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 63 individuals attended the meeting (18 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, Utah DOT
Rick Bradbury, Maine DOT
Jo Daniel, University of New Hampshire
Ervin Dukatz, Mathy Construction Company
Kevin Hall, University of Arkansas
Adam Hand, University of Nevada
Gerry Huber, Heritage Research Group
Ross O. Metcalfe, Montana DOT
Louay Mohammad, Louisiana State University
Dave Newcomb, Texas A&M University
Timothy Ramirez, Pennsylvania DOT
R. Michael Anderson, Asphalt Institute (Liaison)
Audrey Copeland, NAPA (Liaison)
Nam Tan, NCAT (Liaison)
Pamela Marks, Ministry of Transportation (Liaison)

Members of the ETG not in attendance:

Tom Bennert, Rutgers University
Todd Lynn, Thunderhead Testing, LLC
Mark Buncher, Asphalt Institute (Liaison)
Evan Rothblatt, AASHTO (Liaison)
Edward Harrigan, NCHRP (Liaison)

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

Adam Taylor, NCAT
Chris Abadie, Pine Bluff Sand & Gravel Company

Walaa Mogawer, UMASS/HSRC
Stacy Glidden, Payne and Dolan
John Casola, Malvern Instruments
Ronald Corun, Axeon Specialty Products
John D'Angelo, D'Angelo Consulting
Geoff Rowe, ABATECH
Randy West, NCAT
Jim Musselman, Old Castle Materials
Frank Fee, Frank Fee, LLC
Brenton Medeiros, PJ Keating Co.
Salman Hakimzadeh, Reliable Asphalt Corporation
Kieran McGrane, IPC Global
James Reger, MAAPA
Tom Brovold, Testquip
Greg Harder, Asphalt Institute
Chris Strack, Sonneborn LLC
Tanya Nash, PRI Asphalt Technologies
Amir Golalipour, ESC Inc.
CJ DuBois, DuPont Elvaloy®
Andrew LaCroix, InstroTek, Inc.
Con Sinadinos, Pavement Pty Ltd.
Ann Baranov, Infratest USA Inc.
Richard Kim, North Carolina State University
Andrew Hanz, Mathy Construction
Bob Kluttz, Kraton Corporation
Jason Bausano, Injevity
Jack Youtcheff, FHWA-TFHRC
Pouya Teymourpour, Rock Road Companies
Lee Gallivan, Gallivan Consulting, Inc.
Ahmed Faheem, Temple University
Jason Bianchino, Collaborative Aggregates
Jean Paul Fort, COLAS
Yichao Xu, Palmer Paving Corporation
Paul Montenegro, Consultant
Richard Duval, FHWA-TFHRC
Bill Buttlar, University of Missouri – Columbia
Gerald Reinke, Mathy Construction
Matthew Teto, P.J. Keating Company
Brenton Medeiros, P.J. Keating Company
Michael Bryce, RIDOT
Phillip Blankenship, Asphalt Institute

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

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DAY 1: Wednesday, September 14, 2016

1. Call to Order

Shane Buchanan called the meeting to order at 8:00 AM.

2. Welcome and Introductions

John Bukowski welcomed everyone to the meeting and asked everyone to introduce themselves. Bukowski introduced two new members to the ETG, Oak Metcalfe from the Montana DOT and Rick Bradbury from the Maine DOT.

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

3. Review Agenda/Minutes Approval & Action Items, April 2016 Meeting [John Bukowski, FHWA]

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 April 2016 Asphalt ETG meeting. The following is a listing and status of the Action Items from the last meeting.

- 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.
  Update: This item is in progress. There is an ETG task group working on the edits.

- 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."
  Update: Item is on the agenda.

- 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.
  Update: Item is on the agenda.

- 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.
  Update: Report sent to ETG members.

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

- Action Item #201604-6. Shane Buchanan will present on the activities/recommendations of the Balanced Mix Design Task Force at the next meeting.
  Update: Item is on the agenda. A TechBrief for **review was** ***distributed to the ETG prior to the 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."
  Update: Richard Kim is on the agenda.

- 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.
  Update: Item is on the agenda. Revisions have been sent to AASHTO and update from SOM will be discussed.

- 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.
  Update: Item is on the agenda.

4. Subcommittee on Materials Updates/Comments

Metcalfe provided the Subcommittee on Materials (SOM) update. Metcalfe succeeded Chris Abadie as the technical section 2d Chair. The SOM meeting was held in August.

- AASHTO TP 125 "Determining the Flexural Creep Stiffness of Asphalt Mixtures Using the Bending Beam Rheometer (BBR)" was recently published.
- AASHTO TP 124 "Determining the Fracture Potential of Asphalt Mixtures Using Semicircular Bend Geometry (SCB) at Intermediate Temperature" was published in August. However, there are already some revisions, such as changing the name of the test to the IFIT. The changes will be sent out to the technical section ballot.
- The AMPT equipment changes will try to be moved forward to the AASHTO ballot in the winter.
- Changes to AASHTO PP 78 "Design Consideration When Using Reclaimed Asphalt Shingles (RAS) in Asphalt Mixtures" were distributed to the technical section and was

unanimously passed on the technical section ballot. There was a motion at the meeting to send the changes to the full ballot this winter as written with editorial comments.

- Changes proposed from the ETG for AASHTO M 323 "Superpave Volumetric Mix Design" and AASHTO R 35 "Superpave Volumetric Design for Asphalt Mixtures" have been moved forward. Metcalfe needs the redline documents.

Bukowski thanked Jim Musselman and entire task group that worked on changes to AASHTO PP 78. There was a letter sent to AASHTO suggesting additional some comments and objecting to the revision. Some of the comments believe that the revision did not allow for mixture characterization. The ETG and task group will address anything that comes from SOM.

H. Anderson commented that based on the report from Louay Mohammad, proposed revisions to the Hamburg Wheel-Track Testing (AASHTO T 324) were being made. An AASHTO committee led by Scott Anderson was contacting the equipment manufacturers to determine what type of effort would be required to make some of the changes suggested in the report. However, some of the more substantial changes, such as the sinusoidal path, are on hold.

Kim asked for update on the submission regarding the direct tensions' dynamic modulus, which was submitted to the SOM last year but has not been included in the update. Metcalfe will look into this.

Bukowski asked about the changes to the data gathering of AASHTO T 321 "Determining the Fatigue Life of Compacted Asphalt Mixtures Subjected to Repeated Flexural Bending." Metcalfe responded that the changes are going to the concurrent ballot.

Metcalfe stated that the research problem statement (RPS) on balanced mix design was submitted. The subcommittee chairs have been tasked with ranking all RPS and are due on September 16, 2016. The rankings will be discussed on September 23, 2016 and the results will be sent to the Standing Committee on Highways who will then recommend RPS to the Research Committee.

Musselman asked for the schedule in order for items to be balloted by the technical section and to move forward. Metcalfe responded that a technical section ballot can occur at any time. However, for items to reach the SOM ballot, they need to be submitted to Metcalfe before June or July in order to get on the agenda. RPS are due around July 1st. In order for changes to move forward and to get on the fall ballot, changes should be sent to the technical section by April.

The following provisional standards are being balloted to become full standards:

- AASHTO PP 60 "Preparation of Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC)"
- AASHTO PP 61 "Developing Dynamic Modulus Master Curves for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)"
- AASHTO TP 79 "Determining the Dynamic Modulus and Flow Number for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)"

5. Impact of Long Term Aging on RAS Binder Properties [Andrew Hanz, Mathy Construction]

Presentation Title: *Impact of Long Term Aging on RAS Binder Properties*

Summary of Presentation:
Hanz presented a condensed version of a presentation he made to the Asphalt Binder ETG as it was relevant to the Asphalt Mixture ETG as well. The mix design evaluated included 20% binder replacement from RAS. Hanz presented the aging methods included in the study as follows:

- Loose Mix + PAV
    - As-recovered (after 2 hours at 135°C)
    - As-recovered + PAV (blending chart)
    - As-recovered + 2 PAV
- Loose Mix
    - 12 hours at 135°C
    - 24 hours at 135°C
- Compacted Mix
    - 5 days at 85°C (AASHTO R 30)
    - 10 days at 85°C
    - 20 days at 85°C

After the prescribed aging protocol asphalt binder was extracted and recovered from the mix. The recovered residue was evaluated using DSR on 25 mm and 4 mm parallel plates and latroscan to determine composition. Future work will include use of torsion bar modulus on compacted mix samples.

The results of the low temperature PG for the intermediate aging (20 hour PAV, 12 hour loose and 10 day compacted) and extended aging (40 hour PAV, 24 hour loose, and 20 day compacted) showed that the difference between materials almost doubled with the exception of the compacted specimens. The intermediate aging resulted in low temperature grades between -30°C and -34°C.The extended aging resulted in two grades warmer than the intended climate.

Results of the ΔTc testing showed similar values for the intermediate aging ranging from -0.5°C to -4.0°C while results for the extended aging showed a difference for the 24 hour loose mix aging where the ΔTc was -15.0°C while the 40 hour PAV and 20 day compacted resulted in ΔTc of -2.0°C and -5.0°C, respectively.

Hanz stated that these findings bring questions to the current AASHTO PP 78-14 language since there is a difference between 40 hour PAV and 24 hour loose mix aging. Hanz stated that for durability, aging can either be 40 hour PAV or 24 hour loose mix aging and that ΔTc must be greater than -5.0°C. However, with 5% shingles, ΔTc passes at 40 hour PAV aging but completely fails after the 24 hour loose mix aging.

It was recommended to limit shingles use to less than 5% in a mix. Hanz stated that they saw much better relationship between 40 hour PAV and 24 hour loose mix aging with RAP mixtures. He also stated that he was not sure that the 40 hour PAV was viable.

ETG Comments, Questions, and Discussion:
Ramon Bonaquist asked whether 135°C was unrealistic and that you would not get this in a normal pavement. Bonaquist stated that there is quite a bit of research that support 40 hour PAV as realistic. Hanz responded that they did not see this type of deterioration with RAP mixtures and he believes that the problem/issue here is with the shingles.

Louay Mohammad asked whether in the mix design if 100% contribution from RAS binder was considered. Mohammad stated that if 100% contribution is compared to partial contribution, than the original amount of virgin binder can have an influence on how the aging will behave. If there is lower contribution then there will be more virgin binder that will influence ΔTc from a mixture standpoint.

Matthew Corrigan stated that in the current provisional standard, there are two ways to address this. The first is to test the extracted and recovered binder of the source material. The second option is to do mixture performance testing where there is discussion of loose mix conditioning. Hanz is highlighting that there are some differences between the options of 40 hour PAV aging and 24 hour loose mix aging. Corrigan stated that there were more details presented at the Asphalt Binder ETG meeting such as other additives not providing value in terms of long term conditioning. The goal is to try to minimize materials that are severely susceptible to aging in an in-service pavement. Corrigan stated that they are trying to address what the target time is in the future that we are trying to simulate. Corrigan stated that there was additional data from MnROAD that showed ΔTc overestimated service. Corrigan asked whether the target should be 10 or 15 years.

Mohammad stated that the loose mix has both virgin binder and a portion contributed from RAS. Hanz responded that it may have responded better if they would have added a few more tenths of new asphalt binder to the mix, but the aging methods are still not giving the same performance.

Amir Golalipour asked whether the selection of temperature was based on previous research. Golalipour stated that the aging mechanism changes when aging above 100°C. Golalipour suggested that it is critical to consider the temperature selected for aging. Golalipour noted that while trying to be practical by reducing aging duration, the process needs to be comparative to other methodologies. Golalipour noted that Richard Kim had done some research in this area.

Kim stated that at the last Asphalt Mixture ETG meeting he had presented on the difference between 95°C and 135°C aging. Kim stated that there was a definite difference in the chemistry and that was why it was recommended to do loose mix aging below 100°C. The study recommended 95°C loose mix aging. Kim stated that the issue with compacted mixture aging is that there is an aging gradient. Although the specimen may be aged for 8 days, the internal part of the specimen has not been aged that long. Kim stated that is why they had recommend loose mix aging. Hanz responded that the proposed AASHTO PP 78 revision now utilizes a loose mix aging procedure.

Tim Ramirez asked what type of RAS was used. Hanz responded post-consumer RAS.

Bukowski commented that there are two different aging situations that did not give the same result. Bukowski stated that with shingles and other additives, binder aging needs to continue to be investigated; however it appears, as expected, that RAS in a mix ages much greater than RAP.

Buchanan asked what the virgin binder ΔTc was. Hanz responded greater than 0.5°C.

Corrigan commented that the Asphalt Binder ETG has been researching 40 hour PAV and that the emphasis on the Asphalt Mixture ETG is on the correct long term mixture conditioning protocol in the context of aging materials and balanced mix design. Corrigan asked what the right amount of long term conditioning was. The response was that Kim was researching this through NCHRP 9-54.

Ervin Dukatz stated that there was more rapid diffusion of the RAP/RAS with one mechanism of aging versus the other.

Bonaquist stated that the aging except 135°C was fairly linear. Bonaquist asked whether this was realistic. Hanz responded that they did not see non-linearity with other materials but only with shingles.

D'Angelo stated that shingle asphalt have very different chemistry versus paving grade asphalt.

Gerry Reinke commented that they had looked at a RAP/RAS mixture where cores after construction were taken. The cores were aged up to 10 days at 85°C. Reinke stated that from 0 to 10 days of aging, they saw the same response of non-linearity for the extracted binder. Reinke stated that it is indicative when there is shingle binder in mixes.

Action Item #201609-1. Andrew Hanz will present an update on Long Term Aging of RAS at the next meeting.

6. Update Related NCHRP Activities [John Bukowski, FHWA]

Presentation Title: *National Cooperative Highway Research Program*

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."
- Project 9-62: "Quality Assurance and Specification for In-Place Recycled Pavements Constructed Using Asphalt-Based Recycling Agents."

