FHWA Asphalt Mixture Expert Task Group

Asphalt Mixture ETG Purpose The primary objective of the FHWA Expert Task Group is to provide a forum for the discussion of ongoing asphalt mixture technology and to provide technical input related to asphalt mixtures design, production and construction.

A total of 62 individuals attended the meeting (17 members, 2 contract personnel, and 43 visitors). Attachment A is the meeting agenda, Attachment B includes a listing of the Mixture Expert Task Group (ETG) members, and Attachment C is a listing of the Mixture ETG Task Force members.

Member of the FHWA Asphalt Mixture ETG in attendance included:

Shane Buchanan, Old Castle Materials (Chairman)
Ray Bonaquist, Advanced Asphalt Technologies, LLC (Co-Chairman)
John Bukowski, FHWA (Secretary)
Howard Anderson, UDOT
Jo Daniel, University of New Hampshire
Ervin Dukatz, Mathy Construction Company
Kevin Hall, University of Arkansas
Adam Hand, Granite Construction, Inc.
Louay Mohammad, Louisiana State University
James Musselman, FDOT
Dave Newcomb, Texas A&M University
Timothy Ramirez, PA DOT
R. Michael Anderson, (Liaison) Asphalt Institute
Mark Buncher, (Liaison) Asphalt Institute
Audrey Copeland, (Liaison) NAPA
Evan Rothblatt, (Liaison) AASHTO
Nam Tan, (Liaison) NCAT

Members of the ETG not in attendance:

Ross O. Metcalfe, MDOT
Tom Bennert, Rutgers University
Gerry Huber, Heritage Research Group
Todd Lynn, Thunderhead Testing, LLC
Edward Harrigan, (Liaison) NCHRP
Pamela Marks, (Liaison) Ministry of Transportation

"Friends" of the ETG that were in attendance included:

Tim Aschenbrener, FHWA
Amir Golalipour, ESC Inc.

Randy West, NCAT
John D'Angelo, D'Angelo Consulting LLC
Paul C. Ziman, FHWA Utah Division
Kevin Van Frank, CMETH
Stacy Glidden, Payne & Dolan
Danny Gierhart, Asphalt Institute
Richard Kim, North Carolina State University
Ronald Corun, Aveon Specialty Products
Alexander Brown, OHMPA-AI
Bob Kluttz, Kraton Polymers
Adam Taylor, NCAT
Cristian Clopotel, Marathon Petroleum
Imad Al-Qadi, University of Illinois Urbana-Champaign
Gerald Reinke, MTE Services
David Jones, UC Davis/UC Pavement Research Center
William Criqui, Ingevity
Kieran McGrane, IPC Globac
Carlos Del Orbe, Controls Grove
Akhtar Tayebali, North Carolina State University
Pedro Romero, University of Utah
Gary Fitts, Shell Bitumen
Ali Regimand, Instrotek, Inc.
CJ DuBois, DuPont Elvaloy ®
Jack Youtcheff, FHWA
Lee Gallivan, Gallivan Consulting, Inc.
Alan Feeky, Pavetest Pty Ltd
John E. Haddock, Purdue University
Lyndi Blackburn, Alabama DOT
Andrew Cooper, James Cox & Sons
Geoff Rowe, Abatech
Ann Baranov, Infratest USA
Hal Panabaker, DuPont Elvaloy ®
Nelson Gibson, FHWA
Todd Arnold, Pine Test Equipment LLC
Andrew Hanz, MTE Services Inc.
Gaylond Baumgardner, Paragon Technical Services
John Casola, Malvern
Scott Andrus, UDOT
Hasan Ozer, University of Illinois
J-P Planche, Western Research Institute
Frank Fee, Frank Fee LLC

Meeting Coordinator: Carol Fisher, Amec Foster Wheeler
Meeting Technical Report: Beth Visintine, Amec Foster Wheeler

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DAY 1: Monday, April 25, 2015

1. Call to Order

John Bukowski (FHWA) called the meeting to order at 12:00 PM.

2. Welcome and Introductions

Bukowski welcomed everyone to the meeting and asked everyone to introduce themselves. Bukowski announced that there was a new contractor responsible for the meetings, Amec Foster Wheeler.

Beth Visintine noted that the sign-in sheets are being distributed for the ETG members and a separate sign-in sheet for friends of the ETG.

3. Review Agenda/Report Approval & Action Items, September 2015 Meeting [John Bukowski, FHWA]

Bukowski stated that this would be the last time that they would be distributing flash drives with the previous meeting presentations since NAPA is now hosting a website for the ETGs at www.asphaltetgs.org. Bukowski noted that the technical report from the last meeting was distributed to members and that once finalized would be placed on the website. Bukowski asked if there were any revisions or corrections to the technical report. No corrections or revisions were noted. Bukowski asked that any corrections or revisions to the technical report be sent to him.

Bukowski reviewed the Action Items from the September 2015 Asphalt ETG meeting. The following is a listing and status of the Action Items from the last meeting.

- Action Item #201509-1: Ed Harrigan will provide, for distribution to the ETG, a copy of the final draft report from the NCHRP Project 9-52, "Short-Term Laboratory Conditioning of Asphalt Mixtures." Each member is to review for potential implementation and effects on existing standards such as AASHTO R 30.
  Update: Item is on the agenda.

- Action Item #201509-2: Input is requested to be sent to Jeff Withee on the draft AMPT equipment specification standard.
  Update: Item is on the agenda.

- Action Item #201509-3: Randy West is requested to provide the ETG for review and comment prior to the next meeting, a draft report of the NCAT efforts to evaluate a simplified cracking test.
  Update: Item is on the agenda.

- Action Item #201509-4: Louay Mohammad is requested to present at the next meeting an update on Pooled Fund 5(294), “Design and Analysis Procedures for Asphalt Mixtures Containing High RAP Contents and/or RAS.”
  Update: Item is on the agenda.

- Action Item #201509-5: Dave Newcomb is requested to present at the next meeting an update on NCHRP Project 9-57, “Experimental Design for Field Validation of Tests to Assess Cracking Resistance of Asphalt Mixtures.”
  Update: Item is on the agenda.

- Action Item #201509-6: Richard Kim is requested to present at the next meeting an update on NCHRP Project 9-54, “Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction.”
  Update: Item is on the agenda.

- Action Item #201509-7: Nam Tran/Kevin Hall are requested to present at the next meeting the status of the MEPDG asphalt cracking models.
  Update: Item is on the agenda.

- Action Item #201509-8: The T 321 Task Force is asked to finalize and present at the next meeting a summary of equipment/software changes needed on existing test devises as a consequence of recent AASHTO changes in the standard.
  Update: Item is on the agenda.

- Action Item #201509-9: Nelson Gibson at the next ETG meeting will present an update on the status of the FHWA ALF project.
  Update: Item is on the agenda.

- Action Item #201509-10: Input is requested, by the end of September, to be sent to Jim Musselman regarding changes under consideration by the RAS/RAP Task Force on the current RAS standards.
  Update: Item is on the agenda.

- Action Item #201509-11: Balanced Mix Design Task Force to provide update at the next meeting on a definition and outline of needed efforts.
  Update: Item is on the agenda.

- Action Item #201509-12: Construction Task Force to provide update at the next meeting on, “Improvements on Rapid Asphalt Production & Construction Control.”
  Update: Item is on the agenda.

4. Subcommittee on Materials Updates/Comments

The AASHTO, Technical Section representative for the Subcommittee on Materials (SOM) update was not available for this meeting. Bukowski noted that Oak Metcalf will be replacing

Chris Abadie as the representative to the SOM. Metcalf will also serve as the Technical Section 2d Chair.

Bukowski noted that under Technical Section 2c, the Hamburg test has gone to the task force. Bukowski also noted that a write-up regarding changes to AASHTO M 323 was sent to the Technical Section 2d and that a task force was going to be formed. However, this was not done. Bukowski will follow up with Metcalf.

Richard Kim stated that they had submitted three standards regarding dynamic modulus and indirect tension to Abadie to send to the Technical Section, but has not seen an update on these.

5. Update Related Activities [John Bukowski, FHWA]

Presentation Title: FHWA Mixtures and Construction Expert Task Group Meeting, April 2016, John Bukowski, FHWA

Summary of Presentation:
John Bukowski made the presentation on behalf of Edward Harrigan. The presentation provided an update of the progress of NCHRP projects.

The 2017 NCHRP projects include:

- Project 9-61: “Short and Long-term Aging Methods to Accurately Reflect Binder Aging in Different Asphalt Applications” $750,000
- Project 9-62: “Quality Assurance and Specification for In-Place Recycled Pavements Constructed Using Asphalt-Based Recycling Agents.” $750,000

The projects nearing completion include:

- Project 9-49A: “Performance of WMA Technologies: Stage II – Long-term Field Performance,” Washington State University
- Project 9-56: “Identifying Influences on and Minimizing the Variability of Ignition Furnace Correction Factors,” NCAT
- Project 20-07/Task 382: “Longer Pavement Life from Increased In-Place Density of Asphalt Pavements,” Decker.

This recent NCHRP publications include:

- NCHRP Report 818: Comparing the Volumetric and Mechanical Properties of Laboratory and Field Specimens of Asphalt Concrete
- NCHRP Report 815; Short-Term Laboratory Conditioning of Asphalt Mixtures
- NCHRP Report 817; Validation of Guidelines for Evaluating the Moisture Susceptibility of WMA Technologies
- NCHRP Report 807; Properties of Foamed Asphalt for Warm Mix Asphalt Applications
- Web-Only Document 219: Hamburg Wheel-Track Test Equipment Requirements and Improvements to AASHTO T 324.

Proposed AASHTO Standards include:

- "Recommended Practice That Addresses the Cause and Magnitude of Variability Within And Among the Three Specimen Types (i.e., LL, PL, and PF)," from NCHRP Project 9-48
- "Recommended Practice on Measuring the Effects of Asphalt Plant Mixing and Processing on Binder Absorption by Aggregate and Asphalt Mixture Characteristics," from NCRP Project 9-52.

In addition, revision have been proposed to

- AASHTO R 30, "Standard Practice for Mixture Conditioning of Hot Mix Asphalt (HMA)" from NCHRP Project 9-52
- AASHTO R 35, "Superpave Volumetric Design for Hot Mix Asphalt (HMA)" from NCHRP Projects 9-49 and 9-49 B
- "Test for Determining the Expansion and Collapse of Foamed Binder by Using the Laser Distance Measurement Device," from NCHRP Project 9-53
- "Test for Determining the Size Distribution and Surface Area of Binder Foam Bubbles During the Foaming Process," from NCHRP Project 9-53
- "Tests for Evaluating the Workability and Coatability of Foamed Warm Mix Asphalt by A Laboratory Foaming Unit Using a Superpave Gyratory Compactor," from NCHRP Project 9-53
- Revision to AASHTO T 324, "Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA)," from NCHRP Project 20-07/Task 361.

An update of the projects in progress was provided.

- NCHRP 9-54: "Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction," North Carolina State University (August 2016). The objective of this project was to develop a laboratory procedure to simulate long-term aging of asphalt mixtures for performance testing and prediction. It correlated rheology and kinetics of binders aged in the laboratory and long-term in the field, including ARC, MnRoad, FHWA-ALF, WesTrack, and LTPP SPS-1 and SPS-8. Dr. Richard Kim will present current results later during the meeting.
- NCHRP 9-55: "Recycled Asphalt Shingles in Asphalt Mixtures with Warm Mix Asphalt Technologies," National Center for Asphalt Technology (July 2017). The objective of this study is to develop a design and evaluation procedure for acceptable performance of asphalt mixtures incorporating WMA technologies and RAS, with and without RAP, for project-specific service conditions. Testing and analysis of field specimens is in progress.
- NCHRP 9-57: "Experimental Design for Field Validation of Laboratory Tests to Assess Cracking Resistance of Asphalt Mixtures," (completed). The objective of this project was to develop an experimental design for a field experiment to validate (a) laboratory-to-field relationships for selected fatigue tests and (b) criteria for assessing the cracking potential of asphalt mixtures. The project is complete and the final report should be published in the middle of 2016. Dr. Dave Newcomb will present key findings later during the meeting.

- NCHRP 9-59: "Relating Asphalt Binder Fatigue Properties to Asphalt Mixture Fatigue Performance," Advanced Asphalt Technologies (October 2017). The objective of this project are to determine asphalt binder properties that are significant indicators of the fatigue performance of asphalt mixtures and to identify or develop a practical, implementable binder test (or tests) to measure properties that are significant of mixture fatigue performance.
- NCHRP 9-60: "The Impacts on Pavement Performance from Changes in Asphalt Production," contract in negotiation, FY 2016 with funding of $1.0 million. The objective of this project is to propose changes to the current PG asphalt binder specifications and test methods to remedy shortcomings related to incidents of premature failure of asphalt pavements.
- NCHRP 20-07/Task 375: "Improvements to the Dry Back Procedure of AASHTO T 209," Pavement Systems, LLC (September 2016). The objective of this project is to determine the appropriate trigger measures and values, which necessitates use of the Dry Back procedure in AASHTO T 209.
- NCHRP 20-07/Task 391: "Energy Criteria for Maintaining Fully Animated Particles of Lose Asphalt in AASHTO T 209 Testing." The contract is in negotiation. The objective of this project is to establish criteria for sample mechanical shaking in AASHTO T 209 that assures measurement of true G_{mm} values.

ETG Comments, Questions, and Discussion:
It was reported that Project 9-56 has received an extension which is likely about 18 months.

Bukowski later provided an update regarding the February report to the SOM. He announced that the flexure, creep stiffness and BBR passed balloting as a provisional standard. Bukowski clarified that revisions to AASHTO R 35 were balloted to remove the AASHTO R 30 reference and to use AASHTO T 283. However, since the ballot did not include other redline changes, this will go back to the Technical Sections ballot.

6. 9-52 Comments on Short Term Lab Conditioning [Dave Newcomb, Texas A&M Transportation Institute]

Presentation Title: *NCHRP Project 9-52 Short-Term Laboratory Conditioning of Asphalt Mixtures – Texas A&M Transportation Institute, National Center for Asphalt Technology, Pavement Research Center*

Summary of Presentation:
The aging of asphalt mixtures in the laboratory follow the protocols of AASHTO R 30 which states that for mix designs aging should be short term oven aged (STOA) for 2 hours at compaction temperature, performance testing aging should be STOA for 4 hours at 275°F, and for field aging, aging should be long term oven aged for 5 days at 185°F. Mixture components and production parameters that may affect aging characteristics include use of polymer modifiers, inclusion of recycled materials, advent of WMA technologies, drum mix plants (DMPs) replacing batch mix plants (BMP) and increased production temperature.

The research objectives were to validate laboratory STOA protocol to simulate plant aging of asphalt mixtures (Task I), correlate aging of asphalt mixtures with laboratory long term oven aged (LTOA) protocols (Task II) and to identify factors affecting the aging characteristics of asphalt mixtures (Task III).

Field projects are located in Connecticut, Florida, Indiana, Iowa, New Mexico, South Dakota, Texas (2) and Wyoming. All projects used WMA with the exception of the second Texas project. The Wyoming and Iowa projects considered production temperatures. The Indiana and Texas II projects considered plant type (batch versus drum). Texas I and New Mexico projects considered RAP/RAS. Iowa and Florida projects considered aggregate absorption (granite versus limestone) and the Texas II project considered binder source.

