FHWA Asphalt Binder Expert Task Group Meeting

Binder ETG Purpose:
The primary objective of the FHWA Expert Task Group is to provide a forum for the discussion of ongoing asphalt binder technology and to provide technical input for research, development and implementation.

A total of 71 individuals attended the meeting (16 members and 53 visitors and 2 contract individuals). The meeting was held in Baton Rouge, Louisiana.

ETG Members in Attendance:
Gaylon Baumgardner, Paragon Technical Services (Chairman)
Matthew Corrigan, Federal Highway Administration (Secretary)
Audrey Copeland (Liaison), NAPA (represented by Heather Dylla, NAPA
Chris Abadie, Louisiana Department of Transportation
Dave Anderson, Consultant (Penn State, Emeritus)
Lyndi Blackburn, Alabama DOT
Mark Buncher (Liaison), Asphalt Institute
John D'Angelo, Consultant
Gayle King, GHK, Inc.
Pamela Marks, Ontario Ministry of Transportation (Liaison)
Bob McGennis, Holly Frontier Refining & Marketing
Bruce Morgenstern, Wyoming Department of Transportation
Ioan Negulescu, LSU
Jean-Pascal Planche, Western Research Institute
Gerald Reinke, Mathy Construction

Meeting Coordinator: Lori Dalton (SME, Inc.)
Technical Report: Harold L. Von Quintus, (ARA, Inc.)

ETG Members Not in Attendance:
Mike Anderson, Asphalt Institute (Co-Chairman)
Edward Harrigan (Liaison), TRB
Darren Hazlett, Texas DOT
Mihai Marasteanu, University of Minnesota
Geoff Rowe, ABATECH
Eileen Sheehy, New Jersey DOT

Friends in Attendance:
Howard Anderson, Utah DOT
Tim Aschenbrener FHWA
Haleh Azari, AASHTO (AAPRL/AMRL)
Sreelatha Balamurngan, LSU
Jim Barnay, Road Science
Ramon Bonaquist, AAT
Sandy Brown, Asphalt Institute
John Bukowski, FHWA
Doug Carlson, Liberty Tire Recycling
John Casola, Malvern Instruments
Andrew Cooper, James Cox & Sons
William Daly, LSU
Codrin Daranga, Paragon Tech. Services
Jason Davis, Louisiana DOT
Heather Dylla, NAPA
Aadil Elmoumni, TA Instruments
Mike Farrar, WRI
Frank Fee, Frank Fee LLC
Gary Fitts, Shell
Lee Gallivan, FHWA
Danny Gierhart, Asphalt Institute
Amir Golalipour, Anton-Paar, USA
Matt Groh, Associates Asphalt
Elie Hajj, University of Nevada at Reno
Andrew Hanz, Univ. Wisconsin at Madison
Mark Homer, AJAX Materials
Brian Johnson, AASHTO
David Jones, Univ. Calif. Pav't. Res. Ctr.
Robert Klutz, Kraton Polymers
Pavel Kriz, Imperial Oil
M. Emin Kutay, Michigan State University
Larry Larson, ICL
Ashley Lovasik, Sonneborn, LLC
Daryl MacLeod, Husky Energy
Louay Mohammad, LSU/LTRC
Barry Moore, Louisiana DOT
Gale Page, King of Asphalt Consulting
Hal Panabaker, DuPont; Elvaloy
Sebastian Puehalsai, Kraton Polymers
Tom Rosenmayer, Lehigh Technologies
Delmar Salomon, Pav't. Preservation Sys.
Guy Sisler, Calumet Specialty Products
Hassan Tabatabaee, Cargill
Shauna TecleMarian, U.S. Oil & Refining
Pouya Teymourpour,Univ. Wis. At Madison
Nam Tran, NCAT
Kevin VanFrank, CMETG
Scott Veglahn, Mathy Construction
Chao Wang, North Carolina State University
George Way, RAF
Haifang Wen, Washington State University
Jeff Withee, FHWA
Tim Yasika, Sonneborn
Ludo Zanzotto, University of Calgary
Doug Zuberer, Zydex

[Attachment A is the meeting agenda and Attachment B includes a listing of the ETG members].

DAY 1: Tuesday, 16 September 2014

1. Call to Order – John Bukowski (FHWA) called the meeting to order at 8:15 AM. **Welcome, Announcement, and Introductions** – Bukowski made some initial announcements. Co-chairman Mike Anderson will not attend the meeting, but will call in during some of the reports and discussions. Matthew Corrigan (FHWA) is now the official secretary for the Binder ETG; Bukowski will continue to be the secretary for the Mixture ETG.

Chris Abadie welcomed everyone to Baton Rouge. This is the first time they are hosting these meetings at the LTRC Transportation facility. Abadie mentioned some of the housekeeping rules for the facility. Abadie also welcomed Matthew Corrigan as the new Binder ETG secretary.

Lori Dalton announced meeting agendas are available at the front of the room and the sign-in sheets for the members and Friends of the ETG are being passed around the room. ETG members were asked to check their information for accuracy and friends to note their contact information.

2. Review Agenda/Reports and Action Items from April 2014 Meeting and Technical Section 2b Action Items—Matthew Corrigan (FHWA)

Review Agenda – Baumgardner announced the meeting agenda was sent via e-mail prior to the meeting to all members but copies are available at the front of the room. He noted one item will be added to the agenda: degassing which will be lead and reported on by Dave Anderson. He asked whether there were other changes to the agenda. None were noted.

Approval of April 2014 Meeting Technical Report – The technical report from the last ETG meeting was submitted via e-mail. In addition, the minutes from the AASHTO Subcommittee of Materials (SOM) were distributed to all members. Baumgardner reported the Technical Report from the last Asphalt Binder ETG meeting was sent to Friends of the ETG. He asked if there were any corrections or revisions to the Technical Report. No corrections or revisions were noted.

Review Action Items – Matthew Corrigan reviewed the action items and their status from the previous ETG meeting. He reported all of them are on the agenda or moving forward.

1. Lyndi Blackburn will ask the SOM to require a statement at the beginning of each AASHTO provisional standard alerting/warning the user that it is a provisional standard with limited use because it is not a "full" standard.
   Status: Completed

2. Mike Anderson to clarify that a percent recovery test value that plots directly on the Passing % Recovery line is a passing/acceptable result throughout the proposed MSCR Recovery Procedure standard, if plotting the curve in log scale is beneficial, and will submit the final draft document to the ETG for comment and prepare to move forward to the SOM with a commentary to help clarify M 332 (2014).
   Status: Item is on the agenda.

3. Hussain Bahia/Andrew Hanz to update the progress of the LAS work and the updated/new parameters at the next ETG meeting.
   Status: Item is on the agenda.

4. Intermediate Temperature Task Group will continue efforts and will report at the next ETG meeting. New task group member added: Maryam Sakhaeifar, Texas A&M, msakhaeifar@tamu.edu
   Status: Item is on the agenda.

5. Matthew Corrigan to send final draft M320 PAV temperature recommendations to ETG for comment. Provide any comments directly to matthew.corrigan@dot.gov indicating your support or non-support with your rational for the recommendation.

Status: Completed

6. Emin Kutay to provide update on continued efforts and data collection on GTR modified binder at next ETG meeting.
   Status: Item is on the agenda.

7. Frank Farshidi/David Jones to provide update on continued efforts and data collection on GTR modified binders in California at the next ETG meeting.
   Status: Item is on the agenda.

8. Haifang Wen to provide update on continued efforts and data collection on DSR Low Temp Binder Thermal Cracking at the next ETG and bring this work into the ETG Intermediate Temperature Task Group efforts. Haifang Wen will update the draft procedure based on the recent work and provide to the Task Group.
   Status: Item is on the agenda.

9. Mike Anderson to send Haifang Wen binders from ETG Intermediate Temperature Task Group efforts for testing and report back to Task Group.
   Status: In progress.

10. Gerry Reinke to provide update on continued efforts of the Binder ETG Emulsion Task Group at the next ETG meeting. Send any comments on this effort to Gerry Reinke directly gerald.reinke@mteservices.com
    Status: Item is on the agenda.

11. Mike Anderson, Dave Anderson, and Maria Knake will take up the issue of PAV degassing equipment and procedural concerns from Western Regions and report back at the next ETG meeting.
    Status: Item is on the agenda.

12. Dave Anderson to propose work plan and task group membership to address temperature equilibrium time issue for both 4 mm and 8 mm plate testing.

    Status: Item is on the agenda.

13. ETG to provide their specimen preparation (e.g. trimming, temperatures, setting gap/bulge, etc.) procedure for both 8 mm and 4 mm plate testing in order to gain consensus on the details to include in the standards, directly to Dave Anderson at DA.SC@comcast.net.
    Status: In progress.

