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:** **12/31/2014**	**Number of Extensions:** **1**

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~~ Revised to 731,287	698,240	93%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	30,485	

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 RAP 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 three 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. Phase III is a laboratory study to isolate the effects of mixture variables without changing plant production variables.

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.):

During this quarter, the research team has focused on three tasks:

1. Interim report summarizing the Phase I results
2. Phase III testing
3. Additional task development

1. Interim Report

The research team submitted the draft interim report summarizing the Phase I testing results to the technical committee in March and has received some comments. Based on the comments received, the research team will finalize the report.

2. Phase III

The Phase III testing is nearly complete. All of the original asphalt content mixtures have been tested and the results analyzed and presented below.

3. Additional Task Development

The scope and budget for the Silo Storage Study task has been developed and sent to the technical committee. A web conference is being organized to discuss this additional task.

Anticipated work next quarter:

1. Finalize the interim report for the Phase I mixtures
2. Finish testing and analysis of Phase III test specimens, begin drafting Phase III report
3. Develop scope and budget for future tasks, formally add these tasks to the project and solicit funding

4. Finish testing remaining Phase II mixtures, begin drafting Phase II report

Significant Results:

The testing plan for the Phase III laboratory consisted of the mixtures shown below in Table 1. This report presents the results to date on the optimum asphalt content mixtures (top row of Table 1.)

Table 1. Phase IIII Testing Plan

Mixture	Asphalt content	RAP Content (total weight)		
		0	20	40
NH Phase I	optimum	PG 64-28	PG 64-28 PG58-28	PG 64-28 PG 58-28
	+0.5%	-	PG 64-28	PG 64-28 (PG 58-28)
	+1.0%	-	-	PG 64-28 (PG 58-28)

Asphalt Binder Testing

The results of the extractions performed on the optimum asphalt content mixtures are shown in Table 2 below. The measured values for the RAP mixtures are significantly lower than the target asphalt content of 5.8%. The mixtures were fabricated assuming a RAP binder content of 4.6%, the extraction testing showed that the actual RAP asphalt content is 4.3%, which caused the lower total asphalt contents in the mixtures. The research team is in the process of fabricating a set of virgin mixtures at 5.3% asphalt content (optimum -0.5%) to allow for direct comparison of mixture testing results. The extracted RAP binder results to date indicate that the continuous high grade for the RAP is 84.8.

Table 2. Extracted and Recovered Binder Grading Results

Binder Grade	RAP %	PG Grade		AC %	(Measured - Design)
		Continuous	Standard		
PG64-28	0	72.1-30.2	70-28	5.8	**0**
	20	75-27.8	70-22	5.36	**-0.44**
	40	83.4-19.9	82-16	5.19	**-0.61**
PG58-28	20	68.7-26.9	64-22	5.2	**-0.6**
	40	73.7-24.2	70-22	5.44	**-0.36**

The critical cracking temperatures for the binders recovered from the five mixtures are shown in Figure 1 below. The increase in RAP content causes the critical cracking temperature to increase for both virgin binder grades. In addition to PG grading and cracking analysis, the G* master curves have been analyzed using existing techniques for evaluating aging and cracking potential. Figure 2 shows a cross-plot of the crossover frequency and R-value determined from the G* master curves. A position further down and to the right on this plot indicates a more aged material. The PG 64-28 recovered materials indicate an increase in aged material due to the addition of RAP, as expected. The PG 58-28 recovered materials do not show a trend with RAP content. Figure 3 shows the six recovered binders plotted in blackspace along with the cracking potential criteria, as proposed by Geoff Rowe (2013). In this figure, positions further up and to the left indicate an increase in cracking potential. The PG 64-28 recovered materials show an increase in cracking potential with higher amounts of RAP and the PG 58-28 recovered materials show a slightly higher cracking potential with the 40% RAP mixture over the 20% RAP mixture.