In the validation of STOA protocols, lab mix lab compacted (LMLC) and plant mixed plant compacted (PMPC) samples were prepared as well as construction cores taken. The conditioning of the samples was supposed to match the field sampling. Samples of HMA and WMA were STOA for 2 hours at 275°F and 240°F, respectively.

There were equivalent volumetrics for LMLC and PMPC for theoretical maximum specific gravity (G_{mm}). While there was more scatter between the LMLC and PMPC for the percent of absorbed asphalt ($\%P_{ba}$), these were also equivalent. The STOA was representative of absorption and aging during production.

The project showed equivalent Stiffness, M_R (at 25°C/10Hz) for LMLC versus PMPC although there is more variability. Results showed slightly lower Resilient Modulus (M_R) stiffness for construction cores versus LMLC due to higher air voids, 9.0% versus 7.0%, respectively.

The project validated laboratory STOA protocols of 2 hours at 275°F for HMA and 240°F for WMA to simulate plant aging. The rutting resistance of the LMLC and PMPC were equivalent while the construction core was less. Flatter aggregate orientation in the field mix led to a softer mix. The results show that using protocols for HMA and WMA produced equivalent results for LMLC and PMPC.

Quantification of field aging was done using Cumulative Degree-Days (CDD) which is the sum of the daily high temperature above freezing for all the days from time of construction to the time of core sampling. The Property Ratio (PR) was used to quantify the effect of aging on mixture properties and is the ratio of the property after aging divided by the property before aging. The samples before aging were field cores at construction or LMLC specimens with only STOA. Samples after aging were post-construction field cores or LMLC specimens with STOA and LTOA.

The CDD versus PR plot using M_R Stiffness showed that not everything was explained by CDD as there was a fair amount of scatter and the relationship had an $R^2 = 0.831$. Comparing laboratory LTOA to field aging, two weeks at 60°C is equivalent to 9,600 CDD while five days at 85°C is equivalent to 17,500 CDD. The M_R Stiffness had an average of 1.48 and 1.78 and standard deviation of 0.23 and 0.28 for two weeks at 60°C and five days at 85°C, respectively. This shows that temperature has more effect than time (i.e., shorter aging at higher temperature).

The time for WMA to equal HMA was determined. For the warmer climate sites (Texas, New Mexico and Florida) the average was 17 months and 2 months for WMA to equal HMA and HMA initial, respectively. For colder climates (Wyoming, South Dakota, Iowa, and Indiana) the average was 30 months and 3 months for WMA to equal HMA and HMA initial, respectively.

The various factors (WMA technology, production temperature, plant type, recycled materials, aggregate absorption and binder source) were compared to control mixtures to determine the effect. The factor analysis showed WMA had worse properties in the short-term and faster aging in the long-term as a result of reduced production temperatures and WMA additives. Use of RAP/RAS had better properties in the short-term and slower aging in the long-term as a result of over aged binders and less virgin binders available for aging. Aggregate absorption showed worse properties in the short-term and faster aging in the long-term as a result of more effective binders available for aging. Binder source was significant in the short-term and showed that same performance grade (PG) is not equal to the same properties as a result of different oxidation kinetics. Both production temperature and plant type were not significant and produced equivalent mixture properties.

The effect of aging on the field stiffness gradient compared Dynamic Modulus to the depth of field core specimen while the effect of aging on fracture (damage density) compared the number of loading cycles to damage density. There is a need for improved aging models.

ETG Comments, Questions, and Discussion:
Most of the comparison was based on M_R (stiffness) and this has little effect on performance. What are your thoughts going to the future? Newcomb responded that they had to have a way of testing cores in the same way as the LMLC and that the geometry does not always match that needed for other tests so that is why it was used.

Short-term and long-term did not have an effect on production temperature? Newcomb responded that there was no difference between higher and lower production temperatures. Production temperatures were what they were and comparisons for construction cores, WMA was less than HMA based on field cores.

Had all the WMA studies used foaming? Newcomb clarified that not all were foaming, but some were foaming and some were additives.

What was the effect of RAP? Newcomb responded that RAP mixes aged at a slower rate.

How long were the mixtures held at the stabilization temperature? Newcomb clarified that the mixtures were brought to the stabilization temperature and that they were not trying to age additionally but to bring to the same temperature.

7. 9-54 Update Long Term Aging of Mixes [Y. Richard Kim, North Carolina State University]

Presentation Title: *NCHRP Project 9-54 Update – Selection of the Laboratory Aging Method and Aging Temperature*

Summary of Presentation:
This presentation covered the selection of the most promising laboratory aging method, the selection of laboratory aging temperature and interim findings. The objective of the project is to develop a calibrated and validated procedure to simulate long-term aging of asphalt mixtures for performance testing and prediction. To date, selection of the most promising aging method and laboratory aging temperature have been completed.

Selection of the most promising laboratory aging method for performance testing and prediction was completed by evaluation of loose mix versus compacted specimen aging and evaluation of laboratory aging with and without the application of pressure.

The selection criteria included specimen integrity, efficiency and practicality and versatility. Specimen integrity compared compacted specimen and loose mix. Compacted specimen considered geometric and air void changes during aging, oxidation gradient and use for performance testing (Dynamic Modulus and simplified viscoelastic continuum damage (S-VECD) functions). Loose mix considered compactability (number of gyrations, imaging analysis of aggregate structure) and use for performance testing (Dynamic Modulus and S-VECD functions).

The experimental factors included NC S9.5B and FHWA ALF-SBS materials, binder aged with standard rolling thin film oven (RTFO) and pressure aging vessel (PAV) while loose mix and compacted specimen were oven and PAV aged. The mix aging temperatures ranged from 70° - 95°C and the loose mix compaction temperatures were 144° and 157°C. The mix aging durations in the oven were between 8 – 35 days depending on the aging temperature and the PAV was 1 -3 days. The air pressures were 300 and 2,000 kPa.

Kim noted the binder aging index properties for rheology were cross over modulus, zero shear viscosity, G* at 10 Hz and 64°C; properties for chemistry were Carbonyl area, Carbonyl peak, Carbonyl + Sulfoxides area, and Carbonyl + Sulfoxides peak. The dynamic shear rheometer (DSR) was used for the rheology and FDIR was used for the chemistry. The criteria were sensitivity to oxidation levels, variability and sensitivity to the characterization process.

Kim presented the S-VECD material functions (|E*| Master curve, time-temperature shift factor, damage characteristic curve, and energy-based failure criterion). Comparisons between short-term aged – compacted; oven, loose mix – compacted; and oven, compacted specimen did not show enough difference between loose mix and oven compacted. Kim concluded that aged loose mix is compactable.

The aging gradient in large compacted specimens was discussed comparing various rings of the specimen – outer-layer, mid-layer and cores measuring 8 mm, 15 mm and 38 mm in thickness, respectively. The difference in G* (log) at 64°C, 10 Hz showed a 20% difference between core and mid-layer and 28% difference between mid-layer and outer-layer. A 2% C+S is about equal to 15% G* which is about equal to a 10% change in E*. The aging gradient in compacted small specimen compared the 38 mm diameter by 100mm specimen to the core measuring 5 mm x 5 mm x 90mm. The difference in G* (log) at 64°C, 10 Hz showed 9% difference between core and outer layer. Therefore, aging of compacted mix for cracking should use the small specimen since the aging gradient is within the criteria.

The Phase I conclusions presented by Kim were performance testing results indicate no problems of compacting loose mixtures after long-term aging and oven aging of loose mix is the most promising method. Additionally, any specimen geometry (e.g., slabs and beams) can be produced using loose mix aging for performance testing.

Kim next presented the selection of laboratory aging temperature. For this, 8 year field cores from FHWA ALF-SBS were split into three specimens measuring 150 mm diameter with 11 mm height. Loose mix from FHWA ALF virgin materials were made in the lab and aged at 70°C, 85°C, and 95°C. A linear relationship of C+S peaks can determine how many days of aging are required based on C+S of field core. The FHWA ALF-SBS field core showed an aging gradient with depth. The temperature effect on aging time for a constant depth showed that less aging is required at higher temperatures.

In selecting the laboratory aging temperature, Kim noted that increasing temperature expedites oxidation; however, there are potential concerns when aging above 100°C due to chemical effects, physio-chemical effects and binder/mastic drain-down. Chemical effects include thermal decomposition of sulfoxides and changes in relative amounts of functional groups. Physico-chemical effects include disruption of binder microstructure which increases the availability of molecules for oxidation. The performance implications of these effects are unknown. If the rheology of binders aged at 95°C and 135°C are the same, does the performance differ?

The experimental factors included FHWA ALF aggregate and FHWA ALF-SBS (PG 70-28), SHRP AAD-1 (PG 58-28) and AAG-1 (PG 58-10) binders for materials; aging temperatures of 95°C and 135°C; aging durations from 9-21 days and 16.8-52 hours for 95°C and 135°C, respectively; frequency sweep test in the DSR and FTIR for binder testing; dynamic modulus and cyclic direct tension (S-VECD) for mixture performance testing.

The relationship between chemistry (C+S Absorbance Peak) and rheology (G*) showed the field cores (at the surface) falls on the plotted relationship showing that loose mix is equivalent to the field when the loose mix is aged between 70°C and 95°C while the loose mix aged at 135°C has a different fit (e.g., there are two linear relationships plotted). Testing approach – I considers the same chemistry and different rheology while testing approach – II considers the same rheology and different chemistry. Kim explained that since rheology is better tied to performance, testing approach – II was selected.

Using this approach, the duration of aging required was 21 days and 52 hours for the selected rheology of the loose mix at 95°C and 135°C, respectively. In order to check that the two mixtures had the same rheology, complex modulus versus phase angle and reduced angular frequency were plotted as well as reduced angular frequency versus phase angle for the two mixtures and the short-term aged. Performance testing comparison showed a perfect match for E*, damage and almost perfect for failure between the loose mixture aged at 95°C for 21 days and 135°C for 52 hours, respectively. For this binder (SBS), with the same rheology (although the chemistry is different), the performance is the same for the both temperatures and aging.

This approach was repeated with binder SHRP AAD-1 where the duration of aging required was 8.9 days and 16.8 hours for the selected rheology for the loose mix at 95°C and 135°C, respectively. The rheology check of complex modulus versus phase angle and reduced angular frequency and reduced angular frequency versus phase angle for the two mixtures and the short-term aged again compared well. The performance testing comparison showed a slight difference between E* and damage and a larger difference for failure criteria between the loose mixture aged at 95°C for 8.9 days and 135°C for 16.8 hours, respectively. Kim concluded that aging at 135°C decreased the cracking resistance of the AAD-1 mix.

Kim presented the difference in facture surface for specimens short-term aged, oven aged 9 days at 95°C and oven aged 16.8 hours at 135°C which appeared wet, somewhat wet and dry, respectively. There was reduced bond strength for the mixture aged at 135°C for 16.8 hours as shown by the adhesion failure which is likely a result of loss of tackiness.

Kim concluded that the interim findings of the project are that (1) loose mix aging is the most promising aging method for performance test specimens, (2) aging at 135°C changes the binder chemistry, and this change is significant enough to decrease binder tackiness and cracking resistance in highly structured (less compatible) binders, and (3) the optimal temperature for long term aging of asphalt mixture for performance testing should be below 100°C, and 95°C is recommended from the efficiency point of view.

<u>ETG Comments, Questions, and Discussion:</u>
Nam asked how a difference in the amount of days for aging would be handled. Kim responded that the duration should either be fixed that would result in different aging levels or to change the aging duration to match the field. However, this has not yet been decided.

There was a comment that different reactions in asphalt occur at different temperatures. Also, what happens if there is a further change chemistry, for example caused by adding softening agents? These reactions have different activation energy.

There was a comment that the relationship between the storage modulus (G') and the loss modulus (G") will change at different rate than the complex shear modulus (G*). Kim responded that where G" peaks, you are able to differentiate, but with the two mixes aged at different temperatures, they gave the same G* and phase angle.

The question was raised whether low temperature properties have been considered? Kim responded that they have not and that the panel has asked to use another fracture test but this has not been measured. Kim stated that they will do a low temperature mixture test and that BBR will be a helpful test.

With the loose mixture approach, will mixtures with high percent RAP & RAS be compactible? Kim responded that the project has not gone that far but that it is a tough mixture to compact. However, RAP is not in the scope.

Corrigan asked about trying to match different aging times and how since aging models are a function of depth, climate, air voids, and binder properties, what is the vision for the final end product? Kim responded that there is no single answer and that it depends on what the project finds in certain years and climate or the same duration can be used to simulate certain number of years in that climate. The project will have different aging duration for different locations and determine surface aging and how that changes as a function of depth.

Al-Qadi asked that if this is approach is used, if this would be unique for each mix? Al-Qadi expressed concern about comparing two mixes with different aging. Kim responded that if the test is performed in the linear-viscoelastic region, compression and tension-compression will not be different and therefore the modulus will be the same. The target for performing the test is 60-80 microstrain so that there is no difference.

A participant asked if the material was isotropic? Kim responded that it was not, but did not have mobilizing aggregate.

Corrigan commented that he was starting to collect and analyze data, doing AASHTO five and ten days aging and seeing some very stiff behavior and acknowledged Kim was not familiar with these particular mixtures but that there were issues with compactability of the mixture if loose mix aged. Kim responded that his recommendation is to use the smaller 30-mm specimen.

A participant asked why not use an even smaller core and if the (larger) core could still be masking some gradient? Kim responded that they did not have the core bit and acknowledged that it could be.

8. 9-57 Draft Final Report on Tests to Assess Cracking Resistance [Dave Newcomb, Texas A&M University]

Presentation Title: *NCHRP Project 9-57, Laboratory Tests to Assess Cracking Resistance of Asphalt Mixtures*

Summary of Presentation:
Newcomb presented the need for assessing cracking resistance of asphalt mixtures. He asked whether it made sense to use volumetric mix design since the materials have changed so much. A balanced mix design selects the asphalt content between the minimum asphalt set by the cracking test and the maximum asphalt set by that required for 98% density and the rutting test, which must be less than 98% density.

Newcomb stated that the goals of the cracking tests workshop were to select cracking tests for the four types of cracking and identify potential field or Accelerated Pavement Testing (APT) test sections. For the workshops, they prepared an interim report, cracking test webinars, cracking test booklet and nine cracking test videos.

The selected cracking tests were the Disc Compact Tension (DCT), Semi-Circular Bending (SCB), Overlay Tester (OT), Indirect Tension Test (IDT) and Bending Beam Fatigue (BBF). The selected cracking tests from the workshop are as follows for each cracking type:

- Thermal Cracking
    - DCT
    - SCB-IL
    - SCB at low temperature
- Reflection Cracking
    - OT
    - SCB at intermediate temperature
    - BBF
- Bottom-up Fatigue Cracking
    - BBF
    - SCB at intermediate temperature
- Top-down Fatigue Cracking
    - SCB at intermediate temperature
    - IDT-UF

The key factors for designing the field experimental test sections were:

- Climate (temperature, moisture, solar radiation)
- Traffic
- Pavement structure and subgrade
- Asphalt mixtures
- Existing pavement conditions for reflection cracking

The potential field sections identified were Long-Term Pavement Performance (LTPP), Special Pavement Studies (SPS)-10, MnRoad, NCAT Test Track, and test sections under NCHRP Projects 9-55, 9-58 and 9-59.