14. Mike Farrar, Dave Anderson, and Gerry Reinke will provide direction on 4 mm plate ruggedness testing activities at the next ETG meeting.
    Status: Item is on the agenda.

15. Harold Von Quintus to provide presentation on Asphalt Institute's PPA field test section evaluation final report at the next ETG meeting.

Status: Item is on the agenda.

16. Matthew Corrigan will lead the development of an RNS for GTR modified asphalt oven conditioning alternatives for RTFO and PAV or guidance on concentration limits for conventional RTFO/PAV use.
    Status: Item is on the agenda.

17. Gayle King to provide a written request to ETG members for rejuvenator and binder data in support of NCHRP project 9-58 on rejuvenator and high RAP/RAS mixtures.
    Status: Completed

Corrigan asked if there were any corrections or further discussions on the action items at this time. There were none.

3. AASHTO Technical Section 2b Update and Actions—Lyndi Blackburn (Alabama DOT)

Blackburn provided the results from the last SOM meeting, including a summary of action and ballot items.

Summary of Report/Presentation:
Blackburn reported there were two letter ballots this year.

- Standard Method of Test for Determination of Asphalt Binder Resistance to Ductile Failure Using the Double Edge Notch Tension Test (DENT): Four negative votes were received; 3 were found to be non-persuasive and one was withdrawn Blackburn reported this test could be beneficial to the northern climates because of fracture. It was moved forward as a provisional standard.

- Standard Method of Test for Determining the Fracture Properties of Asphalt Binders Using the Single Edge Notched Bending Test (SENB): Three negative votes were received. A task force was created to review the test and the ballot results. West Virginia is the chair of the task group. Arizona, Ontario, and Vermont are members of the task group. Anyone wanting to participate on the task group should contact West Virginia.

- Standard Method of Test for Measuring Asphalt Binder Yield Energy and Elastic Recovery Using the Dynamic Shear Rheometer: One negative received. The negative was found to be persuasive. Montana will chair a task group[for this standard. Colorado, Idaho, Utah, and Wisconsin are members of the task group.

- Revisions to R 29 to eliminate flash point and rotational viscosity testing as part of determining the PG grade: Two negatives received. Negatives were withdrawn after discussion. The method will move forward to the full SOM ballot.

- Revisions to T 49 to update the precision and bias statement and to reference the current ASTM D 5: No negatives were received. It will move forward to the full SOM ballot.

- Revisions to T 201 to update the precision and bias statement and to reference the current ASTM D 2170: No negatives were received. It will move forward to the full SOM ballot this fall.

- Revisions to T 202 regarding the precision and bias statement and to reference the current ASTM D 2117: No negatives were received. It will move forward to the full SOM ballot this fall.

- T 350, MSCR temperature task group: Task group believes no further changes to the standard are necessary, so the task group was closed.

- GTR specification task force: Blackburn is the chair for this group. She hopes to get information from this meeting to move forward and to guide the task force.

- Six standards require reconfirmation: M 320, T 48, T 201, T 202, T 313, and T 315. These are technical committee ballots and not full SOM ballots. Blackburn acknowledged Dave Anderson did a lot of work on T 313. All changes were deemed necessary and it should move forward quickly.

- Research Needs Statements: Abadie presented three Research Needs Statements (RNS) which were discussed at the meeting. *Enhancing Low-Temperature Performance of Performance Graded Asphalt* was ranked second on the list of priorities. *An Assessment of Changes in Asphalt Production on the Effectiveness of the PG Grading System and Related Effects on Pavement Durability* was listed second. It ranked high, so a decision will be made whether it gets funded.

- The Tech Section discussed requiring a statement at the beginning of each AASHTO provisional standard alerting/warning the user that it is a provisional standard with limited use. This was an action item from the last Binder ETG meeting. She presented the proposed wording at the Tech Section meeting. She will keep trying to push the executive committee to move this forward but for now the wording will not be added. It needs to be generic for all standards and not written within the standard.

ETG Comments, Questions, and Discussion:

John D'Angelo noted when provisional standards started being used after SHRP, there was a lot of work to validate the test procedures. Now many provisional standards are being submitted without being vetted. Maybe an additional category defined as experimental standards needs to be created which would be a separate listing of standards. The experimental category separates it out rather than provisional which implies it is almost ready to go.

Blackburn also reported Ontario is using the DENT test and that is why Pamela Marks is the chair for the task force. Bukowski noted he withdrew his negative on this item due to the Tech Section was not opposed to the test procedure. Blackburn reported Alabama withdrew their negative but have no plans to use it. D'Angelo stated the coefficient of variation (COV) is 18 percent for the DENT test. Marks explained the reason for this high COV, which resulted in a debate relative to how the COV was determined.

Baumgardner reported Bukowski has been the voice for this group relative to the DENT test, but the opinions have now appeared to change or objection to the test has changed. Reinke noted the DENT test is a predictor of low temperature performance. It was never on the table as an intermediate temperature test. The biggest hurdle for the DENT test is the amount of material and the time it takes to run the test. There are other tests available with equal prediction capabilities. Pamela Marks commented the test appears to be a good predictor of low temperature cracking.

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4. **Multiple Stress Creep and Recovery (MSCR) Standard Procedure, Task Group Activities—**Mike Anderson (Asphalt Institute)

Summary of Presentation:
Mike Anderson reported on the development of an MSCR percent recovery draft standard. It was created as additional information to the current MSCR standard because industry wants to know how it relates to the elastic properties of the binder.

Anderson reviewed the background on this issue relative to the current M 322 standard and the revisions made as a result of the last ETG meeting. Anderson reported the revisions are finalized and will send the updated document to Corrigan as a standard practice for review by the ETG.

ETG Comments, Questions, and Discussion:
Corrigan noted it is additional information specifically on percent recovery that is not currently captured in the existing standard. It was developed as an additional standalone procedure and the current recommendation is to move it forward as an additional document. Ultimately, it will be AASHTO's decision on whether it gets added to the current MSCR standard or added as a separate procedure.

Blackburn asked for input from the ETG with regards to it being submitted as a new provisional standard or as a full standard? D'Angelo noted that it does not change anything that is already within the current standard, so his recommendation is it gets submitted as a full standard. Baumgardner and Blackburn agreed with D'Angelo's suggestion. Baumgardner re-stated the ETG recommendation to move the document forward as a full standard. The members agreed with the recommendation.

ACTION ITEM #1: Mike Anderson to send the final version of the MSCR Recovery Standard for distribution and move forward to AASHTO SOM as a full standard.

5. **Asphalt Binder ETG Intermediate Temperature Parameter Task Force—**Mike Anderson (Asphalt Institute)

Summary of Presentation:
Mike Anderson first acknowledged the Task Force members and thanked everyone for participating on the recent conference call. He reiterated the purpose of the task force and explained why it was established.

1. Evaluate the intermediate test temperature under M 332,
2. Evaluate the existing intermediate temperature parameter and criterion in AASHTO M 320 and M 332.
3. If necessary, revise and/or develop one or more parameters that do not require significantly more testing than the current intermediate temperature parameter determined using AASHTO T 315, etc.

Anderson focused on differences between binders used today because they may be different enough from the original SHRP binder G* and sin δ parameter and criterion. He reviewed how the binders were classified relative to the old conventional binders, new conventional binders, and new unconventional binders.

The SHRP MRL Binders were used in developing the current PAV DSR parameter. Anderson presented the ALS data for the designated AAA asphalt. The results are rational and noted the slope of the curves get steeper with harder binders and aged binders. He called attention to the column labeled as NC-A, and reported the notation and terminology does change between Reinke, Anderson, and others. They will work on this to ensure the terminology and notation is the same between the different task force members. Materials included in the experiment are both m and S controlled.
Anderson summarized the current status. They have some additional testing to do prior to resolving the issue. Aging is still an issue in R 28. The simple WRI binder aging procedure is an option. Rather than just increase the PAV aging time, maybe we want to look at WRI's universal aging test? Anderson explained their Task Force proposed plan and defined the next steps. They are looking at the R-value, minimum phase angle at the intermediate temperature grade (or more appropriately at G* = 5,000 kPa), and delta T_c which normally requires running the BBR at two temperatures but it is envisioned to use one temperature with graphs for guidance. Anderson illustrated the R-value versus the phase angle in terms of making it an iso-thermal temperature value and suggested either of these parameters might work.

Anderson reviewed the next steps within their plan. The steps include continue with the evaluation of old conventional binders using the 4-mm parallel plates DSR, DSC, SAR-AD, LAS, and other tests; continue evaluation of the new conventional binders using selected tests, and select new unconventional binders for further evaluation.
ETG Comments, Questions, and Discussion:
D'Angelo noted the delta T_c for neat asphalts is reasonable, but things change for polymers. Should that be investigated to reduce problems down the road? Mike Anderson noted the delta T_c will increase for modified binders. More work must be conducted using modified materials.