Recently awarded projects include:

- Project 9-60: “The Impacts on Pavement Performance From Changes in Asphalt Production” awarded to Western Research Institute. The objective of the 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. The research need statement regarding REOB is captured in this project.
- Project 20-07/Task 391: “Energy Criteria for Maintaining Fully Animated Particles of Loose Asphalt in AASHTO T 209 Testing” awarded to NCAT. 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.

Projects in negotiation include:

- Project 20-07/Task 400: “Effect of Elevation on Rolling Thin Film Oven Aging of Asphalt Binders.” The objective of this project is to develop a standard method for adjusting RTFO aging times based on laboratory elevation.
- Project 20-44(01): “Workshop on Increasing WMA Implementation by Leveraging the State-of-the-Knowledge.” The objective of this project is to identify the barriers to implementation of WMA specifications by the State DOTs and to establish performance measures for WMA implementation nationwide.

The projects nearing completion include:

- Project 9-56: “Identifying Influences on and Minimizing the Variability of Ignition Furnace Correction Factors”
    - Findings showed that for mixes without lime, conducting AASHTO T 308 at 800°F reduces correction factors. Additional work was funded to conduct ruggedness test of AASHTO T 308 and to determine the variability of correction factors for asphalt mixes containing significant RAP and RAS contents.
- Project 9-49A: “Performance of WMA Technologies: Stage II – Long-term Field Performance”
    - Draft final report is under review. Findings showed that over the long-term (4 to 10 years), WMA and HMA perform equivalently.

Recent NCHRP publications include:

- NCHRP Research Results Digest 399: Field Validation of Laboratory Tests to Assess Cracking Resistance of Asphalt Mixtures: An Experimental Design.
- NCHRP Synthesis 495, Use of Reclaimed Asphalt Pavement and Recycled Asphalt Shingles in Asphalt Mixtures.

Action Item #201609-2. Louay Mohammad will report on NCHRP 9-49(A) WMA Long Term Field Performance at the next meeting.

NAPA Ronald D. Kenyon Award

Audrey Copeland awarded John Bukowski with the NAPA Ronald D. Kenyon award. The Ronald D. Kenyon Award for Research and Education is awarded in recognition of outstanding contributions to research and education surrounding asphalt pavement technology; environmental, health, and safety; and asphalt pavement sustainability. The Kenyon Award honors those deserving individuals whose work and leadership have made a significant contribution to the advancement of the asphalt pavement industry. Bukowski was recognized with the award for his work in the implementation of Stone Mastic Asphalt (SMA), WMA and most importantly his partnership with industry. In addition, Bukowski initiated the use of cooperative research programs for both asphalt and is very involved and supportive of both NAPA and NCAT.

7. NCHRP 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:
The objective of NCHRP 9-54 is to develop a calibrated and validated procedure to simulate long-term aging of asphalt mixtures for performance testing and prediction. To date, the project has selected the loose mixture aging method, selected 95°C as the laboratory aging temperature and is matching field aging levels. Loose mixture aging was selected over compacted specimen aging due to the aging gradient in compacted specimens. Testing needs homogeneous compacted material properties. The aging temperature of 95°C was selected because there is a change in the chemistry of the asphalt when aged over 100°C and this affects the performance, especially for highly structured asphalts.

The experimental steps included coring in the field, slicing the cores, extraction and recovery of the field binder, and performing DSR testing on the binder. Laboratory aged materials were loose mixed aged, followed by extraction and recovery of the binder and DSR testing. The corresponding oven aging duration was determined and loose mixture was aged for performance testing. Cores were taken from compacted specimens and Simplified Viscoelastic Continuum Damage (S-VECD) performance testing was conducted.

Kim presented data from the WesTrack Project that showed factors that may affect aging gradient. The data presented was G* at 64°C at 10 rad/s versus depth. The effect of air voids considered cores with 12% and 4% air voids and showed that the 12% air voids connected the air void structure, allowing oxygen diffusion to penetrate to the bottom of the asphalt structure. There was a steeper slope for change of G* with depth for the 4% air void sample. The effect of asphalt content (AC) considered cores with 6.1% AC and 4.7% AC. The samples with 6.1% AC had less slope of aging with depth than the 4.7% AC sample which showed that having a thicker asphalt film reduces aging.

Kim next presented different oxidation rates of binder with similar PG-grades showing the log G* versus aging duration. The plot showed a fast reaction at the beginning, followed by a slower, mostly linear trend of aging. The different aging rates were dependent on the binder source and therefore PG grade may not be enough to look at aging rate. Kim presented data from Long Term Pavement Performance (LTPP) sections in Wisconsin, South Dakota and New Mexico. The log G* showed different aging rates for each.

Kim next presented the steps to match field aging levels in the laboratory. First, the field core is sliced to get the extracted and recovered binder to perform DSR testing. The depth versus G* relationship is plotted. Loose mixture made in the laboratory and aged at 95°C is used to establish the laboratory relationship. The first step is to then select a certain depth and find the corresponding G* from the field. This G* is then transferred to the laboratory aging line which is then used to determine the corresponding aging duration at 95°C in days.

Kim presented the WesTrack example for a fine section from 1995. This example showed a significant drop in G* in the first 20 mm of depth. After that, the aging gradient was fairly constant although it was still aging. The WesTrack Coarse section from 1997 showed that after the first 20 mm, the aging remained constant. The LTPP New Mexico section aging was also relatively constant after 20 mm depth. The LTPP South Dakota field aging gradient slope changed with depth. The LTPP Wisconsin field aging gradient changed for the first 40 mm depth and then remained relatively constant.

Kim next presented the required durations of laboratory aging to match field aging levels for the WesTrack project. To match the 19 years aging for WesTrack Fine Coarse at 6 mm depth, 14.4 days of loose mixture aging at 95°C is required. The required aging at 19 mm depth for the same section and age is 5.6 days. The aging requirements for the WesTrack Coarse section for 17 years aging was 8.4 days and 2.1 days for 6 mm and 19 mm depth, respectively. The aging durations required for the Wisconsin LTPP section to match 17 years aging was 8.2 days and 6.5 days for 6 mm and 19 mm depth, respectively. The aging durations required for the South Dakota LTPP section to match 21 years aging was 18.1 days and 15.9 days for 6 mm and 19 mm depth, respectively. The aging durations required for the New Mexico LTPP section to match 18 years aging was 25.7 days and 16.1 days for 6 mm and 19 mm depth, respectively.

The required durations to match field aging levels showed that to match aging at 6 mm depth, 7 to 25 days of loose mixture aging at 95°C is required whereas to match the 19 mm depth, 2 to 15 days of loose mixture aging at 95°C is required.

Kim next presented examples of the field aging gradient and variability. Example from Manitoba using two cores from the same section at 4 years aging showed differences in G* of up to 5 kPa at the same depth. Cores using Evotherm and Advera WMA had even greater variability. This variability will make the model more difficult to develop.

Kim next presented on the fatigue testing on field cores. The testing used 38 mm diameter specimen geometry which allowed for two cores from a single lift when the lift was at least 1.5 inches by coring sideways. The performance testing used cyclic fatigue test under the Asphalt Mixture Performance Tester (AMPT). Testing resulted in master curve, damage curve and failure criteria for the mixtures. There was a significant reduction in failure criteria due to 8 years of aging for the ALF-SBS mixture.

The Layered ViscoElastic pavement analysis for Critical Distresses (LVECD) Program provides 3-dimensional viscoelastic analysis under moving loads and temperature gradients estimated by EICM. Material properties are in input to the program. The LVECD simulation results showed the difference between short term aged materials and extended aging. The cracking pattern showed only bottom up cracking for short term aged but both top down and bottom up cracking with greater magnitudes for the aged condition.

The LTPP Wisconsin section had both a top and bottom lift. This allowed for examination of both top and bottom aging. The top and bottom properties were different. Top down cracking and bottom up cracking were greater at 8 years than for short term aging. The proper aging simulation is very important for the cracking simulation. The use of an aging gradient will also be important.

ETG Comments, Questions, and Discussion:
Dave Newcomb commented that these would primarily relate to top down cracking and asked if for bottom up cracking and looking at lower depths if it would be less aging duration. Kim responded yes, but that the aging gradient does not change much after 19 mm. Kim stated that the 19 mm conditions is not too far away from the bottom of the asphalt concrete layer. Newcomb responded that it would depend on what you are trying to model and that bottom up fatigue or reflection cracking may need to change the protocol. Kim responded that even when looking at WesTrack at 120 mm depth, the aging is not that much less than 20 mm.

Gerry Huber asked about the extent of stiffening happening in the upper layer. Kim responded that they have not checked the original binder G* data, but that G* is what they measured. Kim will do further analysis.

D’Angelo commented that it is expected to see with 17 and 19 years leveling out of aging and that the critical time is between 0 and maybe up to 10 years. D’Angelo asked whether the study had looked at the ratio of aging in the first few years. Kim responded that they still had some sections to test. The other sections have less aging so hopefully will be able to get that data but do not have it now.

Adam Hand asked why there was no difference between the aging conditions at 95°C and 135°C for the ALF performance. Kim responded that he presented three graphs at the last Asphalt Mixture ETG meeting. Two of those graphs, for SBS and AAG binders, did not have a difference. However, for the AAD binder, which is a highly structured asphalt, there was a significant difference. In order to cover all types of asphalt, the recommendation for aging temperature was 95°C. Hand noted that the WesTrack is actually in an area of Freeze and not Dry No Freeze.

Buchanan asked how this work would be utilized in practice. Kim responded that the vision is to recommend 95°C loose mixture aging at certain fixed durations, maybe 2 or 3 durations. Then a back end analysis will be conducted to inform users on what each condition means in terms of age and depth. For example, 5 years 6 mm depth is equivalent to 10 years 20 mm depth.

Nam Tran asked how a new test would be used with the back end analysis, since the input for the back end analysis would be from the AMPT cyclic test. Kim responded that the input would not be from the AMPT but from binder testing. It is the binder aging data that is used to determine the depth and age to determine the loose mixture aging duration. The aging duration does not change as a function of the mixture performance test. Tran asked whether simulating the aging of a mixture at 10 years could be done. Kim responded that it could be done through use of the diffusion model and kinetics to determine the depth, but that the binder aging data would be needed to determine the rate of aging. Once the aging duration is determined, age the loose mixture and then make the specimens for any test.

Kevin Hall asked for clarification stating that for a mixture design lab, binder testing has to be performed first to produce the curve in order to determine the aging duration before mixture testing can be performed. Kim responded yes, that the aging rate must first be captured which is binder specific.

Golalipour asked whether high RAP along with RAS mixtures have been considered. Golalipour stated that compaction of samples after long term aging of loose mixture could be challenging. Kim responded that two sections with 50% RAP will be included and they will look into this, but this is not a RAP study.

Hand commented that if comparing materials in the laboratory using performance test, there may be two different aging conditions because of different materials used. Kim agreed and stated that it is possible to interpolate between two aging conditions to age the same. Kim proposed to run three or four aging conditions in order to result in three or four locations in the performance. From there, interpolation to a point of interest can be done.

Marks commented that needing to have the rate of binder aging makes sense. Marks continued that having a model for mixture is interesting and not sure how as user or agency such a wide window would be needed. Marks noted that mix design does not take into account long hauls, storage, etc. and the actual temperature the mixture is produced at can vary. The variability seen with the Manitoba data could be because it was produced hot and then the temperature lowered. Kim responded that those are ”noises” in the system which can contribute to variability in the data.

Bonaquist asked with laboratory aging at 95°C, what was the procedure for binder aging. Kim responded loose mix aging at different durations. Bonaquist responded that the binder aging rate model is needed.

Reinke stated that based on earlier data, there are binders that could be aged at 135°C. Reinke asked whether there was a mechanism to evaluate binder with rejuvenators, that could inform whether aging at 135°C was suitable or not. Kim responded that it is part of the next project and they could not cover that today. Reinke asked if there was a procedure to determine if a binder can be aged at 135°C for a shorter duration. Kim responded that the only way is to look at the chemistry and rheology. First fix the rheology and let the chemistry change and then compare the results of the performance test. As long as the performance is similar, then the chemistry change does not affect the performance and 135°C could be used for aging. Reinke asked if there was a binder aging test that could be run to inform whether it was suitable to age at 135°C. Kim responded that it was possible and is something to consider.

Frank Fee stated that below 20 mm, the stiffness changes are small. Fee asked how significant was the difference at depth, as most of the aging is in the top lift. Kim responded that there is a difference. Fee responded that it may be true for thinner pavements but that the real concentration needs to be in the upper lifts and one may not have to worry about the bases.

H. Anderson commented that from DOT perspective, many DOTs have lost ability for routine binder extraction and are not confident that they are getting the same grade, even with polymer modified binders.

Kluttz responded to Reinke's question stating that binder aging will have to be done as long as the mixture aging. The test required is GPC, which few laboratories can run.

Action Item #201609-3. Richard Kim will report on the status of NCHRP 9-54 Long Term Aging of Mixes at the next meeting.

8. NCHRP 9-55 RAS in WMA [Randy West, NCAT]

Presentation Title: *NCHRP Project 9-55: Recycled Asphalt Shingles in Asphalt Mixtures with Warm Mix Asphalt Technologies*

Summary of Presentation:
West began the presentation by stating that the draft report should be submitted to the panel in about 6 months. West also commented on the Association of Asphalt Paving Technologist (AAPT) annual meeting and webinar series.

The objectives of NCHRP 9-55 are to develop a mix design and evaluation procedure that provides acceptable performance for asphalt mixtures containing RAS with WMA. To accomplish this, the project will determine RAS characteristics that relate to mix performance and evaluate mixing efficiency of RAS with virgin binders over the range of asphalt mixture production temperatures.