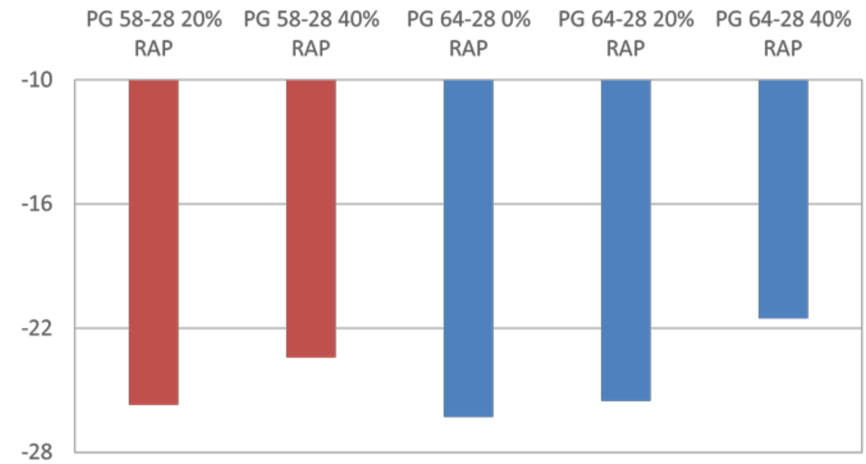

Figure 1. Binder Critical Cracking Temperatures

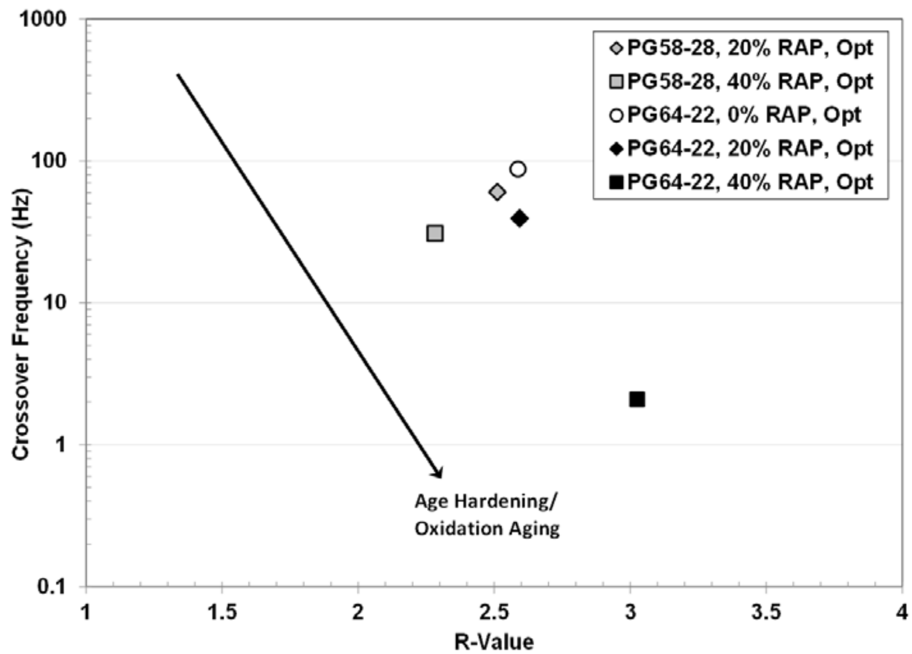

Figure 2. G* Crossover-Frequency vs R-value

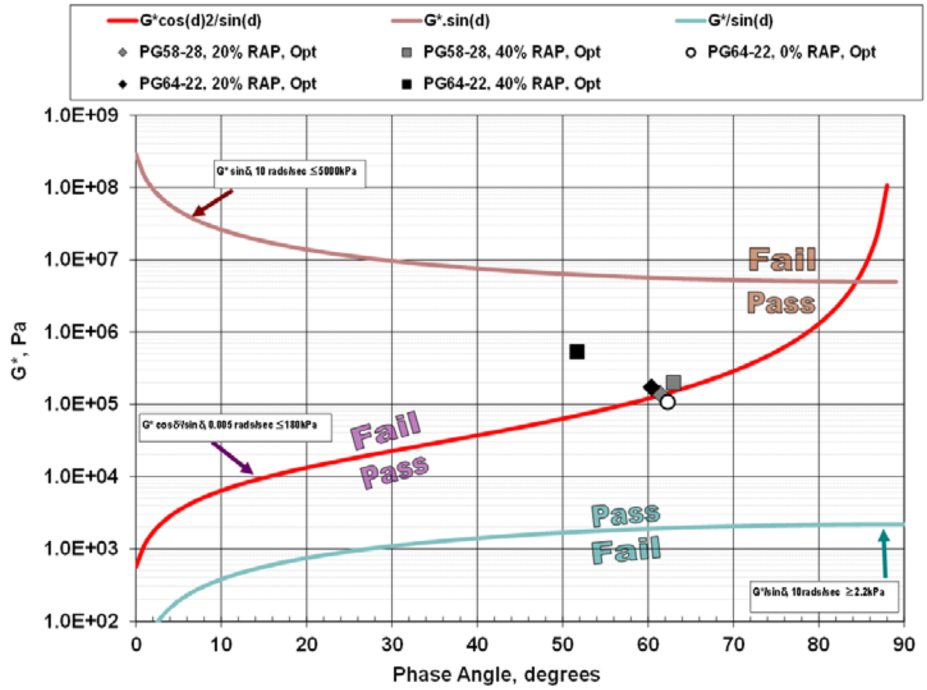

Figure 3. Blackspace analysis of non-load associated cracking potential (Rowe 2013)

Asphalt Mixture Testing

Dynamic modulus master curves for the optimum asphalt content mixtures are shown in Figure 4 and Figure 5 below. The higher RAP content mixtures show a stiffer response, which is likely due to a combination of the stiffer RAP material and the lower asphalt content. The new virgin mixtures with -0.5% asphalt content will allow for a direct evaluation of the impact of the RAP material on the dynamic modulus. Figure 5 shows that there is very little difference in the mixtures with the two different virgin binder grades.

Figures 6 and 7 show the failure criterion curves generated from the S-VECD fatigue testing and analysis. Curves that are further up and to the right indicate mixtures that would be expected to exhibit better fatigue performance in the field. In Figure 6, it is clear that the virgin PG 64-28 mixture shows better fatigue performance than the RAP mixtures and for both PG grades, the RAP mixtures perform similarly, with the lower RAP content slightly better. However, there is the confounding factor of differences in asphalt content between mixtures that is likely contributing to the behavior as well. Figure 7 shows that the softer virgin binder grade is expected to improve the fatigue performance of the mixture.

The results of the triaxial testing are shown for the PG 64-28 and PG 58-28 mixtures in Figures 8 and 9, respectively. The first three graphs show the triaxial stress sweep (increasing stress after 200 cycles) at low, intermediate, and high temperatures. At low temperature, the PG 64-28 0% and 20% RAP mixtures are similar with the 40% RAP mixture showing stiffer performance. At the intermediate temperature, the two RAP mixtures are similar and at the high temperature, all three mixtures are similar for both the stress sweep and the constant stress test. The PG 58-28 mixtures follow a similar trend with the differences becoming smaller at the higher temperatures.

The results of both the S-VECD fatigue testing and the TSS permanent deformation testing will be input to the Layered Viscoelastic Pavement Analysis for Critical Distresses (LVECD) Program for typical thick and thin pavement structures to analyze the long-term cracking and rutting performance of asphalt pavements under moving wheel loads.