Pavel Kriz asked if they were looking at the precision and bias of the existing tests, as well as some of the new tests using the 8 mm diameter parallel plates, and is there any task force activity to address the current precision requirements? Anderson replied there is no current activity through the task force. Kriz asked if there was any effort related to speeding up the PAV conditioning process or any effort to speed up the test procedure? Anderson stated there was no activity.
Dave Anderson noted that it is his opinion that this needs to be looked at from a rheological point of view. Need to know both the relaxation properties in addition to binder stiffness. Will be unsuccessful if look at it from an R-value standpoint.

Gayle King asked why the DENT test was removed for the next round of testing? Mike Anderson noted they have the ability to run the DENT test. The DENT was an option provided to the low temperature task force for a recommendation
For research, there are a lot of tests we can run for research, but for specification tests, we need to use the DSR to fit within the current purchase specification testing requirements.

6. Linear Amplitude Sweep Task Group Report

Corrigan noted the next three reports will focus on activities of the Linear Amplitude Sweep (LAS) test.

6.1 LAS Testing Results – North Carolina State University—Bob Klutz (Kraton Polymers) and Cassie Castorena (North Carolina State University)

Presentation/Report Title #1: *Development of Failure Criterion for the Linear Amplitude Sweep (LAS) Test*

Summary of Presentation:
Cassie Castorena's report focused on the binder fatigue properties captured by the LAS test. She started the report by reviewing the LAS test procedure, and overviewed the fatigue law in pavements relative to the binder component. She identified some of the potential failure mechanisms or concerns during the test; such as distortion due to flow and adhesion failure. Castorena referred to fatigue studies already presented at previous ETG meetings, and pointed out the different failure mechanisms. Castorena reported they adopted the S-VECD approach in their work because the power of the model is that it captures the relationship between material integrity and damage. In other words, one test is used to derive the relationship for quantifying the material integrity; the pseudo strain parameter. She explained; C=1 (unity) for an elastic material that is undamaged, and as damage occurs C decreases from 1. The S-VECD analysis is a unique relationship between material integrity and damage, and allows for a closed form solution to be derived for the fatigue law. The analysis is accomplished using a simple Excel spreadsheet.

The fatigue life prediction originally proposed by the University of Wisconsin is material independent and previously reported to the ETG. The peak shear stress has been proposed as an improvement but there are challenges with this approach. The definition of failure and

failure criterion are based on a pseudo-strain energy analysis. Castorena explained the failure definition uses peak shear stress which is material dependent, but ultimate failure is delayed from the peak stress which is an issue.

They investigated different methods for alternate materials/binder-dependent failure definitions because the peak stress alone is insufficient for defining failure. As such, they looked into using a more fundamental failure analysis for defining failure; a pseudo-strain energy analysis. They propose this as a better means for defining failure in the LAS test. This is the peak stress and phase angle trends in comparison to the energy method. Castorena then showed some results from Kraton to demonstrate the method. The demonstration included graphs comparing the peak stress to the energy method using the pseudo-strain approach.

The next topic of Castorena's report focused on the failure criterion or when does failure occur and what is the material integrity when failure occurs so it can be used by industry. They developed a failure criterion to account for different loading histories. She explained G^R is the energy release rate or something similar to that and showed results for three different LAS conditions/binders. She pointed out this is a unique relationship that can be used to evaluate the binder or material integrity because the relationship between G^R and N_f is independent of loading history. She reported a closed form solution can be derived and incorporated into N_f or number of load cycles to failure.

They used multiple binders and different loading conditions to assess the results from the LAS to predict the time sweep test. She showed some results comparing the c versus s relationship and reported the binders were ranked similarly using this approach. She also compared the damage characteristics curves and failure criterion. All data points were found to fall along the same curve between the LAS and time sweep test and concluded the response is a material property.

The next topic of her report was the prediction of TS from the LAS test. They found this to be a major improvement in using the LAS test. Castorena reported on the field validation using data from the FHWA ALF project for completing a layered viscoelastic evaluation. She pointed out and explained a binder to mix ratio of 80 was used because that value was derived from the last study and it worked reasonably well so they combined it with the follow-on analyses. She mentioned an issue between the lab and field results. The CR-TB had opposite results from the lab and field, so in her opinion, they are not capturing everything needed.

Castorena summarized the conclusion and future research recommended from this work. The conclusions were: peak stress in stored PSE can be used to define failure in the LAS test; and the relationship between G^R and N_f can be incorporated into the S-VECD model for improved performance specification. In terms of future research: more extensive mixture validation is planned as well as investigating temperature effects and considering nonlinearity.

ETG Comments, Questions, and Discussion:

D'Angelo inquired about the testing within an equal-stiffness range for binders, and asked how to determine that value or range? Castorena stated work has shown the temperature corresponding to 5,000 is the temperature, and the specification can be used to determine the intermediate temperature. Klutz referred back to the Kraton results slide; using the isotherm temperatures, all the curves line up but how you determine that practically is the issue. Klutz stated determining the slope of the line is an issue and the bending fatigue data is not capturing everything because the slopes are different.

Kriz inquired about the peak stress and where it occurs relative to the failure definition. Castorena stated determining where the peak stress occurs is a challenge. Kriz referred to the slide showing the prediction of the TS from the LAS test and asked about the difference. Castorena stated they are looking into it and investigating that observation.

Castorena was asked about the failure mechanism. Is the cross sectional area of the specimen constant or a variable; and what is the precision of the test? Castorena stated they target the test temperatures that do not induce flow to get cracking on the outside of the specimen which propagates inward. Taking that into account and varying the cross sectional area changes the results and the precision is generally less than 10 percent from one specimen to another but the observed error is greater.

Dave Anderson stated using a linear analysis on non-linear testing is a big problem. He questioned the specimen behavior along the outside edges of the parallel plates? He also inquired whether this test duplicates or simulates what actually happens in the field?

Casola agreed with Anderson's concerns. He also explained why the phase angle changes and stated a small change can result in a large thermo-dynamic change in the material. Anderson commented; where the change occurs can be a small change relative to self-heating and self-heating is not considered. Castorena replied we do notice a change in the phase angle, but unsure on the cause.

6.2 LAS Ruggedness Progress and New Parameters—Hussain Bahia (University of Wisconsin at Madison)
Corrigan noted the next report on the LAS test will be given by Pouya Teymourpour, who will focus and report on the ruggedness test program.

Presentation Title: *Linear Amplitude Sweep Test—Binder Grading Specification and Field Validation*

Summary of Presentation:
This report will bring the ETG up to date on the activities of the LAS Task Force in four areas: first a review of questions rose at the last ETG meeting and a response to those questions, a comparison to field observations, use of the LAS as a performance grading criteria, and a review of the ruggedness test results.

Teymourpour started the report with a review of the current procedure relative to fatigue cracking. They have changed from a stepped strain sweep to a continuous strain sweep. The current LAS failure criterion was described by Castorena and emphasized they are looking at

peak stress or damage as the failure index, which is described in the current updated procedure as of March 2014. The alternative failure criterion based on peak stress can be used to relate the ultimate failure criterion to a material response indicator.

The next part of Teymourpour's report was focused on the relationship to field performance or the effect of traffic volume and binder properties. He explained fatigue damage can happen as a result of poor binder fatigue resistance at specific strain levels, high truck traffic, and/or a combination of both. He also overviewed a recent Wisconsin DOT sponsored study for implementation of the LAS.

Teymourpour discussed the proposed procedure. Perform the LAS test on the binder at the defined project climate intermediate specification temperature, calculate LAS N_f at 2.5 and 5 percent stain level for the binder stain, and compare the result to the N_f limit corresponding to the design truck traffic using MP 19 or the Superpave mix design definition of truck traffic. He showed the fatigue law for two binders from the LAS in terms of the parameters of A and B. One of the binders was modified and the other was unmodified for both strong and weak pavements in terms of the N_f limit. He summarized some advantages of this proposed procedure; the test can be performed on the same sample as used for the M 320 grading; the calculation is simple; it considers traffic levels consistent with current specifications and DOTs definitions; it considers pavement layer stiffness; and uses the existing framework for MP 19 which can facilitate integration and adoption.