The project includes three existing field projects – two in Texas and one in Illinois. The Texas projects have both HMA and WMA while the Illinois project is only WMA with two aggregate types. The project will also consider five new field projects that were constructed between September 2013 and October 2015. The production temperatures for HMA and WMA for the Wisconsin project were only between 3 and 7 degrees different. The Alabama project had issues with low voids in the mixture. The mixture properties were adjusted. The differences were designated "low" and "adjusted" throughout. The North Carolina project used both post-consumer (PC) and manufacturer wastes (MW) RAS. The Indiana project used MWRAS.

The field performance evaluation included randomly selected three 200-ft sections for each mix. Rutting was measured with a straight edge and wedge. Cracking was determined by visual inspection and the LTPP Distress Identification Manual (DIM). Raveling was determined based on ASTM E965 (sand patch). Five 6-inch cores from between the wheel paths were collected. The in-place density, binder properties and laboratory tests were conducted.

The field performance at 37 months for the US 287 project in Texas showed low severity transverse cracking for the HMA section and 21 feet of low severity longitudinal cracking. The field performance at 47 months for FM 973 project in Texas showed some measureable cracking, but not significant. The three sections (one WMA, two HMA) had longitudinal wheel path cracking and one HMA section had block cracking. The Illinois project at 34 months showed levels of low, moderate and high severity transverse cracking. The Wisconsin project showed minor reflection cracking over the unrubblized portland cement concrete pavement at 25 months. The Indiana project field inspection at 12 months is pending.

Laboratory testing was conducted on plant mix, lab compacted material with no additional aging. Dynamic modulus testing was conducted at 4, 20, 35 and 45°C at frequency range between 10 and 0.01 Hz. Hamburg Wheel Tracking (HWT) test was conducted in accordance with AASHTO T 324 to assess the rutting and stripping potential of mixtures. Flow Number (FN) testing was conducted in accordance to AASHTO TP 79-09 at the LTPPBind 3.1 temperature with 50% reliability at 20 mm from the surface. The IDT Creep Compliance and Strength test was conducted in accordance with AASHTO T 322 to predict the temperature at which the mix will crack due to thermal contraction. The Energy Ratio was tested using the UF Method to assess top-down cracking. The bending beam fatigue test was conducted in accordance with AASHTO T 324 to determine the fatigue endurance limit for mixtures. The Overlay Tester was tested in accordance with TXDOT 248-F. The Illinois Flexibility Index Test (I-FIT) was conducted using preliminary ILDOT criterion of minimum 8.0.

West presented the correlations for all of the laboratory tests. Results showed moderate to strong inversely proportional correlation between Flexibility Index and Modulus values. There was a strong proportional correlation between Flexibility Index and OT cycles to failure. There was moderate to strong proportional correlation between FN and modulus values. There was moderate inversely proportional correlation between OT cycles to failure and modulus values. There was moderate proportional correlation between OT cycles to failure and HWT rutting. The critical pavement temperature (°C) and Energy Ratio values did not correlate with any other test results.

West presented the performance test conclusions as follows:

- At low temperatures, WMA has little effect on mix stiffness.
- At intermediate and high temperatures, WMA had lower E* values for 3 of 5 evaluated projects.
- No effect on E* due to type of RAS used.
- No statistical difference in HWT rutting was found for WMA versus HMA for WI, TN and IN mixtures. TN mixtures were statistically different for the FN test.
- For the AL mixtures, the low void WMA had statistically higher HWT rutting and lower FN. The adjusted void HMA had the least rutting.
- The two NC WMA mixtures had higher HWT rutting and lower FN than the HMA mixtures.
- No effect on rutting due to type of RAS used.
- All 15 mixtures passed the 0.5 inches in HWT rutting criterion.
- For the FN testing
    - 2 of 15 had FN < 3 MESAL criteria
    - 4 of 15 mixtures met the 3 to <10 MESALs criteria
    - 8 of 15 mixtures met the 10 to < 30 MESALs criteria

  - 1 of 15 met the > 30 MESALs criteria
- All of the Wisconsin and Tennessee mixtures have ER values greater than 1.95.
- In total, 11 of 15 mixtures have ER values > 1.95 (highest traffic level).
- The AL adjusted PA HMA and the NC MW HMA had low ER results (below 1.0, lowest traffic level), suggesting susceptibility to top-down cracking.
- HMA vs. WMA was not a significant factor for ER.
- None of the tested mixtures meet the current preliminary I-FIT criterion of 8.0.
- A strong correlation was found between Flexibility Index and OT cycles to failure.
- Based on TXDOT specifications only 4 out of 15 mixtures passed the minimum 300 cycles criterion.

West stated that all sections are performing which makes it challenging to set some performance criteria. Many of the mixtures failed the existing or preliminary criteria for cracking tests, but the field cracking performance has been good for the first 2 to 3 years. West stated that the projects need to be followed for a few more years.

The project is currently working to assess response parameter and predict mixture performance, cost-benefit analysis, and best practices.

ETG Comments, Questions, and Discussion:
Mohammad asked regarding the I-FIT results whether some of the sections had cracking. West responded none really to speak of but this shows that the criteria needs to be validated.

D'Angelo commented that based on work conducted at MnROAD, a difference due to RAS is seen at about 5 years. West agreed that it is too early, and that it may take longer to see more change likely in the 4 to 5 year range.

Buchanan commented that Kim is working on the diffusion of recycled binder and virgin binder. West responded that they looked at scanning electron microscope (SEM) to see if the shingles were dispersed in mix but there were some challenges. West stated that the best indicator they found for determining the RAS particle was to identify some of the fibers through the SEM. However, West does not think that this is a fruitful approach.

H. Anderson commented that at the DOT level, there is pressure to use recycled materials and asked whether it would be better to use RAS in lower lifts or would that just promote cracking at the bottom. West responded that RAS is usually used in the surface course although NCAT did have a 2012 test section where RAS was in the intermediate layer near the neutral axis. However, the section failed quite early likely due to other conditions.

Action Item #201609-4. Randy West will report on the status of NCHRP 9-55 RAS in WMA at the next meeting.

9. Flexibility Index from SCB Testing in Wisconsin [Ramon Bonaquist, Advanced Asphalt Technologies, LLC]

Presentation Title: *Another Approach to Balanced Mix Design?*

Summary of Presentation:
Bonaquist began the presentation by acknowledging the Wisconsin Highway Research Program Project 0092-14-06 “Critical Factors Affecting Asphalt Durability.” The objective of the project was to evaluate changes to the composition of asphalt mixtures that WisDOT should consider to improve durability. The project consisted of three major parts – synthesis of current research, laboratory experiment and analysis of WisDOT specifications. The laboratory experiment included resistance to cracking and aging through volume of binder, recycled binder content, low temperature grade, and polymer modification. Bonaquist explained that with four factors and three levels each, a total of 81 combinations would be needed. Therefore, this project used a partial factorial design using the Box Behnken Design that tests at the mid-points of two factors (e.g., middle factor 1, low factor 2; middle factor 1, middle factor 2; middle factor 1, high factor 2; middle factor 2, low factor 1; middle factor 2, high factor 1) to reduce the combinations to 27.

The 27 combinations for the experiment were presented. For the binder content, the nominal maximum aggregate size (NMAS) was changed (between 9.5, 12.5 and 19.0 mm) instead of changing the binder content. This resulted in about a 1% change in binder. Recycled material was included at 0 (low), 0.25 RAP binder replacement (medium) and 0.25 RAP binder replacement plus 0.1 to 0.15 binder from shingles (high). The low temperature grade ranged from -22°C to -34°C with the target being -28°C. Polymer modification ranged from none, to medium to high.

There were some issues with the semi-circular bending (SCB) test from Louisiana (LA), so the specimens were loaded following the LA method but analyzed using the I-FIT approach. The flexibility Index (FI) is the energy under the curve divided by the post peak slope. The resistance to cracking improves as the FI increases. Bonaquist stated that they wanted an index for aging, so they used the stiffness index.

Bonaquist presented the virgin binder properties which showed that as the Jnr reduces, the percent recovery increases and the ΔTc improves as the modification increased with the exception of the low grade of -34°C for the ΔTc. Bonaquist stated that the mixtures in Wisconsin are typically fine graded.

Bonaquist presented the result of effective binder content for both the short-term oven aged (STOA) and long-term oven aged (LTOA), for FI and the SI Aging Index. The results were reasonable showing that as the volume of binder increased, the cracking resistance improved as measured by the increased FI. The cracking resistance decreased from STOA to LTOA. There was limited change in the SI Aging Index. As the FI increases, the area under the curve is increasing and the post peak slope is becoming flatter.

The effect of virgin binder grade showed that as the binder is stiffened, the FI decreases. The FI also decreases as a function of aging. The SI Aging Index seems to be a little smaller for binders that are initially harder in line with the Witczak global aging binder.

The effect of recycled binder showed that the FI reduces as one moves from virgin binder to higher recycled binder. Bonaquist noted that some of the RAP+RAS mixtures had higher effective binder and this also affected performance positively. The effect of aging was clearly evident with STOA performing better than LTOA. There appeared to be a change in the SI Aging Index, with the mixtures with more recycled materials tending to age less.

The effect of polymer modification showed an improvement in FI with polymer modification. Again the effect of aging was clearly evident with STOA performing better than LTOA. Polymer modification did not change the SI Aging Index.

Bonaquist next presented the regression equation development for relating FI to factors controlled by specifications. The development considered rationality of the coefficients (most important), significance of predictor variables, goodness of fit and residuals.

The FI regression equation was presented as:

$$FI_{STOA} = -18.759 + 1.368 \times VBE - 0.3905 \times \left(T_{Virgin}\right)_{Low} - 10.181 \times RBR_{EFF} + 3.100 \times \left(\frac{R\%}{100}\right)^2$$

Where:

FI_{STOA} = short-term oven conditioned flexibility index
VBE = effective volume of binder, vol %
$(T_{Virgin})_{Low}$ = continuous low temperature grade of the virgin binder, °C
RBR_{EFF} = effective RAP binder ratio
F = ratio of intermediate grade change for RAS to RAP
R% = percent recovery from AASHTO M332

$$RBR_{EFF} = \frac{\%RAPBinder}{\%TotalBinder} + F\left(\frac{\%RASBinder}{\%TotalBinder}\right)$$

The analysis of the coefficients showed that they were all statistically significant. The standardized partial regression coefficient provides an idea of the importance of the variables. The effective binder content and low temperature grade were about the same level of importance followed by effective RAP binder ratio and then percent recovery. The predicted versus measured FI showed the explained variance was 83% and the standard error was 1.33. Bonaquist next presented the FI_{LTOA} as a function of FI_{STOA}. Here, the constant did have a significant effect. The predicted FI_{LTOA} versus the measured FI_{LTOA} showed the explained variance to be 84% and the standard error to be 0.91.

Bonaquist next presented an example design specification. With this, the regression equation was used to determine the minimum design volume of effective binder and the effective RAP binder ratio. The table showed that above the effective RAP binder ratio of 0.3, the low temperature grade controls and the grade must be reduced. The table also showed that as the recycle content is increased, the effective binder content can be increased as well. With the use of polymer modification, less binder can be used. Bonaquist asked whether from an industry standpoint if this approach made sense and would it be easier to implement.

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

Abadie asked whether to change the effective binder content if the NMAS was different. Bonaquist responded that it is the easiest way to change effective binder content and noted that the changes recommended did not seem too big of a stretch from the status quo.

Mohammad commented that this was going back to compositional analysis and asked with similar properties of composition and different mechanical response, how it fit in the response? Bonaquist responded that this is not simply compositional as the regression equation relates composition to controllable factors. Mechanical properties of the mixture can be changed through mix design by changing amount of binder, type of binder, recycling, etc. Mohammad asked whether those variations were able to de detected. Bonaquist responded that from what they were looking at from the modification, it is the percent recovery.

Dangelo commented that this was not a universal chart but that it works well for Wisconsin conditions and materials but other agencies would have to develop a similar unique chart and once an agency established performance test and materials. Bonaquist agreed and stated that it also shows that mixes with recycled materials with binder replacement greater than 0.3, should not be used with the minimum effective binder.

Kluttz commented that he was not surprised that the percent R was not significant because R will be consistent if testing at equistiffness temperature. Bonaquist responded that he would have to do further analysis. The percent R was determined at either 58°C or 64°C. The bulk of the experiment included some sort of modification. The test temperature was all done at constant temperature and not at equal viscous temperature in mixture testing.

Bukowski asked if there was more work to be completed. Bonaquist responded that the work is completed and the final report has been submitted to Wisconsin Highway Research Program and is undergoing the review process.

10. Update of FHWA PRS Project [Richard Duval, FHWA]

Presentation Title: *FHWA Performance Related Specifications for Asphalt Mixtures*

Summary of Presentation:
Duval began the presentation by stating that the Performance Related Specifications (PRS) research began 25+/- years ago and this project began in 2014 beginning with a meeting consisting of 16 State DOTs Materials and Pavement leaders providing feedback on how to ensure that this was a practical approach that could be used by agencies. PRS predictive modeling determines how the finished asphalt pavement product would perform over time. There are different amounts of risks between the owner and the contractor of the various types of projects. PRS allows for a more shared risk between the agency and the contractor, but in doing so, the contractor must have some control which the agency would allow for innovation.

PRS is similar to the Disability Adjusted Life Year(DALY) which measures overall distress burden, expressed as the cumulative number of years lost due to ill-heath, disability, or early death. PRS tries to predict how much life of the pavement is lost or gained. PRS and balance mix design (BMD) are related but use a different approaches such as fundamental testing for PRS and empirical testing for BMD. The purpose of this presentation is to move these two forward together. With PRS, there is already the capability for pavement performance prediction, but it needs to be made simpler through easier standards. With BMD there is no predictive performance with an empirically tested go / no go approach thus the functionality needs to be added to the BMD.

PRS provides performance predictions and has broad applicability. Performance models for specific distresses as a function of pavement age (time) can be associated with specific detailed pay tables for pavement life (based on what that is worth to the agency). PRS consists of fundamental testing by the AMPT, software analysis tools which are being developed, and historical or field calibration. . BMD is straight forward and easier to execute. With BMD, if the mix passes a set of criteria, it will have a higher probability of achieving expected "design" life with respect to distress associated with those criteria. BMD cannot be used to predict distresses as a function of pavement age (time).