The laboratory evaluation included review of existing information and studies regarding SCB ILS – ASTM, Asphalt Institute, NCAT and MnDOT, available test equipment, ruggedness testing and precision and bias.

Newcomb explained the purpose of ruggedness testing was to identify factors that influence test results and determine how closely they must be controlled. This reflects a sensitivity test on variables instead of materials. An example provided was the SCB test which considers specimen thickness, loading rate, test temperature, notch depth and air voids. Newcomb noted that the SCB is on the ballot and that all negatives have been taken care of and that the Louisiana Transportation Research Center (LTRC) version was referenced.

Newcomb presented the purpose of the interlaboratory study was to determine the repeatability (with single operator) and reproducibility (multiple laboratories) of the test method. Newcomb explained that test familiarization is important and that it required training and coordination to make sure everyone is performing the test the in the same way. The test specimens were fabricated at one laboratory and included virgin dense-graded aggregate (DGA) with 19 mm nominal maximum aggregate size (NMAS), virgin DGA with 9.5 mm NMAS and DGA with high binder replacement. The specimens were fabricated in a single laboratory since the objective was to evaluate the test method and not different compaction methods.

The objective of the field validation experimental design was to validate the cracking tests and not a study of cracking mechanisms. This meant the focus was on whether the cracking tests could differentiate mixes that will perform well and poorly (e.g., cracks). The design used was a D-optimal design since full or partial factorials were not practical. D-optimal included a computer generated design that selects the best subset of factor-level combinations and considers important effects with a smaller number of observations. The field validation design included a schedule, cost estimate, material quantities and forensic plan. The forensic plan presented follows LTPP guidelines.

Next Newcomb presented the experimental designs for each cracking type. The thermal cracking design included six test sections, with three in cold climates and three in diurnal cycling regions. The cold climate covered the northern US (north of Salt Lake City, Denver, Indianapolis and DC) with the exception of the western portion of Washington, Oregon and California. The diurnal cycling area included the Texas panhandle, New Mexico and most of Arizona. The three mixtures used in each climate were DGA with regular PG binder, stone mastic asphalt (SMA), and DGA with a lower PG grade. The pavement structure was differentiated as thick or thin and traffic as high or low.

The reflection cracking experimental design included seven test sections with four in steady state climate and three in temperature cycling. The steady state cycling area included the Texas panhandle, New Mexico, Arizona, southern Utah and southern/western Nevada. The existing pavement included cracked AC on granular base, cracked AC with cement treated base (CTB), jointed Portland cement concrete (JPCP) with low load transfer efficiency (LTE) and JPCP with high LTE. Experience shows that there is less cracking over granular base than CTB. The asphalt mixtures included DGA, a special crack resistance mix such as Strata or Texas CAM, and a performance mix such as SMA or A-R. SMA generally has higher cracking resistance, partly due to higher binder content. The pavement thickness was either 2 inches or between 2 and 6 inches. The traffic level was high with greater than 300,000 ESAL/year.

The bottom-up fatigue experimental design included eight test sections with four in high temperature/moisture cycling regions and four in all other climates. The high temperature climate included the Texas panhandle, New Mexico, Arizona southern Utah, southern/western Nevada and parts of Colorado and Kansas. The moisture cycling region included South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, southern Arkansas and eastern Texas. The traffic was split between high (> 300k KESAL) and low (≤ 300k KESAL). Four mixture types included a very good cracking resistant mix, a good cracking resistant mix, a medium cracking resistant mix and poor cracking resistant mix. The pavement structure included AC with CTB base and AC with granular base with subgrades classified as either good or poor. The thickness was limited to less than 6 inches since bottom-up cracking is more likely in thinner pavements.

The top-down cracking experimental design included nine test sections with two in hard freeze, high solar climate, two sections in hard freeze, low solar climate, and three in no freeze, high solar climate and two in no freeze, low solar climate. The hard freeze, high solar climate included parts of Nevada, Utah, Colorado and Kansas. The hard freeze, low solar climate included the northeast US, New York, Pennsylvania, northern Ohio, northern Indiana, northern Illinois, Michigan, Wisconsin, Iowa, Minnesota, North Dakota, South Dakota, Montana, northern Idaho and eastern Washington. The no freeze, high solar climate included southern California, southern Arizona, southern New Mexico and the Texas panhandle. No freeze, low solar included eastern Texas, southern Arkansas, northern Louisiana, northern Mississippi, northern Alabama and parts of North Carolina and South Carolina. Solar gain is a key contributor to brittlement and starting cracks at the top of the surface. The traffic volume varied with low volume, low speed, high volume low speed, and high volume, high speed. The mixture varied with DGA fine, high air voids (AV); DGA fine, low AV; DGA coarse, high AV, and DGA coarse, low AV. All pavement thickness was greater than 6 inches since top-down cracking is more likely for thicker pavements.

Newcomb presented the available facilities and characteristics including APT, full-scale test tracks, full-scale test roads and in-service pavements.

<u>ETG Comments, Questions, and Discussion:</u>
A participant asked Newcomb to expand on solar gain and the difference between high and low. Newcomb explained that solar gain is basically solar radiation. It measures the amount of energy coming in from the sun or the amount of heat being generated and uses a device that looks like a flat solar panel.

A participant asked what was the next step for the project. Newcomb responded that the project has just cleared the panel and next will be to write up a problem statement to do the validation. Newcomb speculated that it would probably be broken down in contracts for each type of cracking and one for ruggedness.

A participant asked if the project had to estimate funding. Newcomb responded that the project did but it was rudimentary and did not estimate construction costs but rather cost of the sampling, testing, etc.

Bukowski stated that the first step has to be ruggedness testing since it will set foundation for the rest of the effort.

Corrigan asked that acknowledging all the other studies that need to be done, if we were to take another step back, the suite of tests that were isolated from the effort (ruggedness, sensitivity, etc.), would we potentially be missing something if we were to have that data? Newcomb responded that sensitivity testing needs to be done and that is somewhat what the ILS testing is set up for. Newcomb stated the important thing in his view is really the need to establish whether the test can distinguish between something that is crack prone and something that is not.

Corrigan asked that during AAPT, Fujie Zhou presented some of the material and asked if Newcomb was to do it all over again, what would you do differently? Newcomb responded that it would be nice to have some information on ruggedness and sensitivity. Corrigan continued asking if we should consider a couple more tests that we have gained more knowledge on since this project was initiated. Newcomb responded that one problem with that is something new is being developed all the time. Newcomb explained that at some point, we have to move forward, but need to do so with the best knowledge at the time. The way to balance it, is to get a cracking test and it is needed sooner rather than later. We need something that at least can give us some assurance that a pavement will not crack, or this is what will make it crack.

Bukowski stated that he does not see all be accomplished in just a few years. This is a lot of tests that need to be done. Newcomb responded that this is what they were tasked to do and that he is not sure we can wait to do everything.

There was discussion regarding a quick test but there not being a path to get a quick test accepted. Newcomb responded that some states are trying to develop a test. However, there is danger in having too many tests. It is important to make sure that once a test is defined that it has value. Part of the answer is collaboration between NCAT and MNDOT.

Al-Qadi had a response to Bukowski's comment that in the last few years in aerospace, they are dealing with composite material and that there is one crack test. Al-Qadi continued that we are looking at each crack differently, but a crack is a crack but the condition of material is different. Al-Qadi stated that we need a test to look into fundamental properties that allow us to look into this and that we are still missing the point of what we are trying to measure. Newcomb responded that if a test is able to distinguish between brittle and ductile, maybe that is good enough.

9. 20-07 Task 361 Hamburg Wheel Track Test [Louay Mohammad, Louisiana State University]

Presentation Title: *NCHRP Project 20-07/Task 361 Hamburg Wheel-Track Test (HWTT) Equipment Requirements and Improvements to AASHTO T 324*

Summary of Presentation:
Mohammad presented an update to the NCHRP 20-07/Task 361 study. He stated that it is time to re-ballot the test method because there were many State-specific standards that created issues and that is the reason for this study. He acknowledged Dr. Ed Harrigan and the Technical Review Panel of NCHRP and the Louisiana DOTD. Mohammad provided the background that HWTT is a laboratory-controlled rut depth test that uses a loaded wheel to apply a moving load on compacted asphalt mixture specimens to simulate the traffic load applied on asphalt pavements. A task force under the SOM Technical Section 2C was formed due to concerns with AASHTO T 324-11. The task force identified several issues within the standard that could not be resolved due to unknown impacts on the test results or unknown impacts to State DOT-specific acceptance criteria resulting from the changes. The objective of the study were to document the capabilities of available commercial Hamburg test equipment, determine Hamburg test equipment capabilities, components, or design features that ensure proper testing and accurate, reproducible results and provide proposed revisions with commentary to AASHTO T 324 to enable the use of a performance type specification for Hamburg test equipment. The study methodology included reviewing available Hamburg test equipment specifications, engineering

desk analysis of existing Hamburg test systems, proposing revisions to AASHTO T 324, and developing a framework for future laboratory evaluation.

The review of available Hamburg test equipment included a nationwide survey of State agencies on the use of HWTT. The survey achieved a 100% response rate. The responses show that 21 agencies used the HWTT, 17 used the Asphalt Pavement Analyzer (APA), and 12 agencies used none. There are four HWTT vendors and five commercially available HWTT equipment.

Mohammad presented the required loading mechanism and emphasized the importance of using a sinusoidal wheel speed. A comparison of the five HWTT equipment was provided based on the temperature measurement and control systems, impression measurement system, specimen length and track length, and data collection and reporting.

The experimental program was designed to identify issues with different aspects of the AASHTO T 324 standard procedure including:

- Wheel position waveform, frequency, and maximum speed
- Impression measurement system
- Temperature measurement and control system
- Wheel dimensions and load
- Specimen and track length
- Free circulating water on mounting system
- Data collection and reporting

In order to record the position of the wheel as a function of time, two approaches were considered: accelerometer and video camera. The latter was selected and used a GoPro attached to the equipment. The wheel position analysis compared the mathematically determined sinusoidal movement to the GoPro results. Two of the manufacturers did not have true sinusoidal movement which results in the wheel spending more time on the back half of the track (55%) as compared to the front half (45%). The waveform root mean square error (RMSE) and AMD, which is another way to measure scatter and bias of data of the equipment were compared and was smaller for the vendors that had a true sinusoidal waveform and higher for those that did not have a true sinusoidal waveform.

The specified wheel dimensions from AASHTO T 324 is 203.2 mm diameter and 47.0 mm thickness with no tolerance. The study found some of the wheels' diameters were slightly below and the thickness was slightly greater than the specified dimensions because of normal wear. The wheel load was also compared and all vendors fell within the specified range.

Sections 5.5 and 5.6 of AASHTO T 324 requires that the specimen mounting system must suspend the specimen and provide a minimum of 20 mm (0.8 in.) of free circulating water on all sides. Comparison of the equipment showed two of the vendors did not meet this requirement for two of the measurements.

Section 5.2 of AASHTO T 324 specifies a water bath capable of controlling the temperature within ± 1.0°C over a range of 25 to 70°C with a mechanical circulating system stabilizing the temperature within the specimen tank. The verification requirements include temperature in the bath at four locations and a preconditioning time of 30 minutes. Four RTD were placed on each Superpave Gyratory Compacted (SGC) specimen, two at the top and two at the bottom. Two vendors (C and D) met the low temperature requirement. It was noted that vendors A and B were in a warmer climate than vendor C. Vendors A – C met the high temperature condition as did vendor D after addition of a small water circulator to increase water movement.

Mohammad explained to assess the impression measurement system, linear variable differential transformers (LVDTs) were calibrated and calibration specimens were developed with known deformation. These were used to compare the measurements from the equipment. The calibration specimens were used to verify the locations of impression readings and the curvature. The reference profile of the calibration specimen was compared to the readings from the equipment. Vendor A readings had significant deviations from the reference profile, with a marked skew to the right. Vendor B had reasonably good agreement with the reference profile. Vendor C had good agreement with the reference profile from location of -80 to 80 mm but had a slight deviation outside of the -80 to 80 mm location. Vendor D had good agreement with the reference profile.

Section 10 of AASHTO T 324 requires five parameters to be collected and reported to quantify the performance of a mixture to rutting and moisture susceptibility: number of passes at maximum impression, maximum impression, creep slope, strip slope and stripping inflection point (SIP). A mixture with a larger creep slope value is more sensitive to rutting. A mixture with a larger strip slope is more sensitive to moisture damage. Mohammad reported that there were not sufficient details to allow for consistent analysis and reporting.

Mohammad concluded his presentation with a summary of the equipment evaluation as follows:

- Two machines were able to produce a sinusoidal wave (Vendors B and D)
- A majority of machines do not have a cooling system; meeting the specified temperature of 25°C dependent on the incoming water temperature
- Averaging temperature at the end of 30 minutes of conditioning were within the specification limit of 50 ± 1°C, some locations in the HMA specimen were not within specified range; longer pre-conditioning time is recommended.
- There are discrepancies among manufacturers regarding the impression measurement
- Differences were observed amongst different analysis methods especially in reporting of the SIP; analysis methods are machine specific
- Based on results, revisions to AASHTO T 324-14 are recommended to ensure repeatable measurements and results from different manufacturers are comparable

Mohammad summarized the proposed modifications to AASHTO T 324

- Define a tolerance for wheel dimensions
- Define a tolerance for “wheel be required to reciprocate over the specimen such that its position varies sinusoidally over time”
- Define a tolerance for maximum speed
- Recommend to modify low temperature range to 35°C and upper range to 64°C and increase pre-conditioning time to 45 minutes

- Recommend deformation readings at 11 locations along the length of the track, with zero being the midpoint of the track
- Recommend verification of location of deformation measurements using method developed in this study
- Report average rut depth based on five middle deformation sensors
- Recommend method to calculate the SIP and other reporting parameters which are not clearly defined in the current specification

ETG Comments, Questions, and Discussion:
A participant asked whether a reading should be taken at 0, since it could be at the interface of two cores. Another participant added that there is a lot of problems in cutting specimens and that if this is a known issue, maybe it should be a consideration. Stacy Williams commented on the difficulty of reporting right at 0 and was surprised that it is recommended to include in average. Mohammad responded that the problem seems to be outside that area and added that another issue is there being a difference in the location the equipment is reporting and the location where the measurement is actually taken (e.g., it is at 0 but it is not at 0).

A participant stated having an issue with the recommended upper temperature being 64°C as there are many places in the country that are higher than 64°C. Mohammad responded that you could have manufacturers make it higher and that this recommendation is for the AASHTO standard.

A participant stated that the sampling numbers are small and asked if the measurements from the instruments are representative of machines across the country or world and to make a conclusion on vendors. Mohammad responded that the study focus was the standard and that it provides good information to give to manufacturers. He added that the value is for vendors to go back and see where they need to make changes and that it was a limited study of machines in the marketplace.

A participant asked if there could be implications of these vendors if they do not meet the specification and whether this study should be limited to the machines tested. Mohammad responded that if there is a specification, there needs to be compliance to the specification. A participant asked if these recommendations were under consideration in AASHTO. Mohammad responded that the recommendations have been forwarded to the appropriate Technical Sections.

Bukowski adjourned the meeting at 5:20 PM.

