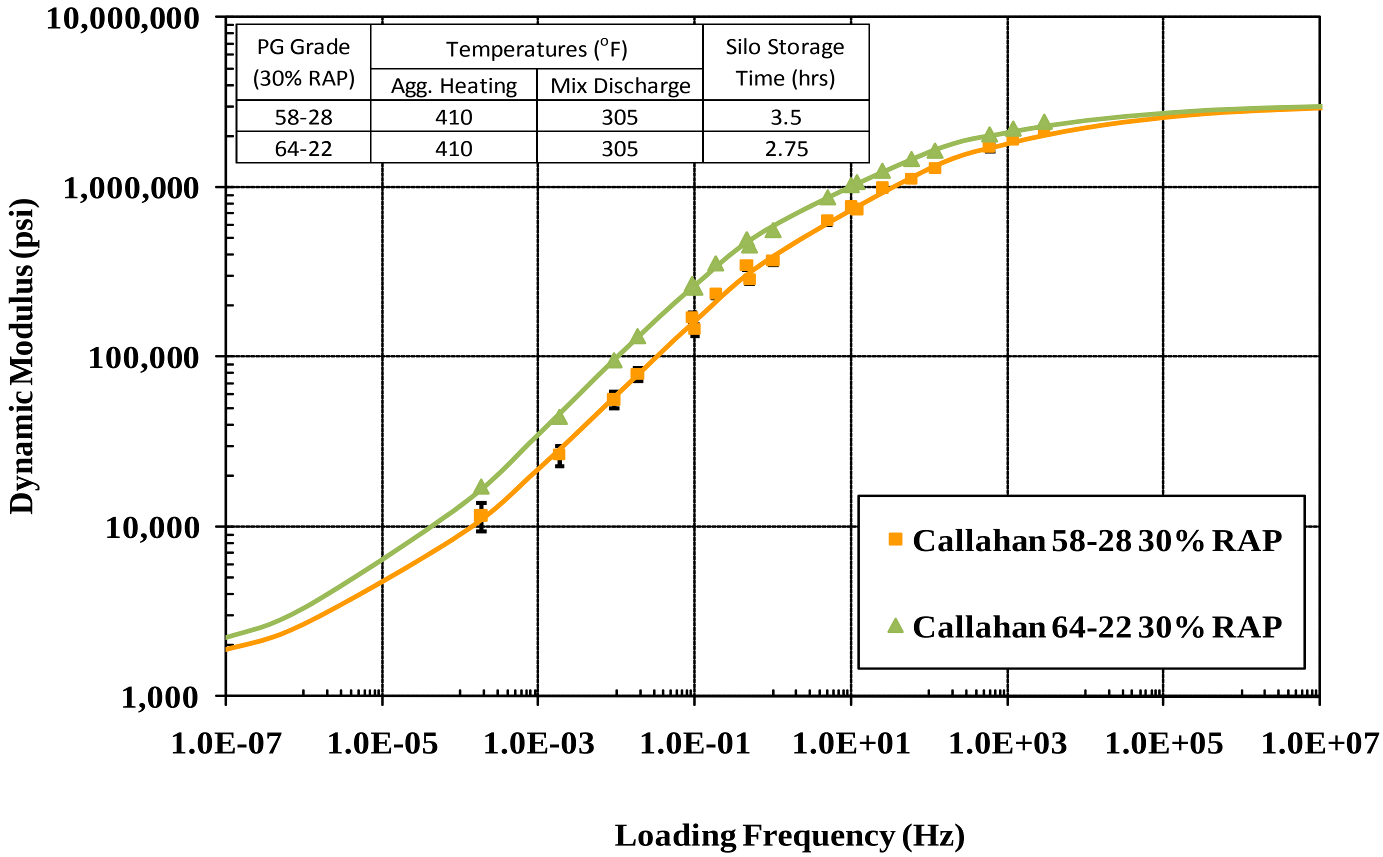

Figure 4. Dynamic Modulus Master Curves for NY Callanan 30% RAP Mixtures

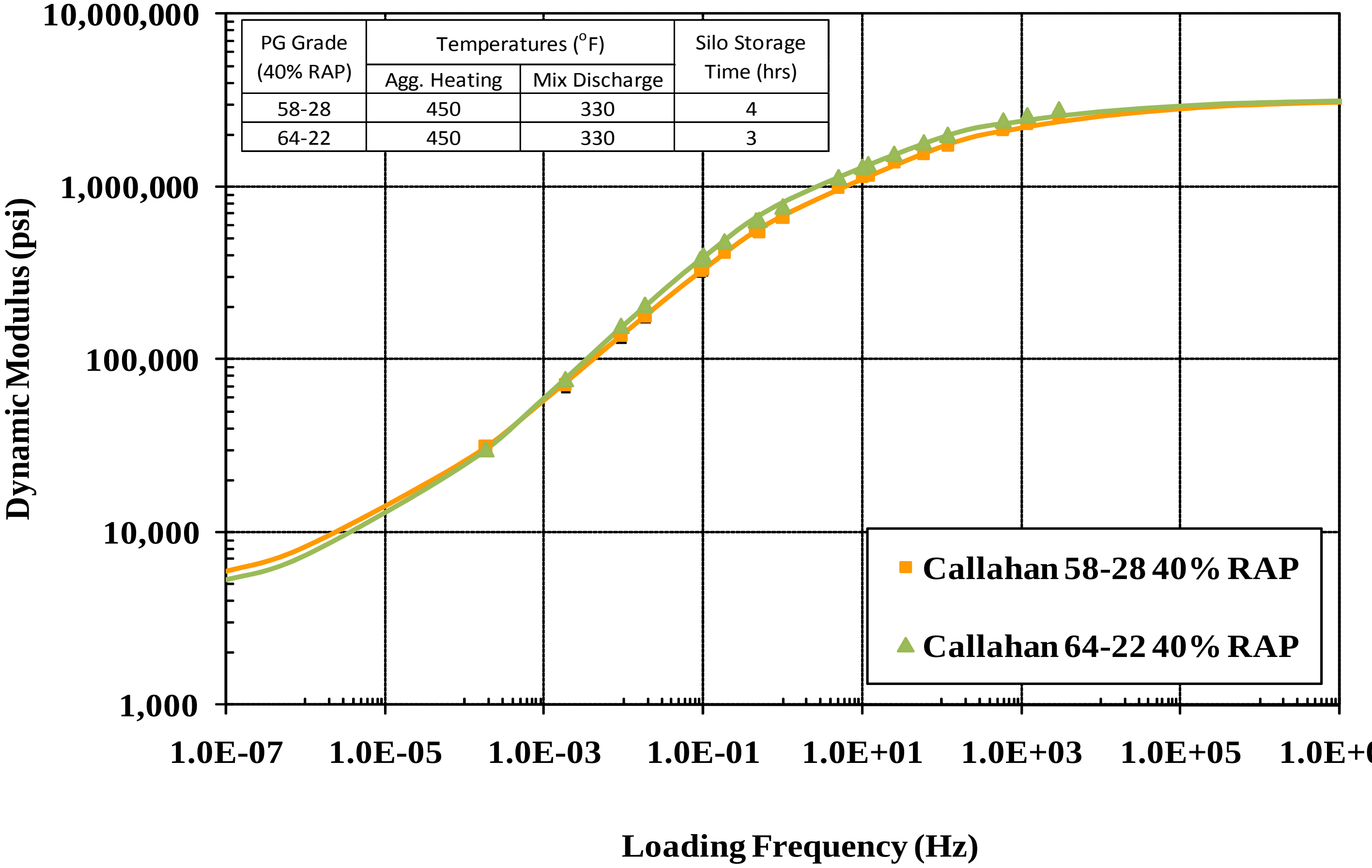

Figure 5. Dynamic Modulus Master Curves for NY Callanan 40% RAP Mixtures

A comparison of the dynamic modulus curves for the plant compacted and laboratory compacted (reheated) mixtures is shown in Figure 6. Reheating the mixture in the laboratory stiffens the mixture. Stiffening due to reheating is observed for all of the RAP mixtures as well.The degree of stiffening varies with test temperature and loading frequency, but is greatest at higher test temperatures and lower loading frequencies. Table 4 shows the average percent increase in dynamic modulus for the various test temperatures.