The AMPT results are assessed with the structure, traffic and climate to predict rutting and cracking. The Pavement Analysis software is used for determining the pavement life. This is not moving away from the Mechanistic Empirical Pavement Design (PavementME) and the models are used for concrete pavement and the HMA-PRShave been and will be further calibrated against the field performance data so in the software and there is now direct linkage between design and construction.

PRS test equipment and protocols include AASHTO R 35/M 323, AASHTO TP 79, ASHTO PP 60, AASHTO TP 107, AASHTO TP 116 Simplified Triaxial Stress Sweep, and the Pavement Analysis Software (aka -LVECD).

Property	Operation	Time(Includes Prep)
Modulus	AASHTO TP 79 - Dynamic Modulus Test	1 day
Cracking	AASHTO TP-107 - AMPT Cyclic Fatigue Test	1 day
Rutting	AASHTO TP-116 Option B - S-TSS Test	1.5 days
Pavement Performance	Asphalt Pavement Analysis Program	40 min.

Total Time for PBMD Performance Testing	For Index Properties	3 days
	For Pavement Performance	4 days

1)For a particular project, from the pavement design you wouldstart by establishing performance criteria and establish the Acceptable Quality Characteristics(AQC) or target values which the agency sets as a level of pavement performance the contractor/ pavement life needs to obtain.
2) From that the specification is set up for a contractor to be able to understand their risks and how to bid on a project. This is accomplished by incorporating the pay tables into specifications and project letting. The specification is then used for pavement construction, QA(sampling and testing). As it is currently the standard, volumetrics are used during construction to assess the pay factors and expected life to make pay adjustments along with the asphalt pavement analysis software.

3) Once the contract is awarded then either the contractor or agency performs the performance mix design which consist of volumetric and AMPT fundamental performance testing and compare the results to the established AQCs for approval.
4) During construction software is used to compare the design AQC versus the as-constructed AQC. This is used to model the performance and the difference between the as-designed and the as-constructed. This is used to determine the pay factor.

As a part of the PRS development effort, the FHWA project include using the PRS on paving projects as a shadow specification to document the impacts on agency and contractor operations and pay. The process for shadow/full implementation of PRS for State DOTs in part is being conducted through SHRP 2 R07 implementation. However, additional shadow projects with DOTs are being sought and we are looking for volunteers. The future technology transfer of PRS includes videos/TechBriefs, animated whiteboards, and success story reports.

Duval presented the PRS parallel success to date. For concrete, the Illinois Toll Authority had full implementation of PRS with great success, after starting with a shadow project.. For asphalt, existing QA procedures are been more advanced compared to concrete and in the eyes of SHRP 2 R07, is considered a level of performance specifications.

Duval presented the price decrease realized by the Illinois Tollway once more control was given to the contractor through PRS. Part of the price decrease may also be due to a decrease in the cost of cement and other sustainability initiatives. Duval stated that this would be covered in a TRB paper at the upcoming annual meeting.

The challenges in PRS acceptance include the following:
Testing efficiency and simplicity
Standardization of test methods
Reliability of performance prediction models
Predictive relationships between AQCs and performance prediction model parameters
Same principles and methods between mix design and PRS

Duval mentioned the instructional videos developed by Nelson Gibson regarding AASHTO TP 107. Duval concluded with mentioning the TechBrief for “Testing for Fatigue Cracking in the Asphalt Mixture Performance Tester.”

ETG Comments, Questions, and Discussion:
Hand stated that most specifications have density and ride as well. Hand asked if this specification was only for the mixture. Duval responded that acceptance specifications will continue to include ride and density. Hand asked how this specification as well as ride and density will be used and if it would be a composite specification. Duval responded that he would defer the decision to the States on how to bring the specifications together. Duval noted that on the concrete side, ride is included in the PRS specification and obviously no in-place density.

Corrigan commented that part of that is also going to depend on how the performance measure rule moves forward.

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

Presentation Title: *Balanced Mix Design (BMD) Task Force Update*

Summary of Presentation:
Buchanan presented a brief history of the task force development. The BMD task force was formed at the September 2015 ETG meeting in Oklahoma City. The membership is focused on improving mix quality and performance and more agency membership was actively sought.

The task force work items that have been completed included defining BMD, survey of agency current practice (both laboratory BMD protocols and field acceptance protocols), and research problem statement (RPS) submitted to AASHTO. Currently the task force is working on a TechBrief on BMD. A draft of the TechBrief has been prepared and reviewed and is currently being revised.

Buchanan presented the definition of a BMD as 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.

Buchanan presented revised descriptions of agency approaches that were identified. These approaches are defined as follows:

- Performance Design – involves conducting a suite of performance tests at varying binder contents and selecting the design binder content from the results. Volumetrics would be determined as the 'last step' and reported – with no requirements to adhere to the existing M323 limits. Example States: New Jersey w/ draft approach.
- Performance-Modified Volumetric Design – the initial design binder content is selected using M323/R35 prior to performance testing; the results of performance testing could 'modify' the mixture proportions (and/or) adjust the binder content – and the final volumetric properties may be allowed to drift outside existing M323 limits. Example State: California.
- Volumetric Design w/ Performance Verification – basically, it is straight Superpave with verifying performance properties; if the performance is not there, start over and re-design the mix. Volumetric properties would have to fall within existing M323 limits. Example States: Illinois, Louisiana, New Jersey, Texas, Wisconsin. This is the most commonly used.

The agency approaches were presented in a revised single flow chart with volumetric design on the left, performance-modified in the middle, and performance design on the right. With the first two on the left, volumetric analysis is conducted first. With the performance design, performance testing is conducted first.

The BMD task force submitted a RPS in June 2016. The anticipated results of the RPS are as follows:

- Review of the state-of-the-practice for asphalt mixture design.
- Review the development and state-of-the-practice for performance testing.

- Development of a Recommended Practice for Balanced Mixture Design to implement performance testing in the design of asphalt mixtures.
- Development of a training and implementation plan and materials to move BMD ahead in State Highway Agencies (SHAs).

The RPS was reviewed by several external sources prior to submittal for guidance and input including Dr. Ed Harrigan, Skip Paul and Jack Springer. The estimated problem funding and research period was $1.7 million over two phases and 5 years.

The RPS received a favorable response during the August SOM. Comments from Oak Metcalfe were that there were eight total research statements from the SOM with the BMD statement being the only one in the area of asphalt mixture or binder although there were several on pavement preservation. The Technical Section chairs each rank the RPS from highest to lowest priority. The rankings will be discussed later this September. The evaluations will be sent to the submitters in early December 2016. The ballot will be sent to the SCOR and RAC members in mid-December 2016 with the ballots due in February 2017 prior to the SCOR meeting in March 2017.

The FHWA TechBrief “Balanced Mixture Design Approach for Asphalt Pavement Construction” has been prepared and reviewed by the full ETG. The revisions to the TechBrief is currently being handled by the task force. The target for the final draft is October 2016. Bukowski will then take the TechBrief through the FHWA publishing process.

Action Item #201609-5. Shane Buchanan will present on the activities/recommendations of the Balanced Mix Design Task Force at the next meeting.

12. Performance Based Mix Design [Y. Richard Kim, North Carolina State University]

Presentation Title: *Performance-Based Mix Design*

Summary of Presentation:
Kim began the presentation by giving the integration between performance based mix design (PBMD) and PRS. The same test methods and same underlying principles and models are used in PBMD and PRS. Index properties can be used in PBMD whereas full models are used in PRS. Integration is necessary to apply incentive/disincentive to contractors. PBMD index properties allow go/no-go decisions during construction and allows for changes in mix production during construction. Kim stated that contractors could not be penalized for PRS without allowing them to design the mix. PBMD is same as using BMD in comparison to PRS.

The PBMD framework combines the minimum required percent asphalt content based on the cracking resistance requirement and the minimum percent asphalt content based on the rutting resistance requirement to determine candidate performance optimum asphalt content. Predictive equations or tables, similar to what Bonaquist presented earlier, can be used if the volumetric optimum is not within this candidate performance optimum range in order to move the volumetric optimum into the candidate performance optimum range.

The PBMD framework includes the following steps:

Step 1: Perform Superpave volumetric mix design to determine the volumetric optimum.
Step 2: Conduct performance tests on the volumetric optimum using AMPT.
Step 3: Check against the minimum performance criteria.
Step 4: If okay, the volumetric optimum becomes the final optimum.
Step 5: If not okay, adjust the asphalt content using predictive equations.
Step 6: Conduct performance tests on the adjusted optimum.
Step 7: Check against the minimum performance criteria.
Step 8: If okay, the adjusted optimum becomes the final optimum.
Step 9: If not okay, use different aggregate gradation and repeat the above steps.

There are two possible scenarios for PBMD – pavement structure unknown and known. When the pavement structure is unknown, use of index properties to determine pass/fail or run LVECD program on critical pavement designs with measured mixture properties to check against the minimum required pavement performance. When the pavement structure is known, run LVECD program on known pavement design with measured mixture properties to check against the minimum required pavement performance.

Kim next presented the test methods and models for PBMD. The AMPT is used for both cracking and rutting performance prediction. The AMPT Cyclic Fatigue Testing requires 38 mm cores, which one gyratory specimen can provide. With cores from the field, horizontal cores can be taken from the field core for the specimens. With this procedure, Kim was able to match 80% cracking susceptibility in a forensic project where North Carolina was experiencing premature cracking and early failure.

The SVECD material functions include dynamic modulus master curve, time-temperature shift factor, damage characteristic curve and energy-based failure criterion. These characteristic relationships remain the same under different modes of loading, different temperatures, different stress/strain amplitudes, and different loading histories. The S-TSS for rutting test use permanent strains determined from machine displacements and do not require on-specimen LVDTs. The Shift Model is used as the rutting model as this accounts for the effects of stress level, temperature, and loading time on rutting.

Kim next presented how to use these models using the LVECD for pavement model, which is a 3-D viscoelastic analysis under moving load and changing temperature. The software can simulate 20 years in about 40 minutes. Kim presented examples of the damage after 20 years of loading for three types of WMA and a control. The control had the least top-down cracking while the Evotherm had the least bottom-up cracking. From images, the percent damage is determined which is then converted to percent cracking on the surface via a transfer function. The rut depth prediction in LVECD allows to look at different layer permanent deformation. The required testing time when the pavement performance analysis is desired only adds 1 day and 40 minutes. A full analysis requires about 3.5 days which includes the temperature conditioning but not the specimen preparation.

Kim next presented the validation using field data. Kim showed the correlation between the LVECD analysis and the field cracking for the FHWA-ALF (100 mm pavement). The LVECD analysis showed similar trend for the rankings. The fatigue predictions for the NCAT test track were not as good before calibration and was slightly questionable. However, the shapes looked similar. Transfer functions were used to calibrate the analysis and these results were close to the field. The fatigue prediction for the MIT-WMA was similar to the field with the use of a transfer function. Kim stated that the models have been field validated and transfer functions are available.

Kim next presented the rutting performance prediction comparison between field and LVECD prediction. The LVECD prediction did not capture the proper trend for the MIT-RAP section, but did mostly for the MIT-WMA sections. The LVECD prediction did capture the trend for the ALF and mostly for the NCAT sections with the exception of two.

The $S@C_{avg}$ was used as the cracking index property for pass/fail. The $S@C_{avg}$ is the cumulative effective dissipated pseudo strain energy. An $S@C_{avg}$ equal to 80,000 is the preliminary minimum required value. This shows that more binder content and binder grade effects are captured. The MSR is used as the rutting index property for pass/fail. The AASHTO TP 116 criteria is used for the PBMD. Using the MSR to classify NCDOT mixes showed reasonable results.

Kim next presented the predictive equations. Kim stated that what is important is adjusting when the performance does not meet the volumetric requirements. ALF data was used with AMPT Cyclic Fatigue and TSS Testing. The predictive equations for the damage characteristic curve included two coefficients that were a function of air voids and VMA and the air voids and effective binder content. These relationships will be a function of aggregate size, PG grade, etc. This relationship needs to be verified. Kim presented prediction results for Mix B. The prediction matched the measured pretty well. The prediction for Mix O was the worst but the actual was less than the predicted.

The current PBMD database has relative and not absolute distress. These are applicable for a particular structure and traffic but a catalog can be generated with LVECD. Although other mixtures will be different, the pattern should be the same. Other mixtures need to be verified, including WesTrack.

Kim presented a summary of PBMD as follows:

- Starts with Superpave volumetric mix design.
- AMPT cyclic fatigue and S-TSS tests as the performance tests.
- LVECD program for pavement performance analysis.
- Either index properties or pavement performance as the pass/fail criteria.
- Predictive equations to adjust the mix design.

Kim concluded the presentation with the following additional remarks:

- PBMD is a necessity in adequately implementing PRS.
- PBMD and PRS must be based on the same test methods and engineering properties.
- PBMD and PRS models have been successfully validated using the field data.

- Excel programs to be available for determination of material properties.
- Predictive equations are being developed by testing additional mixtures at different volumetrics.

<u>ETG Comments, Questions, and Discussion:</u>
Newcomb commented that a step beyond the PBMD framework was the initial plant start up and initial volumetrics and what happens next. Kim responded that it was a construction issue. The predictive equations can be used to make adjustments so that it falls within the range of the criteria. Kim noted that the predictive equations/table are very important.

Duval commented that the concern is that the design does not meet plant requirements. Duval stated that they were going to develop guidance but that this requires work still remaining. If the volumetrics do not work, then there may need to be a redesign phase.

Hall asked in second scenario, who designed the pavement and what was used to design it. Kim responded that the design was based on typical material properties database and DOT staff can design it.