The next part of Teymourpour's report was on the verification of the range of temperatures for running the LAS test in terms of the temperature-stiffness range. The binders used in this effort were from the LTPP and MnROAD programs. In summary, all binders were tested at four temperatures, photographs were taken from cracked surfaces, and time-temperature superposition was checked for VECD damage curves. He reported a relationship was observed between binder stiffness and the apparent geometry change through specimen bulging. He colored coded (in red) the specimens in the tabular presentation in terms of those with excessive bulging. Teymourpour presented the applicable temperature limits derived from this data. He reported the LAS test targets cohesive fracture based crack propagation. At high temperatures, geometry change and bulging initiates the maximum temperature and G* is greater than 10 MPa at 10 Hz. At low temperature excessive brittleness and adhesion failures occur between the DSR plates and G* is less than 60 MPa at 10 Hz. He demonstrated the failure parameter within the applicable temperature stiffness range and discussed the effects of aging on the fatigue life. He asked if we should test using RTFO or PAV conditioned material? Their recommendation is to keep it consistent with M 320 and test the PAV conditioned binder and collect more data in the future.

Teymourpour summarized and reviewed the LAS ruggedness test results. He reported samples were sent to 6 laboratories and four rheometers are being used (Anton Paar Smartpave, TA ARES, TA Discovery Hybrid 3, and Malvern Kinexus). The ruggedness test program was performed in accordance with ASTM E1169. Teymourpour provided some details of the test program in terms of the experimental testing matrix for four factors; sample loading temperature, stain amplitude, frequency accuracy, and sample placement method. Three binder conditions were tested at 19 °C; an RTFO aged neat asphalt, an RTFO and PAV aged neat asphalt, and an RTFO and PAV aged highly polymer modified asphalt.

Teymourpour provided results from the ruggedness tests in terms of the N_f values from the new analysis method. The results were found to be rugged for all four variables.

Teymourpour summarized two conclusions: (1) the LAS is shown to be closely related to observed field performance but more data is needed to establish specification limits; and (2) the Superpave PG intermediate temperature is suitable for the LAS test and a range of applicable temperatures and stiffness have been defined. He also summarized and listed the next steps: (1) add more field performance data for development specification limits based on mixture design categories or AASHTO MP 19 framework; and (2) draft a separate AASHTO procedure document for binder selection and specification limits.

ETG Comments, Questions, and Discussion:
John D'Angelo stated that more information is needed on how to conduct the field validation. He questioned testing in the laboratory with different binders and then using mixtures to determine the correlations while varying other properties. He then commented on the work needed to tie these things together—control in the laboratory is possible but not in the field.

D. Anderson stated diffusion and other items in the field are difficult to simulate in the laboratory. Accelerated testing and laboratory testing should not be used or combined. Klutz emphasized the test needs to be run at a constant stiffness value and asked if the frequency can be modified to conduct testing at a constant equal-stiffness value? John Casola emphasized the need to hold the frequency constant and vary the temperature. Sreelatha Balanurngan ran the LAS test on extracted binder, but the results seemed incorrect because the number of cycles was greater for harder materials. Teymourpour referred to the two stain levels they used. They got the same results at both strain levels. Bahia agreed with the need to test at equal-stiffness but need to test at the PG climate temperature.

Bahia stated the standard has been updated and provided to AAHSTO, but does not know if it will be published. Bukowski stated the standard was submitted directly to AASHTO and not the ETG
Baumgardner asked Abadie for AASHTO's recommendation. Abadie replied the AASHTO task group (steward of the standard) will look at this one via the ETG Task Force. He stated either the AASHTO task group or the Binder ETG should continue to vet this item. Baumgardner noted the ETG will await the AASHTO task group for their suggestion or recommendation. Lunch

Corrigan called the meeting back to order at 1:05 PM after lunch.

6.3 ABLAOS (Asphalt Binder Large Amplitude Oscillatory Shear)—Mike Farrar (WRI)

Presentation Title: *Large Amplitude Oscillatory Shear for Asphalt Binders*

Summary of Presentation:
Farrar explained linear viscoelasticity using strain control in terms of the Lissajous-Bowditch curves and how they are used in the analysis. This explanation included some of the background information in terms of stress versus strain in the linear viscoelastic range and using the entire load cycle data. Traditionally, the work includes only peak stress but if you

have a perfectly elastic material, you get a straight line in terms of dissipated work and if you have 90 degree offset you have a circle. Farrar defined the Lissajous curve and explained why you lose the ellipse, and why there is a need to fit the distorted sine or stress wave through a series of sine waves. If this fitting process is not done a lot of information is missed. If the stress wave is a perfect sine wave then you have one harmonic. Farrar discussed the ratio of the first to third harmonic to ensure the material is in the linear viscoelastic range for testing. Once the Lissajous curve gets distorted away from an ellipse, the material is in the nonlinear viscoelastic range.

Farrar discussed specific details of the LAS Test method through a series of four graphs in terms of flow during the test. Flow probably does not occur as a result of micro-cracks but due to a change in molecular structure. He highlighted an area on the slide and noted if you are in the area dashed and blue, then you are damaging the sample along the edges. Farrar explained using a graph of shear strain versus phase angle; the response from the binder is edge cracking rather than micro-cracking. This is not yielding but probably disruption of the molecular structure. Further, strain hardening is stretching something and it starts to get harder through stretching until it tears. After strain hardening, it fractures as shown in the graph.

Farrar referred to and showed the effect of distortion in terms of the change in binder response of stress versus phase angle and how the Lissajous curve characteristics change along the binder response. He also defined the Pipkin diagram and identified some serious issues with inertia and methods to deal with these which are not readily available. The Pipkin diagram should be 3-dimensional using temperature, shear strain, and phase angle.

Farrar explained; a single loading head has much greater inertia effects in comparison to a dual loading head. Sample inertia is highly dependent on the viscosity of the material. Sample inertia can become very important and dominate the response in some conditions. As such, a parallel plate correction is needed in calculating the true stress response in the nonlinear range. In addition, when calculating the stress there are a lot of inconsistencies and a debris field within the specimen. More importantly, this condition is probably not radiating inward consistently in the specimen.

Farrar discussed the software which used for analyzing rheological properties in large amplitude oscillatory shear and showed some output examples. The material is determined to be strain hardening or strain softening. Farrar concluded it provides a whole new framework for looking at the linear and nonlinear material response of complex fluids and soft solids. More importantly, the common practice has been to apply the viscoelastic moduli corresponding to the first harmonic Fourier coefficients $G_1'(\omega)$, $G_1''(\omega)$. However, in many cases that can be misleading in describing the nonlinear phenomena. In the nonlinear regime, at intermediate temperature, asphalt binders appear to strain soften. At very large strain amplitudes, however, binders appear to strain harden and then fracture. The data so far suggest edge fracture, and inertia effects can dominate when the binder fractures causing a dramatic drop in stiffness.

ETG Comments, Questions, and Discussion:

Dave Anderson commented that the work is good but there are stress concentrations which have not been taken into account. This is appropriate for a research laboratory but not for a specification. Farrar replied they are trying to make the LAS test better.

7. Ground Tire Rubber Task Force Report

7.1 *Development of Research Needs Statement (RNS) and GTR Binder Conditioning—* Matthew Corrigan (FHWA)

Summary of Report:
Matthew Corrigan gave a verbal report on the ground tire rubber modified asphalt activities related to RTFO conditioning issues. . This is an extension of the discussions from the last meeting to generate further discussions and move this topic forward. The issue is that GTR modified binders either don't fully coat the RTFO bottle with a uniform film thickness or they tend to creep out of the RTFO bottles and onto the oven's heating elements during conditioning. It appears to be an issue with binders modified with around 15% and higher GTR concentrations. This issue is similar to polymer modified binders when they were first introduced to the RTFO oven conditioning protocol. Additionally, these high GTR percentages are difficult to form BBR, DTT and ABCD test specimens.

ETG Comments, Questions, and Discussion:
John D'Angelo proposed turning the RTFO bottle at the beginning so you do not have a large mass at the beginning. Corrigan and others have attempted to pre-coat the bottle by rotating it prior to loading in the oven carriage but still have the same issue with the binder creeping out of the bottles. There was a lot of debate between Corrigan and D'Angelo on what may cause the issue.

Emin Kutay: have you considered adding a rod in the bottle? Corrigan stated rods were used in the past for polymer modified binders but he wasn't aware if it had been done with GTR. D'Angelo thought using rods was a good suggestion which might be appropriate for the material. Dave Anderson thinks this issue must be discussed in greater detail with data because he does not agree with using rods. Dave Anderson referenced past work with rolling rods and the results were not favorable. Shauna TecleMariam stated the rolling rod did not help them with GTR modified binders she has evaluated on the West Coast. She is exploring keeping the sample and the RTFO bottle hot and putting it directly in the oven. Her opinion is that the issue may be mitigated by not allowing the material to cool prior to placing the bottles in the RTFO oven. Chris Abadie stated he decided not to use the rods, but did not remember the outcome, since it was a long time ago.