DAY 2: Tuesday, April 26, 2016

10. Call to Order

Bukowski called the meeting to order at 8:00 AM.

11. Overview of Performance Tests

11.1 AMPT Equipment Specification [Matthew Corrigan, FHWA]

Presentation Title: *Asphalt Mixture Performance Tester – Specifications*

Summary of Presentation:
Corrigan presented the update for Jeff Withee. Corrigan noted that the goal was to find a home for the specification for the equipment within AASHTO. Four documents were drafted – MP XX Equipment Specification, Equipment Specification Commentary, TP 79 Dynamic Modulus and TP XX Flow Number. These documents were distributed for review and comment including members of the Asphalt Mixture ETG.

Corrigan provided the specification update. The equipment specification was based on NCHRP 9-29. The revisions to address were TP-107 Direct Tension Cyclic Fatigue and TP 116 iRLPD. The update includes splitting TP 79 into two standards, one for modulus and one for flow number. The calibration of equipment that is currently in TP 79 is moved to the equipment specification and the computations that are currently in the NCHRP equipment specification are moved to the test standard.

Corrigan stated that comments were received and the next step is to address comments and revise draft documents and forward to the AASHTO SOM, Technical Section 2D.

ETG Comments, Questions, and Discussion:
A participant asked when the revisions will be completed and submitted to the AASHTO SOM. Corrigan responded that the goal was to have the revisions ready for the next round of AASHTO meetings as at this time they can still move forward to get on ballot. However, Corrigan was not sure if the Technical Section will advance as a full ballot or Technical Section ballot first to resolve some issues.

Action Item #201604-1. The draft of the proposed AMPT equipment specification with edits from the meeting will be forwarded to the AASHTO SOM (Technical Section 2d) for consideration.

11.2 NCAT Activity-Simplified Cracking Test [Randy West, NCAT]

Presentation Title: *Update on Work on Simple Mixture Durability Tests and Plans for the MnROAD-NCAT Partnership to Validate Cracking Tests*

Summary of Presentation:
West began the presentation by covering the tests conducted which included the Overlay Tester, SCB Louisiana, IDT Nflex Factor, Cantabro and Illinois Flexibility Index Test (I-FIT) (tested by University of Illinois Urbana-Champaign). West noted that the test specimens were prepared in normal practice for quality control/quality assurance (QC/QA) and that loose mix of material from the FHWA ALF were used in the preparation.

West presented the amount of cracking observed in the ALF lanes and noted that one lane had a considerable amount of water in the subgrade that resulted in rutting and that data was not included.

WESLEA was used to calculate the maximum tensile strain to try to account for variations in the various ALF lanes based on the difference in thickness of asphalt and stiffness of base. This was used to determine the different strain ratios using lane 1 as the control. The relationship between fatigue life and tensile strain was established based on the number of cycles to failure (reach 20 feet of cracking) known for lane 1. The estimated number of cycles to failure based on the strain values for each lane were then determined and the ratio of the estimated cycles to failure to the number of cycles to failure for lane 1 were computed. These ratios were used to adjust the measured ALF passes to 20 feet of cracking.

West presented an overview of the performance tests. The Cantabro test is primarily used for open graded friction course (OGFC) mixes. One compacted specimen is placed in the LA Abrasion drum at a time without steel balls and subjected to 300 drum revolutions. The mass loss is calculated. West presented the Modified Overlay Test that was modified by NCAT. The method is conducted in the AMPT at 25°C with displacement equal to 0.381 mm, a cycle of 1 Hz and a failure peak equal to the peak of normalized load times cycle. The Semi-Circular Bend Test, LTRC method, uses 50 mm thick specimens, ram rate equal to 0.5mm/min with notch depths of 38.1, 31.8 and 25.4 mm. The I-FIT was conducted by University of Illinois on specimens compacted to 7 ± 0.55% AV that were 50 mm thick with a notch of 1.5 mm wide and 15 mm deep at a loading rate of 50 mm/min at a test temperature of 25°C. The IDT Nflex Factor test uses 50 mm thick specimens tested with a ram rate of 50 mm/min at a test temperature of 25°C. The toughness was calculated as the area under the stress strain curve to post peak inflection point. The Nflex factor is the toughness divided by slope at that point.

The results of the ALF Cantabro test had an average coefficient of variation (COV) of 19% and had three Tukey statistical groupings. The correlation of Cantabro loss to ALF passes to 20 feet of cracking was 0.5371. The corrected Cantabro correlation was 0.5884.

The results of the ALF Overlay Test had an average COV of 32% and had two Tukey statistical groupings. The control did not distinguish from other mixes. The correlation of the OT-NCAT cycles to failure and ALF passes to 20 feet of cracking was 0.467 and 0.664 for uncorrected and corrected, respectively.

The results of the ALF SCB-LTRC test had an average COV for area to peak load of 27% and had two Maghsoodloo's statistical groupings with four mixes statistically different from the control. The correlation of the SCB-LTRC to the ALF passes to 20 feet of cracking was 0.0558 and 0.3032 for uncorrected and corrected, respectively.

The results of the ALF I-FIT Flexibility Index had an average COV of 16% and visually had three groupings. The correlation of Flexibility Index to the ALF passes to 20 feet of cracking was 0.9038 and 0.5722 for uncorrected and corrected, respectively.

The results of the ALF IDT Nflex factor had an average COV of 11% and had four Tukey statistical groupings. The correlation of the IDT-Nflex factor and the ALF passes to 20 feet of cracking was 0.5839 and 0.503 for uncorrected and corrected, respectively.

West presented the preliminary assessment of the test methods including the time required to conduct the test after the specimens are made.

West presented the refining of Nflex Factor that is a draft test method in AASHTO format. The experiment considered the effects of temperature (completed), loading rate, asphalt content, AV, and PG grade.

The cracking maps of two lanes from the ALF, E07B and E08B, showed 15% and 73.4% cracking, respectively. E08B was a more brittle mix (contained both RAP and RAS) whereas E07B was more ductile (virgin, hybrid binder).

The tensile strain versus horizontal strain of the two mixtures at 10°C, 17.5°C, and 25°C were presented along with the Poisson's ratio, toughness, brittleness slope and Nflex Factor for the two mixtures. West stated that they tried to calculate Poisson's ratio and to determine how it is affected by temperature. As the temperature changed, there is a significant difference in the brittleness slope.

The second part of West's presentation was an update on the NCAT and MnROAD cracking group experiments. West stated the objective was to validate laboratory cracking tests by establishing correlations between the test results and measured cracking in real pavements using real loading conditions. The goals are to evaluate various tests based on relatability to field performance, practicality of the tests for mix design verification and quality control testing and ability to accommodate recycled materials, new and future additives, and mix combinations.

There are a total of eleven sponsors including FHWA. The scope of the NCAT Test Track and MnROAD are top-down cracking and low-temperature cracking, respectively. West noted that the sections at the NCAT Test Track have base and intermediate layers that are fatigue resistant to try to force cracking at the surface layer. NCAT is conducting SCB-LA, SCB-IL, OT-TX, OT-NCAT, Energy Ratio, Nflex Factor, and Cantabro on both LMLC and PMPC samples that are aged and unaged. These tests were selected by the sponsor group and influenced by NCHRP 9-57. Three of the sections have a low cracking expectation, two sections have a medium cracking expectation and two have a high cracking expectation. The test sections were built in August 2015 and trafficking began on October 8, 2015. To date, there have been 2.5 million ESALs but no visible cracking. PMLC testing began on October 1, 2015 and the Energy Ratio testing has been completed. It is expected to complete the experiment in a 3 year cycle. West presented results from the Cantabro test for four different mix designs included in the study that showed that the Cantabro test is sensitive to asphalt content and air voids.

West continued with the discussion of the MnROAD-Cracking Group experiment. The Cracking Group cells are located on the MnROAD Mainline (Interstate 94) and will consist of eight different mix designs with different amounts of RAP and RAS as well as binder grade. The types of cracking to be investigated are low-temperature, top-down, and fatigue. The experiment will use the following post-construction testing:

- Low temperature: DCT-MN and SCB-MN
- Intermediate temperature: I-FIT (SCB-IL)
- Top down, fatigue: Overlay Tester, BB Fatigue
- ME Design: E*
- Loose mix, cores

In addition, there will be BBR mix beams from a related study with separate funding.

The pre-bid meeting is scheduled for May 4, 2016 with letting following on May 20, 2016. The mix designs are scheduled for July and August 2016 and construction is expected in September 2016.

<u>ETG Comments, Questions, and Discussion:</u>
A participant asked why the modified overlay tester was used. West responded that there was not enough mixture to conduct both tests and based on internal data of both tests, there was evidence that for mixes with RAP/RAS, the Texas standard reports low numbers and that for top-down it requires much higher cycles.

A participant asked for clarification on the correlation performed. West clarified that it was the corrected R-squared that was adjusted for different thickness and modulus in order adjust to the number of cycles to cause 20 feet of cracking. If the adjustment was made using the elastic method, it could introduce error. However, if the sub-layer is appropriate elastic theory can be used since this is at the control temperature at 20°C.

D'Angelo stated that performing tests at N_{design}, at the lower air voids mixtures there is improved performance in all mixes. In doing that, the mixes are compressed and there is not much difference. West responded that the purpose of this was to determine if it is possible to use these tests without additional burden and that although this might not be the best procedure, it is to help implement some of these tests quickly.

Kim commented that Nelson Gibson has SVCED data for the ALF and this data should be added to the study.

A participant asked how many samples were tested on the Overlay Tester. West responded that four samples were used. It was stated that usually five samples are used in Texas.

A participant asked what the binder content was used with the mix designs containing RAS. West responded that he did not have the specific numbers but that he knows it does have additional binder in those mixtures. He noted that Gibson has the data. The participant commented that it was surprising that there was not more differentiating mixtures with RAS.

A participant commented that with going in sigmoidal form from high stiffness to low stiffness, to be cautious about the precision of measuring Poisson's ratio and including that in the determination instead of using a standard value. This may increase variability if it is not measured precisely and that it is better to use a standard value. West responded that it was preferred to use a standard value, but before the procedure was completed, wanted to see how far off we are in that value. The participant commented that a value of 0.35 is commonly used for Poisson's ratio but that it varies as a function of mix or binder stiffness.

Al-Qadi asked whether the testing was investigating cracking or the capacity of the material to crack. For example, if fiber is used in the material, you must measure the capacity of the material and not the crack propagation since there is nowhere for the crack to go. West responded that they may put that in the second phase.

A participant asked about the aging and conditioning protocol. West responded that the aging protocol has not yet been selected, but that it will have two different conditions on all tests.
A participant asked whether any additional mixtures that are not reheated would be used. West responded that there were too many sections and that their experience shows that reheating is not much of an issue.

Mohammad asked if a consistent aging method was used on the testing conducted on the ALF mixtures. West responded that those specimens were not aged and that the testing was part of the normal QC/QA process. All testing of the ALF was done within 2 – 3 years.

11.3 LSU Pooled Fund TPF 5(294) [Louay Mohammad, LSU]

Presentation Title: *Develop Mix Design and Analysis Procedures for Asphalt Mixtures Containing High-RAP Contents – TPF 5(294)*

Summary of Presentation:
Mohammad presented that the objective of the Pooled Fund is to evaluate fatigue/fracture tests that can be conducted on plant mixtures (lab or field compacted) from participating States including ranking the quality of RAP and or RAP/RAS mixtures as compared to virgin mixtures and to develop a score card.

The project consists of two field projects with two mixtures each. The mix design and pavement design records were collected including job mix formula (JMF), loose mixtures and cores. The material characterization utilized both mixture experiment (cracking tests) and binder experiment (rheology and chemistry). The binder rheology was determined using PG grading, Multiple Stress Creep Recovery (MSCR), Gel Permeation Chromatography (GPC), SARA and others. The mixture testing included fracture and fatigue testing using SCB, OT, Energy Ratio Test, Beam Fatigue Test and SVECD.

The field projects included the FHWA ALF and an FDOT project. Each test will be ranked and used to develop a score card. The rankings will be based on specimen preparation, instrumentation, standard test method, testing, training, interpretation, sensitivity to mix composition parameters, routine application, correlation to field performance, data analysis and repeatability.

The fracture and fatigue testing used direct tension cyclic fatigue (SVECD) according to AASHTO TP 79-15 for stiffness and AASHTO TP 107-14 for the damage characteristic curve (C vs. S). The results of the C(S) damage characteristic curves showed that stiffer mixtures have higher C(S) curves and that tests with end failures usually produce shorter curves (i.e., the curve stops at higher C value or smaller S value). The stain-based SVECD fatigue simulation resulted in a plot of number of cycles versus microstrain input. The results showed that as stiffness increased fatigue resistance decreased. The mixtures were ranked based on the damage evolution rate from the SVECD alpha which showed that a smaller alpha is favorable for fatigue resistance.

The SCB test conducted included three notch depths which controls the path of crack propagation. The test results produce the critical strain energy release rate (J_c). At intermediate temperatures, the fracture energy COV was about 15%.

Mohammad presented the ranking of the sections from the ALF compared to the SVECD simulation, SVECD alpha and SCB. The SVECD was fairly consistent with the ALF and will be one of the tests used in developing the score card.

Mohammad stated that there have been issues with the Texas Overlay Test using the AMPT device. The issue is there being a significant residual load once the experiment is set up that has not been resolved.

<u>ETG Comments, Questions, and Discussion:</u>
Clarification of the Texas Overlay Test problem was requested. Mohammad explained that when the device is set up in load control and the load is zeroed, a significant load is applied when the equipment is switched to displacement control. Adam Taylor stated that the tightness of screws in the frame is important in that version (version 2) of the device and a detailed procedure of installation is provided. Mohammad noted that the procedure was followed but there were still issues. Corrigan asked for the difference between versions 1 and 2 of the device. Mohamad explained that the fixture is much stiffer and that there were issues with buckling in version 1.

