The objectives of this study are:

1. To determine the challenges and successes of using polymer and crumb rubber modified binder from the existing literature and the state of practice. These include types of polymers, test methods to evaluate polymer modified binder and field and lab performance of mixtures.
2. To conduct traditional Superpave binder tests as per AASHTO M 320 table 1 in order to determine the true grade of binder with various modified binders used in the state of New Jersey.

3. To determine the properties of the polymer modified binders based on table 3 in AASHTO M320 and to determine the recoveries based on the elastic recovery (ER) test.

4. To quantify the molecular weight distributions of polymers present in the binders using Gel Permeation Chromatography (GPC). If necessary, additional tests such as FTIR or NMR will be used to identify and further characterize the polymers.

5. To determine the sensitivity of $J_{nr}$ and percent recovery from MSCR and ER tests.

6. To develop appropriate specification limits and the database of mechanical properties of modified binders and the type of modification of the binder.

7. To provide recommendations to the state of New Jersey on whether parameters from MSCR and ER can be used for the material selection specifications for polymer and CRM modified binders and appropriate specification limits.

**BACKGROUND AND RESEARCH PROBLEM**

Currently, the Superpave Performance Grade (PG) binder specification, AASHTO M-320, is used throughout the United States to grade asphalt binders (D’Angelo et al, 2007). This asphalt binder specification was based on a strategic highway research program (SHRP) and was based primarily on the study of neat asphalt binders with no polymer additives. The applicability of this specification to the polymer modified asphalt binders raised concerns by industry and state highway agencies. The inadequacy of the Superpave high temperature specification parameter in Table 1 of AASHTO-M320, $G^*/\sin \delta$, to correctly grade the superior field performance of modified asphalt binders has been demonstrated by several researchers (D’Angelo et al, 2007). Therefore, as a replacement for the existing high temperature binder test ($G^*/\sin \delta$), the FHWA has developed the multiple stress creep and recovery test. This test is used to characterize the asphalt binder high temperature properties at which the pavement has to actually perform, in other words, at the environmental use temperatures. As such, many state DOT’s have implemented additional tests called Superpave PG Plus or SHRP Plus tests in an attempt to ensure that a modifier is included in the binder. The SHRP Plus tests do not relate to performance but only indicate the presence of a particular modifier in the binder.

At present, the state of New Jersey requires the use of styrene-butadiene or styrene-butadiene-styrene formulations. In-lieu of the polymer shortages, the state of New Jersey would like to expand the use of polymers and rubber in the binder. Before the state of New Jersey can allow the use of other modifiers, there is a need to first determine whether parameters such as the $J_{nr}$ and the recoveries determined from MSCR (and ER) are sensitive to the polymer or rubber modification of the binder.
PROGRESS THIS QUARTER BY TASK

TASK 1 – COMPREHENSIVE LITERATURE REVIEW
The rheological properties of bitumen are improved by addition of small quantities of polymers. As mentioned in the earlier quarterly report, the physical, mechanical and rheological properties of the bitumen primarily depend on its colloidal structure, linked to the chemical composition especially to the proportion of asphaltenes and maltenes. Asphaltenes are polar materials of high molecular weight (10,000 to 100,000) that are insoluble in n-heptane, a non-polar solvent, and constitute 5% to 25% of the bitumen. The influence of chemical composition of asphaltenes and maltenes on the rheological properties of different polymer modified binders such as SBS, SBR, EVA and PPA is presented in Appendix A in this report.

TASK 2. CONDUCT TRADITIONAL SUPERPAVE BINDER TESTS (AASHTO M 320 TABLES 1 AND 3) TO DETERMINE THE TRUE GRADE OF BINDERS WITH VARIOUS MODIFICATIONS USED IN THE STATE OF NEW JERSEY
Task 2.1. Determine the true grade of the modified binders and conduct PG plus tests, including MSCR (AASHTO TP 70) and ER (AASHTO T301) and compare the recoveries measured from the two methods.
The true grade was determined from M320. A true grade will also be performed on the RTFO aged portion of proposed Table 3 of AASHTO M 320. The results are incorporated in Appendix B.