Ludo Zanzotto inquired what GTR particle size was used because he had never encountered that problem? Corrigan stated his experience was with 30 mesh material specified on two projects and that the gradations for both 30 mesh GTR supplied was very different for each project. Additionally, there was oversize material larger than 30 mesh encountered on both projects. Both projects used a PG 64-22 with one using 15.9% GTR and the other using 20% GTR. TecleMariam stated the PCCAS has a task group looking into this issue because they have encountered the same issue with GTR modified binders creeping out of the RTFO

bottles They are conducting a round robin to determine how many West Coast laboratories are encountering this issue. TecleMariam agreed she would do a report on the round robin results at the next ETG meeting.

Bukowski summarized that most everyone is interested in this topic and in getting it through AASHTO or NCHRP. He suggested Corrigan think about this on a broader scale related to GTR, aging, and other topics. Reinke inquired about the applicability of using the parallel plate in terms of GTR modified binder rheology? Corrigan referenced previous work conducted on GTR modified binder test geometry. The consensus from this earlier work was to use the concentric cylinder (cup and bob) geometry which helps alleviate some of the particle size issues with the parallel plate geometry but the GTR concentration issue is still there. Corrigan stated the focus on aging is a first step, and agrees with expanding the scope to include percentage GTR issues if the ETG agrees.

D'Angelo stated the need to review some of the previous work prior to going to an NCHRP project. There is sufficient work already done in order to move this forward to a specification test. D'Angelo suggested maybe a quick synthesis on this topic prior to doing an NCHRP project.

ACTION ITEM #2: Shauna TecleMariam to provide a PCCAS task force report on RTFO conditioning, testing geometry, and particle size influence of GTR modified binders and present at next ETG meeting. Specifically, this will be a report on the round robin results with the RTFO.

7.2 ***DSR Testing of Ground Tire Rubber and Particle Size Effects—***Emin Kutay (Michigan State University)

Summary of Presentation:
Emin Kutay presented the testing plan to determine the effect of GTR particle size. He showed the crumb rubber sizes and percentages included in the testing plan using the parallel plate geometry. He also reviewed the sample preparation for the wet process and described some of the testing conditions with the DSR. Kutay defined the DSR testing parameters and temperatures and presented the data.

Kutay presented an illustration on the particle sizes using X-ray CT for 15 percent GTR. This illustration showed the micro structure of the GTR. Kutay then showed the effect of GTR size on various parameters; including G* versus angular frequency. As the particle size increases, the stiffness increases. The ratio is about 2.3 at higher temperatures, and as the temperature decreases, the ratio decreases until they are equal. Kutay then showed the entire master curve for the data sets for the 15 percent GTR concentration. Kutay then presented the results for the 20 percent GTR concentration level and its effect on stiffness.

Kutay compared the results for high and low temperatures. At high temperature, the asphalt is soft while the rubber is relatively stiff, while at low temperatures the opposite was observed Kutay reported there is a point where the stiffness is about equal for both the binder and rubber.

At low GTR percentage concentration and high DSR temperatures there is a significant effect of GTR particle size, while at low GTR percentage concentration the particle interaction or cushioning effect becomes visible with increasing GTR particle size. At high GTR percent concentration and low DSR temperatures there is no effect of GTR particle size. At high GTR percentage concentration, regardless of particle size, the particles are already interconnected, and at low DSR temperatures the binder between the GTR particles are as stiff or stiffer than the GTR itself, therefore no effect is visible.

ETG Comments, Questions, and Discussion:
John D'Angelo complimented Kutay on his work related to the different percentage and sizes of GTR. He stated that he also evaluated these effects however; he did not go to the same particle size limits that Kutay showed. He looked at 40, 30, and 20 mesh material at different percentages. D'Angelo also noted he used the parallel plates for the smaller than 30-mesh size materials and got the same answer and noted his results were very similar to those included in Kutay's report. D'Angelo pointed out Kutay's 30 mesh size is not actually 30 mesh because of the distribution of particles shown between 30 and 40 mesh material.

Corrigan noted ASTM GTR specifications allow a certain percentage of oversized material for each mesh size specified. John Casola also noted the particle size gradation and suggested the need to look at particle distribution between the different tests and their results. It might help explain the size distribution effects between the results. Casola asked for details on the shift factors used and how they are impacted by dispersion in the material.

Tom Rosenmayer stated the aspect ratio of the particles needs to be considered; it is not just the size. In addition, the type of rubber and it's compatibility with the binder is important. Some rubbers lose their stiffness faster than others, and rubber varies by region. He suggested more work to characterize the rubber itself.

George Way inquired what is expected from the results and what can be done to simulate similar results from the bending beam test. He stated Ergon has a study for testing 5 to 30 percent GTR with different particle sizes and noted E*, mixture sliver testing, Hamburg, low temperature BBR, and many other tests are being used.

Jean-Pascal Planche inquired about wetting the rubber and its effect on the rheological properties. Baumgardner replied; he already did those comparisons and there is a big effect.

8. **Development of Asphalt-Rubber Binder Specifications in California—**David Jones and Farshiddi (University of California Pavement Research Center)

Summary of Presentation:
David Jones gave a verbal report on the asphalt rubber binder specification in California. Jones reported the specification and Superpave mix design for rubber asphalt mixtures. The report has been written and the results can be shared with the ETG at the next meeting. The testing with the rubberized RAP in conventional mixtures has started but nothing to report at this point it time. In addition, testing with RAP and RAS has also begun but nothing to report right now. In place recycling has been completed, but no issues identified thus far. Jones

reported the legislature is getting interested and noted they are in discussions to require every drop of binder used will be required to include 5 percent rubber.

ETG Comments, Questions, and Discussion:
Gayle King inquired if there were any field trials done with rubber and RAP included in the mixture? Jones was unsure but noted there is no control study because contractors do not segregate these materials out of their mixture designs. They are looking at a laboratory study under controlled conditions to identify items of interest. King asked if anyone has or knows of a controlled field trial with binder testing to please let him know. George Way reported he had information about where mixtures have been placed, but is unsure about how much RAP was used. Pamela Marks also noted she was aware of some mixtures placed in Ontario but she is unsure about the percentages used. Kutay noted they have placed mixtures at 40 percent RAP with terminal blend binders in Michigan, which do include some test sections.

ACTION ITEM #3: Dave Jones awaiting feedback on University of California at Davis GTR work elements from CalTrans and will provide update at next ETG meeting

9. DSR Reference Fluid—Dave Anderson (Consultant)

Presentation Title: *Comments on Use of Reference Fluid to Verify DSR*

Summary of Presentation:
Dave Anderson noted this report is on more practical related items than a theoretical presentation. He referred back to the last meeting for background information on how and why reference fluid is used. A reference fluid is used to verify the torque transducer. Anderson explained why we should be comparing the viscosity measured with the DSR to the viscosity published for the reference fluid. The reasons include measuring the viscosity of reference fluid at combinations of temperature, frequencies, and strains where the response is Newtonian; because the viscosity is independent of shear rate, the elastic and viscoelastic response is negligible, and the calculation for the measured viscosity becomes straight forward.

Anderson explained how the viscosity of the reference fluid is determined.
There are two options with the DSR. The first is the steady state shear which is the more difficult test to run. The second uses the sinusoidal oscillation and assumes resistance to deformation is entirely viscous flow. It is more commonly used and considered the better approach. Thus, limiting the strain to the region where the reference fluid is used is very well defined. Anderson identified the items that can affect the accuracy of the DSR measurements using the reference fluid, but noted that each one can be easily controlled with proper laboratory procedures. These include:

- Measurement temperature; verify the temperature of the fluid.
- Fluid expiration date; do not use beyond the expiration date.
- Heating the fluid can cause it to deteriorate; so make sure you use proper storage temperatures.
- Improper test specimen preparation; bubbles can reduce the measured value, as well as the gap and improper bulge.

Anderson emphasized the torque is the only parameter that has uncertainty and needs to be determined accurately in measuring the complex viscosity, n*. At this point in the report, Anderson noted some of the issues with measuring the torque and recommended a checklist be used to ensure accurate determination. The checklist should include:

- Incorrect specimen geometry.
- Improperly formed specimen.
- DSR thermometer not being verified.
- Angular displacement transducer.
- Accurate internal instrument calibration.
- Machine compliance.

Anderson then explained why a single test temperature is used. The motor only knows it needs to apply a torque which has nothing to do with the temperature. Anderson showed some typical results and measured viscosity versus temperature. He recommended the calibration reference fluid temperature should be at 64 °C and only one temperature be used.