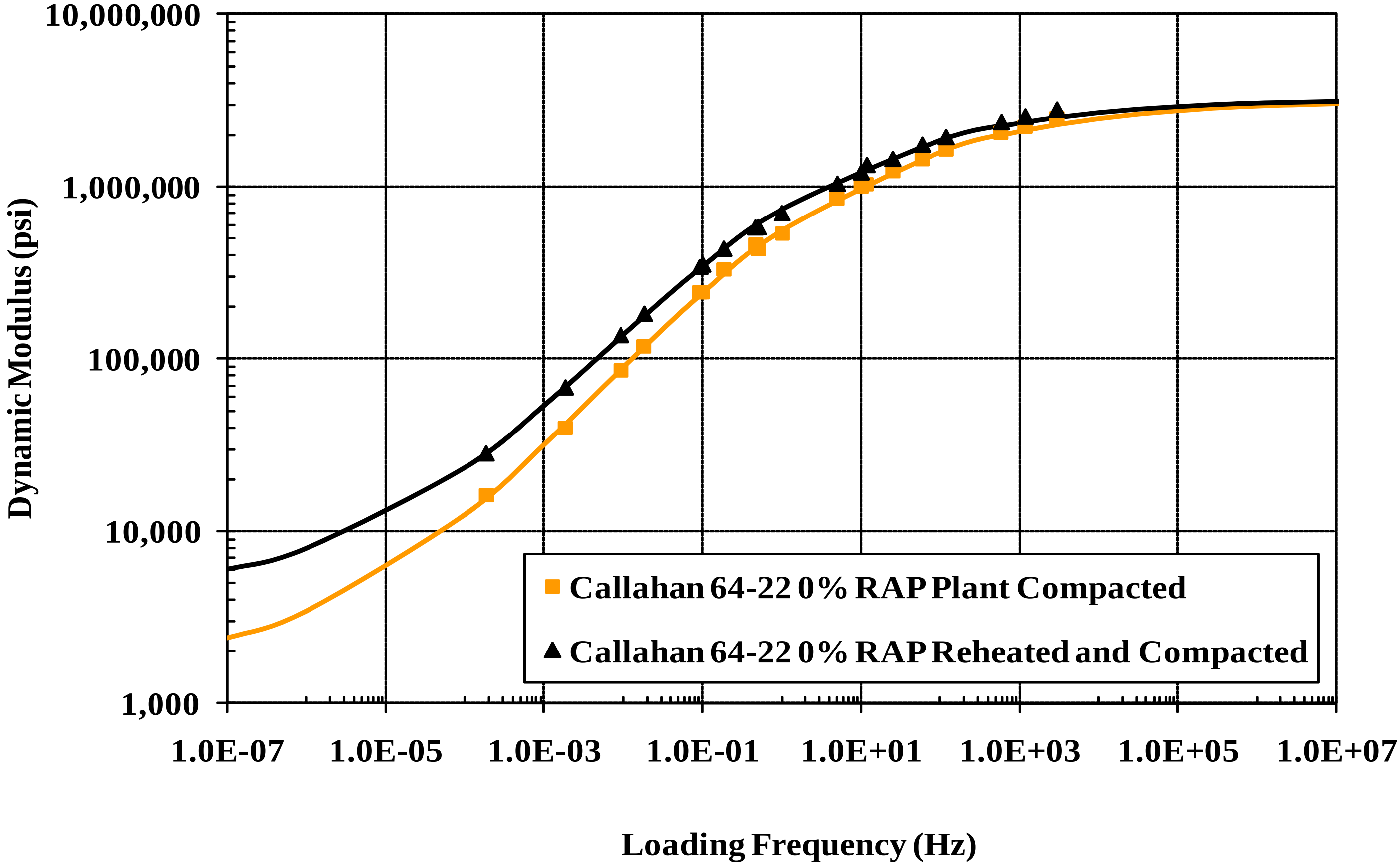

Figure 6. Comparison of Plant Compacted and Laboratory Compacted (Reheated) Dynamic Modulus Curves for Callanan 64-22 Virgin Mixtures