D'Angelo stated that his big concern was that rutting testing is limited in high temperatures and geometry of specimens. D'Angelo stated that high temperature properties are not linear and cannot really predict upwards. Kim responded that to look at the effect of that type of high temperature, dynamic modulus test at that high temperature should be used to get the shift factor, which is not in the specification. The error that comes out should be in transfer function. Kim continued that reason why only a few tests are needed is because of the fundamental principles behind those models. Mechanics models will simplify analysis if understood.

Hall asked in terms of design, how are your proposing to handle design reliability, based on standard deviation. Kim responded that they are not that far yet but it would likely be similar to Pavement ME/MEPDG.

Bonaquist commented that you should not use predictive equations at beginning without having to do volumetric design to see if the normal volumetric design give properties desired. Kim responded that it depends on how good predictive equations/tables are going to be. If good enough, it is possible and then keep adjusting.

Buchanan asked where Kim envisioned this being used, for what level of pavements, such as high risk. Kim responded that this could be used wherever PRS is going to be applied. Dukatz asked where PRS was going to be used and commented that it is an issue. Kim responded that there is applicability to interstate, tollway, etc. Once a benefit is seen, it may spread to lower volume roadways but it will begin with higher profile roadways.

13. Update on TP 107 Direct Tension Cyclic Fatigue [Y. Richard Kim, North Carolina State University]

<u>Presentation Title:</u> *AASHTO TP 107: AMPT Cyclic Fatigue Proposed Revisions*

Summary of Presentation:
Kim presented proposed revision to the AASHTO TP 107: AMPT Cyclic Fatigue. Kim started that the revised standard contained updated figures for only the AMPT. Originally, the standard tried to include all type of machines which caused confusion. The sample preparation and test setup information was updated to be clearer for AMPT users. Appendix X7 (strain selection to target specific cycles to failure) was eliminated. The previous numbers were not meant to be exact fatigue life but to provide a wide range of data points for analysis.

Kim presented on a new strain selection appendix. The appendix is based on the family of curves method. This allows for simpler estimation of AMPT input "target on-specimen strain." The initial test is run at a strain specified by fingerprint dynamic modulus. The included table is used to reach an approximate number of cycles to failure for subsequent specimens. Kim presented an example showing that if the fingerprint dynamic modulus is 7,500 MPa, the first target strain is 500 microstrain. The test is performed and the number of cycles to failure is 4,900. Based on this, look at the table for guidance on the next strain values. For this example, 450, 550 and 400 microstrain.

The number of specimens was clarified. The material ranking or index property requires a minimum of three strain levels. Pavement performance analysis requires a minimum of four strain levels. This allows for better extrapolation of energy based failure criteria (G^R) vs. number of cycles to failure curve in log-log scale.

The platen size limit was revised. Previously the standard called for 100 plus or minus 0.5 mm. The new standard calls for the platen size to be between 100 and 105 mm with a recommendation for diameters closer to the sample diameter to improve alignment. The gluing jigs are allowed to hold a small weight (no greater than 10 pounds) on the sample without holding a fixed height.

The previous "ball joint" language caused confusion. This was only meant for non-AMPT machines and is now removed for the AMPT-specific standard. Some users were placing ball bearings between the upper platen and the machine. Ball bearing is not recommended because there is a potential to tighten the upper platen unevenly and damage the sample.

Calculations were added for the energy based failure criteria (G^R). Dynamic modulus ratio (DMR) and tensile strain-based fatigue model coefficients (K_1, K_2, K_3) terminology were added.

The method to calculate the alpha value term was changed to a simpler and more stable method based on the tangential slope of E(t) versus time in log-log scale.

An appendix was added to include small specimen testing possibility which mirrors AASHTO TP 79-15. This opens doors to testing field cores and more specimens from one gyratory specimen.

Bukowski will work with Dave Mensching and Amir Golalipour to distribute the latest version of the standard to the ETG for comments and to compile the comments together in time for the next SOM cycle to move forward. Due date for the comments is September 25, 2016.

Action Item #201609-6. ETG members are requested to provide comments on TP 107 (Cyclic Fatigue – AMPT) to David Mensching. Comments will be summarized and either forwarded as a draft provisional standard to the SOM or if significant comments, discussed further at the next ETG meeting.

ETG Comments, Questions, and Discussion:
Corrigan acknowledged the work that Nelson Gibson provided to this effort.

Bonaquist commented that the number of cycles in the table presented should be rounded so that people understand that the numbers are approximate. By leaving the numbers as they are, precision is implied that the user is not expected to use. Kim responded that he could round the values to the nearest 100. Bonaquist responded that it could even be rounded to the nearest 1,000.

14. Overview of Performance Test – AMPT Equipment Specification [Matthew Corrigan, FHWA]

Summary of Presentation:
Corrigan stated that this would be an update on the presentation from the previous ETG meeting he provided with Jeff Withee. Corrigan stated that the draft revisions to the standard with regards to the equipment specifications were already distributed. Corrigan stated that the goal was to move this towards AASHTO for adoption.

The revisions to the standard included recommended changes to accommodate TP 107 and the restructuring of standards for clarity. This document was meant to be stand alone and more user friendly.

Corrigan noted that they are continuing to coordinate/collaborate the standard through the technical section. Withee added a commentary to the standard.

15. Overview of Performance Test – NCAT Activity – Simplified Cracking Test [Randy West, NCAT]

Presentation Title: *Update on the MnROAD-NCAT Project to Validate Mix Cracking Tests and other one-off studies on Simple Mixture Cracking Tests*

Summary of Presentation:
West began by stating that the presentation was based on the partnership between NCAT and MnROAD on the cracking group experiment which has over 21 different sponsors. The objective of the study is to validate laboratory cracking tests by establishing correlations between the test results and measured cracking in real pavements using real loading conditions. NCAT is focusing on the top-down cracking while MnROAD is focusing on low-temperature cracking. The NCAT experiment includes seven sections at the test track. The sections are divided into three levels of cracking expectations – low, medium, and high. Three sections with low cracking expectation include a high density with 20% RAP binder ratio (N2), a HiMA PG 76-28E binder (S6), and an Arizona style asphalt-rubber mix (S13). Two sections with medium cracking

expectation include 20% RAP binder ratio with PG 67-22 (N1) and 25% RAP with PG 58-28 S5). Two sections with high cracking expectation include 20% RAP binder ratio with PG 67-22 with 0.5% low AC and low density (N5), and 20% RAP and 5% RAS with PG 67-22 (N8). To date, none of the sections have any cracking after the application of 2.3 MESALs.

The tests for top-down cracking resistance that will be conducted include the SCB-LA, SCB-Il, OT-TX, OT-NCAT, Energy Ratio (ER), and Cantabro. These tests will be conducted on both LMLC and PMLC. To date, testing has been done on PMLC samples.

The ER results showed the highest ER for the mix with 5% RAS and 20% RAP. The mix with asphalt rubber had the lowest ER. The ER includes creep compliance. Since the RAS mixture is stiff and the rubber mixture is compliant, and the creep compliance is in the denominator of the ER calculation, the RAS mixture has higher ER. The $DSCE_{HMA}$ minimum suggested criteria to determine if the mixture is brittle i.e. less than 0.75 kJ/m^3 and all mixtures met this criteria.

The TX-OT results showed N8 (20% RAP and 5% RAS with PG 67-22) failed on the second cycle. S13 had high variability but had far superior performance. The S6 (HiMA PG 76-28E binder) performance was lower than expected. The TX-OT ranking results were similar with the OT-NCAT except for N5 and S6.

The SCB-LA results showed most mixes were essentially equal ranging between 0.3 and 0.4 kJ/mm^2 but with the high density mixture (N2) and rubber mixture (S13) performing better with J-integral of 0.61 kJ/mm^2 and 0.51 kJ/mm^2, respectively. The SCB-LA test produced the lowest CV out of all the tests. The SCB-IL (IFIT) results ranged from a Flexibility Index of 0.4 (brittle for RAS mixture) to 10.4 (ductile for rubber mixture).

The NCAT cracking group experiment has completed the reheating PMLC testing. Sample preparation is underway for unaged LMLC. The aging protocol has yet to be established for aged LMLC and aged PMLC.

West next provided an update for the MnROAD test sections. The test sections are on the MnROAD mainline of Interstate 94 and represent cells 16 to 23. Cells 16 to 19 have been built and the experiment is about one year behind the NCAT portion of the study. Cells 16 to 19 use a PG 64S-22 binder. Cell 16 and 17 include RAS and 30-40% and 20-30% asphalt binder replacement (ABR), respectively. Cells 18 and 19 do not include RAS and have 15-25% ABR.

The types of cracking to be investigated include low temperature cracking, top-down cracking is likely and fatigue cracking is possible. The PMLC testing will include DCT-MN and IDT Creep of SCB-MN for low temperature cracking and SCB-Il, OT, BBF for intermediate temperature. TSR, E*, Hamburg, loose mixture and cores will also be tested.

The IDT Nflex Factor test considers the area under the stress-strain curve to the post peak inflection point (toughness) divided by the slope of the inflection point. The test uses specimens fabricated at N_{design}. A test method was drafted for the Nflex Factor in AASHTO format. The effect of temperature has been completed. The effect of loading rate, asphalt content, air voids and PG grade still remain. The testing includes PMLC samples from the test track including virgin mix with hybrid binder (e.g., rubber and polymer) and a RAP and RAS with PG 76-22. The crack map from the test track showed the hybrid binder has 15% of lane area cracking while the RAP and RAS section had 73.4% of lane area cracking. The binder replacement was at least 40%. As temperature increases, the toughness of the Nflex Factor increases. The Nflex Factor appeared unaffected by loading rate, though the toughness and slope both increased with loading rate, they increased at proportionally the same rate. The effect of air voids showed that Nflex Factor was not affected too much by air voids until about the 7% range for ductile mixes. For brittle mixtures, it was difficult to get the data points and the data was not reliable.

West provided the following summary (to date):

- Nflex Factor ranks mixture ductile versus brittle behavior.
- Nflex Factor increases with temperature.
- Poisson's Ratio from instrumented specimens fell in expected range at 25° (0.24 to 0.38).
- Assume Poisson's Ratio of typical HMA is 0.35.
- Nflex Factor did not change with loading rate, though the slope and toughness change.
- Load-Displacement curves are significantly different for specimens compacted to a height versus to a gyration level.

West next presented additional SCB and IDT experiments where the primary objectives were to examine the effects of reheating the mixture for specimen compaction and the effect of loading rate (0.5 mm/minute and 50 mm/minute). The mixes were obtained from three field projects with test sections to evaluate rejuvenators or WMA. The plant mix samples were compacted to N_{design}. The loading rate did not have consistent or statistically significant effect on Nflex Factor. However, reheating significantly reduced Nflex Factor. Reheating did not have consistent or statistically significant effect on J-integral. The higher loading rate statistically increased J-integral values and its variability. The Nflex Factor also significantly reduces for mixtures with rejuvenators when reheated. WMA improved Nflex Factor results regardless of mix, loading rate and reheating. WMA did not have a consistent effect on J-Integral results except for reheated samples tested at 50 mm/minute.

West concluded the presentation by stating the different cracking test provide very different results for mixes. As a result, the agreement with field performance will have to be the key factor in deciding which test(s) should be used.

<u>ETG Comments, Questions, and Discussion:</u>
Golalipour commented that for viscoelastic material, temperature and loading rate are related and it was surprising to see Nflex Factor was affected by temperature but not loading rate. West responded that the loading rate does have an effect on stress and strain, but by dividing by the slope, which is also affected, the overall effect is canceled out. West stated that there is an effect but the Nflex Factor does not illustrate it. Golalipour asked what was changed with the brittleness slope. West responded that it was actually a negative slope, but reported as positive.

Al-Qadi commented that for completely elastic materials, the cracking will occur in the middle of the specimen, but for nonhomogeneous material such as asphalt, the inflection point is related to the speed of the crack. When starting with a non-cracked specimen, do not know where the crack initiation will be. This may explain the variability. West responded that the highest tensile strain is expected to be in the middle of the specimen. The specimen is allowed to fail at the weakest point. West noted that there is some sloppiness to the test but that it is trying to capture whether overall the mixture is brittle or ductile.

Mohammad commented that rocking can be an issue and asked if that was observed during testing. Mohammad noted that this can especially happen if there is debris on the loading strip. West responded that in repeated load, it can be an issue, but that it is not a significant issue if using a monotonic load. Mohammad responded that where the specimen sits is where the specimen is going to break. The stress distribution allows to break at the center but if there is not complete contact between the loading strip and specimen, there can be issues. West responded that it has not affected the area under the curve or the post-peak inflection.

16. Overview of Performance Tests – LSU Pooled Fund TPF 5(294) [Louay Mohammad, Louisiana Transportation Research Center]

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

Summary of Presentation:
Mohammad began the presentation by stating that the mixture experiment was using ALF data including 10 test lanes, SCB and OT-TX testing. The experiment compared the structural performance versus the mixture performance. The sample preparation for the SCB test is critical. The test records the rate of change of damage (load and vertical deformation) to compute the critical strain energy (Jc). The quality control for making the notch in the specimen is extremely important. LTRC has established a QC sheet to track the notch depth, notch width, specimen thickness and specimen diameter. For the 10 lanes, there were about four groupings for the SCB test results, dependent on the makeup of the mixtures. The LTRC SCB test at intermediate temperature was able to identify the three mixtures with the worst crack resistance (e.g., lowest number of cycles to failure).

Mohammad next presented whether the SCB test results were sensitive to the RAP, RAS content. With increasing RAP or RAS, the E* increases and the cracking resistance based on the critical strain energy reduces. The SCB test results also showed a sensitivity to asphalt binder grade.

The SCB test results versus the number of ALF passes to 20 feet of cracking showed a stronger relationship with the LTRC method than the NCAT method with the R^2 values being 0.56 and 0.0558, respectively. Next Mohammad presented the results that considered the pavement responses under load. The ALF lanes have various thicknesses and moduli. This was used with the WESLEA program to correct the ALF number of passes for 20 feet of cracking. This improved the R^2 value for the SCB results to 0.3032 and 0.68 for the NCAT and LTRC methods, respectively.