Task 2.2. Conduct PG plus tests, including MSCR (AASHTO TP 70) and ER (AASHTO T301)
In this study, Multiple Stress Creep and Recovery and the Elastic Recovery tests were performed (Appendix B).

Task 2.3. Compare recoveries between those measured from MSCR and ER
In this task, the research team compared the recoveries measured from the two test methods. In addition the research team compared the true grade of modified binders with the recoveries and the \( J_{nr} \). This task will provide the sensitivity of the parameters measured from MSCR and ER with the true grade of the binder (Appendix B1).

TASK 3: CORRELATE MECHANICAL PROPERTIES FROM STANDARD PG TESTS AND PG-PLUS TESTS TO POLYMERS DETERMINED FROM VARIOUS METHODS
- In this task, the polymers from various methods were determined and then correlated with mechanical properties.
- Task 3.1 Conduct Gel Permeation Chromatography (GPC) to determine the polymers in the modified binder.
Gel permeation chromatography (colloidal characterization) separates compounds based on how quickly the molecule travels through a column. The GPC approach utilizes columns containing finely divided, porous particles. Polymer molecules that are smaller than the pore sizes in the particles can enter the pores, and therefore have a longer path and longer transit time than larger molecules that cannot enter the pores. Motion in and out of the pores is statistical, being governed by Brownian motion. The larger molecules cannot fit through the pores in the column and elute earlier in the chromatogram, while the smaller molecules have to travel through the pores in the column and elute later. This is largely an entropically governed phenomenon. It provides the information about the presence of different compounds but not the actual concentration. Since GPC is a relative method, such instrumentation needs to be calibrated. For example, it can be used to determine the measure
of dispersion of asphaltene after a reaction with PPA. This could be related to the coating and stripping of asphalt from the aggregate. The purpose of the GPC to determine if a given binder grade has similar modification. To determine this, the GPC analysis was conducted for several binders of similar binder grade during different production cycles. The results are incorporated in Appendix C.

PROPOSED ACTIVITIES FOR NEXT QUARTER BY TASK

✓ In the next quarter the research team will continue to test and determine the true grade and MSCR properties of additional modified binders sent by NJDOT.
✓ In addition, Elastic Recovery (ER) will also be conducted on the above mentioned binders
✓ The research team will conduct Gel permeation chromatography (GPC) to determine the polymers in the modified binder.

LIST OF DELIVERABLES PROVIDED IN THIS QUARTER BY TASK

✓ Task 1 Appendix A: Polymer modified binders and their impact on mechanical properties of the binder
✓ Task 2 Appendix B: Traditional Superpave binder tests (AASHTO M320 Tables 1 and 3) to determine the true grade of binders with various modifications used in the state of New Jersey
✓ Task 2.1 Appendix B: The true grade of the modified binders and PG plus tests, including MSCR (AASHTO TP 70) and ER (AASHTO T301) and comparison of recoveries measured from the two methods
✓ Task 2.2 Appendix B: PG plus tests, including MSCR (AASHTO TP 70) and ER (AASHTO T301)
✓ Task 2.3 Appendix B1: Comparison of recoveries between those measured from MSCR and ER
✓ Task 3 Appendix B1: Correlation of mechanical properties from standard PG tests and PG-plus tests to polymers determined from various methods
✓ Task 3.1 Appendix C: Gel Permeation Chromatography (GPC) to determine the polymers in the modified binder

PROGRESS ON IMPLEMENTATION AND TRAINING ACTIVITIES

Not scheduled

PROBLEMS/PROPOSED SOLUTIONS

None foreseen at this juncture.

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NJDOT Research Project Manager Concurrence: _________________ Date: ____________