12. Task Group Review Update T-321 [Geoff Rowe, Abatech]

<u>Presentation Title:</u> *Bending Beam Fatigue Test - Update*

<u>Summary of Presentation:</u>
Rowe acknowledged the task group members. Rowe stated the objective was to review actions and decisions made and agree on a path forward on recommended changes to ASTM D7460 and AASHTO T 321. The goal is to bring ASTM D7460 and AASHTO T 321 closer together in order to remove variability of running either test or running a different test. The recommended changes included:

1. Wave form
2. LVDT reference location
3. Rotational and lateral translation at clamping locations
4. Clamping stress
5. Response sampling intervals and numbers
6. Details concerning calculations at each reporting interval

7. Strain level selection for testing
8. Add discussion about test termination and fatigue life where Nf is desired outcome.
9. Add note about NMAS min and max variability
10. Minimum results that must be reported

Rowe summarized the proposed revisions for each of the 10 items as follows:

1. Wave form
    a. Both standards should use a sine curve about the zero position. No haversine or versine or offset language in specification, which makes it simpler. This is consistent with a majority view on what most of the test labs have been doing in the US. Use of other wave forms is not statistically significant in a recent review by UC Davis.
2. LVDT reference location
    a. All standards will use the method originally proposed by SHRP A003a research. The target reference is at the midpoint of the beam with agreement from major equipment manufactures.
3. Rotational and lateral translation at clamping locations
    a. This is not considered an issue. The wording in ASTM had raised concern initially but the equipment provides for this.
4. Clamping stress
    a. Provisional agreement on 300 N ± 30 N with an area of 25 mm. Will need to check with manufacturers to make sure it is not an issue but will be written into both standards.
5. Response sampling intervals and numbers
    a. The following table will be written into the standard

Repetitions	Intervals (space equally within each range)	Cycles at each collection points included in average reported
0 to 100	1-10, then every 10 to 100	5 (except for 1-10, report individual cycle)
100 to 1,000	10	5
1,000 to 10,000	40 equally spaced data points	5
10,000 to 100,000	At least one every 1,000 repetitions	5
100,000 to end of test	At least one every 10,000 repetitions	5

6. Details concerning calculations at each reporting interval
    a. Manufacturers both noted that they have been implementing the AASHTO TP 79/NCHRP 9-29 methods. Refine report value to include errors reported in TP 79. Essential agreement on way forward.
7. Strain level selection for testing
    a. Dave Jones will provide a guidance note on this. Advice to the user about how to start test depends on the initial stiffness estimate for beam.
8. Add discussion about test termination and fatigue life where Nf is desired outcome.

   a. Run test to S.n with at least a reduction of 15% beyond failure defined as S.n peak is currently in AASHTO and ASTM. Need agreement from equipment manufacturers to terminate test on this criteria. Agreement on use of six order polynomial fit with differential method instead of having choice and will be the same in both ASTM and AASHTO standards.
9. Add note about NMAS min and max variability
   a. Agreed to use the note from the ASTM standard for both standards.
10. Minimum results that must be reported
   a. Agreed to make consistent with item 5 and item 6. This will add errors reported, but is a small change to both standards.

Rowe stated the need for a new AASHTO practice for, "Use of and Interpreting Bending Beam Fatigue Results." The new practice should include the number of results versus confidence in result, specification advice, averaging results – log basis not linear, and how to make a fatigue curve. This will be drafted by the next meeting.

Action Item #201604-2. Recommended edits to T321 "Determining the Fatigue Life of Compacted Asphalt Mixtures Subjected to Repeated Flexural Bending" as presented at the meeting will be forwarded to the AASHTO SOM (Technical Section 2d) for consideration. Geoff Rowe will lead in the preparation and presenting at the next meeting a proposed practice on, "Use & Interpretation of Bending Beam Fatigue Results."

<u>ETG Comments, Questions, and Discussion:</u>
Tayebali stated that the haversine wave used to be used because the test was conducted in tension. Tayebali asked that if using a sine wave, whether the test was now conducted as a tension-compression test. Rowe responded that because of the relaxation of the beam after it is loaded that it does not make a difference (to use sine versus haversine wave) in fatigue life because the material is viscoelastic and referenced work by John Harvey.

Rowe clarified that the purpose of the work was to reduce the number of differences between the standards that have potential to create sources of error and variability. In doing this, it improves the repeatability and reproducibility of the test and possibly makes it more appealing to perform. Tayebali stated that with regards to the clamping, there needs to be a statement in the standard that the 300 N load needs to remain constant during the test.

It was agreed that the averaging of test results should be done on log basis since the data follows a normal log distribution.

Tayebali stated that the number of specimens cannot be fixed but that it should be based on the COV of the instrument. Rowe responded that the procedure needed to be robust and simple and that the equipment [today] has better repeatability. Rowe added that guidance could be developed for a DOT based on their equipment. Rowe stated that the goal was to produce a revised standard.

Bukowski asked Rowe to provide him the changes to T321 by the middle of May. He also asked Rowe to have the stand alone Practice suggested formatted for the September meeting so that it could make the next SOM cycle. Bukowski will give Rowe the Microsoft Word document.

It was emphasized that in order to be included in the 2017 version of the standard, it needs to be balloted soon and therefore the revisions are needed immediately.

Rowe noted that the goal was to submit to ASTM for concurrent ballot. He clarified that the standards are standalone but that the goal was for the technical content to be equal so that the numbers produced from one method match those produced from the other method.

13. Status of MEPDG Asphalt Cracking Model [Kevin Hall, University of Arkansas and Nam Tran, NCAT]

Presentation Title: *Updates on Cracking Models and Transfer Functions in ME Design*

Summary of Presentation:
Hall presented the types of cracking and the mixture properties used for the cracking models as:

- Bottom-up: fatigue strength from flexural beam fatigue test
- Top-down: fatigue strength from flexural beam fatigue test
- Transverse (Thermal): indirect tensile strength; indirect tensile creep compliance
- Reflection: none (regression equation)

Hall presented the bottom-up cracking prediction steps including determining the allowable load applications, cumulative damage index, percent lane area of cracking and stated that there were no changes or enhancements planned for the short-term. Hall stated that the allowable load applications model needs calibration for special materials and that it can be done using the bending beam fatigue test.

Hall next presented the top-down cracking prediction steps and noted that it uses the same fatigue form as bottom-down but assumes cracks initiate at the surface and that the mechanisms were the same but with different locations. (Newcomb stated that the propagation of bottom-up and top-down cracking is different and that this may be a reason for changes to the model.) Hall stated that NCHRP Project 1-42 recommended two primary models for top-down cracking initiation and propagation and that it provided a framework for the planned enhancements of the model. NCHRP Project 1-52, “A Mechanistic-Empirical Model for Top-Down Cracking on Asphalt Pavement Layers,” is targeting a fracture mechanics approach, which is similar to the approach used for the ME based transverse cracking model and ME based reflection cracking model. This approach should be easier to implement in Mechanistic-Empirical Pavement Design Guide (MEPDG) as it has already been completed for reflection cracking.

Next, Hall presented the transverse cracking steps of determining stress intensity factor, change in crack depth, measuring A&n parameters and calculating the amount of thermal cracking. Hall explained that the current AASHTO software predicts transverse cracks only caused by low temperature events. Based on multiple local calibration projects, transverse cracks were exhibited in warmer climates and it was found that the MEPDG will not predict transverse cracking without a significantly high local calibration factor of the transfer function. The mechanism of transverse cracks in warm climates for predicting transverse cracks resulted in an AASHTO white paper, but with no action to date. [D'Angelo commented that it is a result of embrittlement of the mixture and that this is not captured with the testing and that it cannot be predicted from unaged conditions.] Tran stated that low temperature cracking is a single event many times; however, thermal cracking in warmer climates is caused by thermal cycling that occurs daily. It is recognized that there are issues with the transverse model but no solutions have been determined to address these issues to date.

Hall stated that the reflection cracking model in version 2.1 and earlier of MEPDG was based on an empirical regression equation and only applicable to load-related cracks. Version 2.2 of MEPDG included a major revision to the reflection cracking model that was developed from NCHRP Project 1-41. This revision integrated the ME based fracture mechanics model in the software for predicting reflection cracks and is applicable to load and non-load related cracks of flexible, semi-rigid, intact PCC, and fractured portland cement concrete (PCC) pavements. The key features of the revised model include traffic impact, temperature profile computed using the Integrated Climatic Model (ICM), asphalt concrete (AC) mix and binder properties and thermal stress computation done using the existing ME Design approach, utilization of ME Design AC materials properties (A, n), and adapting the procedure for cracking for the longitudinal and transverse directions (i.e., for alligator cracking). The revision to the model considered three different mechanisms for reflection cracking: shear, bending and thermal caused by differential vertical deflections across joints and cracks, bending or increased tensile strains above joints and cracks, and thermal expansion and contraction of joints and cracks, respectively.

Hall presented the reflection cracking prediction process:

- Define layer properties subjected to bending, shear, and thermal stresses
- Generate stress intensity factors for a specific rehabilitation strategy
- Characterize existing transverse cracks and fatigue cracks
- Calculate damage increments and crack propagation from the three mechanisms
- Predict total transverse and fatigue cracks

Hall summarized the MEPDG cracking models as:

- Bottom-up: no changes or enhancements; none planned for the short-term
- Top-down: no changes to date; changes anticipated (NCHRP 1-52)
- Transverse (Low Temp): no changes to date; need to change identified (long-term)
- Reflection: major enhancements in Version 2.2 (replaced regression with ME)

<u>ETG Comments, Questions, and Discussion:</u>
Clarification on which properties were included for the reflection cracking process and where the stress and strain were populated. The response was that the main mechanistic engine of MEPDG and artificial neural networks (ANN) were both used. The user can characterize the properties based on the library provided by NCHRP 1-41 which was verified with LTPP. Because of this, the fracture mechanics test is not required.

Clarification of the output of the reflection cracking model was provided as the amount of reflection cracking over time, similar to other cracking models. Threshold values reflect the allowable amount of cracking at a certain time.

In response to a statement that the cracking models within the MEPDG are inadequate, Hall stated that there is no push to change the bottom-up fatigue model or transfer function because local calibration eliminates bias. Hall added that the majority of pavement work is rehabilitation and that for this, reflection cracking is the issue and that the model is being revised.

A participant asked if there has been a tremendous difference in thicknesses after local calibration. Hall responded that there has not been a large change after local calibration and thickness increases on average 1-1.5 inches.

Tran stated that for states that have done local calibration, the bottom-up fatigue is what drives, more so than the rutting with the caveat that often times rutting will exceed the threshold but it is allowed.

Fee asked for a sense of how MEPDG is being used for new pavement [design] versus existing pavements [rehabilitation]. No States commented that they were using MEPDG for overlay design.

Copeland stated that NAPA, State Asphalt Pavement Associations and NCAT are working to optimize flexible pavement design and have a report on MEPDG implementation that provides a summary of local calibration efforts and summarizes efforts around the country. Copeland will try to make this available to the ETG. The NCAT Newsletter has a summary of this report. The final task of project is to link materials information with design, such as recycled materials and warm mix.

Action Item #201604-3. Kevin Hall and Nam Tran will present at the next meeting an update on their effort related to analysis of the asphalt fatigue cracking model in the ME-Design procedure.

Action Item #201604-4. A copy of the NCAT/NAPA, "Pavement ME-Design – A Summary of Local Calibration Efforts", draft final report, will be sent to the ETG members for their information and comment.

In Canada, the MEPDG User Group has recommended to delay local calibration due to clean-up of the code that is expected to result in changes.

14. Update on BMD Task Group [Shane Buchanan, Old Castle Materials]

<u>Presentation Title:</u> *Balanced Mix Design Task Force Update of Activities*

<u>Summary of Presentation:</u>
Buchanan explained that due to the concern nationally that dense graded mixes are experiencing early age durability related performance issues and that many States have started the process of

using performance testing during mix designs and/or production, referred to as a balanced mix design (BMD) approach, the Balance Mix Design (BMD) Task Force was formed at the September 2015 ETG meeting in Oklahoma City.

The goals and activities of the task force included defining balanced mix design, determining the current state-of-the-practice of BMD and performance testing, recommending approaches/ concepts for immediate use, to recommend future needs (potential research) to advance BMD approaches, and for effective dissemination of material.

The definition of a BMD is an asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate, and location within the pavement structure. The reasons for using the BMD approach include:

- Evaluating the quality of a mix design relative to anticipated performance using a rational approach
- Designing mixtures for performance rather than only a volumetric mix design
- Addressing performance issues that may exist in some areas
- Addressing increased binder replacement from use of recycled materials
- Evaluating mix additive(s) effects which are not directly considered within only a volumetric mix design

Examples of performance tests considered under this include HWTT, APA, dynamic modulus, beam fatigue, and SCB.

The hierarchy of mix designs was presented as performance based design [top], Superpave (Volumetrics) ± Plus Performance [middle], and Superpave (Volumetrics) Plus Performance [bottom]. Performance based design is a mix design to meet performance prediction requirements with measureable performance properties. This was labeled Level A. A Superpave (Volumetrics) ± Plus Performance design is a mix design the meets requirements of performance tests that address rutting, cracking or other performance criteria as the governing principle of the design with allowable adjustments to volumetric criteria in AASHTO M 323. This was labeled Level B. A Superpave (Volumetrics) Plus Performance design is a mix design according to AASHTO M 323 that governs the design, plus the addition of performance tests to address rutting, cracking or other performance criteria. This was labeled Level C.

Flowcharts for each mix design were presented. The Level A flowchart starts with performance testing. The cracking test is used to define the lower limit of binder content and the rutting test is used to define the upper limit of binder content. If the mix design passes the performance testing, moisture damage is checked next. If the moisture damage is not passed, the design is adjusted to satisfy the moisture damage. If the moisture damage does pass, the volumetric properties are determined. With this design, AASHTO M 323 can inform the starting point (e.g., gradation, etc.) but it is not controlling how the mix is assessed.

The Level B flowchart begins with a traditional mix design, based on AASHTO M 323 and AASHTO R 35 with the volumetric analysis passing AASHTO R 30. Performance tests are then conducted. The key to this flowchart is the mix design is based on performance and that revisions to the mix design are only based on passing performance testing and not volumetrics. It was discussed that the flowchart should be revised to add that the adjusted mix design meets a range of AASHTO M 323. The Level C flowchart is similar to the Level B flowchart with the exception that if the performance testing does not pass and the mix design must be adjusted, the volumetrics of the adjustments must pass AASHTO R 30, in addition to the performance testing. For the Level B mix design, the adjustments to the mix are not checked against the volumetrics.

Aschenbrener presented case histories of setting the JMF development during a BMD compared to a volumetric mix design. New Jersey has proposed to complete a Level A design. California has used a Level B design on seven interstate projects. Illinois, Texas, Wisconsin, Louisiana, and New Jersey were highlighted for Level C designs. Level C is the most commonly performed and illustrates that States do not necessarily have confidence in the performance tests.

Aschenbrener next presented the Field Acceptance Guidelines developed for the BMD. Case histories showed there are a variety of methods for field acceptance. A few approaches presented included California not using performance testing for field acceptance, although it was noted that they do require Hamburg testing. Texas, Wisconsin and Illinois use both volumetric and performance testing for acceptance and New Jersey and Louisiana use performance testing for field acceptance. The schedule of field performance testing included initial go/no-go and then ongoing go/no-go which is commonly conducted every 10,000 tons. Aschenbrener pointed out that these tests were not being used to determine pay factors but whether the mixtures were go or no-go. The acceptance quality characteristics presented in the table (AC, VTM, VMA, or field density) can be used to determine pay factors.

Buchanan presented the state-of-the-practice based on results of the BMD questionnaire that was conducted by Louay Mohammad. The survey showed that 21 States reported performance tests were used in their current mix design specifications while 6 States reported that they were not. The States were then asked whether the same performance tests were used to evaluate mix during production. Twelve State DOTs reported they do use the same performance tests to evaluate mix during production, 10 States reported that they did not, and 5 States reported that may use the same performance tests to evaluate mix during production. They only use it if specific issues arise but not every time. Observations of the state-of-the-practice show that widespread confusion exists and that current mix design procedures and requirements vary considerably among DOTs.

The path forward is to prepare a document on the current state-of-the-practice and task force work including definitions, mix design hierarchy, BMD approaches, agency survey results and pertinent literature on BMD and performance testing. It was noted that it is important to collaborate between AFK10 and this task force. Another proposed work item is to identify issues and deficiencies in the current knowledge base and prepare future Research Needs Statements (RNS).

The considerations of implementation for BMD include a simplified monotonic loaded single temperature, national standard test methods with equipment requirements, long-term versus short-term aging, ruggedness testing, precision and bias, sensitivity analysis, acceptance criteria, and correlation to actual pavement performance.