Anderson concluded with:

- If the DSR measured viscosity equals the reference fluid published viscosity, the DSR is likely working correctly and the torque transducer is verified.
- If the DSR measured viscosity differs from the reference fluid published viscosity, something is wrong. It could be related to the torque transducer or other internal DSR calibration items. The difference is likely not machine compliance if strains are not small; not temperature errors if temperature was verified; and likely not a specimen issue if the technician is competent.

ETG Comments, Questions, and Discussion:
D'Angelo suggested this information should be directly provided in AASHTO T 315. Dave Anderson stated there is something already in T 315 on this topic, but he is looking to make it a lot stronger. Reference fluid is a useful tool but can lead to trouble if not used correctly. D'Angelo asked if the ETG: should recommend this information be provided in the DSR test standard? Dave Anderson stated he is working on getting this information into the test method through other means and no ETG action is needed at this time.

10. PAV Degassing Issues – R 28—Dave Anderson (Consultant) and Mike Anderson (Asphalt Institute)

Presentation Title: *Vacuum Degassing of PAV Residue Always – Never - Optional?*

Summary of Presentation:
Anderson provided background on this topic and informed the group the issue was again raised at the Rocky Mountain User Producer Group meeting. He first reviewed the initial efforts and envisioned a simply study to validate a previous decision that degassing should be optional.

The work investigated the linearity of the PAV chambers pressure release rate; reviewing previous degassing experiments; and conducting an informal survey of the RMAUPG workshop attendees. Future activities will re-evaluate the direction based on ETG input; develop and conduct experiments; and develop recommendations for test procedure updates.

Anderson reported they captured the pressure release versus time and showed typical pressure release rates. From the results, they concluded: the release rate is not linear for one PAV manufacturer, the test method requirements are ambiguous, and the effect of the release rate on bubble formation and measured properties are unknown. Anderson thought the linear release rate was used in the original PAV development study. If that is required, however, that will put one vendor out of business. It appears the original intent of the PAV has been lost over time.

Anderson provided a historical perspective on vacuum degassing. The vacuum degassing was adopted to enhance repeatability of the direct tension test data. There was extensive discussion between Anderson, D'Angelo, Bukowski, and Klutz on the original meetings to include the degassing effort because it was originally not required in the standard. Anderson referred to Reinke's recommendation to drop the degassing requirements if the direct tension test was going to be dropped. Another previous degassing study was conducted by the Asphalt Institute, and a third study was conducted by WCTG. All of these studies showed outliers. In Anderson's opinion, there is a need to reevaluate some of the data sets because of the outliers.

Anderson reported on the survey of the RMAUPG workshop attendees. Six questions were asked and the results summarized. Reinke commented the trend appears to be in the wrong direction in comparing the data sets with and without the degassing. Anderson concurred with that observation stated the need to review what we want redone because of the differences. Reinke stated bubbles will continue to escape out of the specimen, even when degassing multiple times; there are always bubbles. The result will always be a softer material when degassed than before degassing.

There are several questions that need to be answered on the topic.

- Is the pressure release rate a factor?
- Bubbles flashed from pan upon removal?
- Residue properly stirred? Is there extra heating?
- Improper heating before degassing?
- Does degassing increase variability?
- Does degassing make a difference on the BBR and DSR test results?
- Should the PAV spec be modified to accommodate non-conforming equipment?

In his opinion, the BBR test method needs to state whether degassing is or is not used; it needs to be uniform, not optional. Findings from the effort include:

- Relative to the pressure release rate; none of the data show a contribution to problem.
- Some laboratories use vacuum degassing as fallback for bubble removal whether needed or not. Is this good practice?

- Test methods are inconsistent. The requirement for degassing and the linearity issue need clarified.
- Anecdotal information contradicts previous findings; practitioners question the conclusion that not degassing caused no effects.

Anderson concluded by defining the future activities needed.

- A study to quantify effect of selected variables.
- Recommended updates to test methods.
- Round robin study.

ETG Comments, Questions, and Discussion:

Corrigan asked about the laboratories that were using the nonlinear pressure releasing PAV model and whether there was a concern with its use. Anderson stated he did not know.

11. PAV Temperature Recommendations – M 320—Matthew Corrigan (FHWA)

Presentation Title: *PAV Temperature Selection (Take No. 3) – Discussions*

Summary of Presentation:
Matthew Corrigan provided an initial briefing and reminder how the topic was progressing from previous meetings. He showed what was resolved from the last ETG meeting. Due to the amount of discussion on other topics, this item was not discussed in detail. Corrigan continued to collect information from the group and friends on this topic. Corrigan noted there were responses both pro and con related to these changes.

ETG Comments, Questions, and Discussion:
. Reinke: this could have been avoided if you PAV age at 100 degrees for everything but you can age down depending on the condition. He suggested this is still an option to PAV all at 100 degrees. McGennis inquired on what AASHTO was planning to do with this guidance. Corrigan replied he was asked to present the information at the midyear webinar and he will report there are differences of opinion and reiterate there is not a consensus from the ETG.

Corrigan adjourned the meeting for Tuesday at 4:55 PM.

DAY 2: Wednesday, 17 September 2014

Call to Order – Gaylon Baumgardner called the meeting to order at 8:05 AM.

12. Low Temperature DSR Rheology Report
The report from the low temperature DSR rheology group was provided by Dave Anderson. He is providing the status report on all 4 mm parallel plate test protocol and measurements activities for the group.
Presentation Title: *Thermal Equilibrium and Test Protocol for 8 mm and 4 mm DSR Measurements*

Summary of Presentation:
Dave Anderson opened with some background information and suggested before adopting the 4 mm plates in the binder high stiffness zone, we need to get a procedure documented that is appropriate for DOT practice.

Anderson summarized the scope of the work to provide guidance for the development of 4 mm parallel plates (PP) geometry as a tool for specification testing but not research. He emphasized the scope does not include protocols for using test data, nor does it include acceptance and material specification requirements based on the 4 mm PP. The goal is to ensure we get repeatable results.

Anderson presented the task force work plan, which consists of three steps or activities. (1) to develop a testing protocol that is appropriate for routine use and provide data of acceptable accuracy and precision; (2) conduct ruggedness testing; and (3) conduct round robin testing. Anderson reported the current focus has been on step 1 in terms of developing and recommending test protocols based on limited laboratory testing. This also includes instrument standardization, specimen preparation, specimen conditioning, thermal equilibrium and physical hardening, verification of data integrity, and provide rational for the protocol based on test results. Results from step 1 will be used to prepare a formal ruggedness test program and define minimum requirements for suitable rheometers.

The issues identified by include instrument verification, specimen preparation, conditioning prior to testing, testing sequence, linearity region, and data quality. Anderson noted they are looking at much smaller angular displacement with the 4 mm PP which is important.
The next part of Anderson's report focused on those issues within step 1.

- Torque transducer verification with a reference fluid at the ambient temperature and the current practice of using 25 mm plates at ambient temperature
- Temperature transducer can be a genuine problem that is difficult to resolve. The 25 mm diameter wafer is difficult to use. It is questionable for 8 mm PP and unacceptable for the 4 mm PP.
- Machine compliance is another issue related to the specific instrument and is fixture specific.

Placing the sample on the plates requires a new protocol and adhesion is the primary concern. More care is needed within current protocol relative to trimming. In addition, bulging and specimen dimensions require a new protocol because of the temperature at which the bulge and final gap is formed, as well as control of normal forces during final closure. Anderson reported two protocols are being written by WRI and Mathy which are addressing all of these issues. These protocols will address the primary difference in bulge formation, but both of the two procedures need to be refined and evaluated. Anderson provided a summary of each protocol.

- Mathy protocol: Anderson mentioned a heat gun may replace the torch that Reinke showed in his summary at the last ETG meeting due to laboratory concerns with use of an open flame. During trimming the specimen, it is very important to monitor the normal forces on the specimen.

- WRI protocol: This procedure softens the binder on the plate. Anderson mentioned the difference between the WRI and Mathy protocols

Thermal condition prior to testing is important. The wait time is about 10 minutes for the 8 to 25 mm PP which is too long for the 4 mm plate. The wait time for 4 mm PP is about 2 minutes. Anderson reported physical hardening is considered with the BBR but needs to be resolved for the 4 mm PP because physical hardening appears to be rheometer specific. Anderson reviewed the test protocol for establishing the wait time, which is a new procedure documented within AASHTO T 315.

Anderson reported the protocol is based on linear behavior, but how do we ensure linear behavior and specify the strain limits. He also noted they are looking into specifying the strain as a function of modulus.

Another item the group is focused on is verifying data integrity. This is related to the fall-off in G* with strain during the stain sweep and relates back to the yesterday's presentation from Mike Farrar. He mentioned the Lissajous figures that were used in Farrar's presentation and highlighted the first and third harmonics and their impact on the result to establish linearity and if significant distortions exist in the data.