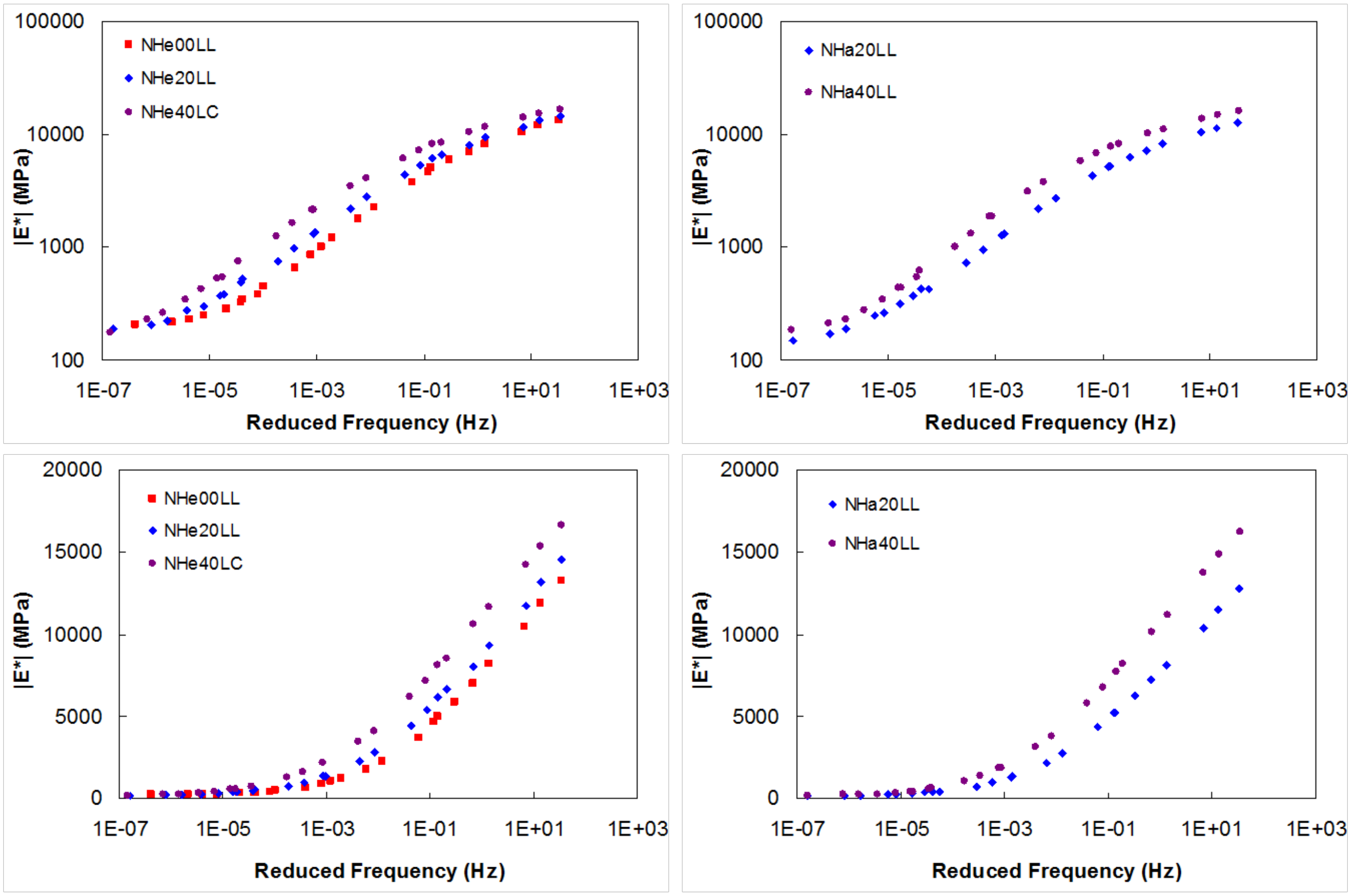

Figure 4. New Hampshire Dynamic Modulus Master Curves for PG 64-28 mixtures (left) and PG 58-28 mixtures (right). Log-log scale (top), Semi-log scale (bottom)