Action Item #201604-5. ETG members are requested to provide comments on the Balance Mix Design presentation and related efforts to Shane Buchanan.

Action Item #201604-6. Shane Buchanan will present on the activities/recommendations of the Balanced Mix Design Task Force at the next meeting.

ETG Comments, Questions, and Discussion:
Questions regarding the performance test design, such as whether the production QC/QA was based on performance testing or volumetrics and how to begin a performance mix design (i.e., not starting with volumetrics). Aschenbrener explained that the Level A mix design was aspirational and that the other two BMDs were based on actual practice. Aschenbrener noted that Level A designs are more in theory currently and they are working to advance this.

Musselman stated this this was an approach and might be something the State can do in 4 to 5 years. From an agency perspective he added that they do not have a level of confidence that the performance tests accurately portray performance. From the industry side, if a mix design does not pass that test, then what? Because of the status quo, that test would not be used.

West stated the importance of having a test that was useful for field performance because there are too many uncertainties between the laboratory and the plant produced mixtures and this is bigger challenge than validating tests. West continued that in order for the tests to be useful, the required time to conduct the test has to be reasonable when dealing with testing field mixes and that it must be limited to one day otherwise there is too much risk introduced. West believes this is achievable in 2 to 5 years.

The critical issue remains, can existing simplified performance tests accurately portray performance.

Mohammad stated that the LADOT has adopted BMD and that it allows for innovation since they can substitute traditional mix design with others if the mix meets the mechanical tests.

Fee suggested that Tom Bennert provide the New Jersey performance based specification that has been around for four years and to provide a summary to the task force on their experience. Bennert is a proponent of Level A and States are interested, but there is a lack of confidence in performance tests.

A comment was made that Superpave was envisioned to have volumetrics and performance but due to lack of easily used performance tests, only volumetrics have been used.

D’Angelo commented that when introducing SMA mixes, revisions were made to the volumetrics. Bukowski stated that volumetrics were not changed as air voids remained the same but voids in mineral aggregate (VMA) were increased. D’Angelo commented that this is not new to the construction industry.

A participant commented that beam fatigue tests are time consuming and asked whether the contractor would have to mill and replace the roadway if the test failed. The response was that the test has been used as a report only and so far none of the beams have failed.

15. FHWA ALF Update/Performance Testing [Nelson Gibson, FHWA]

Presentation Title: *FHWA ALF Update & Performance Testing*

Summary of Presentation:
Gibson began the presentation by stating that if anyone was interested in obtaining mix from the next ALF experiment, they should send buckets soon.

Gibson presented the rate of crack growth stating that it is fairly linear after propagation. Gibson stated there was underdrain maintenance that caused lane 2 and lane 8 to be redone. Lane 8 should be completed before the temperature increases to a prohibitive level.

Gibson presented the comparison of the modulus measured by the Portable Seismic Pavement Analyzer (PSPA) versus the number of passes on the ALF facility. The results show a decrease in modulus with the number of passes and that lanes that were not fatigue resistant (i.e., low number of passes until crack initiation) had a larger loss in modulus after cracking was initiated. The analysis showed that fatigue resistant mixes were able to sustain a larger loss in modulus while providing acceptable performance as opposed to less fatigue resistant mixes showing smaller reductions in modulus.

Gibson stated that the point is modulus reduction and that real pavement damage is accumulated over multiple events, not a single event. The pavement remains intact while it loses a lot of modulus and then a crack occurs which can be measured by beam or AMPT cyclic fatigue.

Gibson next presented on performance based specifications and BMD. He explained that with performance based specifications the life lost or gained is determined to establish pay whereas with BMD, the performance target is determined and produced. Performance prediction needs to include traffic, structure and climate and although we have this capability, it needs to be simpler and add functionality.

The National Performance Management measures were used as the performance criteria using a design life of 20 years and 13 million ESALs. Twenty-one mix designs were created using a single virgin binder, one RAP stockpile, three virgin aggregate stockpiles, three design air voids (3, 4, and 5%), three design VMA (13, 14, and 15%) and three compaction levels (5, 7, and 9%). The in place air voids, design air voids and design VMA were key indicators to create a 3D box inference space established using a methodical volumetric variation.

The structural analysis considered of a 4-inch asphalt concrete over 22-inch crushed aggregate base with M_R of 12,000 psi and subgrade with M_R of 9,000 psi with traffic of 13,000,000 ESALs in 20 years with the climate based on National Airport readings. For the combinations from the inference space, the minimum years differences in life from the 20 year target were determined.

This shows how the selection of VMA, compaction or design air void content can affect performance given a structure.

Gibson presented the 3D plot of the example production data containing the various combinations of air voids and VMA and the relationship of those mixes between rutting and fatigue life. The goal is to be close to the expected design life represented by the line at 20 years so that you can select a mix close to the line and determine the options for VMA, compaction and design air void content.

Gibson next presented on the proposed improvement and changes to AASHTO TP 107. He stated that there are instructional videos posted to YouTube covering reheating and compacting, coring and cutting, cleaning and gluing LVDT tabs, platen cleaning and gluing, running |E*|, choosing the strain level and attaching the specimen and running the test.

Gibson developed guidance on choosing the strain levels by identifying the failure pattern based on 64 different mixes tested based on various strain levels. A table was produced that suggests a stain level to begin with as a function of the number of cycles to failure. From the table, a graph was produced with curves that relate the cycles to peak phase angle and the programmed actuator strain level. This relationship will help improve the usability of the test as it will not be as daunting to determine the input strain level.

Next Gibson emphasized the importance of proper gluing in order to cause the type of failure in the specimen required. A proof of concept was then presented based on various types of segregated mixes. The ability to perform AMPT testing is improved if you follow the instructional videos and use the table developed to determine strain levels.

The next ALF experiment will aim to provide APT performance data (fatigue and rutting) for the FHWA, “Increased Durability from Increased Compaction” initiative to provide some actual accelerated pavement testing data on increased density and the effect on rutting and cracking. The contractor can utilize WMA, alternative rollers and patterns or adjust discharge temperature. Gibson clarified that the experiment will be temperature controlled for fatigue and rutting and wheel wander will be used.

The effect of design air voids, design VMA, and compaction density on the fatigue and rutting performance were presented. For every 1% increase in design air voids, there is a 40% increase in fatigue cracking and a 22% decrease in rut depth which equates to an 18 year decrease for fatigue and 34 year increase for rutting. For every 1% increase in design VMA, fatigue area is decreased 73% but rutting is increased 32% which corresponds to a 3 year increase in fatigue and a 38 year decrease in rutting. For every 1% lower in-place air voids, fatigue cracking decreased 19% and rutting decreases 10% which corresponds to 6 and 17 year increases for fatigue and rutting, respectively. These results are based on a simplified average of the project’s comprehensive results that were distilled into a single rule-of-thumb. Gibson explained that the tool was designed to show what increment of which input variable can be changed and by how much in order to obtain the performance needed.

<u>ETG Comments, Questions, and Discussion:</u>

Bonaquist commented on the importance of this concept and that mixes that cracked the quickest had the slowest rate of change while mixes that perform better sustain more loss in modulus per cycle but have a greater tolerance. It is not the reduction that matters or how fast the changes occurs but how tolerant the mixture is to that change. He added that this trend is similar to the stiffness and relaxation with binders.

A participant commented that the strongest variable for fatigue performance is mixture type. D'Angelo commented that using modulus to predict cracking does not capture the failure mechanism that is needed, such as flexibility. Rowe stated that the bending beam fatigue test showed opposite results with lower phase angles having longer life at a constant strain level. He stated that the structure must be considered.

Al-Qadi stated that the strain level at which the test is performed determines how stiffness impacts fatigue and this must be considered. He also noted that material does not fail because of a single point and that it is the result of the bulk of the material and based on modulus. Defining damage by a single point could not be the correct procedure. Gibson responded that the proper way to interrupt cyclic [fatigue] is to look at the cross section of the asphalt layer and look where there are hot spots and not hot spots. This can be isolated or limited in area, although it takes higher strain to reach the failure.

Buncher suggested for the next ALF to keep variables constant across all three density levels including use of WMA and alternative rollers. Another comment was to use smaller than 19 NMAS since that would never be used as a surface mix. Newcomb stated that mixes with larger aggregates are more prone to cracking and this may influence the ability to distinguish between performance and density. It was also suggested to consider more differentiation with the compaction ranges for the next ALF and that the temperature should be specified and not allowed to change.

Action Item #201604-7. Nelson Gibson will prepare recommended revisions to TP107, "Determining the Damage Characteristic Curve of Asphalt Mixtures from Direct Tension Cyclic Fatigue Tests."

16. Recommendations RAS Task Group (PP78-14) [Jim Musselman, FDOT]

Presentation Title: *RAP/RAS Team Update*

Summary of Presentation:
Musselman stated that the proposed revised standard and corresponding commentary were sent to both ETGs prior to the meeting. The purpose of the presentation is to summarize the revisions to the standard and to get the ETG's endorsement of the changes.

Musselman presented the two main issues as how much of the RAS binder becomes effective binder (quantity of binder) and how to address the stiffness/brittleness of the RAS binder (quality of the binder). The existing approach in AASHTO PP 78-14 uses a RAS binder availability factor of 0.70 – 0.85 and recommends the following binder grade adjustment guidelines:

- No change in virgin asphalt binder grade if RAS or RAS + RAP binder percentage is less than 15%
- One virgin binder grade softer if RAS or RAS + RAP binder percentage is between 15 and 25%
- Use of blending charts if RAS or RAS + RAP binder percentage is greater than 25%

The task force recommendation for the quantity of binder was to raise the minimum VMA by 0.1% for every 1% RAS by weight of the total aggregate. This is based on the assumption of 70% binder availability and will increase the effective binder in the mix to offset the potential for non-effective binder on the RAS. It provides a simple way of addressing binder availability which can improve durability. Because of the angular aggregate and stiffer binder in RAS, there is minimal risk of rutting.

The recommendation for the quality of the binder was to focus on the critical low temperature difference of the binder using ΔT_c which is equal to the difference of the stiffness critical temperature (S) and the relaxation critical temperature (m-value) as measured using the bending beam rheometer (BBR). The recommended criteria for ΔT_c for the blended binder based on binder PAV aged for 40 hours is ΔT_c greater than or equal to -5.0°C.

Musselman presented two approaches for checking the quality of the binder. The first approach is a binder blending procedure where the agency sets allowable RAS tiers, and extracts, recovers and blends typical materials (RAS, RAP, base binder, etc.) at varying percentages (RASBR = 0.00, 0.15, 0.30). The blended binders are then PAV aged for 40 hours and BBR tested to determine ΔT_c and the allowable tiers are set based on the criteria that ΔT_c must be greater than or equal to -5.0°C, and the appropriate PG grade is met. The second approach is a mixture extraction procedure where individual mixes are fabricated, extracted, the binder recovered and then PAV aged for 40 hours. The recovered binder is tested to determine ΔT_c, which must be greater than or equal to -5.0°C, and the appropriate PG grade met.

A mixture performance test for cracking implemented by the State is acceptable in lieu of the binder testing for $\Delta T_{c.}$ The default value option allows a maximum RASBR of 0.10 to be used in lieu of testing.

An alternate loose mix aging procedure was presented for the mixture extraction procedure. For this, individual mixes are fabricated and the loose mix is conditioned at 135°C for 24 hours then the mix is extracted and the binder is recovered. The recovered binder is then BBR tested and ΔT_c must be greater than or equal to -5.0°C, and the appropriate PG grade must be met. The loose mix procedure will be included as an appendix. Musselman noted that based on the presentation from Kim earlier in the meeting, the 135°C criteria may need to be revisited.

Musselman stated that with the ETG agreement, the revised standard would be sent to AASHTO Technical Section 2D.

<u>ETG Comments, Questions, and Discussion:</u>

D'Angelo stated that AASHTO will have comments and questions on the 40 hour aging. The response was that the existing criteria is not enough time to age mixtures, especially with shingles.

Agreed that these revisions are a vast improvement over exiting criteria in PP-78.

Sam Cooper stated that angular aggregates and fibers in RAS can increase VMA.

The comment was made that if there was concern that the binder is too aged, this will be addressed by ΔT_c.

Al-Qadi stated that the VMA is increased based on 70% replacement should maybe allow for changes in VMA. Al-Qadi also stated that in analyzing the binder, blending was forced after extraction. He is not sure that happens in the field and that it should be clear that blending was forced. Musselman responded that there is a note on blending in the table in the revised standard.

There was discussion on the blending being diffusive and higher with higher temperatures and that additional conditions may change some of the blending and diffusing that do not occur at operational temperatures. With RAS, much higher temperatures (185°C) are needed in order to see blending.

West stated that none of the data they have looked at from recovered mixes were able to meet ΔT_c of -5.0°C and that using 40 hours PAV aging will only make the performance worse. He stated that this may eliminate use of RAS. Reinke replied that it may still be possible with use of different types of additives to soften the binder.

Action Item #201604-8. The RAP/RAS Task Force recommendation as presented on PP78, "Design Considerations When Using Reclaimed Asphalt Shingles (RAS) in Asphalt Mixtures" and related commentary will be sent by John Bukowski to the AASHTO SOM (Technical Section 2d) for consideration.

Bukowski adjourned the meeting at 4:00 PM.

DAY 3: Wednesday, April 27, 2016

17. Construction Task Force – Rapid Asphalt Production/Construction Controls [Ervin Dukatz, Mathy Construction]

Presentation Title: *Rapid Asphalt Production/Construction Feedback – PCF*

Summary of Presentation:
Dukatz stated that they changed production/construction controls to production/construction feedback and that PCF are controls and devices designed to provide rapid feedback to the user to improve the density and hence the performance of asphalt pavements. The areas of concern included aggregate moisture, asphalt sampling, and compaction.

The task force conducted a survey of State DOTs construction divisions with 24 States responding to date. The first question was whether the States used moisture sensor(s) on the plant and if they were used for QC with Vermont, Louisiana, and Mississippi responding yes. Moisture control is important because increased moisture, if unaccounted, will lead to a decrease in mix density and aggregate blend and proportions. The next question was if moisture sensors were used whether automatic aggregate belt samples were used on plants and used for QC and Oklahoma, South Dakota and New Hampshire in addition to Vermont, Louisiana and Mississippi responded yes.

Dukatz next presented the needs for asphalt mix sampling to obtain samples of mix as produced, providing quick access to the lab, and being safe for technicians. States that responded to the survey for having truck samplers included Louisiana, Mississippi, Ohio, and Minnesota.

Temperature tools were presented next including the FLIR, MOBA and Pave-IR Scan. States that responded that they use real-time measuring of paving temperature include Maryland, Tennessee, South Dakota, Oregon, Washington, Minnesota, Oklahoma and South Carolina used it for QC as well.

Dukatz next presented use of intelligent compaction (IC) equipment and the results of the survey showed that Vermont, Minnesota, Oregon, Oklahoma and Tennessee use IC for real-time monitoring of pavement rolling. With automatic data collection, less than 1% of data is lost compared to 40% with manual data collection. IC does require a radio to send the signals. The accelerometer on the IC measures the bounce of the steel drum to determine the compaction. Minnesota, Oregon and Vermont are using IC to monitor passes, monitor percent coverage and Minnesota and Tennessee are monitoring stiffness. Minnesota also pre-maps base stiffness before paving. Oklahoma has correlated the CMV values to density using IC. IC helps to meet the goal of rolling so that each section is compacted at the same temperature (±6°F) and receives the same number of passes.