Anderson then reported on some of the results related to the testing protocol. In specific:

- Machine compliance is the responsibility of the manufacturer and is considered resolved.
- Sample preparation protocol is still in progress.
- Temperature sequencing is being investigated, probably later this year or early next year.
- A protocol for evaluating data integrity is also being developed.

ETG Comments, Questions, and Discussion:
Gayle King stated his belief that this is extremely important work with activities that relate to emulsion specifications. There is a desire to get low temperature properties from 4 mm parallel plates. Industry is counting on the 4 mm parallel plates to get an accurately measured value.

Klutz inquired if the temperature control for the 4 mm testing is possible? Dave Anderson does not know the answer and did not want to speculate. Temperature control will be an important component to the success of the 4 mm test protocol.

13. RAS Considerations—Louay Mohammad (LTRC, Louisiana State University)

Presentation Title: *Design Consideration of Asphalt Mixtures Containing RAS: Impact of Recycling Agents*

Summary of Presentation:

Louay Mohammad reported on work being completed at LTRC regarding the impact of recycling agents on mixtures containing recycled asphalt shingles (RAS). Their objective for this project was on how to incorporate and design for RAS in asphalt concrete mixtures. The experiment was composed of three basic parts regarding design with RAS: (1) design mixtures with no shingles, (2) add shingles to the mixtures, and (3) add shingles with recycling agents to the mixtures. The objective of the mixture experiment is to evaluate the intermediate and low temperature laboratory performance. The objective of the binder experiment is to correlate the molecular structure of asphalt binders to fracture property of the mixture using Gel Permeation Chromatography (GPS) and Fourier Transform Infrared Spectroscopy (FTIR).

A 5 percent level for RAS was used in the experiment with six mixtures. The first three had no recycling agent and second three included recycling agents. The recycling agents were grouped into two classes: rejuvenating agents and softening agents. Three different recycling agents were included in the experiment.
Recycling agent (RA) 1 increased the available binder up to 50 percent, recycling agent 2 provided 100 percent, and recycling agent 3 provided 86 percent. When you increase the RBR you need less virgin binder, but is that a good or bad thing?

Triplicate testing was done on the mixtures. The performance tests included the semi-circular bending (SCB) test for the intermediate temperature performance and the thermal stress restrained specimen test (TSRST) for the low temperature performance. The Jc from the SCB test significantly decreased for the mixtures with recycling agents, while variable results were found for the fracture temperature from the TSRST test on the mixtures with and without recycling agents.

Mohammad then introduced Bill Daly for the report on the binder experiment, which was to investigate the impact of recycling agent on the binder through the use of the Gel Permeation Chromatography (GPC) and FTIR for the chemical analysis. The binder used in the experiment was extracted from laboratory aged asphalt concrete mixtures (5 days at 85 °C). He provided typical results for the molecular weight (MW) distribution of molecular species of the PG70-22M extracted binder containing no RAS and compared that distribution to the one with the RAS. Recycling agents only increased the amount of material extracted – they did not improve the properties.

Daly reported the curvilinear index was used to evaluate aging of the binder. He presented a correlation of VHMW, carbonyl index, and Jc. In summary, rejuvenating agents do not break down the association of the asphaltenes, so polymers get added to improve the material to retain the crack resistance. Adding polymer is the key to making these materials compatible.

Mohammad summarized the findings reached based on the laboratory performance evaluation of the asphalt mixtures containing RAS with and without recycling agents.

- RAS binder credit is much lower than what was recommended at the beginning of the experiment.
- AASHTO PP 78 overestimates the actual shingle asphalt binder availability factor.
- Volumetric-based design is insufficient when using these materials.

- Lower Jc values are obtained from the SCB test when using recycling agents and there does not appear to be any adverse effects when not using recycling agents.
- Carbonyl index did not result in a good indicator or predictor of fracture resistance.
- Regarding the recycling agents:
    - The use of soft binders (RA 1) did not improve the crack resistant properties.
    - RA 3 enhanced the extraction of the asphaltenes from the RAS.
    - RA 3 performed better than RA 2 at the intermediate test temperatures.
    - RA 2 enhanced the extraction of the asphaltenes in great concentrations.
    - Molecular fractionation using the GPC of the RAS samples:
        - High concentrations of heavy MW asphaltenes decrease the fracture resistance of the asphalt mixtures.
        - The presence of SBS additives enhances the compatibility with the heavy MW asphaltenes.
    - Use of recycling agents in this study did not reduce the concentration of the highly associated asphaltenes and did not improve the cracking resistance.

Mohammad concluded with some questions to consider as we move forward. Do we really want to get 100 percent from the RAS? Is utilization of RAS as a "black rock" an option? What is the benefit of adding recycling agents to enhance the compatibility with the heavy MW asphaltenes?

ETG Comments, Questions, and Discussion:
John D'Angelo suggested the recycling agents did not get the asphalt out of the RAS. It just softened the virgin binder to meet the volumetric properties. The mixture data shows it is still hard asphalt and was never rejuvenated. Mohammad responded the assumption is that the asphalt was recovered from the mix. Bill Daly explained the same extraction procedure was used in comparing the RA 2 and RA 3 and they were different.

Zanzotto stated the asphaltenes are changing when we go from "black rock" to shingles. In the case of shingles, the material is highly oxidized and not just through air blowing. When using PMA as the virgin material, you help improve some features so we can use a high quality binder to reinforce the asphalt from the poor RAS performance. Jean-Pascal Planche stated Germany uses PMA as a high quality asphalt virgin binder when going to high RAP/RAS concentration mixtures.

Gayle King stated the HPCP results suggest adding a heavier molecular material that is highly polar. Is it a fatty acid product or it is still esters? Daly replied it is still esters, and is more polar. The association is not strong and it can be broken down
Reinke stated once you improve the material, the improvement then continues to deteriorate over time. Mixtures with polymers look really good at first, but that benefit might deteriorate over time.

Hussain Bahia inquired if the SBS is breaking down the asphaltenes or are SBS modified improvements able to overcome the poorer asphaltenes from the highly aged RAS material? Mohammad replied the later understanding is correct. It is the better material can cover up the sins or inadequacies of the poorer material.

Break at 9:45 AM.

14. PPA Field Study—Harold L. Von Quintus (ARA, Inc.)

Presentation Title: *Performance of Asphalt Mixtures Containing Polyphosphoric Acid*

Summary of Presentation:
Von Quintus reported the study has been completed and the report will be published through the Asphalt Institute. The purpose of the study was to quantify the effect of polyphosphoric acid (PPA) as compared to non-PPA modified mixtures in terms of surface distress and field performance, and to identify site features and/or mixture properties that maximize the effect of PPA relative to performance. Von Quintus emphasized that no laboratory testing or field destructive testing was completed within this project, other than what was already available from construction records and other studies.

Field projects were identified with multiple companion projects both with and without PPA. A comparison of surface distress was made for all of the companion projects, as well as an overall summary for raveling, rut depth, fatigue cracking, and transverse cracking.

The findings or observations from the field study were:

- No consistent and significant difference in performance between the PPA and non-PPA modified sections.
- There was insufficient data available and too many confounding factors to determine any mixture characteristic or site features that increase or decrease pavement life.

The recommendations made from the study included developing a structured experimental plan using NCAT and MnRoad to answer two questions: (1) does PPA negate the impact of lime and/or amines, and (2) what level or amount of PPA should be avoided because it is detrimental to performance.

ETG Comments, Questions, and Discussion:
Tim Aschenbrenner inquired what was planned for future investigations and reporting on the Colorado companion projects and what concentration of PPA was included? Von Quintus replied the reporting on final construction and distress surveys from Colorado DOT should be available at the end of 2015and it was less than 1.25 percent by weight of asphalt.

Pamela Marks: referred to some of the experiences with PPA modified asphalt mixture used in Ontario. Their observations are similar to those reported. She also asked about the different levels of PPA included in the mixtures used in the study. Von Quintus replied all levels of PPA reported in mixture design or construction documents were less than 2.0 percent; some were greater than 1.0 percent. The levels or concentrations of PPA are included in the report.

15. Pavement Temperature Profile Prediction—Elie Hajj (University of Nevada at Reno)

Summary of Presentation:
Elie Hajj gave a summary report on the capabilities and outcomes of the software package entitled Pavement Temperature Profile Prediction—TEMPS. This is a standalone software package for pavement structures to predict the temperature profile through the pavement layers. It has been alpha tested and the alpha version is available. Hajj also reported this software can be used for both asphalt concrete and Portland cement concrete surfaces, but most of the work has been focused on asphalt concrete surfaces.