The structural fatigue performance depends on the mixture’s crack resistance, structural layout, stiffness of all layers, traffic loading, and environmental conditions. The prediction of allowable number of load repetition to fatigue cracking should incorporate mixture cracking parameter. AASHTO Pavement ME was used to compute the number of cycles to failure for the fatigue life for structures. The strain response is important and must include in-situ conditions such as the modulus and thickness of the pavement structures. The LVECD was used to determine the strain response. The LVECD considers the asphalt mixture linear viscoelastic, the base and subgrade linear elastic, and the interface fully bounded. The LVECD was used to predict the tensile strain at the bottom of the asphalt layer. The ALF lane fatigue life measured number of passes to the first crack was compared to the predicted number of passes using the AASHTO Pavement ME and showed that the magnitude and trend of the AASHTO Pavement ME equation were off base. With this equation, the highest stiffness mixtures will be predicted to have the highest fatigue life. The AASHTO Pavement ME equation lacks a material parameter representing the mixture's fatigue crack resistance.

Mohammad next presented the Jc-based fatigue model that incorporates a parameter representing the mixture's crack resistance. The measured versus predicted number of cycles to failure using the Jc-based fatigue model had an RMSE of 9.4%. The next step is to predict performance with data that was not used to create the equation.

Mohammad stated that previously there was concern with the OT-TX due to the load not starting from zero. Mohammad stated that a different jig for testing was provided and the software was updated and the problem was resolved. The OT-TX analysis considers the peak load in each cycle. The peak tensile load versus cycle number is plotted. The maximum load is determined and the reduction in peak tensile load versus cycle number is plotted. The number of cycles to failure is defined as the cycle number at 93% percent decline in load. The ALF results for the OT-TX showed that the average COV was 31.6%. The OT-TX was able to determine the three worst performing lanes. The OT-TX showed that it was effective in showing the sensitivity to RAP/RAS content with E* increasing with increasing RAP or RAS. The number of cycles to failure were most for virgin mixture followed by 20% RAP. The crack resistance was greater for the mixture with 40% RAP than 20% RAS. The OT-TX showed higher crack resistance for lower binder grade.

Mohammad next presented the comparison of the results for the ALF structure ranking versus the OT-TX cycles to failure which showed an R^2 value of 0.7281 and a generally good agreement between the rankings of the performance trends.

Mohammad presented a summary of the presentation as follows:

- SCB test at intermediate temperature
    - Variability
        - Average COV ~ 15%
    - Mixture from the FHWA test lanes
    - Sensitive to RAP/RAS content
        - Increased %RBR SCB Jc
    - Sensitive to binder grade
        - More pronounced effect on mixtures with %RBR from RAP than RAS
    - Structural performance to mixture characterization
        - Good correlation, R^2=0.68
    - Pavement ME fatigue crack prediction
        - Mixture stiffness

        - Inconsistence ranking/magnitude
    - Proposed fatigue predictive equation with SCB J_c
        - Good correlation to measured N_f from ALF test lanes
        - More field data
- Overlay Test
    - Variability
        - Average COV 31.6%
    - Sensitive to RAP/RAS content
        - Decreased number of cycles to failure
    - Sensitive to binder grade
        - More pronounced effect on mixtures with %RBR from RAP than RAS
    - Structural performance to mixture characterization
        - Good correlation, R^2=0.73

ETG Comments, Questions, and Discussion:
Rowe asked what the improvement was when the parameter was added for the fatigue relationship. Mohammad responded that the predicted versus measured from the MEPDG improves with the addition of the fracture resistive parameter as it captures the effect of mixtures with high stiffness due to aged binder.

Bukowski adjourned the meeting at 4:30 PM.

DAY 2: Thursday, September 15, 2016

17. Call to Order

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

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

Presentation Title: *Cracking Wars: The Fatigue Awakens*

Summary of Presentation:
Hall began the presentation by reviewing the current Pavement-ME fatigue cracking estimation, stating that the release of Build 2.3 did not change anything with the cracking models. Hall stated that the mixture properties for the cracking models in Pavement-ME Build 2.3 for bottom-up and top-down cracking was fatigue strength from flexural beam fatigue test and for transverse and reflection cracking was indirect tensile strength and indirect tensile creep compliance.

Hall presented the MEPDG cracking summary as follows:

- Bottom-Up cracking – no changes or enhancements; none planned for the short-term
- Top-Down cracking – no changes to date; changes anticipated (NCHRP 1-52)
- Transverse (low Temperature) cracking – no changes to date; need for changes identified (long-term)

- Reflection – Major enhancements in version 2.2 (replaced regression with M-E)

Hall next presented on the NCAT study stating that the study objectives are to identify where other cracking models, laboratory cracking tests and MEPDG cracking models overlap as well as to identify gaps. Hall explained the purpose of this is to consider the entire pavement system from design, materials, construction, management, preservation, to rehabilitation and back to design. These elements cannot be treated separately, but need to be treated as a system. Hall stated that we need to consider where we are going with the cracking models, material design and how these two come together. Hall concluded that this is the direction that we need to push so that the MEPDG becomes the platform for the pavement system.

<u>Presentation Title:</u> *NCHRP 9-59 – Binder Fatigue Test: Update*

<u>Summary of Presentation:</u>
Tran presented the objective of NCHRP 9-59 as to develop a test or tests that will help to effectively and efficiently control the properties of asphalt binders that contribute to the fatigue resistance of asphalt mixtures. The problem is that the current binder specification was not working as it should be. The problem to address included whether $|G^*|\sin\delta$ can be improved, added to or replaced, the effect of modulus on fatigue performance, the relationship between fracture and fatigue performance, and binder versus mix.

Tran presented the generalized failure theory for fatigue strain capacity (FSC). The number of cycles to failure is the ratio of FSC to the strain of the binder raised to an exponent that includes the phase angle for binder. To apply this theory to the mixture, the strain for the binder is replaced by the strain of the mixture divided by the effective binder content divided by 100. The summation of the damage is presented for when the strain is not constant.

Tran presented the typical failure envelope as the relationship between the failure strain or FSC, % versus the secant modulus divided by three. On the graph, data from various projects were plotted and fit the envelope nicely. The Heukelom failure envelope compares well with this fatigue envelope. The data points that did not fit the failure envelope as well were polymer modified asphalts, which is capturing the effects of the polymer as opposed to the asphalt since it was tested at low stiffness.

The fatigue/fracture performance ratio (FFPR) was presented as the ratio of observed to expected failure strain. Standard unmodified binder data was used to develop this preliminary equation. Polymer modified and mixture fatigue data were not used. FFPR values significantly above 1 are good while FFPR values below 1 are poor.

Tran next presented preliminary results from the testing of Accelerated Loading Facility (ALF) binders. Most of the binders for the first and second ALF fatigue experiments were tested including PG 70-22, air blow binder, terpolymer, SBS-LG, crumb rubber binder, AC 5 and AC 20. The binders were short-term aged using the rolling thin film oven test (RTFOT). The binder test methods included the Dynamic Shear Rheometer (DSR) frequency sweep (R-value), modified double edge notched tension (MDENT), linear amplitude sweep (LAS), single edge notched bending (SENB) and various others from existing data such as direct tension.

Tran presented the correlation between various binder testing FFPR as:

- LAS versus MDENT – 82%
- LAS versus Direct Tension – 79%
- Direct Tension versus MDENT – 65%

The ALF binder correlation between cycles to 25 meters of cracking and FFPR was presented as:

- MDENT – 90%
- LAS – 94%
- Direct Tension – 90%
- Binder R-value – 57%

Tran next presented the testing plans to determine whether this approach will work for the new binders considered under the project and if the binder and mixture test data will correlate. The project will test 16 different binders. The project is not looking to rank the binders, but to have a wide range of performance specifications for the binders. At this time, three binders have been tested – PG 76-22 with SBS/PPA, PG 64-22 and a PG 58-28 with REOB.

The mixture testing conducted under the project included the uniaxial fatigue (SVECD), Texas Overlay Test (OT), and bending beam fatigue for which there is no data to date.

The laboratory aging used included RTFOT plus 40-hour pressure aging vessel (PAV) for the binders and standard short term aging followed by loose mix aging at 95°C for five days for the mixture. The goal was to have equivalent binder and mixture aging which was based on data available at the start of the project. The mixture and binder laboratory aging was compared by determining the temperature where the loss modulus was 5,000 kPa. The comparison included testing on extracted binder from the mixture and laboratory aged binder from NCAT and AAT. The results showed that the laboratory aging although close was a little low.

Tran next presented the preliminary test results for the three binders tested to date. The MDENT test results followed expected trends with the SBS binder having an FFPR above 1, the PG 64-22 having an FFPR around 1 and the REOB binder having an FFPR below 1. Tran noted that there had been problems running the LAS test and that the results would be revisited. The uniaxial fatigue and Texas OT showed the same trends as the MDENT. For the Texas OT, although the cycles to failure are greater for the REOB binder than the PG 64-22 binder, the measured fatigue strain capacity needs to be considered. The differences in the expected FSC are due to the differences in modulus which is taken into consideration during the analysis, which shows that the REOB binder does not perform better than the PG 64-22 binder.

The FSC versus G* or Stiffness (divided by 3) to approximate shear modulus was plotted for the various tests and binders. As compared to the typical failure envelope, the SBS binder fell above, the PG 64-22 was close and the REOB binder was below. There is concern that the fatigue test was performed at too low of a temperature.

Tran next presented correlations between the FFPR of the uniaxial fatigue and the various binder testing as:

- MDENT – 85%

- Energy-based MDENT – 93%
- LAS – 61%
- R-value – 38%

The correlations between the Texas OT and the various binder testing was:

- MDENT – 92%
- LAS – 46%

The uniaxial fatigue data was slightly lower when compared to the binder testing. As stated previously, there might have been problems with the LAS testing and it is planned to revisit the data as there may have been a bonding issue. Tran also stated that calculating the ratio may reduce the importance of the R-value and hence the low correlation.

Tran presented the interim findings as:

- The proposed general failure theory and failure envelope appear to provide a powerful tool for evaluating the fatigue and fracture resistance of asphalt binders and mixtures.
- The RTFOT plus 40-hour PAV binder aging appears to produce a similar degree of aging as the five day loose mix aging at 95°C, but much more research is needed to verify and fine tune these aging protocols.
- The MDENT test correlates to both field fatigue performance in the FHWA ALF studies and in laboratory test conducted in the first stage of NCHRP 9-59 testing.
- The LAS test is also promising but some adjustments may be needed.

Tran presented the future work of the project as testing the additional 13 binders and the SENB test, healing study, parametric study on relationship between modulus and fatigue performance and validation testing. Tran ended the presentation by acknowledging those from whom he borrowed data, support of NCHRP, the NCHRP panel, industry suppliers, associates at NCAT, and his associates at AAT.

<u>ETG Comments, Questions, and Discussion:</u>
Golalipour commented regarding the LAS test, that Tran stated that the poor correlation may have been related to a bonding issue but Golalipour was not sure that was the cause. Golalipour stated that the test temperature for the LAS test is intermediate and that bonding issues are generally seen at sub-zero temperatures and not at intermediate temperatures. Golalipour stated that the issue was likely an age effect stating that when trimming the binder, there are micro-cracks. For a test, where the specimen is loaded very rapidly, such as in the LAS test, and there is highly aged or high stiffness material, the micro-cracks propagate to the center of the material, which has been shown by researchers. Golalipour suggested that Tran look at those sources.

Golalipour asked if it was better to run the test at isostiffness temperatures instead of running all tests at the same temperature although they are trying to use the model to take into account for stiffness. Tan stated that it would be difficult. Don Christensen responded that they did run at isostiffness temperatures and that the DSR frequency sweep was used to calculate the stiffness to run the tests at. Golalipour stated that in the table, the temperatures are all listed as 20°C. Christensen responded that they were not all done at 20°C but at different temperatures and noted that the G* was not correct either. Christensen stated that they were trying to get the same stiffness and stated that there is a very narrow stiffness range where the test works. Christensen stated that it seemed promising looking at the ALF data but that it did not seem as promising with these aged binders.

Reinke commented that when Christensen presented on Monday, that they had not looked at Hanz's data. Reinke commented that when going through the data and comparing, the 40-hour PAV of the recovered asphalt and 12-hour 135°C loose mix aging recovered, were nearly identical. Reinke stated that this should be considered in light of discussion had yesterday about aging over 20 days at 95°C. Reinke stated that this should be investigated further. Tran agreed stating that even 5 day loose mix aging can be difficult. Christensen responded that when the aging regimes were determined, the panel wanted to look at extended aging but were reluctant because they were only looking at a limited amount of research. Christensen agreed that work is needed and noted that 20 day aging would be difficult. Christensen noted that this study was not looking at laboratory aging but was trying to get similar amounts of aging between the mixture aging and 40-hour PAV aging.

Rowe commented on the REOB that scatter in data is normally seen. Rowe asked what the expected scatter was and whether it was scatter or noise. Christensen responded that the error bars were not on the graph but that they would be calculated in the future. Christensen noted that the SBS is almost all above the line and the REOB are below the line and stated that there was not too much scatter. Christensen noted that the lower right was mixture fatigue values which are the most variable. Rowe responded that relaxation is incredibly important and only have one part of that parameter here. Christensen agreed that failure strain is only one piece of the failure of fatigue.

Buchanan commented that with the effective binder content (V_{be}) and measuring the specific gravity of the specimen, it should have two extremes. Christensen responded that with the aging of cylinders, volumetrics were not done but it may change. Tran commented that he has asked his student to look at the difference in V_{be} before and after aging. Christensen noted the variability in the test and stated that it could be because of V_{be}.

Action Item #201609-7. 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.