Minnesota, Oklahoma, Tennessee and Vermont have standard specifications for the different devices while South Dakota has a special provision for belt samplers. Idaho, Indiana, Delaware, Mississippi, New Hampshire, Ohio and Virginia do not have State specifications and allow as contractor options.

The survey showed the most promising devices as IC roller, pavement temperature, ground penetrating radar (GPR), and moisture sensor with the most States planning to try IC roller, GPR, and pavement temperature.

Action Item #201604-9. At the next meeting, the Task Force on Construction will present an update of “Improvements on Rapid Asphalt Production & Construction Control” and the status of the “Enhanced Asphalt Pavement Durability Through Increased In-Place Pavement Density” project.

<u>ETG Comments, Questions, and Discussion:</u>
It was clarified that the Quarter Master (sampling device) was approved by AASHTO.

Musselman stated that FDOT does not specify methods but that does not mean that they are not being used in the State.

Hall does not think that Oklahoma is accepting based on the CMV value but are working towards that. Hall believes they are still accepting based on density.

Hall asked whether any States were reporting compaction (stiffness) on granular base or only asphalt layer. Dukatz responded that only Tennessee reported using on granular base and that Minnesota is using on cold-in-place and full depth reclamation with some experimental projects on base.

Buchanan added that Texas uses the pass count system with IC and that it has worked well.

18. Status Pavement Density Initiative [Tim Aschenbrener, FHWA]

Presentation Title: *Enhanced Durability through Increased In-Place Pavement Density*

Summary of Presentation:
Aschenbrener presented the FHWA demonstration project that is being conducted in 2016 with the focus of enhancing asphalt pavement durability by increasing in-place density. The premise of improved pavement durability is achievable with even small increases in pavement Compaction has been recognized as an essential for long-term pavement performance. Many improvements have been made over the years to aid in compacting asphalt pavement to the required density such as vibratory rollers, and more recently intelligent compaction. Many have stated throughout the highway community that mixes using WMA technology are much more workable and easier to compact. Therefore, compaction goals specified by the States should be been improving.

Aschenbrener presented results from past studies that showed the adverse effects of increased in-place air voids on the fatigue performance of asphalt pavements which showed that depending on the mix type and experiment, a 1% increase in air voids was estimated to reduce the fatigue performance of asphalt pavements between 8% and 44%. Previous studies have also indicated the adverse effect of in-place air voids on permanent deformation with a 1% increase in air voids reducing rutting resistance between 7% and 66%. Research from New Jersey showed that the time after construction until an overlay was needed showed that a 1% increase in air voids equaled a 1 year reduction in performance.

Aschenbrener stated the focus of the project is the assumption that asphalt pavement density using existing methods can be increased with minimum additional cost. The long-term objective is that States will increase their in-place asphalt pavement density requirements resulting in increased pavement life. The project will encourage States to target a 1-2% increase in density from their current requirement since even a 1% increase in field density is claimed to increase asphalt pavement service-life by at least 10%.

A case study with NYSDOT showed good best practice with an average of 94.5% of maximum specific gravity. The next steps for the increased density initiative are to contact FHWA Division

Engineers, discuss project goals and identify potential State participants, fund State agency trials/reports on feasibility and on-site training by the Asphalt Institute. NCAT is providing support services to help with construction. Ten States were selected for demonstration projects including Alaska, Washington, Oklahoma, Minnesota, Wisconsin, Indiana, Pennsylvania, Virginia, Florida and the District of Columbia. Of the demonstration States current specifications, 4 States (MN, OK, PA and WI) set minimum lot average at 89.5, 90 to 92% of Gmm; 2 States (DC and PA) have minimum individual test set to 90 to 92% of Gmm with one State using Gmb, Virginia sets minimum control strip density with lot average set at 90% of Gmm and five States (AK, FL, IN, PA, and WA) use percent within limits (PWL) setting the LSL at 91 to 92% of Gmm with the average generally 93 to 94% Gmm.

The experimental plan for the demonstration projects will include a control section and one or two test sections. The first test section will utilize procedures normally being used on a particular project but optimize roller patterns, adjust temperatures, or utilize other methods that will capture minimal to no extra cost to see if they can achieve higher densities. The second test, which is optional, will allow (if not already being used) WMA, additional roller types, or other techniques to improve density. Some of these unique enhancements include incentives to increase density by partnering with contractors, mix adjustments, additional rollers, use of an IC rollers, SHRP2 IR scan and statistical evaluation. For example, Minnesota is going to use IC roller, thermal imaging and changing roller patterns for the first test section and for the second test section consider adjustments to the mix design procedure including changes in NMAS and use of WMA.

The planned schedule for the project is to identity the 10 States in March (completed). By December 2016 State agencies will host an Increased Density Asphalt Construction workshop and will place the increased density pavement section. In 2017, the project will document the number of States that modify existing standards.

<u>ETG Comments, Questions, and Discussion:</u>
Copeland asked whether there has been an effort to gather information from States that already have higher density specifications and have had success in order to document a best practice. Aschenbrener responded that part of the AI workshop is to find success stories and best practices and to present that in a workshop. Copeland added that it may be beneficial to capture case studies. As an example, Maine increased density to 95% but still had issues with raveling. Aschenbrener responded that could be because performance is not just a function of compaction.

Hall asked whether there had been a LCCA performed regarding the time to first overlay and the incremental cost. Aschenbrener responded that the report by Tran on the website considers LCCA.

Hall asked what States were using to measure density, whether it was the SSD method of Gmb or the Corelock and stated that if using the SSD method it was likely over reporting density. Aschenbrener responded that there is a report for what States are using for density (e.g., cores, nuclear gauge, etc.) but it does not provide that level of detail. Aschenbrener referenced the FHWA TechBrief on specific gravity and that it was critical to promote acceptable procedures. This will be part of the AI workshop.

Fee asked whether they should propose a standard method for this. Aschenbrener responded that it is being drafted.

Bukowski stated that the purpose of this project was not to force the States to utilize any one method or technology, but to work with the States to help them realize what is achievable with current practices. The AI course will be available to States outside of the study. The course is a 6 hour course that covers why compaction is important; how to do a better job getting through mix design and pavement design; permeability; mix temperature; environmental factors; roller speed; number of passes; enhanced technologies and others. Any agencies interested in the workshop should contact Bukowski or Aschenbrener.

Musselman stated that FDOT has seen improvement since having better density levels. They were able to achieve this by offering incentives to the contractors. He noted that this project could greatly benefit other agencies.

19. AASHTO TP125 [Pedro Romero, University of Utah]

Presentation Title: *AASHTO TP 125: Bending Beam Rheometer for Low Temperature Performance of Asphalt Mixtures*

Summary of Presentation:
Romero started the presentation with an introduction to transverse cracking and that it is caused by shrinkage of the asphalt concrete layer due to low temperature and occurs perpendicular to the centerline of pavement.

The existing test used to evaluate the asphalt mixtures' low temperature mechanical properties and predict low temperature distress are IDT and Thermal Stress Restraint Specimen Test (TSRST). These are not used on a regular basis because it requires specialty equipment and the tests are complex.

Romero presented the BBR test that is normally used in binder grading and that a modified BBR test is valid for asphalt mixtures. This was recently voted as the AASHTO TP 125 provisional standard.

SGC specimens can be used and specimens cut with a masonry and tile saw. A SGC specimen can produce 20 – 30 BBR specimens. The sample preparation for the BBR should be 12.7 mm x 6.35 mm x 127 mm ± 0.25 mm tolerance and the span of the BBR equal to 101.6 mm. Romero presented a mold used to check the dimensions of the beam. The BBR test provides the stiffness and the slope of the stiffness as the m-value.

Romero next presented on whether the BBR test specimen was too small for asphalt mixtures due to representative volume element (RVE) analysis. Composite theory shows that in materials having spatial disorder with no microstructural periodicity (asphalt concrete) the stress, strain, or energy field is averaged over the domain. This approach is not valid for strength (fracture) of materials but BBR measures flexural creep modulus. The aggregate to beam dimensions ratio for the test are:

- 4.75-mm mixture
    - NMAS/width ratio ~ 1/3
    - NMAS/thickness ratio ~ 3/4

- 9.5-mm mixture
    - NMAS/width ratio ~ 3/4
    - NMAS/thickness ratio ~ 1.5/1
- 12.5-mm mixture
    - NMAS/width ratio ~ 1/1
    - NMAS/thickness ratio ~ 2/1

A visual analysis was then conducted for the three mixtures sizes. Thirteen different areas within each mixture were analyzed and statistical analysis confirmed equal amounts of aggregate between scaled images of the mixture. The statistical analysis also showed homogeneity of variances across sample groups. This shows that if the modulus data sets for all mixtures have equal variances then the beams (12.7 mm x 6.35 mm x 127 mm) meet RVE requirements.

The large particle effect on variability compared to small particle effect on variability with respect to BBR was also evaluated based on 18 samples using 12.5 mm, 9.5 mm, and 4.75 mm NMAS mixes. The 12.5 mm NMAS mixture introduce no more variability in BBR testing than a scaled equivalent 4.75 mm NMAS mixture and therefore it was concluded that large aggregates do not create outliers within data sets.

Even though the BBR test has been shown to be valid, there is no standardized specification. The research set out to ensure that the BBR test can be performed in multiple labs for the same asphalt mixture and produce consistent results; examine effects of varying the testing time interval between sample creation and testing to check for steric hardening; and verification of whether a single specimen can be reused across multiple tests without compromising the consistency of the test results.

The experimental procedures included fabricating 60 beams cut from three asphalt mixture pucks and then randomly selecting 40 of these beams with 20 beams to be tested at the University of Utah laboratory and 20 beams to be tested at the UDOT laboratory. Each lab's set of 20 specimens were divided into 4 groups of 5 beams to run each group at different time intervals: 2 days, 3 days, 1 week, and 2 weeks since cutting.

The stiffness and m-value results of the asphalt mixture specimens were compared between labs. The percent difference of stiffness of both labs' testing samples at 60 and 120 seconds for all four intervals were below 10%. This indicated the difference for both labs' testing results are acceptable and the stiffness measurements using the BBR test between two labs are consistent. In addition, for stiffness variation for both labs over different test intervals at 60 and 120 seconds, there was no obvious difference in the stiffness measurements across labs. On the other hand, the m-value measurements for both labs has a large variation and provides inconsistent measurements of m-values across labs. The repeatability conclusions were that the BBR test has reasonable reproducibility across multiple laboratories for quantifying the low temperature properties of asphalt concrete; steric hardening has no effect on BBR test results after 48 hours, since measurements of stiffness and m-value did not vary with time interval; and stiffness has less variation than m-value in all of the comparisons.

Next, a field evaluation of the mixtures was performed to evaluate whether the BBR results were related to performance which included seven State roads which required PG binder of -28°C for low temperature. The mixtures did have different aggregates and amount of RAP which is the reason for differences in stiffness and m-value. The relationship between creep modulus and m-value shows two distinct groups: high modulus and low m-value (likely to crack) and low modulus and high m-value (not likely to crack). After a recorded low temperature event, there was a crack in one pavement with another two appearing the next year. Of the four mixtures that fell in the "likely to crack" area of the plot, three of the four pavements cracked. The field validation conclusions were that binder testing alone is not sufficient to determine mixture performance and that the BBR mixture test results can be used to predict sections with potential for low temperature cracking.

The overall project conclusions were that BBR testing is practical and repeatable across labs. A specification to predict low-temperature performance of asphalt concrete must include the creep modulus and relaxation modulus and this performance-related specification will allow for innovation.

<u>ETG Comments, Questions, and Discussion:</u>
Rowe asked the load that was being used during testing and asked if it was possible that it was not causing enough deflection for the mixture. Romero responded 4,000 N. However, it is possible that this load is not enough for 10 – 20% of mixtures. D'Angelo added that the test could be conducted at a higher temperature in these cases.

Tran asked for clarification on how the areas of "failing" and "at-risk" were established. Romero stated that they were done manually as an example. Tran added that a horizontal line at 6000 MPa could be used.

Rowe stated that the slope and position of lines presented (creep modulus versus m-value plot) were similar to that with dynamic data but that the position may need to be adjusted. Whether this is plotted on a linear scale or log scale is important. A participant asked if testing on extracted binder from a core would produce similar results. Romero responded that although binder testing is necessary, a performance test is needed for the performance of the mix. However, he would expect the binder testing to be similar. It was stated that it needs to be shown that the tests agree.

It was asked whether testing has been done on conditioned specimens. Romero responded testing was conducted on field cores.

D'Angelo stated that it is the binder that cracks with low temp cracking. Although the mix has an effect, it is the mix in relation to binder ratio and the binder needs to be tested. In order to validate this, the binder volume and properties should be evaluated and then see if the mix test produces similar results. Romero responded that a mix test is needed in order to test or predict field performance. A participant agreed with Romero on the need for a mixture test and that this test can be used to see damage in the mixture. Extracting binder from a cracked pavement is indirect.

Bukowski added that this procedure needs to be validated and that data could provide insight into differentiating the areas of "failure" and "at-risk."

Adam Hand asked about the differences in the mixes and amount of RAP used. It was also asked whether any testing was done on mixtures that contain RAS. Romero responded that all mixtures had RAP between 20 - 25% and various sources of aggregates. RAS was not used in any testing because UDOT discourages use of RAS. Romero also noted that all mixtures were within 0.5% of air voids. Including RAS in additional testing should be done in the future.

Rowe stated that specimens could be made at various depths and could test how materials are aging with depth.

Buchanan asked whether adding 1% more effective binder would the mixture pass or at least move to at risk. Romero responded that they looked at the sensitivity of the binder sweep but that there was an issue with changing air voids and that he will have to look into further in order to respond.

What is the limit for NMAS for the test? Romero responded that they have tested up to 19 mm NMAS for dense graded mixtures.

A participant stated that using virgin mixtures you could compare mixture data and binder data in order to see what compares well and to possibly determine what else effects the mixture. Romero agreed that this could be done and beneficial but first they needed to show that the mixture test reflected the performance. The field performance will continue to be monitored.

20. Alternate Method for Evaluating Moisture Sensitivity [Akhtar Tayebali, North Carolina State University]

Presentation Title: *Alternate Test Methods for Evaluating Moisture Sensitivity of Asphalt Mixtures*

Summary of Presentation:
Tayebali presented alternate test methods for evaluating moisture sensitivity of asphalt mixtures. He acknowledged the NCDOT for funding the research effort. Tayebali first presented the AT-Index Test method for determining compatibility between asphalt-aggregate mixtures. Moisture damage causes stripping and loss of adhesion between the aggregate and binder. There are many subjective methods in the literature including examination of moisture sensitivity of aggregate-bitumen bonding strength using loose asphalt mixture and physico-chemical surface energy property tests and use of image analysis. However these test are time consuming and depend on the quality of the camera or scanner and the software and computer used.