Table 4. Average Percent Increase in Dynamic Modulus due to Reheating

Mixture	Test Temp (°C)	% RAP			
		0	20	30	40
NY 58-28	4.4	n/a	n/a	19.3	16.6
	20			37.7	26.
	35			68.2	44.1
NY 64-22	4.4	18	52.1	17.2	1.6
	20	27.7	81.5	22.9	8.7
	35	50.6	118.9	43.4	30

The results of the Hamburg testing for the NY and NH mixtures are shown in Figures 7 and 8, respectively. All mixtures except the NY PG 64-22 0% and 30% RAP mixtures pass the HWTD criteria.

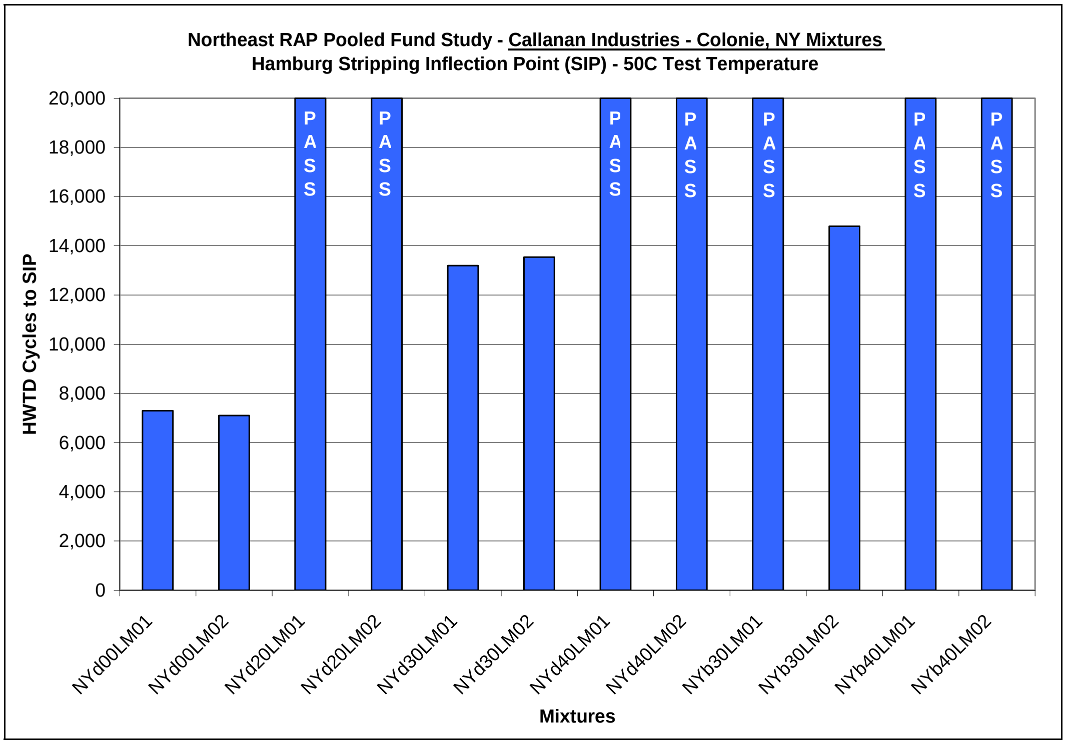

Figure 7. Hamburg Wheel Tracking Results for NY Callanan Mixtures

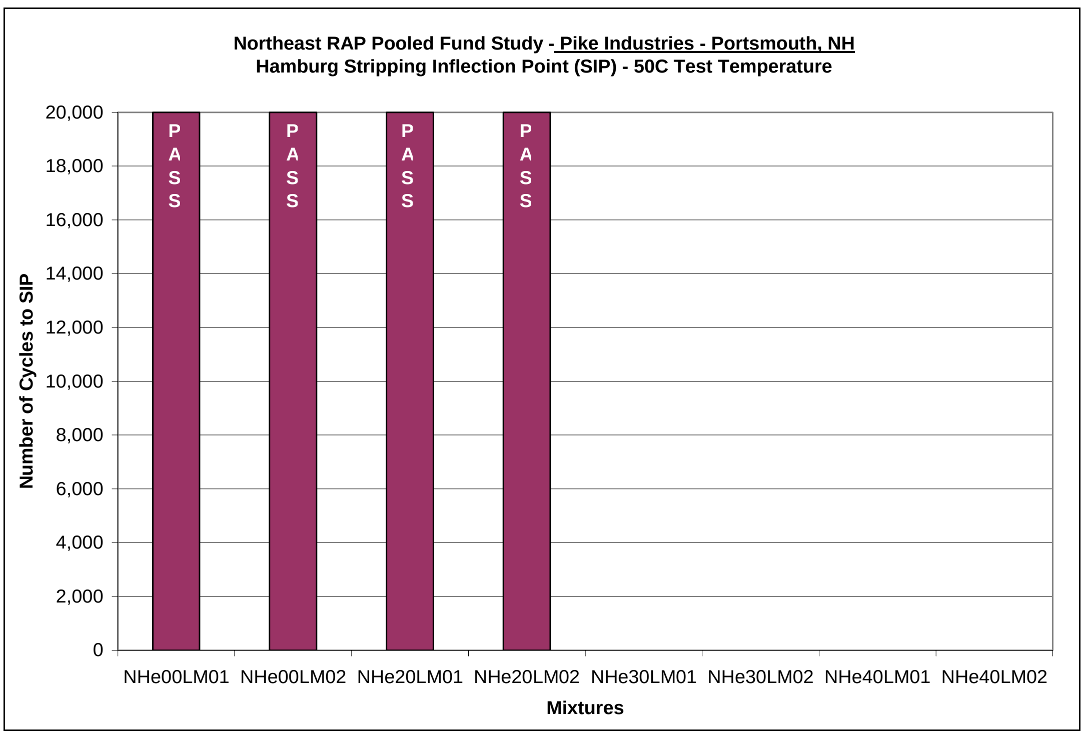

Figure 8. Hamburg Wheel Tracking Results for NH Pike Mixtures

Observations from Testing Completed to date:

- NY Asphalt binder PG grading indicated difference in PG58-28 binders low temperature grade depending on date used. PG64-22 similar for both dates
- Dynamic Modulus for NY 64-22 binders showed a stiffness dependency to silo storage time
  - 20% RAP mix only stored for 0.75 hours resulted in lower stiffness than 0% RAP mix stored for 2.75 hours
- Dynamic Modulus of NY 58-28 binders appeared to be more influenced by larger difference in low temperature PG Grade
- For identical NY RAP content mixtures, 30% RAP mixtures showed larger difference in modulus than 40% RAP mixtures
  - Possibly due to larger difference in low temperature continuous PG grade
    - 58-28, 30% RAP: -34.6o
    - 64-22, 30% RAP: -25.5o