19. Simplification of Asphalt Technology to Improve Design [Dave Newcomb, Texas A&M Transportation Institute]

Presentation Title: *Quality Improvement through Simplification or Fighting Entropy in Pavement Engineering and Construction Knowledge*

Summary of Presentation:
Newcomb stated there are a lot of incorrect applications of pavement decisions on lower level roadways. Newcomb showed that for many engineers, contractors, and consultants, as technological sophistication increases (e.g., LCCA, ME Design, intricate specifications, etc.), the technological understanding is decreasing as a result of fewer courses, less time, few instructors,

etc. Newcomb stated that there are a number of factors contributing to the gap and that he wants to investigate ways to bridge the gap and improve the level of construction and pavement engineering.

Newcomb stated that there are issues with pavement design, material quality, mixture type selection, RAP content, life cycle costs and construction.

Newcomb presented an example of a current pavement standard for developers to select the minimum pavement thickness. The criteria was effectively showing that 2 inches of asphalt over 8 inches of limestone was equivalent to 6 or 8 inches of concrete. As a result, developers select the asphalt pavement since it is the cheapest option with little or no inspection and allow construction traffic on the roadway. As a result, the pavement starts to fail. The fault does not fall on the developer since the selected design was an option. The issue lies with the engineer and the fact that the designs were not equivalent in terms of design ESALs. Newcomb presented other examples showing the issues with LCCA, construction and specifications.

Newcomb stated that there needs to be a discussion about the issues and solutions. Newcomb presented some possible solutions as follows:

- Design catalogs for low-volume roads
- Simplified specifications
- Reach out to engineers about common problems and solutions (webinars, seminars, YouTube)

ETG Comments, Questions, and Discussion:
Kluttz commented that he agreed but questioned who would execute these solutions. Newcomb responded that the community encompasses public agencies, both state and federal, material suppliers and contractors. Newcomb stated that a roadmap is needed to accomplish this. Kluttz responded that during NAPA meetings, it has been discussed to write catalogs. Kluttz stated that writing the catalogs is the easy part but that disseminating and having an audience is the difficult part.

Bukowski commented that it needs to be recognized that the focus should be on training and improving technology through contractors. Bukowski stated that it was difficult since contractors are in a competitive businesses. Newcomb responded that people (including contractors) need to understand why they have a vested interest to help with the issue.

Musselman commented that this was a common problem in Florida, especially with each county using standards they selected. Musselman commented that State agency staffs are decreasing in size and ultimately, NAPA will need to work with State associations to partner with DOTs. Musselman commented that PaveXpress may be a resolution to some things.

Hall commented that from a university perspective, at TRB there will be a launch of an international academic group called the Academy of Pavement Scientist and Engineers. Hall commented that the group could inform the Civil Engineering Departments and possibly allow for shared courses between universities. Hall also commented that it is difficult to balance simplifying for general public use but understanding that it is complicated and that simplifying it too much can be detrimental. Newcomb stated that for the most part, few are pavement engineers, so design catalogs are needed. Hall agreed but stated that if simple tools are continued to be developed, there will be no change in mindset due to lack of incentive.

Huber commented that state asphalt pavement associations need to have a role and that they have had receptive audiences in Indiana. Each state has an LTAP. Huber commented that the relationship between the contractors and the agencies is important. Huber agreed that PaveXpress received positive comments.

Bill Butler commented that for a bike trail project, they developed simplified design books using modern tests that were validated. The design books suggested minimum lift thicknesses and resulted in good performance. However, Butler noted that the design books needs to be revisited regularly. Butler also commented that the Missouri asphalt paving association was developing a simplified parking lot guide with specifications.

Kluttz commented that the issue is that simplified designs are usually over-designed but that cost is the driving factor now. Newcomb responded that the entire life cycles needs to be considered. It is the initial reaction to select the cheaper option first, but to understand how that will affect the cost in the future is important. This needs to be articulated.

Jean-Paul Fort commented that contractors need to improve training. Fort also commented that value engineering could benefit these issues since it is not only based on cost. Newcomb agreed but stated that local entities are not involved in value engineering.

Marks commented that in Ontario, many municipalities use different specifications unless it is dictated to use MOT specifications due to funding. Marks stated that the municipalities have an organization and system in place that allows them to use different specifications.

Action Item #201609-8. Pamela Marks will present on the Ontario Ministry of Transportation's Asphalt Testing Innovations at the next meeting.

Bradbury commented that there are not asphalt inspectors similar to inspectors for concrete in states and this needs to be considered.

H. Anderson commented that maintenance of traffic and smaller construction windows make it appear that quality is secondary. Newcomb agreed that there are other pressures.

Frank Fee commented that pavement design and materials people need to work together and show the value to the administration.

Abadie commented that education needs to improve and that there are gaps between the highest level and what is done. Abadie stated that it would be ideal to bring together government, industry, private and suppliers to recognize that progress is needed.

Hall asked for a task group to be set up with the charge of the task group to focus on local paving operation. Bukowski stated that he was not sure that the ETG was the right group to solve this. Newcomb responded that the issue needs to be acted on and moved forward.

Dukatz commented that communication needs to increase. Dukatz stated that there needs to be support from the top of companies agreeing that they want to do a better job. The key will be engaging people.

Youtcheff commented that contractors have incredible staff turnover and that access to videos for training could be helpful. Youtcheff also commented that universities could reach out to community colleges to reach locals.

Copeland commented that the Executive Director of FHWA is focusing on expertise and now is the time to act. Copeland stated that agencies need to communicate with the FHWA Division offices. Copeland stated that NAPA has a meeting with the FHWA leadership to offer help. Copeland also mentioned that NAPA has partnerships with state asphalt pavement associations and they are working on training. PaveXpress was developed to bridge the gap between AASHTO 93 and MEPDG design. NAPA has developed other products. NCAT has published a report that looks at minimum thickness but Copeland noted that they needed a vehicle to distribute this. NCAT is also working on training modules on asphalt pavement technology.

Copeland also commented that NAPA projects with NCAT and undergo robust review process and that summaries will be posted to the NCAT and/or NAPA website. NAPA is also developing marketing and educational videos to target young people and show the benefits of the industry. Copeland stated that NAPA would be happy to make a presentation regarding activities and would also like to input and help with implementation.

Action Item #201609-9. Audrey Copeland will present on NAPA's technical activities at the next meeting.

Action Item #201609-10. Kevin Hall and Dave Newcomb will present on the challenges of introducing pavement related subjects into the engineering curriculum.

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

Presentation Title: *Bending Beam Fatigue Test – Update*

Summary of Presentation:
Rowe presented an update on the 10 items from the April 2016 meeting as follows:

1. Agreed that both standards would use sine curve about initial zero position for the wave form.
2. Agreed that all standards would use method that was originally proposed by SHRP A003a research for the LVDT reference location – midpoint of beam on specimen.
3. Rotational and lateral translation at clamping locations was not considered an issue.
4. There was concern over the evidence for the importance of the clamping stress. At this stage, there is nothing to address and no evidence of an issue. This may be revisited later.

5. The response sampling intervals and numbers were agreed. The number of data points collected is no longer a limitation.
6. Agreed that the details of the modulus and phase angle calculations needs to be documented.
7. There will be a note on how to select the strain. There is a draft of the note.
8. The test termination and fatigue life where number of cycles of failure is desired outcome is being implemented in the software. The S.n method gives similar results to other methods and can used for other tests such as Hamburg, Creep Flow Number and OT-TX.
9. Agreed to add note about NMAS minimum and maximum variability.
10. Agreed minimum results that must be reported.

A draft of the new practice was to be completed by this meeting but is behind schedule. Rowe stated that it would be completed by the next meeting. The AASHTO T 321 edits were submitted to AASHTO on May 9, 2016. The ASTM D7460 updates are being redrafted after issues with wording not being accepted.

ETG Comments, Questions, and Discussion:
Phil Blankenship commented that they had issues with consistency and analysis with the beam fatigue test. Blankenship stated that the data from the test needs to be post-analyzed and that this makes a large difference with additives. Rowe commented that some laboratories and agencies are not using the newest version of the standard and this needs to be communicated.

Mohammad asked for Rowe's opinion between the two equipment types (e.g., cross head and agitator at bottom). Rowe responded that he did not have a comment and that the main goal was make the analysis methods the same. Reproducibility and repeatability will be the next issue to consider that may look at different types of equipment and applying loads at different places.

Action Item #201609-11. Geoff Rowe will lead in the preparation and present on proposed practice changes for to T321 "Determining the Fatigue Life of Compacted Asphalt Mixtures Subjected to Repeated Flexural Bending" at the next meeting.

21. FHWA ALF Update [Jack Youtcheff, FHWA]

Presentation Title: *Evaluation of Asphalt Mixture Cracking Performance Using Monotonic Direct Tension test in the AMPT*

Summary of Presentation:
Youtcheff began by stating the objective was to develop a performance test to quantify cracking resistance. The sample preparation can use five specimens from a gyratory specimen and four from a field core with two from the top and bottom layer each. The test setup results in the specimen failing in the middle. Using 10 ALF loose mix, the exploratory research effort for loading rate showed that 50 mm/minute and 100 mm/minute were not providing useful data.

The effect of loading rate and aging condition were investigated by considering the peak load, area under the peak load, total area and inflection point. Results showed good correlation with total energy for STOA. For LTOA, the E values drop and there is about 30% diminishment with aging. The Kendall Tau statistical method was used to correlate laboratory test to the field cracking performance.

A paper on the loose mix data for this evaluation was submitted to AAPT and the field core testing is underway.

Youtcheff next presented on the FHWA High RAP (AS) + WMA Accelerated Pavement Test. The loose mix testing included dynamic modulus, fatigue (AASHTO TP 107), monotonic direct tension and aging. Cores have been taken at age 0, 6, 12 and 24 months and will also be taken at 36 months. The next steps will be conducting performance tests on 40% RAS and RAP-binder with addition of 0.5%, 0.75% and 1.0% binder to determine how much binder needs to be added for RAS and 40% RAP binder mixes to exhibit equivalent performance. Youtcheff asked the group which mix should be the reference mixture. The response was 20%.

Youtcheff next presented the ALF update. The 10 lanes at the ALF were built in 2013 with two binder grades, two mixture types, two WMA technologies, and three RAP contents. Cracking measurements are taken by individually tracing cracks with a planimeter.

Youtcheff stated that the next experiment will investigate asphalt concrete field density and aggregate based geosynthetic reinforcement. The compaction of asphalt concrete mixtures is a critical component in the process of achieving optimal pavement performance. The quality and strength of the substructure (base and subgrade) have great influence on pavement performance. The objective is to investigate asphalt concrete compaction and its impact on performance of pavements built with and without geosynthetic base reinforcement.

The experiment will use one AC mixture with three different compaction levels – high (94% compaction), medium (91% compaction) and low (87% compaction). The structure will be unreinforced or reinforced with a standard BS-1200. The performance measures will be cracking and rutting. The aggregate base is currently being placed and the HMA will be paved in a few days. Falling Weight Deflectometer (FWD) testing was conducted on the aggregate base. The geosynthetic is proposed to be in the midpoint of the new crushed aggregate base. Loading is expected to begin in late fall 2016.

<u>ETG Comments, Questions, and Discussion:</u>
West commented that on the WMA experiment, there were variations in thickness and base modulus which confounded results in a number of cycles. West noted that he and Mohammad had both done analysis to compensate for this. West asked whether there was a plan to look at field performance that is corrected for this. Youtcheff responded that they have been measuring from the field cores but that he would like input.

West also commented that the proposed density levels for medium and low are too low. West proposed at least 92% for medium and 89-90% for low. West stated that 87% was too far out of the range and 91% was more realistic. Youtcheff responded that his initial target was 93-96%.

Huber agreed with West regarding the density targets. Huber stated that in China, they are accomplishing 95% in-place density with heavy pneumatic tire rollers. Huber stated that 96% is likely too high but that 95% was acceptable although it would still be difficult for the industry to achieve.

Adam Taylor asked with respect to monoatomic loading what the key parameters were and if it had been compared to the IDT strength from the field core. Taylor also asked what the advantage to the test was. Youtcheff responded that he has similar questions. Youtcheff mused what was the COV and what equipment people have.

Bradbury asked whether there would be any intentional moisture on the ALF study. Youtcheff responded that they do not plan to flood the ALF but that there should be a good amount of snow melt.

Ramirez asked whether the placement of the geosynthetic would analyze the ability to reduce pavement thickness. Duval responded that he believes that is a part of the experiment to see how it will benefit the base.

Mohammad asked whether they are planning to reduce thickness. Youtcheff responded no. Mohammad stated that they have done several things on their ALF and reduced thickness with the geogrid. Mohammad suggested for Youtcheff to look at work they had done.

Al-Qadi stated that they had done extensive studies with geogrid and geotextiles with highly instrumented section. Al-Qadi stated that the most important outcome is to optimize the location of the geogrid placement where the highest shear is. Al-Qadi stated that this is usually in top third of base. The stiffness of aggregate below and above the geogrid is increased because of interlock. Al-Qadi stated that there is some good work to refer to. Youtcheff responded that that part of the experiment is largely directed by Michael Adams.

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

<u>Presentation Title:</u> *Rapid Asphalt Production/Construction Feedback – PCF: Part 2 – Contractor Responses*

<u>Summary of Presentation:</u>
Dukatz began the presentation by stating that the production/construction feedback (PCF) are controls and devices designed to provide rapid feedback to the user to improve the density and hence the performance of asphalt pavements. PCFs area of concern include aggregate moisture, asphalt sampling and compaction.

There were 30 contractors responding from 14 states and one province that responded to the survey with some states having multiple responses while other states only received responses from the State Executive. The survey was sent through the AASHTO SOM.

Dukatz presented the agency and contractor responses to the survey. There was not always a good agreement between the contractors and agencies. This shows some confusion between contractors and State Executives or within DOTs which shows there is a communication issue.

This is a result of some PCFs being implemented as a specification while other cases are allowed by omission of a specification precluding it but not everyone is aware that the PCFs are allowed.