The colorimeter can evaluate the loss of adhesion in percentage based on measuring the color index of the loose asphalt mix or fractured surface of asphalt concrete specimen from the TSR test to measure the amount of stripping of asphalt from aggregate. The colorimeter is relatively inexpensive, easy to use, provides repeatable and accurate measurements and has a testing time of 2 to 5 minutes per sample. ASTM E284 color definition is used as a basis to measure the color index. Values of L* (light-dark index), a* (red-green index) and b* (blue-yellow index) are measured. There are several subjective methods to test loose asphalt mixtures such as the Boil Test – ASTM D3625 and Tex 530-C. By looking at asphalt and aggregate in terms of adhesion, measuring the difference between an unboiled specimen and virgin aggregate to represent full stripping in asphalt mixtures can be used to determine the damage (stripping) caused by boiling. A scale is developed for L* with L* = 0 being pure black and 100 pure white. The damage or loss of adhesion is determined as the ratio of the difference of L* of the boiled specimen and the dry specimen to the L* of the dry specimen. If the virgin aggregate L* is also known, the damage can be calculated with respect to that. The effect of anti-stripping agent is plotted and shows a decrease in the difference of L*.

The boil test was conducted on loose mixtures without anti-stripping to determine whether the test was sensitive to boiling time - which it appeared to be. The same mixtures were also tested with anti-stripping additive and boiled for 60 minutes which showed little effect of conditioning and that the bonding strength between asphalt and aggregate was good. The AT-Index was compared to TSR test results and the color index correlated well with TSR results.

The value of the AT-Index method is that it can be used as a starting point in mix design to (1) assess asphalt-aggregate compatibility with respect to moisture susceptibility and loss of adhesion, (2) determine antistrip additive content (%), (3) compare effectiveness of different antistrip additives and determine the most cost effective percentage and type of antistrip and (4) quality control of plant mixtures to ensure proper adhesion throughout production.

Tayebali next presented the quantification of visual stripping in the TSR test by comparing TSR (%) to L* ratios and reported that L* less than 3 corresponds to TSR greater than 85. The equation to estimate the TSR value from L* ratio is TSR ratio equal to 94.609 minus 3.341 time the L* ratio. This equation was used to estimate the TSR value from L* ratio values for independent laboratory supplied specimens to adjust the equation to TSR ratio equal to 96.888 minus 3.4927 time the L* ratio. If the L* ratio is known for a sample, the TSR value can be estimated.

Tayebali next presented the impact resonance test on vary diameters and thicknesses of samples to determine stiffness. The ratio of unconditioned to conditioned stiffness from IR compares well with TSR. This can be used in combination with the TSR ratio because a mix that may not perform well may have a good ratio, but this can measure modulus value.

<u>ETG Comments, Questions, and Discussion:</u>
Mohammad asked if different dry strengths were compared and if there was an effect. Tayebali responded that each test was full scale TSR and the dry specimen was provided on the left. However, only one strength was used as this was a proof of concept.

A participant asked about cohesion as TSR condition only affects adhesion. Tayebali responded that his hypothesis was that this worked here because cohesion damage is about the same because vacuum pressure, saturation and saturation level is the same in all mixes. If this deviates a little bit, this equation would not work so we took cohesion out of the question.

21. Action Items and Next Meeting Planning

Action Items:
Action Item #201604-1. The draft of the proposed AMPT equipment specification with edits from the meeting will be forwarded to the AASHTO SOM (Technical Section 2d) for consideration.

Action Item #201604-2. Recommended edits to T321, "Determining the Fatigue Life of Compacted Asphalt Mixtures Subjected to Repeated Flexural Bending" as presented at the meeting will be forwarded to the AASHTO SOM (Technical Section 2d) for consideration. Geoff Rowe will lead in the preparation and presenting at the next meeting a proposed practice on, "Use & Interpretation of Bending Beam Fatigue Results."

Action Item #201604-3. Kevin Hall and Nam Tran will present at the next meeting an update on their effort related to analysis of the asphalt fatigue cracking model in the ME-Design procedure.

Action Item #201604-4. A copy of the NCAT/NAPA, "Pavement ME-Design – A Summary Of Local Calibration Efforts," draft final report, will be sent to the ETG members for their information and comment.

Action Item #201604-5. ETG members are requested to provide comments on the Balance Mix Design presentation and related efforts to Shane Buchanan.

Action Item #201604-6. Shane Buchanan will present on the activities/recommendations of the Balanced Mix Design Task Force at the next meeting.

Action Item #201604-7. Nelson Gibson will prepare recommended revisions to TP107, "Determining the Damage Characteristic Curve of Asphalt Mixtures from Direct Tension Cyclic Fatigue Tests."

Action Item #201604-8. The RAP/RAS Task Force recommendation as presented on PP78, "Design Considerations When Using Reclaimed Asphalt Shingles (RAS) in Asphalt Mixtures" and related commentary will be sent by John Bukowski to the AASHTO SOM (Technical Section 2d) for consideration.

Action Item #201604-9. At the next meeting, the Task Force on Construction will present an update of "Improvements on Rapid Asphalt Production & Construction Control" and the status of the "Enhanced Asphalt Pavement Durability Through Increased In-Place Pavement Density" projects.

22. Next Meeting Location and Date

The next meeting date was coordinated with the Binder ETG and will be during the week of September 12th with the potential location of Fall River, MA. Bukowski asked that if anyone had other suggestions to let him know. Also, if anyone wanted to present at the next ETG meeting to contact Bukowski regarding the next agenda and presentations.

23. Meeting Adjournment

Shane Buchanan and John Bukowski thanked all attendees for their participation on the ETG and attending the meeting. The meeting was adjourned at 11:30 PM.

ATTACHMENT A – AGENDA

Asphalt Mixture Expert Task Group
Salt Lake City, Utah
April 25-27, 2016
Meeting Agenda

Day 1 – April 25, 2016

1:00 pm	Welcome and Introductions	**Buchanan/Bonaquist**
1:15 pm	Review Agenda/Minutes Approval & Action Items September, 2015 Meeting	**Bukowski**
1:30 pm	Subcommittee on Materials Updates/Comments	**AASHTO**
2:00 pm	Update Related NCHRP Activities	**Harrigan**
	• 9-52 Comments on Short Term Lab Conditioning	**Newcomb**
	• 9-54 Update Long Term Aging of Mixes	**Kim**
3:15 pm	Break	
3:45 pm	Update Related NCHRP Activities (continue)	
	• 9-57 Draft Final Report on Tests to Assess Cracking Resistance	**Newcomb**
	• 20-07 Task 361 Hamburg Wheel Track Test	**Mohammad**
5:00 pm	**Adjourn for the Day**	

Day 2 – April 26, 2016

8:00 am	Overview of Performance Tests	
	• AMPT Equipment Specification	**Corrigan/Bonaquist**
	• NCAT Activity-Simplified Cracking Test	**West**
	• LSU Pooled Fund TPF 5(294)	**Mohammad**
10:00 am	**Break**	
10:30 am	Task Group Review Update T 321 (Beam Fatigue)	**Rowe**
11:00 am	FHWA ALF Update/Performance Testing	**Gibson**

Noon - Lunch Break

1:00 pm	Update on BMD Task Group	**Buchanan**
2:15 pm	Status of MEPDG Asphalt Cracking Model	**Hall/Tran**
3:00 pm	**Break**	
3:30 pm	Recommendations RAS Task Group (PP 78-14)	**Musselman**
4:30 pm	**Adjourn for the Day**	

Day 3 – April 27, 2016

8:00 am	Status - Pavement Density Initiative	**Aschenbrener**
9:00 am	**Break**	
9:30 am	Construction Task Force – Rapid Asphalt Production/ Construction Controls	**Dukatz/Ramirez**
10:00 am	Alternate Method for Evaluating Moisture Sensitivity	**Tayebali**
11:00 am	Action Items and Next Meeting Planning	**Bukowski**

Noon **Adjourn**

ATTACHMENT B – ETG MEMBER LIST

FHWA Asphalt Mixture & Construction Expert Task Group Members

Chairman: **Shane Buchanan** Asphalt Performance Manager Old Castle Materials 133 Sheffield Lane Birmingham, AL 35242 Cell: 205-873-3316 Shane.Buchanan@oldcastlematerials.com	Co-chairman: **Ray Bonaquist** Chief Operating Officer Advanced Asphalt Technologies, LLC 40 Commerce Circle Kearneysville, WV 25430 Phone: 681-252-3329 aatt@erols.com
Secretary: **John Bukowski** Asphalt Team Leader FHWA Federal Highway Administration 1200 New Jersey Ave., SE; E75-332 Washington, D.C. 20590 Phone: 202 366-1287 Fax 202-493-2070 John.Bukowski@dot.gov	
Members:	
Howard J. Anderson Engineer for Asphalt Materials UDOT Materials Division, Box 5950 4501 South 2700 West Salt Lake City, Utah 84114-5950 Office: 801-965-4426 Cell: 801-633-8770 Fax: 801-965-4403 handerson@utah.gov	**Ross O. Metcalfe** Testing Engineer/Physical Test Section Supervisor Materials Bureau Montana Department of Transportation 2701 Prospect Avenue Helena, Montana 59620 406-444-9201 rmetcalfe@mt.gov
Tom Bennert Rutgers University Center for Advanced Infrastructure and Transportation (CAIT) 93 Road 1 Piscataway, NJ 08854 Phone: 732-445-5376 bennert@rci.rutgers.edu	**Jo Daniel** University of New Hampshire W18313 Kingsbury Hall Durham, New Hampshire 03824 Phone: 603-826-3277 jo.daniel@unh.edu

Ervin L. Dukatz, Jr. V.P. Materials and Research Mathy Construction Company 915 Commercial Court Onalaska, WI 54650-0189 Phone: 608-779-6392 ervin.dukatz@mathy.com	**Kevin D. Hall** Professor and Head Department of Civil Engineering University of Arkansas 4190 Bell Engineering Center Fayetteville, AR 72701 Phone: 479-575-8695 Cell: 479-640-2525 kdhall@uark.edu
Adam J.T. Hand Director Quality Management Granite Construction, Inc. 1900 Glendale Avenue Sparks, NV 89431 Phone: 775-352-1953 Cell: 775-742-6540 adam.hand@gcinc.com	**Gerry Huber** Assistant Director of Research Heritage Research Group 7901 West Morris Street Indianapolis, Indiana 46231 Phone: 317-439-4680 Gerald.huber@hrglab.com
Todd A. Lynn Principal Engineer Thunderhead Testing, LLC Phone: 918-519-6698 todd@thunderheadtesting.com	**Louay N. Mohammad** Professor, Dept. of Civil & Envir. Engineering Director, Engr. Materials Research Facility Louisiana Transportation Research Center Louisiana State University 4101 Gourrier Ave. Baton Rouge, Louisiana 70808 Phone: 225-767-9126 Cell: 225-252-7046 louaym@lsu.edu
James A. Musselman State Bituminous Materials Engineer Florida Department of Transportation State Materials Office 5007 NE 39th Avenue Gainesville, FL 32609-8901 Phone: 352-955-2905 Jim.Musselman@dot.state.fl.us	**Dave Newcomb** Senior Research Scientist Texas A&M Transportation Institute Texas A&M University 3135 TAMU College Station, Texas 77843-3135 Phone: 979-458-2301 d-newcomb@ttimail.tamu.edu
Timothy L. Ramirez Engineer of Tests Pennsylvania Department of Transportation Bureau of Project Delivery Laboratory Testing Branch 81 Lab Lane Harrisburg, PA 17110-2543 Phone: 717-783-6602 tramirez@pa.gov	

Liaisons:	
R. Michael Anderson Director of Research & Lab Services Asphalt Institute 2696 Research Park Drive Lexington, KY 40511-8480 Phone: 859-288-4984 Fax: 859-288-4999 manderson@asphaltinstitute.org	**Evan Rothblatt** Associate Program Manager, Materials AASHTO 444 North Capitol Street, NW Washington, D.C. 20001 Phone: 202-624-3648 Fax: 202-624-5469 erothblatt@aashto.org
Mark S. Buncher Director of Engineering Asphalt Institute 2696 Research Park Drive Lexington, KY 40511-8480 Cell: 859-312-8312 Phone: 859-288-4972 Mbuncher@asphaltinstitute.org	**Audrey Copeland** Vice President-Research and Technology National Asphalt Pavement Association 5100 Forbes Boulevard Lanham, MD 20706-4413 Phone: 301-731-4748 Fax: 301-731-4621 Audrey@asphaltpavement.org
Edward Harrigan Transportation Research Board 500th Street, NW Washington, D.C. 20001 Phone: 202-334-3232 Fax: 202-334-2006 eharrigan@nas.edu	**Nam Tran** Assistant Research Professor National Center for Asphalt Technology 277 Technology Parkway Auburn, AL 36830 Phone: 334-844-7322 Fax: 334-844-6248 NHT0002@auburn.edu
Pamela Marks Materials Eng. & Research Office Ministry of Transportation Building C, Room 238 1201 Wilson Avenue, Ontario M3M 1J8 Phone: 416-235-3725 Cell: 416-779-3724 Pamela.Marks@ontario.ca	

ATTACHMENT C – TASK FORCE MEMBERS AND ASSIGNMENTS

Task Force Members and Assignments

	Task Force Identification:	Members Assigned to Force:
1	Performance Test Review	Mike Anderson (Lead), Ray Bonaquist (Lead); Richard Kim, Elie Hajj, Haleh Azari, Audrey Copeland, Kevin Van Frank, Phil Blankenship, Nam Tran, Raj Dongre, Nelson Gibson, Harold Von Quintus
	T 320; Simple Shear Test	Louay Mohammad, Tom Bennert, Richard Steger, Becky McDaniel
	T 321; Bending Beam Fatigue	Geoff Rowe, Tom Bennert, Phil Blankenship, Bill Criqui, John Harvey, Kieran McGrane, Mike Mamlouk, Richard Steger, Louay Mohammad, Elie Hajj, and Andrew Copper
	T 322; Indirect Tension	Jo Daniels, Becky McDaniels, Rey Roque, Richard Steger
2	WMA Mixture Design	Matt Corrigan (Lead): Louay Mohammah, Charlie Pan (for Reid Kaiser), Gerald Reinke, Kevin Hall, Dave Newcomb, Randy West, Tim Ramirez, Walaa Mogawer, and Jason Lema.
3	Construction Task Group	Erv Dukatz (Lead); Jim Musselman, Kevin Hall, Gerry Huber, Adam Hand, Ron Sines, Audrey Copeland, Tom Harman, and Mark Buncher
4	AMPT, TP 60: Air Void Tolerance and Sample Preparation Issues	Ramon Bonaquist (Lead); Haleh Azari, Matt Corrigan, Richard Kim, Gerald Reinke, Richard Steger, and Randy West
5	RAP/RAS	Jim Musselman (Lead): Timothy Aschenbrener, Audrey Copeland, John D'Angelo, Lee Gallivan, Danny Gierhart, Gerry Huber, Timothy Ramirez, Ron Sines, Hassan Tabatabaee, Randy West, and Richard Willis.
6	LTPP WMA Group	Jim Musselman (Lead); Ramon Bonaquist, Adam Hand, Georgene Geary, Audrey Copeland
7	Balanced Mix Design	Shane Buchanan (Chair), Kevin Hall (Co-Chair): Chris Abadie, Andrew Hanz, Gerry Huber, Lee Gallivan, Pamela Marks, Louay Mohammad, Randy West and Tim Aschenbrener