  - Possibly due to storage time: 40% RAP mixtures more similar in storage silo time than 30% RAP mixtures
    - 30% RAP: 58-28 (3.5 hours) vs 64-22 (2.75 hours) = 0.75 hr difference
    - 40% RAP: 58-28 (4 hours) vs 64-22 (3 hours) = 1 hr difference
      - As higher RAP mixture stored closer in time to softer PG grade, larger differences in dynamic modulus were observed
      - The greater the difference in storage time between the softer PG grade (58-28) over the stiffer PG grade (64-22), the closer the dynamic modulus properties are between the mixtures
- Reheating the mixture increases the dynamic modulus with a larger percent increase observed at high testing temperatures
- The NY PG 64-22 0% and 30% RAP mixtures did not pass the HWTD criteria

Work Planned for Next Quarter:

- Continued dynamic modulus and Hamburg testing of Phase I mixtures
- Begin low temperature creep and strength and T-283 moisture sensitivity testing of Phase I mixtures
- Begin fatigue testing of Phase I mixtures
- Extraction & recovery of binder from Phase I mixtures by Pike Industries, Inc.
- Begin testing of extracted binders

Problems Encountered:

- The Instronservo-hydraulic testing machine at UNH has been out of service since the end of October, delaying the low temperature creep and strength and AASHTO T283 testing. It is anticipated that repairs will be completed by the end of January and testing will begin in mid-February.