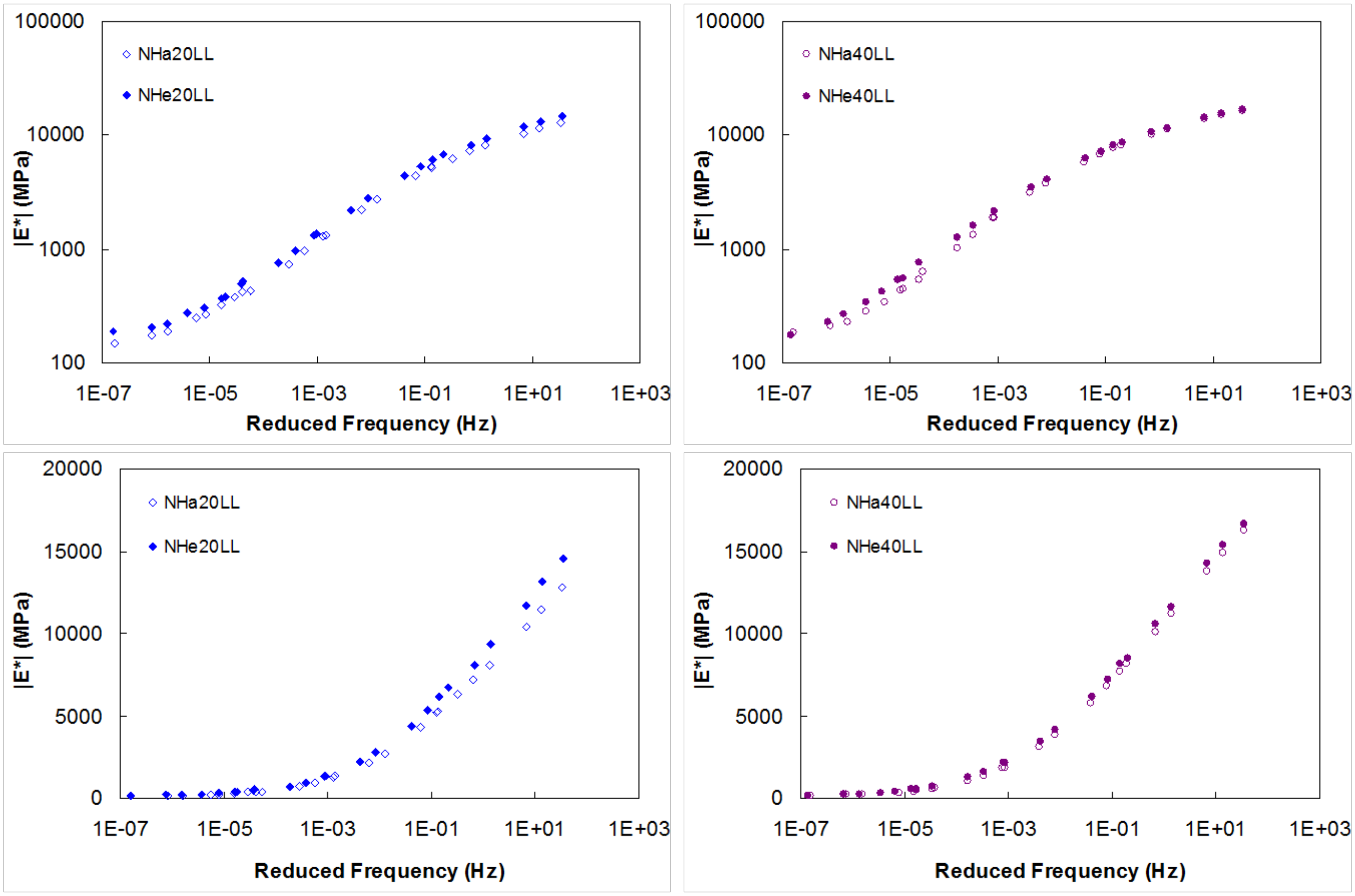

Figure 5. New Hampshire Dynamic Modulus Master Curves for 20% RAP mixtures (left) and 40% RAP mixtures (right). Log-log scale (top), Semi-log scale (bottom)