Dukatz presented the responses for the PCFs. The temperature devices were surprisingly low and there were more responses for measuring the pavement temperature but not specified which type of equipment. The IC Roller had the most responses followed by the ground penetrating radar (GPR).

The responses for the most promising PCFs to add value showed that the contractors and agencies switching rankings for the pavement temperature and IC roller for the most responses with agencies placing more value on the IC roller. Moisture sensors were also highly ranked by the contractors. Dukatz stated that the most successful way IC rollers have been used is to monitor the number of passes and to monitor the temperature. Pavement temperature is important in order to get density.

Dukatz presented the following questions to consider:

- How does use of R-PCF devices correlate to FHWA density initiative?
- Are the tools key or is understanding, which makes the tools useful?
- What are the next steps?

<u>ETG Comments, Questions, and Discussion:</u>
Newcomb commented that the tools are not helpful if no action is taken. Newcomb asked whether this information is useful at the lower level projects that are not high profile and how to make it useful at that level. Dukatz responded that there can be an imbalance between focusing on the density values and not taking into account the effect on ride. Newcomb responded that if the ride bonuses are greater than the density bonus, the emphasis will be on the ride and as a result, quality suffers. Dukatz stated that both density and ride can be achieved through preparing a smooth pavement by paying attention to the details.

Bukowski commented that some the ideas proposed have existing initiatives, but asked the task group to narrow down their ideas in order to move forward.

Bradbury commented that Maine DOT has implemented IC and PaveIR and that a couple of issues that are impeding implementation are which are appropriate for QC and which is best for acceptance. Bradbury noted that data management is key and to consider what needs to be captured and what the best way to analyze the data is. Bradbury stated that PaveIR is used by the contractor but they are not analyzing it to see how to improve.

Hall stated that a question to add to the list is whether the tool itself is helping the person do the job or is it taking the place of the person doing the job. Hall commented that technology is taking the place of expertise.

Bukowski commented that if focus of pay incentive should be ride or density, it may be worth investigating. Bukowski asked whether the pay incentive should be on the aspect of pavement that gives the largest life. Bukowski also noted that the final rule for pavements will likely include other factors than IRI and may make states reconsider their incentives and specifications.

Dukatz agreed and stated that looking at incentive/disincentives and how that affects density should be considered.

Action Item #201609-12. Erv Dukatz will present on activities of the Task Force on Construction at the next meeting.

Prior to the lunch break, Buchanan thanked John Bukowski for his service to the ETG and the hosting and contribution of nearly 50 continuous Asphalt ETG meetings. Buchanan and the ETG thanked Bukowski for his effort and wished him the best in retirement. Corrigan added that working with Bukowski has been a privilege and that his mentorship has been rewarding. Corrigan thanked Bukowski both personally and professionally.

23. Recommendations RAP/RAS Task Group (PP-78-14) [Jim Musselman, Old Castle Materials]

Summary of Presentation:
Musselman presented a brief update of the task group stating that nothing else has been done since submitting the draft revisions on AASHTO PP 78 to the SOM technical section 2d where it passed. Musselman stated that the technical section comments were mostly editorial and the draft will go through the full SOM ballot next. The task group will remain intact in the event they will need to address any comments from the SOM. Musselman stated that there could be an issue with some of the suggested aging in the draft standard.

Metcalfe stated that the ballot will be in January or February. If approved, the draft standard would be published around September 2017.

Musselman asked if there was a difference with how full and provisional standards get reviewed and what the benefit of being a provisional standard was if it still takes 18 months to makes changes. Metcalfe responded that there is only a ballot once a year and the point of the provisional is to allow them to be updated continually as they are refined. Metcalfe stated that the provisional standard should take one year and not 18 months. Bukowski noted that editorial changes can be made without going to full ballot under the authority of the Chairman.

Musselman asked if the group should be maintained. Bukowski responded that the group should be maintained because looking ahead for next year, RAP and RAS will be a big part and that changes will still be needed.

Action Item #201609-13. Jim Musselman will present on activities of the RAP/RAS Task Force at the next meeting.

24. Construction Task Force – Pavement Density Initiative [Tim Aschenbrener, FHWA]

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

Summary of Presentation:

Bukowski presented on behalf of Aschenbrener who could not attend. Bukowski stated that the project desired states that were willing to look at different ways they could change density targets through construction. The project consisted of 10 demonstration projects. The states were asked to roll more passes than normal to see if this could increase density. States were allowed to include other test sections to test other methods to increase density. Bukowski noted that NCAT helped with the field construction and the Asphalt Institute prepared the course on compaction and density that was presented prior to the construction. The compaction workshop was well received. AI will continue these workshops with other states beyond the 10 included in this project through March 2017.

Five of the demonstration projects have been constructed and the remaining five are scheduled. The lessons to date from the five constructed projects are as follows:

- 4 of 5 projects had significant increases in density – 1.0 to 3.0% increase over control.
- 1 of 5 projects had slight increase in density – 0.5% increase over control.
- Successful approaches included additional roller and/or increased passes on three projects and a mix design change on one project.

It was found that pneumatic rolling could increase density on some projects. A summary report on the 10 projects' construction with potential follow-up on field performance will be drafted. Bukowski noted that the report goes into more detail. There is the potential to extend the project with more states but that is dependent on funding and state interest.

The overall objective was ultimately achieving the in-place asphalt pavement density that results in the highest asphalt pavement performance.

ETG Comments, Questions, and Discussion:
Hall asked whether there was any indication from states that saw these increases whether they would make changes to their specifications. Bukowski responded that some states looked at changing their specifications target density and also looked at better ways to write the specification.

25. Asphalt Institute Density Specification Survey [Phil Blankenship, Asphalt Institute]

Presentation Title: *State Highway Agency Density Specification Data Mining*

Summary of Presentation:
Blankenship provided the background for the data mining and noted that it was meant to stay at a high level. The goals of the data mining was to determine how SHA's specify mat density including the method of measure (cores, gage, roller pattern), baseline measure (maximum theoretical gravity (G_{mm}), lab bulk sample (G_{mb}), control strip, sampling (lot/sublot size and how averaged), specification type (percent within limits (PWL), other advanced statistics, simple average), specification limits, incentive.

Asphalt Institute regional engineers gathered information from latest SHA specification and direct agency contacts. Data was sent to Blankenship to compile and review. Data was reviewed with specifications as much as possible. The focus was on a high-level review of specifications to gather density requirements for SHA highest level compaction standard (interstate/primary route pavements). The density limits were on acceptance of samples or QA (how low before pay is reduced below 100%). If a states used PWL, the lower limit of the PWL was assumed to be lowest level for 100% acceptance. When specifying PWL the minimum is usually about 1-1.5% above the lowest specified value.

Blankenship presented examples of good and poor standards written with the good example being easy and to the point. Blankenship noted that many of the standards leave things up to interpretation and are not specified.

Blankenship next presented the results of the data mining. First, the baseline for density acceptance showed that 49 agencies use field maximum theoretical gravity while one agency uses plant mixed, control strip bulk specific gravity and field lab compacted bulk specific gravity, each. The acceptance methods used to measure density were mostly cores (38) followed by density gage (8) and core or density gage (5). A map showed that neighboring states tend to use similar methods. Acceptance is determined using simple average for 23 agencies, PWL for 24 agencies and other advanced statistics such as AAD for four agencies.

Blankenship presented the lowest specification density for 100% pay using simple average data. The majority of agencies fell between the 92.0 – 92.4%. The PWL lower limit for 100% pay showed that most fell between 92.0 – 92.4%. Thirty-five agencies provide incentive for compaction while 16 agencies do not.

Blankenship presented the following broad observations:

- Maximum theoretical gravity is the majority acceptance of the density baseline.
- Cores are the majority for acceptance of pavement density.
- About an equal split of states who use PWL and Simple Average method for acceptance.
- 92% of Gmm is the majority target for states using a simple average.
- Most states offer a compaction incentive.
- Most who do not offer an incentive are the Simple Average states.
- Neighboring states tend to match specifications and incentives.
- Some specifications were very difficult to understand.
- Some base specifications allow lower densities.
- Several specifications allow for > 4% air voids design (~4.3 to 4.5%) or field adjustments up to 5% air voids.

<u>ETG Comments, Questions, and Discussion:</u>
Musselman noted that the map showed that Tennessee used nuclear gage to measure in-place density but that Blankenship had said cores were used. Abadie asked whether percent G_{mm} was screened out for the lowest specification. The response was no.

Corrigan asked whether the low acceptance limit was on G_{mm} or acceptance and cautioned that acceptance is meaningless by itself. All components are needed to understand what the specification is trying to accomplish.

Huber commented that although the lower acceptance limit is 91.0%, given the number of test specimens in a lot and the typical standard deviation, a mean of 93.1% is required for 100% pay. Huber noted that with a different number of cores, this could change. It was commented that PWL should not be mixed unless it is specified how the PWL system is used. Huber stated that the average is dependent on the variability of the density and it complicated the limit.

Corrigan noted that there are some states that legislatively cannot give incentives.

Musselman asked whether these findings were going through any type of quality control with respect to the states as he had noted some errors from Florida. West agreed that having the maps reviewed would be beneficial as the maps are helpful.

Bradbury noted that Maine could provide data for mining. Metcalfe stated that Montana also could provide data. Metcalfe noted that Montana has tied density and ride incentives together because otherwise either ride or density was being sacrificed to reach the other. Ramirez noted that Pennsylvania provides data each year to the annual state asphalt pavement association conference.

Buchanan commented that it would be helpful to know the typical lift thickness and NMAS. Blankenship agreed but stated that it was out of scope.

26. Action Items and Next Meeting Planning

Action Items:

Action Item #201609-1. Andrew Hanz will present an update on Long-Term Aging of RAS at the next meeting.

Action Item #201609-2. Louay Mohammad will report on NCHRP 9-49(A) WMA Long Term Field Performance at the next meeting.

Action Item #201609-3. Richard Kim will report on the status of NCHRP 9-54 Long-Term Aging of Mixes at the next meeting.

Action Item #201609-4. Randy West will report on the status of NCHRP 9-55 RAS in WMA at the next meeting.

Action Item #201609-5. Shane Buchanan will present on the activities/recommendations of the Balanced Mix Design Task Force at the next meeting.

Action Item #201609-6. ETG members are requested to provide comments on TP 107 (Cyclic Fatigue – AMPT) to David Mensching. Comments will be summarized and either forwarded as a draft provisional standard to the SOM or if significant comments, discussed further at the next ETG meeting.

Action Item #201609-7. 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 #201609-8. Pamela Marks will present on the Ontario Ministry of Transportation's Asphalt Testing Innovations at the next meeting.

Action Item #201609-9. Audrey Copeland will present on NAPA's technical activities at the next meeting.

Action Item #201609-10. Kevin Hall and Dave Newcomb will present on the challenges of introducing pavement related subjects into the engineering curriculum.

Action Item #201609-11. Geoff Rowe will lead in the preparation and present on proposed practice changes for to T 321 "Determining the Fatigue Life of Compacted Asphalt Mixtures Subjected to Repeated Flexural Bending" at the next meeting.

Action Item #201609-12. Erv Dukatz will present on activities of the Task Force on Construction at the next meeting.

Action Item #201609-13. Jim Musselman will present on activities of the RAP/RAS Task Force at the next meeting.

27. Next Meeting Location and Date

The next meeting date will be coordinated with the Asphalt Binder ETG. Members were asked to consider the weeks of April 24, 2016 and May 1, 2016 with the preferred date being the week of May 1, 2016.

28. Meeting Adjournment

John Bukowski thanked all attendees for their participation on the ETG and attending the meeting. Bukowski thanked Walaa Mogawer for hosting the meeting. The meeting was adjourned at 1:52 PM.

ATTACHMENT A – AGENDA

Asphalt Mixture & Construction Expert Task Group

Fall River, MA

September 14-15, 2016

Meeting Agenda – Final Draft

Day 1 – September 14, 2016

8:00 am	Welcome and Introductions	**Buchanan/Bonaquist**
8:15 am	Review Agenda/Minutes Approval & Action Items April, 2016 Meeting	**Bukowski**
8:30 am	Subcommittee on Materials Updates/Comments	**Metcalfe**
9:00 am	Update Related NCHRP Activities	**Harrigan**
9:30 am	**Break**	
10:00 am	Update Related NCHRP Activities • 9-54 Update Long Term Aging of Mixes • 9-55 RAS in WMA	 **Kim** **West**
11:00 am	Flexibility Index from SCB Testing in Wisconsin	**Bonaquist**
11:30 am	Update on FHWA PRS Project	**Duval**

Noon - Lunch Break

1:00 pm	Update on BMD Task Group	**Buchanan**
2:00 pm	Performance Based Mix Design	**Kim**
2:30 pm	Update on TP107 Direct Tension Cyclic Fatigue	**Kim**
3:00 pm	**Break**	
3:30 pm	Overview of Performance Tests • AMPT Equipment Specification • NCAT Activity-Simplified Cracking Test • LSU Pooled Fund TPF 5(294)	 **Corrigan/Bonaquist** **West** **Mohammad**
4:30 pm	**Adjourn for the Day**	

Day 2 – September 15, 2016

8:00 am	Status of MEPDG Asphalt Cracking Model	**Hall/Tram**
9:00 am	Simplification of Asphalt Technology to Improve Design	**Newcomb**
10:00 am	**Break**	
10:30 am	Task Group Review Update T-321 (Beam Fatigue)	**Rowe**
11:00 am	FHWA ALF Update	**Youtcheff**
Noon - Lunch Break		
1:00 pm	Construction Task Force – Rapid Asphalt Production/ Construction Controls	**Dukatz/Ramirez**
2:00 pm	Break	
2:30 pm	Recommendations RAP/RAS Task Group (PP-78-14)	**Musselman**
3:00 pm	Construction Task Force – Pavement Density Initiative	**Aschenbrener**
3:30 pm	Action Items and Next Meeting Planning	**Bukowski**
4:00 pm	**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	
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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 Mohammad, 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