This software package includes an improved Heat Transfer model and the application of finite control volume method (FCV) with implicit scheme which relates to considering discontinuity in pavement layers materials and improving the time efficiency of calculation. The numerical computation is based on the finite control volume method, so this also includes the asphalt concrete and unbound materials or layers.

The inputs to the software are grouped into different parameters; Materials, Climate Data, Surface Characteristics, Pavement Structure, and Mesh Generator. There are specific options included in the software allowing the user to enter their own temperature monthly data. The user can specify as many layers as needed up to 3 meters in depth. Every layer is assigned the materials properties already entered. The mesh generator has two options: uniform and non-uniform. The option is decided on by the user.

t takes less than 10 seconds to run for a 20 year design life using a 1-hour time step. The 1-hour time step was selected to increase the computational efficiency and reduce run times without jeopardizing model accuracy. The user has an option to select any depth or depth interval within the pavement. It can generate temperature profiles at any point in time, as well as a general summary for the entire analysis period, and the minimum and maximum temperatures at any depth and time.

Hajj showed some comparisons of the measured and predicted temperatures. . He described how Glover's process is used in the prediction model. A Particle Swarm Optimization (PSO) algorithm is used to calibrate the model to significantly improve the predictions. This is being worked on more extensively to improve the model regarding the maximum and minimum values. In his example of the predicted versus measured temperature values using the Great Falls, Montana LTPP site, he focused on the over prediction of the measured values, as well as lower predicted values. Using the PSO process for this example, all bias can be removed, but you still have some differences on the low temperature side.

There is a plan to optimize the surface characteristics for the U.S. using a PSO algorithm. There is also a plan to create and include input fields for the LTPP SMP sections and provide a summary of the average 7-day pavement temperature at various depths, as well as provide a summary of pavement cooling and warming rates.

ETG Comments, Questions, and Discussion:
There was no further discussion after the report.

16. Prediction of Complex Shear Modulus and Fracture Properties of Asphalt Binders with Oxidative Aging—Haifang Wen (Washington State University)

Summary of Presentation:
Wen discussed some of the different studies related to this topic and indicated that a better model is needed for predicting asphalt binder mechanical properties from oxidation. Only limited work has focused on predicting asphalt binder oxidation. The global aging model included in the MEPDG software potentially induces a lot of error because it does not consider the individual aging path. Thus, another aging model should be pursued. Thus, the objectives of this project are: (1) to predict the viscoelastic properties of the asphalt binder with oxidative aging, and (2) to determine the fracture properties of the asphalt binder with oxidative aging.

The experiment includes aging three binders typically used throughout the state of Washington. Different aging times were used over different aging temperatures. The types of measurements included in the experiment are: Carbonyl area measurements, frequency sweep test, and a monotonic test.

Wen presented a flow chart showing how the different modules fit together. The different modules were defined as: (1) the crossover modulus and carbonyl area, (2) an analysis of crossover modulus data, (3) the evolution of crossover frequency, (4) and the predicted master curve of G* and δ.

- Relative to the crossover modulus and carbonyl area—the same relationship was observed for all three binders.
- An analysis of the crossover modulus data showed it is not linear.
- Using the same relationship, you can predict the crossover modulus.
- Binder master curves agree with other relationships. The predicted master curve of G* and δ (CA model) versus measured values compare very well.
- Predicted G* and δ of the three binders matched well with the calculated G* and δ from the sigmoidal function. The model can accurately predict when the phase angle is between 10 and 60 degrees. There is little deviation between the predicted and calculated master curve when it approaches high temperatures or low frequencies.

Wen reported they borrowed an idea to develop an empirical conversion method, for mixture stiffness and tensile strength relationship, using a generalized Maxwell model that was originally developed by Ninomiya and Ferry. A linear relationship exists between G(t) and shear fracture stress. A linear relationship also exists between G(t) and the crucial stain energy density. The relationship between the G(t) and failure strain contained more data scatter than the others so more work is needed relative to this parameter.

The observations from this project include:
- The relationship between carbonyl area and the log of the crossover modulus is approximately linear, but it is asphalt dependent.
- The inverse of the log crossover modulus data showed correlations between the Arrhenius kinetics parameters and the predicted values using the oxidation kinetics model as a function of aging time and temperature.

- The log crossover frequency and log crossover modulus are highly linearly correlated with aging time for both neat and modified binders.
- The CA model can be used to predict complex modulus and phase angle master curves, for both neat binders and modified binders.
- G* can be converted to shear relaxation modulus which can be related to the fracture properties of asphalt binders.

The recommendations from Wen were: (1) more work needs to be done by including more binders and PMA; and (2) predict fracture properties of mixtures from these results.

ETG Comments, Questions, and Discussion:
There was no further discussion after the report.

17. Update of Binder ETG Emulsion Task Force—Gerald Reinke (Mathy Construction)
No formal report was provided on this topic in the interest of time.
A consensus was reached on the paddle viscometer. The thin film recovery procedure is being revised. Their focus is on using the 4 mm DSR procedure. The ASTM Vacuum Residue Recovery procedure has been balloted. Results from the ballot are not yet available. No other follow-up is needed right now.

18. Other Business—Gaylon Baumgardner (Paragon Technical Services) and Matthew Corrigan (FHWA)
No other business was initiated or discussed.

19. Summary of Action Items/Next Meeting—Gaylon Baumgardner (Paragon Technical Services) and Matthew Corrigan (FHWA)

Action Items: Matthew Corrigan summarized the action items from this meeting, which are:
1. Mike Anderson to send the final version of the MSCR Recovery Standard for distribution and move forward to AASHTO SOM as a full standard.
2. Shauna TecleMariam to provide a PCCAS task force report on RTFO conditioning, testing geometry, and particle size influence of GTR modified binders and present at next ETG meeting.
3. Dave Jones awaiting feedback on University of California at Davis GTR work elements from CalTrans and will provide update at next ETG meeting.

20. Wrap-Up and Meeting Adjournment
Baumgardner adjourned the meeting at 12:20 PM.

ATTACHMENT A

Asphalt Binder Expert Task Group
Baton Rouge, Louisiana
September 16-17, 2014
Meeting Agenda – Final

Day 1 – September 16, 2014

8:00 am	Welcome and Introductions	**Baumgardner/M. Anderson**
8:15 am	Review Agenda/Minutes Approval & Action Items	**Corrigan**
8:30 am	AASHTO SOM Technical Section 2b (Asphalts) Actions	**Blackburn**
9:30 am	**Break**	
10:00 am	MSCR Recovery Standard Procedure – M 332 Comments	**M. Anderson**
10:30 am	LAS Testing Results – NC State University	**Klutz**
11:00 am	LAS Ruggedness Progress and New Parameters – TP 101	**Bahia**
11:30 am	LAOS (Large Amplitude Oscillatory Shear)	**Farrar**
Noon	**Lunch Break**	
1:00 pm	Development of RNS for GTR Binder Conditioning	**Corrigan**
1:30 pm	DSR Testing of Ground Tire Rubber and Particle Size Effects	**Kutay**
2:00 pm	Development of Rubber Binder Specifications in California	**Jones/Farshiddi**
2:30 pm	**Break**	
3:00 pm	Intermediate Temperature Task Force Activities	**M. Anderson**
3:30 pm	DSR Reference Fluid	**D. Anderson**
3:45 pm	PAV Degassing Issues – R 28	**M. Anderson/D. Anderson**
4:00 pm	PAV Temperature Recommendations – M 320	**Corrigan**
4:30 pm	~~DSR Low Temp Binder Thermal Cracking Procedure~~	~~**Wen**~~
5:00 pm	**Adjourn for the Day**	

Day 2 – September 17, 2014

8:00 am	Low Temperature DSR Rheology - Sample Preparation - Temperature Equilibrium 4mm vs. 8mm plates - 4mm DSR Ruggedness Testing	**Farrar/Reinke/D. Anderson**
9:00 am	RAS Considerations	**Mohammad**
9:30 am	**Break**	
10:00 am	Emulsion Task Force Update	**Reinke/Gallivan**
10:30 am	PPA Field Study	**Von Quintus**
11:00 am	~~Binder Rheology 101 – Relaxation Spectra~~	~~**D. Anderson/Rowe**~~
11:45 am	Summary of Action Items	**Baumgardner/Corrigan**
Noon	**Adjourn**	

Note: The topics of **Recycled Engine Oil Bottoms (REOB)**, **RAP Binder Diffusion,** and **NCHRP 9-58 RAP/RAS/Recycling Agents** will be presented during the Mixture ETG meeting.

ATTACHMENT B

ASPHALT BINDER EXPERT TASK GROUP MEMBERS

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