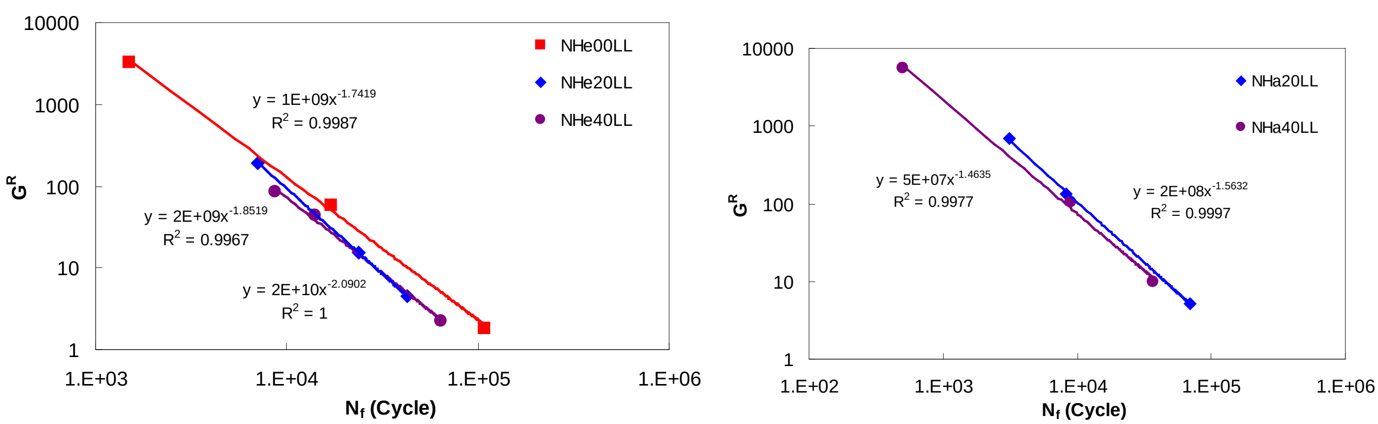

Figure 6. S-VECD Failure Criterion Curves for the PG 64-28 (left) and PG 58-28 (right) mixtures

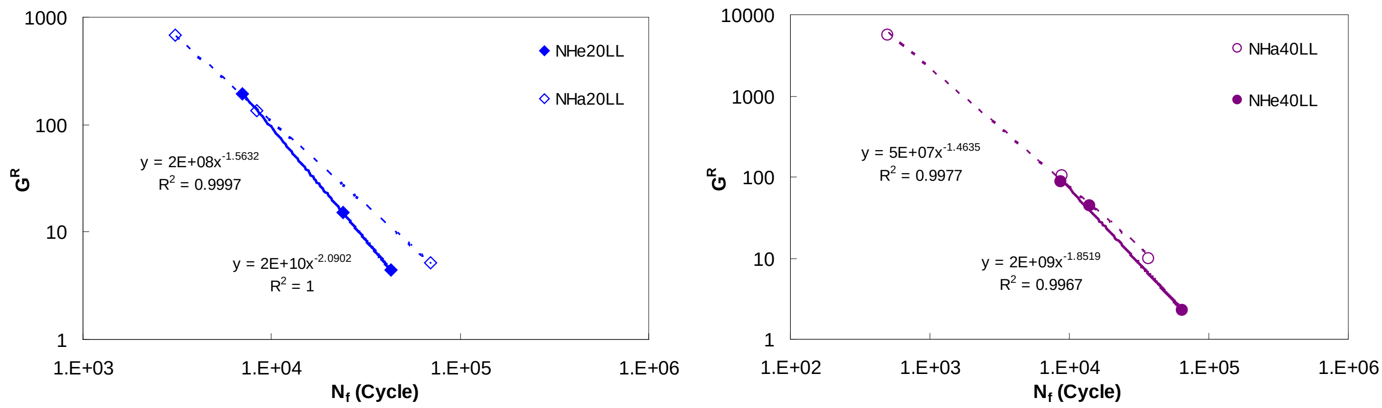

Figure 7. S-VECD Failure Criterion Curves for the 20% RAP mixtures (left) and 40% RAP mixtures (right)

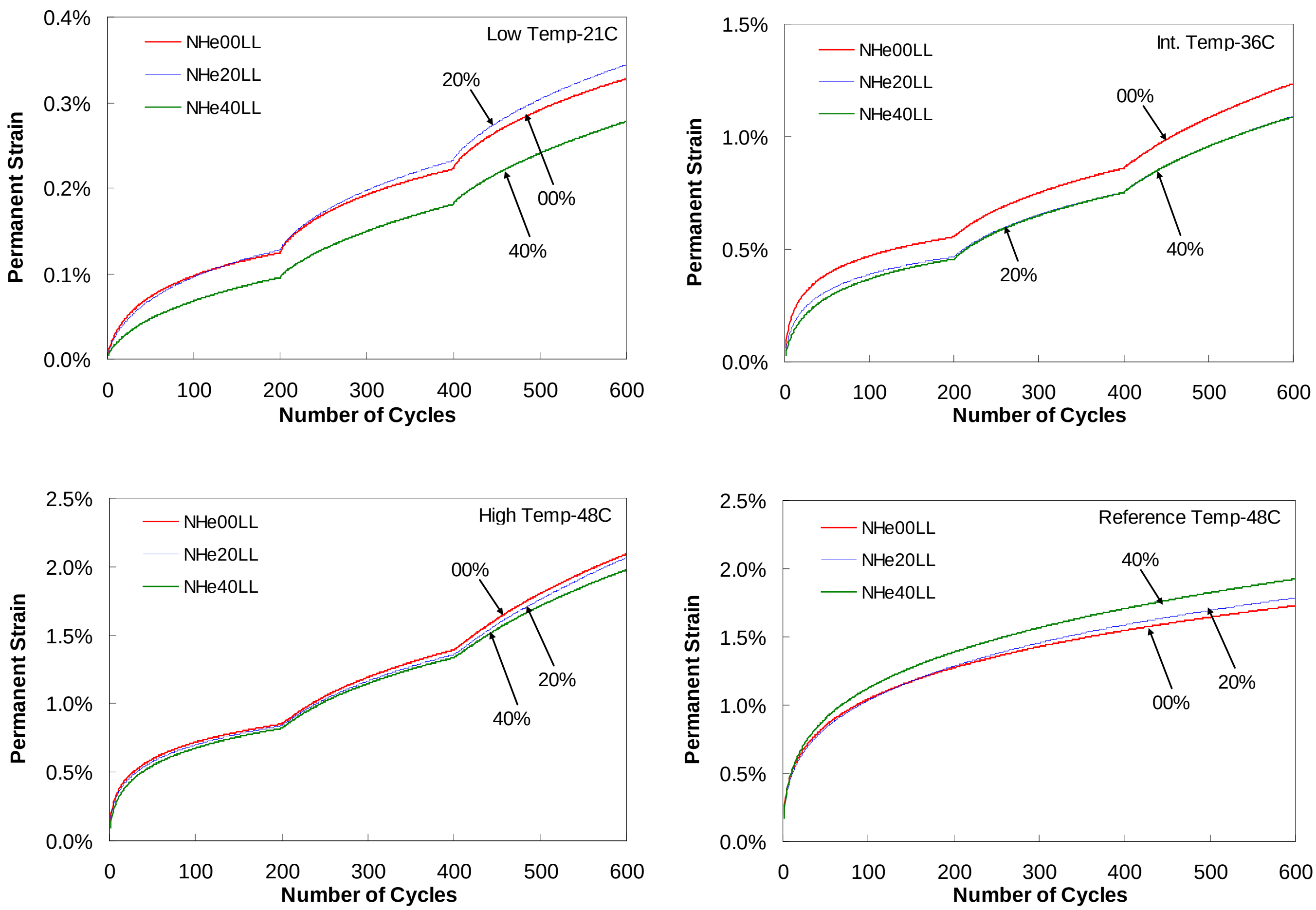

Figure 8. Triaxial testing results for the PG 64-28 mixtures

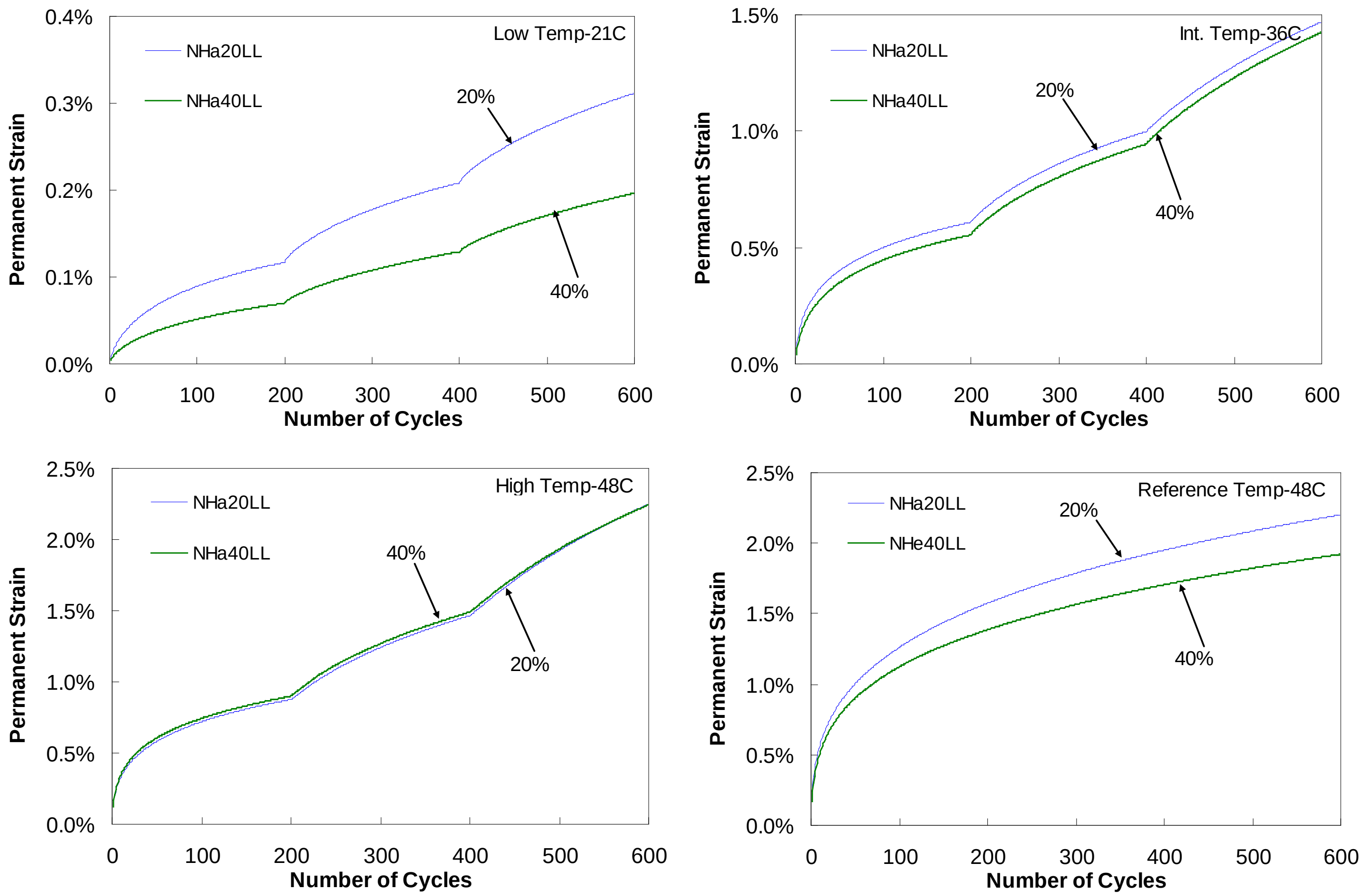

Figure 9. Triaxial testing results for the PG 58-28 mixtures

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).

None this quarter

Potential Implementation: