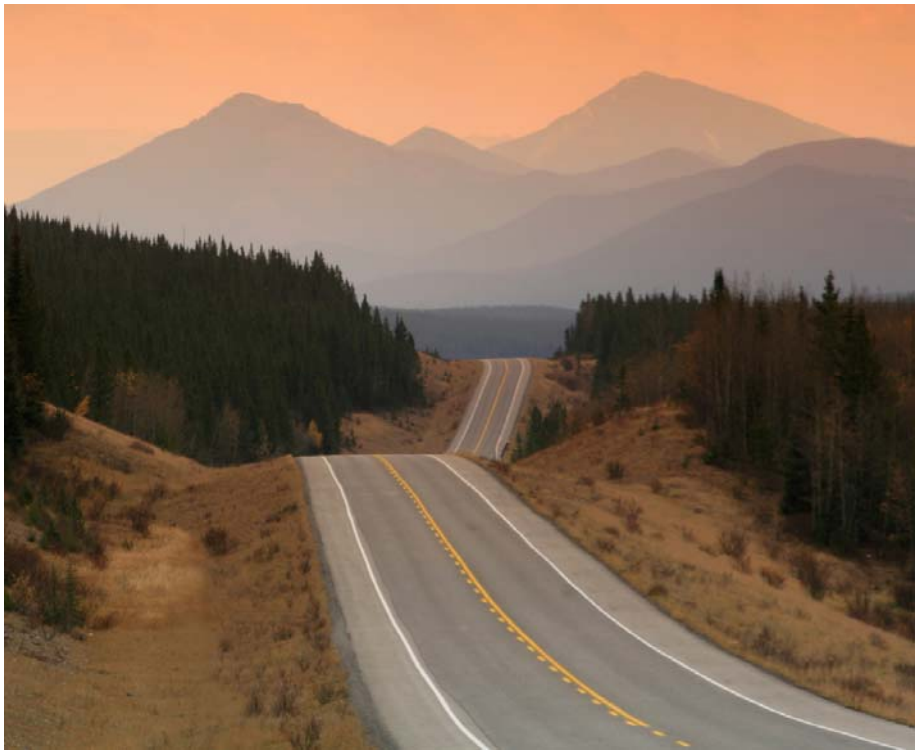
56th Petersen Asphalt Research Conference

University of Wyoming
Gateway Center

Laramie, Wyoming

July 14-17, 2019



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Welcome

Welcome and *Bienvenue!*

. . . To the 56th Petersen Asphalt Research Conference! As PARC chairman, I invite you to soak up the high plains hospitality to be found here in Laramie, Wyoming. Let the warm atmosphere of this unique gathering be a spark - igniting new friendships, exploring cutting edge ideas and discovering new approaches in the constant quest for knowledge and answers. Research thrives and grows in an environment of professional interaction where we can share and question, prodding us all to think outside the box.

PARC 2019 presenters have come from across the globe to share their recent findings, representing a wide cross-section of asphalt/bitumen stakeholders. We are all inquisitive by nature, some are scientists by trade, others are manufacturers bringing research from the lab into production. We all know that the elusive answers we seek can have significant long term impacts on vital everyday materials such as roofing and pavement.

"Chemistry Matters" remains the universal focus point, defined by conference founder Dr. Claine Petersen. As THE widely recognized forum for research in progress, PARC 2019 is proud to offer a high number of presentations on this year's themes: Asphalt Variability and Innovative Solutions; Asphalt Binder Rheology, Aging, Recycling and Rejuvenating; Emulsification; Modification by Polymers or Rubber; and Asphalt Mixes and Pavement Analysis.

Rapidly changing circumstances around the world drive us toward innovative solutions. New petroleum product specifications, such as IMO 2020 on marine fuels, broaden our fields of inquiry. Advances in crude oil production and refining, additives and modifiers, and increased pavement recycling have become a large part of this big research picture. We find challenges around every corner, triggering the development of relevant models, analytical tools and test methods to meet these needs. Developing cost effective solutions with lower environmental impact addresses continuing concerns at all levels: global, continental, national, regional, local and personal.

Home to the University of Wyoming, Laramie enjoys an atmosphere of active curiosity. "The World Needs More Cowboys" is the university motto, tied closely to the western ethic of striking out into new territory and working hard to bring fresh ideas and innovative solutions to reality.

I encourage you to soak up this western perspective and take it with you as a gift from Wyoming. You will find it nearby - Laramie is situated on a high plain at 7,200 feet (2,195 meters) in elevation, surrounded by majestic peaks on the eastern edge of the Rocky Mountains. Nearby adventures await you in every direction. PARC offers organized activities and there are additional opportunities to explore on your own.

Whether you traveled from near or very far, enjoy the experience of these few special days - broadening your scientific and personal frontiers. Thank you for attending, and be sure to offer your thanks to all of our sponsors and exhibitors who help make this conference possible.

Howdy and *Bonjour!* I offer you my personal greeting and look forward to seeing you during the 2019 Petersen Asphalt Research Conference!

Jean-Pascal (JP) Planche
Senior Vice President, Asphalt and Petroleum Technologies
Western Research Institute
Laramie, Wyoming


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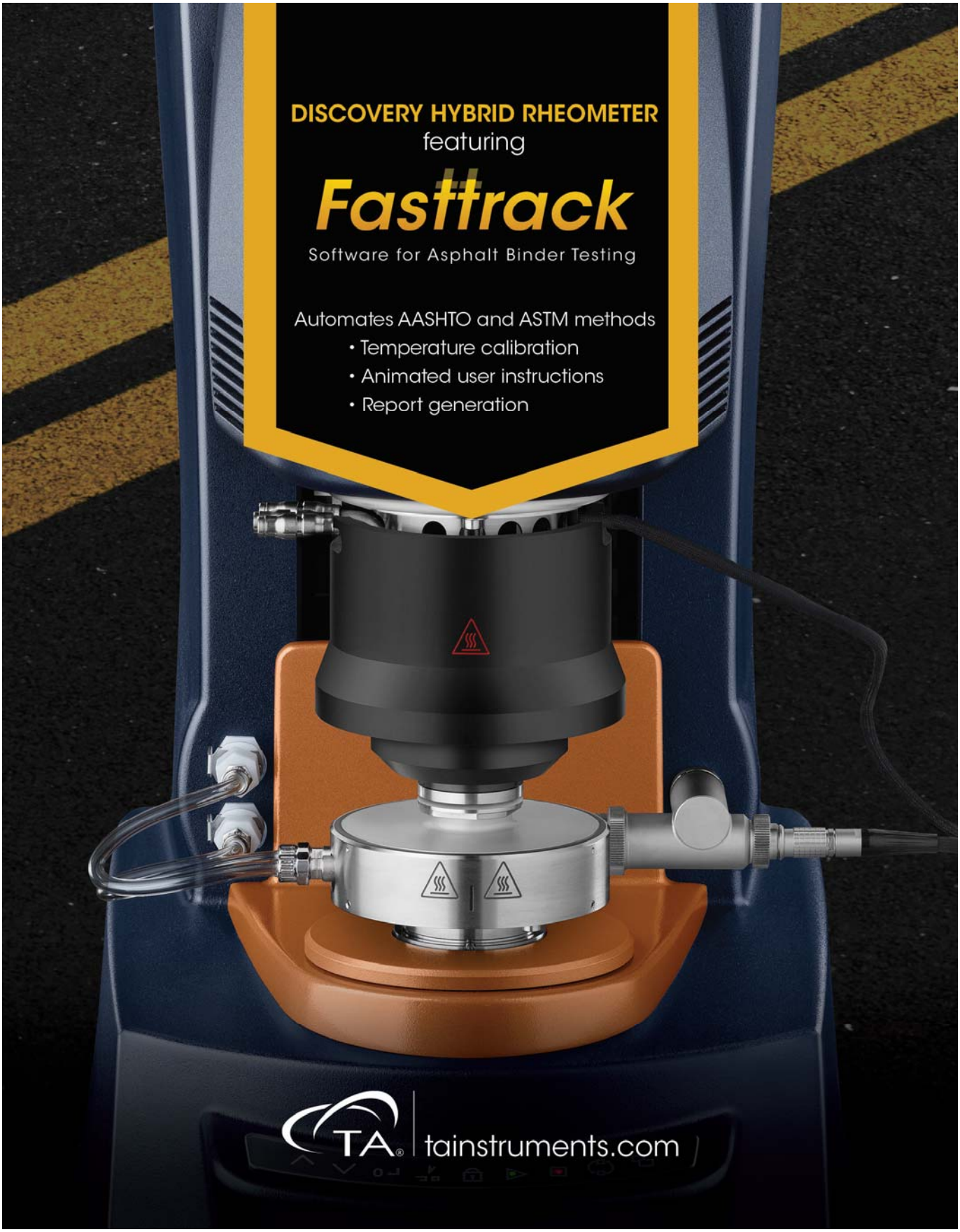
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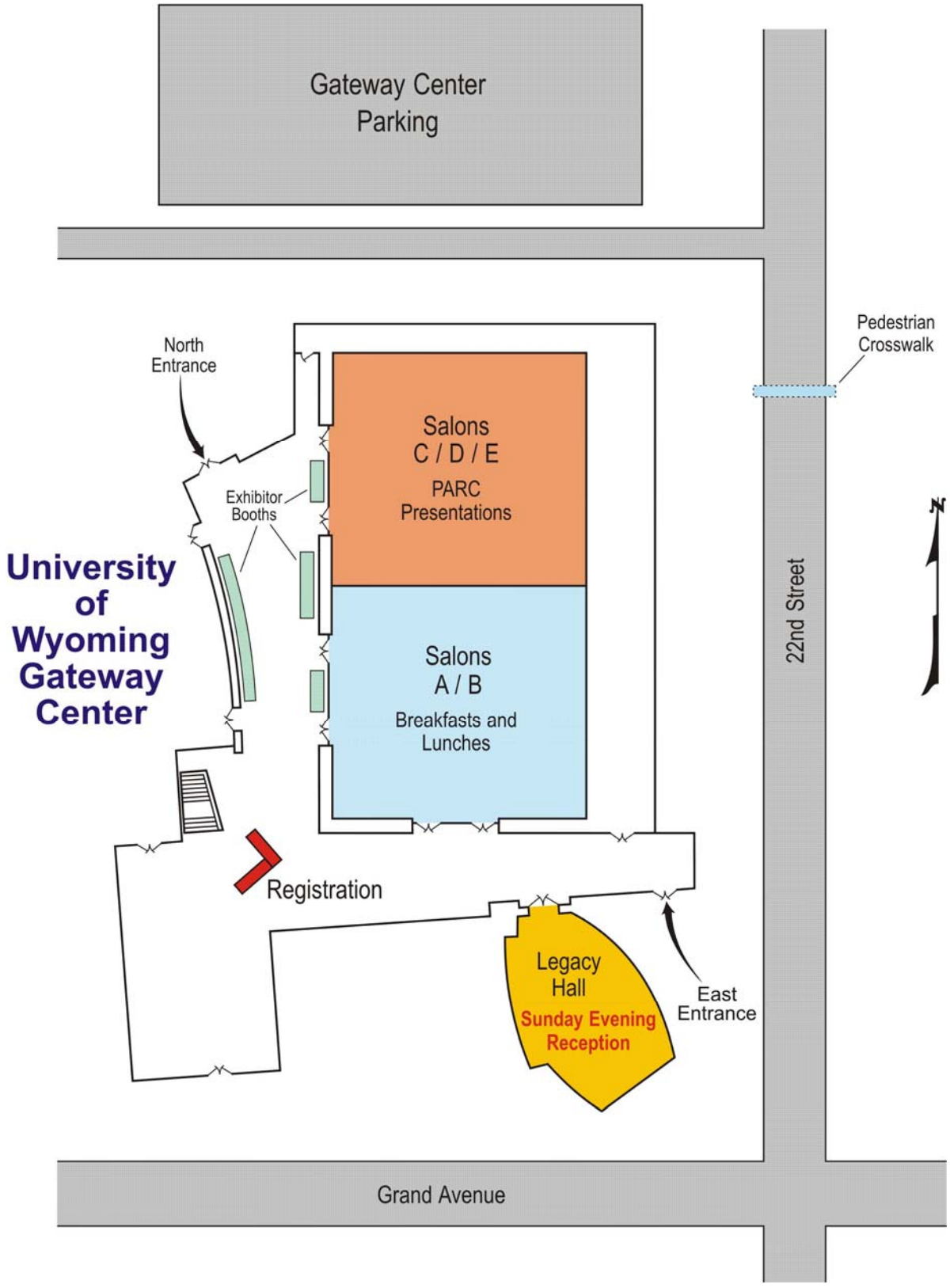
56th Petersen Asphalt Research Conference
Event Plan



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- Binder molecular weight to control asphalt ageing
- Benchmarking and comparison of competitive products
- Recycle Engine Oil Bottoms (REOB) trace element identification and analysis
- And so much more...

Conference Agenda

Sunday, July 14

6:00-9:00 p.m.	Welcome Reception *(Pick up conference materials for preregistered participants only)*	University of Wyoming Gateway Center, Legacy Hall

Monday, July 15

7:00-9:00 a.m.	***Breakfast - UW Gateway Center, Salons A & B***	
7:00 a.m.	Registration *(Pick up conference materials)*	University of Wyoming Gateway Center
8:00-8:15	Welcome and Opening Remarks **Salons C / D / E**	Jean-Pascal Planche and Joe Rovani *Western Research Institute*

All PARC Presentations in Salons C / D / E

Session 1 - Asphalt Variability, Challenges and Innovative Solutions

Session Chair: John D'Angelo, Chief Operating Officer, D'Angelo Consulting

8:15-8:40	IMO and the Effect on Bitumen Quality	Geoffrey Rowe, *Abatech*
8:40-9:05	Coal Additives for the Paving Industry from Solvent Refined Coal	Devang Khambhati, Jeramie Adams, Jianqiang Huo, Jean-Pascal Planche and Joe Rovani *Western Research Institute*
9:05-9:30	Use of Bio-Based Additives for Increased Structure and Performance of Styrene-Butadiene-Styrene Block Copolymers in Low Quality Asphalt Binders	Austin Hohmann, Joseph Podolsky, Conglin Chen, Paul Ledtje, Christopher Williams, Michael Forrester, Nacu Hernandez and Eric Cochran *Iowa State University*

Monday, July 15 (Continued)

9:30-9:55	Recycled Plastics for Performance Graded Asphalts	C.J. DuBois, Hayley Brown and Cristina Serrat *Dow*
9:55-10:20	***Break***	
10:20-10:45	Flash Chromatography as an Alternative to Traditional SARA Fractionation	Michael Forrester, Nacu Hernandez, Austin Hohmann, Eric Cochran and Christopher Williams *Iowa State University*
10:45-11:10	Asphaltenes: Influence of Chemical Structure on Ageing	Dawid D'Melo and Sathish Subramani *Shell India Markets* Richard Taylor *Shell International Petroleum*
11:10-11:35	Asphalt Binder Quality Test (ABQT) - Progress Report	Raj Dongre, *Dongre Laboratory Services* Jack Youtcheff *Federal Highway Administration* Jean-Pascal Planche and Michael Elwardany *Western Research Institute*
11:35-12:00	Correlation Analysis Coupled with Artificial Neural Networks to Investigate Asphalt Binder Chemo-Mechanical Relations	Michael Elwardany, Jeramie Adams, Jean-Pascal Planche, Joseph Rovani and Ryan Boysen *Western Research Institute* Nicola Ferralis *Massachusetts Institute of Technology*
12:00-1:00	***Lunch - UW Gateway Center, Salons A / B***	

Monday, July 15 (Continued)

Session 2 - Asphalt Binder Performance Indices

Session Chair: Cristian Clopotel, Sr. Asphalt Technologist, Marathon Petroleum

1:00-1:25	Evaluation of Glover-Rowe Parameter	Adrian Andriescu and Satish Belagutti *SES Group* David Mensching and Jack Youtcheff *Federal Highway Administration* Raj Dongre *Dongre Laboratory Services*
1:25-1:50	The Change in the Physical Properties of Asphalt Binders with Conditioning	Geoffrey Rowe *Abatech*
1:50-2:15	Rheological Properties of Phase-Incompatible Bituminous Binders	Pavel Kriz, John Noël, Mohammad Quddus and Stephanie Maria *Imperial Oil*
2:15-2:40	Impact of High-Polymer Modification on Rheological and Chemical Properties of Asphalt Binders	Robert Kluttz *Kraton Polymers* Jhony Habbouche *Virginia Transportation Research Council* Elie Hajj *University of Nevada, Reno*
2:40-3:05	Development of New Performance Indices to Evaluate the Fatigue Performance of Asphalt Binders with Aging	Runhua Zhang, Jo Sias and Eshan Dave *University of New Hampshire*
3:05-3:30	***Break***	

Monday, July 15 (Continued)

Session 3 - Asphalt Aging, Recycling and Rejuvenating

Session Chair: Troy Pauli, Principal Scientist, CertainTeed

3:30-3:55	Towards a Better Assessment of Recycling Agents Effects on Bitumen and Asphalt Mix During Hot Recycling	Fayçal Lahjiri, Frédéric Delfosse, Sabine Gazeau and Jacques-Antoine Decamps *Eurovia Management* Anne Dony and Layella Ziyani *IRC ESTP* Virginie Mouillet *Cerema Méditerranée* François Henn *Université de Montpellier*
3:55-4:20	Impact of Rejuvenation: Is Undisturbed Quantification of Bitumen Compatibility and Asphaltene Association Possible?	Hassan Tabatabaee and Tony Sylvester *Cargill Industrial Specialties*
4:20-4:45	Effect of Bio-Oils on Binder Extracted from RAP	Robeam Melaku and D.S. Gedara *University of North Dakota*
4:45-5:30	Evaluation of an Age Retarding Binder Additive Focused on the Re-Aging Rate of the Treated Binder as Measured by Rheological Properties of the Binder at Six Treatment Levels and Four Aging Levels	Gerald Reinke, Seth King and Andrew Hanz *MTE Services* Gaylon Baumgardner *Paragon Technical Services*
	Evaluation of an Age Retarding Additive Focused on Change in SARA Fractions, Carbonyl Content and Atomic Force Microscopy Properties Due to Re-Aging of the Age Retarding Additive Treated Binder	Gerald Reinke, Seth King and Andrew Hanz *MTE Services* Gaylon Baumgardner *Paragon Technical Services*

Tuesday, July 16

7:00-9:00 a.m. ***Breakfast - UW Conference Center, Salons A & B***

Session 3 - Asphalt Aging, Recycling and Rejuvenating (Continued)

Session Chair: Dawid D'Melo, Portfolio Implementation Manager, Shell India Markets

8:15-8:40	Asphalt Binder Laboratory Short-Term Aging: Effective Parameters and New Protocol for Testing	Hamzeh Haghshenas, Robert Rea and Dale Byre *Nebraska Dept. of Transportation* Davoud Haghshenas *Amirkabir University of Technology* Gerald Reinke *MTE Services* Martins Zaumanis *Swiss Federal Laboratories for Materials Science and Technology*
8:40-9:05	A Simple Test for Quality Control of RAP Piles - Progress Report	David Mensching and Jack Youtcheff *Federal Highway Administration* Raj Dongre *Dongre Laboratory Services* Xinjun 'Sean' Li and Adrian Andriescu *SES Group*
9:05-9:30	Assessing the Effect of Rejuvenators on the Glass Transition Temperature, Crossover Temperature, and Intermediate Region Temperature Range (TIR) of Reclaimed Asphalt	Mohamed Elkashef, David Jones and John Harvey *University of California Pavement Research Center* Michael Elwardany and Jean-Pascal Planche *Western Research Institute*

Tuesday, July 16 (Continued)

9:30-9:55	Reclaimed Asphalt Pavement Binders: Chemical Analysis	Richard Taylor *Shell International Petroleum* Dawid D'Melo and Preetika Rastogi *Shell India Markets*
9:55-10:20	***Break***	

Session 4 - Asphalt Emulsions

Session Chair: Didier Lesueur, Materials Development Associate Director, Lhoist Southern Europe

10:20-10:45	What is a "Mix-in-Place" Mixing Grade Emulsion?	Dennis Krivohlavek *ButaChem*
10:45-11:10	Determining the Quality of Asphalt Emulsions by Size and Zeta Potential	Ragy Ragheb, Kiwan Park, Ulf Nobbmann and John Casola *Malvern Panalytical*
11:10-11:35	Zeta Potential as a Measure of Asphalt Emulsion Stability	Irvin Pinto and Ashley Buss *Iowa State University*

Session 5 - Asphalt Mastic, Mixture and Pavement Analysis

Session Chair: Edith Arámbula Mercado, Associate Research Engineer, Texas A&M Transportation Institute

11:35-12:00	Use of Void Reducing Asphalt Membrane (VRAM) to Improve the Performance of the HMA Longitudinal Joint	Joyce Wairimu Kamau, Christopher Williams and Joseph Podolsky *Iowa State University*
12:00-1:00	***Lunch - UW Gateway Center, Salons A / B***	

Tuesday, July 16 (Continued)

Session 5 - Asphalt Mastic, Mixture and Pavement Analysis (Continued)

Session Chair: Edith Arámbula Mercado, Associate Research Engineer, Texas A&M Transportation Institute

1:00-1:25	Application of Artificial Intelligence for Design and Construction of Pavements	Raj Dongre *Dongre Laboratory Services*
1:25-1:50	Physical and Chemical Interaction Mechanism Between Asphalt and Aggregate in Asphalt Mastic	Jing Ding and Benjamin Shane Underwood *North Carolina State University*
1:50-2:15	Improving the Durability of Asphalt Mixtures with Hydrated Lime: Field Results from Recent French Sections	Didier Lesueur and P. Métais *Lhoist, France* P. Pibis *Vosges Dept.* S. El-Bédoui *Cerema* H. Ruat *North-West Road Admin.* S. Bouron and F. Hammoum *IFSTTAR*
2:15-2:40	Laboratory Evaluation of Moisture Damage and Impact of Additivation	Frédéric Delfosse and Justine Vinet *Eurovia Management* Vincent Gaudefroy and Emmanuel Chailleux *IFSTTAR* Everett Crews *Ingevity Corporation*
2:40-3:05	Use of Boil Test to Determine Type and Optimum Antistrip Additive Content for Asphalt Mixtures	Shivpal Yadav, Zahra Tayebali and Akhtarhusein Tayebali *North Carolina State University* Abhilash Kusam *Trimat Materials Testing* Andrew LaCroix *InstroTek*
3:05-3:30	***Break***	

Tuesday, July 16 (Continued)

Session 5 - Asphalt Mastic, Mixture and Pavement Analysis (Continued)

Session Chair: David Mensching, Asphalt Materials Research Program Manager, Federal Highway Administration

3:30-3:55	Assessment and Implementation of Low Temperature Mixture Cracking Criteria for Iowa	Joyce Wairimu Kamau, Christopher Williams and Joseph Podolsky *Iowa State University*
3:55-4:20	Freezing Damage in Asphalt Paving Mixture Saturated with Water-$CaCl_2$ Solutions	Sang Soo Kim, D. Tarawneh, A. Hosainat and J. Garcia Ruiz *Ohio University*
4:20-4:45	A Contribution to Understanding the Thermo-Mechanical Behavior of Partially Saturated Asphalt Concrete Under Freezing Condition	Ferhat Hammoum, Olivier Chupin, Jean-Michel Piau and Thang Van Vu *IFSTTAR* Didier Lesueur *Lhoist, France*
4:45-5:10	Binder and Mix Performance Testing for Cracking: The Effect of Aging	John D'Angelo *D'Angelo Consulting* Gaylon Baumgardner, Codrin Daranga, Trey Jordon and Mike Hemsley *Paragon Technical Services*

6:00-10:00 ***Conference Dinner and Entertainment***

For more information see following page

Petersen Asphalt Research Conference Dinner

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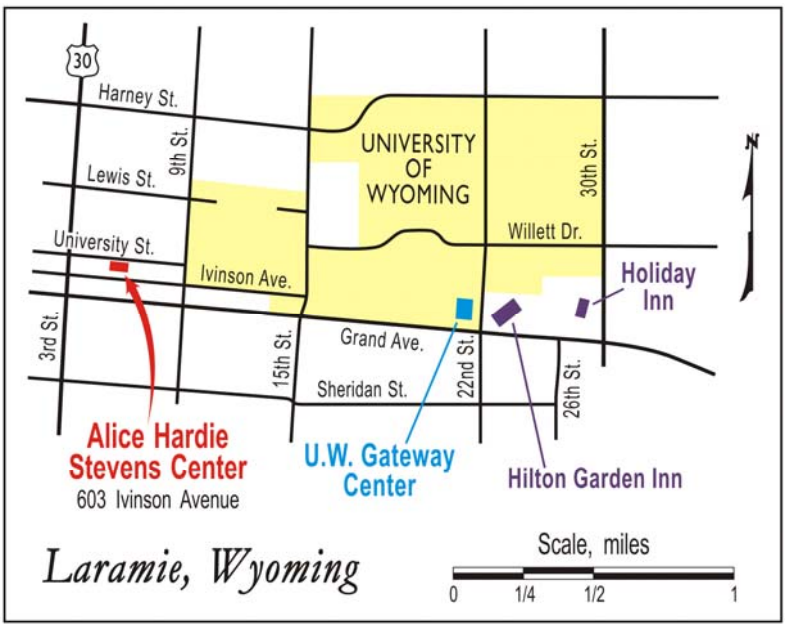
6:00 Social Hour
(Cash Bar)

7:00 Dinner

8:00 - 10:00 Music and Dancing

Southern Fryed Band

Additional banquet tickets can be purchased for $55/each on the conference website registration page at *www.petersenasphaltconference.org*



Wednesday, July 17

7:00-9:00 a.m. ***Breakfast - UW Conference Center, Salons A & B***

Session 6 - Polymer– and/or Rubber-Modified Asphalts

Session Chair: Andrew Hanz, Technical Director, MTE Services

8:15-8:40	Faster PMA Processing	Dennis Krivohlavek *ButaMix*
8:40-9:05	Effect of Polymer Concentration, Cross-Linker Concentration, Blending Temperature and Asphalt Binder on Rheological Properties of Highly Concentrated PMA Made with SBS	Sebastian Puchalski and Marsha Thompson *Kraton Polymers*
9:05-9:30	Characterization of Asphalt Reactivity Using Advanced Mass Spectrometry Techniques in Conjunction with NMR and IR Characterization	William Winniford, Hayley Brown, C.J. DuBois, Tony Gies, Junho Jeon, Dan Baugh III, Anna Leal and Praveen Boopalachandran *DOW*
9:30-9:55	Rheological Properties of Isocyanate Modified Binders: An Assessment of Rutting and Cracking Potential	Pravat Karki, Edith Arámbula-Mercado and David Newcomb *Texas A&M Transportation Institute*
9:55-10:20	***Break***	
10:20-10:45	Sustainable Polyolefin Performance Additives for the Modification of Asphalt Binder	John Almey *GreenMantra Technologies*
10:45-11:10	Evaluation of ΔT_c and Other Rheological/Fracture Parameters as Incompatibility/Fatigue Performance Criteria	David Mensching and Jack Youtcheff *Federal Highway Administration* Adrian Andriescu *SES Group* Raj Dongre *Dongre Laboratory Services*

Wednesday, July 17 (Continued)

11:10-11:35	Evaluation of High Polymer Modified Binders to Improve the Durability of Open-Graded Friction Courses	Edith Arámbula-Mercado and Pravat Karki *Texas A&M Transportation Institute* Silvia Caro, Carlos Rivera Torres and Mauricio Sánchez-Silva *Uniandes*
11:35-12:00	Understanding the Principals of Storage Stability in Ground Tire Rubber Modified Asphalt	Christopher Williams, Brittany Hallmark-Haack, Nacu Hernandez and Eric Cochran *Iowa State University*
12:00-12:25	Long and Short Term Aging in Asphalt Rubber Binders	Hashim Rizvi *University of California Pavement Research Center*
12:25-12:35	***Closing Remarks***	

Session 1 - Asphalt Variability, Challenges and Innovative Solutions

IMO and the Effect on Bitumen Quality

Geoffrey Rowe
Abatech

The ultimate effect of the implementation of new IMO 2020 regulations on the use of fuel oil contain sulfur on the quality of bitumen is currently unknown. However, some interesting factors may be deduced from historical data and comments on the sulfur content of bitumens and the discussions be held at various industry meetings/ conferences on this subject. IMO (International Maritime Organization) has been introducing rules to lower the use of high sulfur fuel oils (bunker fuel) over the past years.

Data on Sulfur in bitumen has been collected since the 1930's and limits on the amount of Sulphur have been proposed in the industry since this time. Many heavy oils that have been used for good quality bituminous binders have had Sulphur contents that tend to be towards the higher part of the range of in asphalt. As the market dynamics change refiners will face challenges regarding use of sour crudes and this will inevitability effect the binder supply. This paper presents some discussion of changes ongoing in the industry with refiners preparing for the IMO changes. The effects of Sulphur on traditional properties is discussed and the possible implementations to the asphalt industry.

Coal Additives for the Paving Industry from Solvent Refined Coal

Devang Khambhati, Jeramie Adams, Jianqiang Huo, Jean-Pascal Planche and Joe Rovani
Western Research Institute

Coal is a vast and cheap domestic feedstock that has encountered recent challenges as a fuel for power generation, due to climate concerns and competition with abundant low cost natural gas. Besides fuel for power generation, this complex carbonaceous material has tremendous untapped potential as a chemical feedstock useful for industries ranging from bulk commodity materials and chemicals to specialty chemicals and advanced engineered carbon materials. Coal is cheap, abundant and accessible making it desirable for the selective extraction of useful molecules for various industries. Within the range of possible industries lies the high volume asphalt market. Coal products are a largely untapped frontier for asphalt paving binder applications. In the past, high temperature pyrolysis coal tar pitch, from destructive distillation of metallurgical grade coals, was used to pave roads. However, with the discovery of the carcinogenic effect of polycyclic aromatic hydrocarbons (PAH) that are prevalent in high temperature coal tar pitch, paving with coal tars has been banned in many places around the world. The release of PAH from coal is dependent upon the processing conditions applied to the coal, just as PAH can be released from steak at the right conditions: e.g. on the barbeque grill. At the University of Wyoming, in conjunction with the Western Research Institute, it has been demonstrated that different suites of molecules can be efficiently extracted from Wyoming Powder River Basin (PBR) coal. With proper control and processing, chemical feedstocks with very low PAH content can be produced. Furthermore, PBR coal extracts are rich in oxygen which lends themselves to a variety of rich chemistries which can be used to tune their solubility, and ultimately compatibility within petroleum asphalts. Preliminary results will be shown how chemically modified coal extracts can be used to enhance upper and lower temperature properties of petroleum asphalt.

Use of Bio-Based Additives for Increased Structure and Performance of Styrene-Butadiene-Styrene Block Copolymers in Low Quality Asphalt Binders

Austin Hohmann, Joseph Podolsky, Conglin Chen, Paul Ledtje, Christopher Williams, Michael Forrester, Nacu Hernandez and Eric Cochran
Iowa State University

Various products have saturated the asphalt marketplace due to their potential to enhance asphalt binders and the economic opportunity this task presents. Advances in oil-refining and increases in polymer costs have created the need for effective modification agents that work well in Low Quality Asphalts, such as vacuum tower bottoms (VTBs) or recycled asphalt pavement (RAP). These additives need to have the capabilities to revitalize the properties of the asphalt to those of a virgin binder, while enhancing the interaction between the styrene-butadiene-styrene (SBS) polymers and the asphalt. Iowa State University has developed a bio-based additive that minimizes the amount of SBS required to modify asphalt. This additive has demonstrated: to have a positive effect on the interaction of the polymer and asphalt, it has shown an increase in the solvation (rejuvenation) of asphaltene rich asphalts, an increase in the homogenization of SBS modified binders, as evidenced by fluorescence microscopy, and an increase in the SBS modified asphalt rheological properties. The increase in performance along with the economics provides an excellent opportunity to asphalt contractors that has lead to several planned demonstration paving projects.

Recycled Plastics for Performance Graded Asphalts

D.J. DuBois, Hayley Brown and Cristina Serrat
Dow

The incorporation of existing streams of certain recycled polymers into asphalt could offer not only benefits from a sustainability perspective, but also from a performance and economics stand-point. In this talk we present a study in which recycled plastics were successfully incorporated into asphalt binders that met AASHTO M320, including upper, intermediate, and lower temperature tests, as well as AASHTO M332, through formulating blends with a Reactive Elastomeric Terpolymer (RET). Furthermore, these systems passed ASTM 5976 (separation of polymer), AASHTO T301 (elastic recovery), and critical temperature (.Tc). Compositions containing recycled plastics in dosages as high as 2 wt % and RET dosages as low as 0.6 wt % were studied. A one lane mile test section using a 1.5% LLDPE-rich recycled plastic and 0.6% RET binder that met TX DOT PG 70-22 specification was placed in Dow Texas Operations (Freeport, TX) in January 2019, and has been opened to traffic since then. Further demonstration projects are underway with the objective of generating relevant data for a breadth of variables.

Flash Chromatography as an Alternative to Traditional SARA Fractionation

Michael Forrester, Nacu Hernandez, Austin Hohmann, Eric Cochran and Christopher Williams
Iowa State University

Bitumen is a dynamic material that can have dramatically different rheology depending on the source of the material. In order to better understand the materials being utilized, SARA (Saturate, Aromatic, Resin, and Asphaltene) fractionation was developed. This technique allows for the isolation of the various components of asphalt; however, it has some major drawbacks. The test can be done on an analytical scale, providing low quantities of materials to verify compositions, or it can be done on a benchtop scale, providing enough material to do some more detailed analysis. This has significant limitations as well: low bitumen loading (<5% by mass of column material), large amount of solvent usage, requires significant time and someone skilled at chromatography to provide consistent results. Automated flash chromatography can offer an attractive alternative. Instruments are now available that can provide high loadings (10-20% by mass of column material), with less solvent usage, better resolution and reproducibility, and the results are less dependent on the operator's skills. Because of the larger loading, significantly more of each fraction can be obtained, allowing for more detailed analysis, such as blend formulations and rheology.

Asphaltenes: Influence of Chemical Structure on Ageing

Dawid D'Melo and Sathish Subramani *(1)*; Richard Taylor *(2)*
(1) Shell India Markets; (2) Shell International Petroleum

Asphaltenes have been shown to be an important component in bitumen, influencing a number of bitumen properties including the ageing behavior of bitumen. Previous work has shown that the asphaltenes present in bitumen influence the properties of bitumen, including its ageing characteristics.

The spectroscopic characterisation of bitumen and asphaltenes was carried out and structural insights correlated with the ageing behavior of bitumen. It could be seen that for samples with comparable sulphur contents the overall aromatic nature of the asphaltenes showed a strong correlation with the ageing behaviour.

The pressure ageing vessel was used to study the reactivity of various asphaltenes towards oxygen. The results showed that the increase in oxygen content of the asphaltenes showed a strong correlation with the change in softening point of the parent bitumen. Attempts to correlate reactive carbon sites on the asphaltenes with reactivity towards oxygen indicated that potentially sulphur speciation and other factors would also need to be considered. The insights obtained from these studies increase our understanding of the structure property relationships between bitumen, its components and properties. This allows for the formulation and manufacture of bitumen with required performance based on the structural properties of the raw materials.

Asphalt Binder Quality Test (ABQT) - Progress Report

Raj Dongre *(1)*; Jack Youtcheff *(2)*; Jean-Pascal Planche and Michael Elwardany *(3)*
(1) Dongre Laboratory Services; (2) Federal Highway Administration; (3) Western Research Institute

The ABQT device determines the creep and recovery characteristics of asphalt binders at 25°C. An innovative air jet and laser-based system is used to produce an indentation. The deflection and subsequent recovery is measured using the laser. One challenge in analyzing indentation data is the complicated strain-displacement relationships and stress calculations that are needed to obtain the rheological compliance function. In polymer rheology, indentation tests are commonly used and formulas to calculate compliance have been proposed and validated. These formulas however may not be directly applied as the indenters used are of solid type unlike the air jet used in the ABQT.

To determine creep compliance from the ABQT data, approximately 800 binders were analyzed. These binders were tested in both the ABQT and the DSR at 25°C under same creep conditions. An Artificial Neural Network model was developed to predict the creep compliance using the data from ABQT as input. The model was validated using v-fold cross validation technique and showed better that 98% accuracy with respect to the DSR data. Recently WRI has shared with FHWA 73 asphalt binder samples representing a wider spectrum of sources and methods of refining some of which are not currently used in asphalt production. This presentation will discuss the results of the ABQT and its PG grade predictive ability on these binders as well as theoretical aspects of obtaining creep compliance characteristics from the ABQT test. Results from the continuing evaluation of the ABQT by various DOTs will also be updated.

Correlation Analysis Coupled with Artificial Neural Networks to Investigate Asphalt Binder Chemo-Mechanical Relations

Michael Elwardany, Jeramie Adams, Jean-Pascal Planche, Joe Rovani and Ryan Boysen *(1)*; Nicola Ferralis *(2)*
(1) Western Research Institute; (2) Massachusetts Institute of Technology

The formulation and manufacture of asphalt binders have changed considerably since the implementation of Superpave specifications, developed under the Strategic Highway Research Program, owing to a number of economic, technical, and environmental reasons. Some of these changes have not had a significant impact on binder quality while other have reduced binder quality and consistency. As these changes alter binder chemistry and composition, they may be blind to current specifications which are focused on physical/mechanical properties. In some cases, the focus on physical/mechanical properties appears insufficient to ensure satisfactory field performance of the end products. The WRI Asphalt Industry Research Consortium, launched in 2015, has been helping twelve industry partners to perform chemo-mechanical characterization of about 100 binders. The material characterization includes (1) chemical characterization: elemental analysis, SAR-AD™, FT-IR, and Waxphaltene Determinator, (2) microstructural evaluation: size exclusion chromatography, (3) thermal analysis: differential scanning calorimetry (DSC) and Modulated DSC, and (4) rheological investigation: Superpave performance grading, Black space plots and parameters, and multiple stress creep and recovery test.

In this study, correlation heat maps were generated using Pearson (linear) and Spearman (monotonic) pair correlations. Heat maps were then used to identify meaningful correlations and robust interrelated material properties. The heat maps were also used to down-select appropriate combinations of material properties as inputs for the targeted predicted outputs using Machine Learning, Artificial Neural Network, algorithms. The aforementioned approach, also known as “Targeted approach”, was also compared to the “Holistic” approach that indiscriminately uses all available parameters for the prediction. The targeted approach requires supervision based on field knowledge in establishing correlations. However, it leads to more robust predictions by reducing unnecessary complexities and the probability of overfitting. The targeted approach goes beyond merely predicting binder’s mechanical properties from its chemical and compositional properties, but it provides a method to understand observed trends from the chemical and physical standpoints.

Session 2 - Asphalt Binder Performance Indices

Evaluation of Glover-Rowe Parameter

Adrian Andriescu and Satish Belagutti *(1)*; David Mensching and Jack Youtcheff *(2)*; Raj Dongre *(3)*
(1) SES Group; (2) Federal Highway Administration; (3) Dongre Laboratory Services

The Glover Rowe parameter is being investigated as a possible indicator of fatigue performance of asphalt binders. During the development of the G-R parameter, a damage zone where cracking likely begins due to brittle rheological behavior was defined between 180 and 600 kPa. This correlates to low ductility values of 5 cm to 3 cm, respectively. These limits were previously related to surface raveling and cracking by Kandhal (1977). The genesis of the G-R parameter was the work of Glover et al. (2005) defining the DSR function (G'/(.'/G')) and later reformulated for practical use by Rowe (2011) and in a discussion of Anderson et al. (2011) as G'/(.'/G')/w= G* · (cos d)2/(sin d), where all rheological properties are referenced to 0.005 rad/s and 15°C.

Several asphalt binders with known laboratory and/or field performance were tested to determine the G-R parameter. The newly developed DENT test data was also collected for these binders.

In this presentation, the original correlation between G-R parameter and ductility behavior using the DENT data will be examined. The implications of the strength of the correlation between G-R and brittleness as characterized by the DENT test will be discussed. Suggestions for changes to the G-R parameter (range, temperature, and frequency) will be proposed.

The Change in the Physical Properties of Asphalt Binders with Conditioning

Geoffrey Rowe
Abatech

As a binder is conditioned in the laboratory procedures of RTFOT and PAV the stiffness characteristics of the change. In a series of studies, an extended PAV condition of 40 hours has been used with data sets that represent binders used in Africa, Asia and the USA including those graded by Penetration, Viscosity and PG specifications. In all conditions of aging BBR tests have been conducted to carefully define the low temperature rheology whereas isotherms of stiffness collected with a DSR has been used to define the high temperature properties. The parameters calculated from the BBR data include the glassy modulus and the shape parameters of the master curve. The BBR data is combined, via an interconversion process, with the DSR and the complete master curve is obtained. Various parameters have been determined such as the R-value, glassy modulus, G-R parameter and the cross over modulus. It was observed that various parameters are strongly correlated for data sets. For example, the R-value relates well to the ΔT_c. The changes observed in Glassy Modulus also correlates to the R-value, suggesting that oxidation effect the value of glassy modulus as well as the overall shape of the master curve.

Rheological Properties of Phase-Incompatible Bituminous Binders

Pavel Kriz, John Noël, Mohammad Quddus and Stephanie Maria
Imperial Oil

The SuperPave™ specification system was developed and validated for straight-run refinery-produced asphalts and it has been implemented in the USA and Canada throughout the 1990s. Since then, there has been increased use of modified grades, Recycled Asphalt Pavement and artificial "softeners" such as recycled engine oil bottoms, aromatic or paraffinic oils, bio-based oils, etc. Not all these compositional changes manifested in adequate asphalt long-term performance in the field. It was demonstrated that the current SuperPave™ system cannot prevent acceptance of some of the lower quality materials. There has been a significant effort in the US and Canada to improve the SuperPave™ system to address these challenges, more specifically to prevent premature binder aging and pavement cracking. Current paper is showing how excessive oxidative aging and physical hardening susceptibility together with loss of cohesion and relaxation properties in inadequately modified binders relates to phase compatibility and how this can be reliably manifested in measurement of rheological phase angle in Dynamic Shear Rheometer (DSR). It is shown that the DSR test performed on the Pressure Aging Vessel (PAV) residue can be simply modified to exclude phase incompatible binders from passing the specification.

Evaluation of ΔT_c and Other Rheological/Fracture Parameters as Incompatibility/Fatigue Performance Criteria

David Mensching and Jack Youtcheff *(1)*; Adrian Andriescu *(2)*; Raj Dongre *(3)*
(1) Federal Highway Administration; (2) SES Group; (3) Dongre Laboratory Services

The current performance grade system for asphalt binder selection does not reliably capture pavement durability. In addition, the composition of asphalt binders and asphalt in the mix have become quite complex; new asphalt blends are formulated with various additives and mixtures are incorporating higher levels of RAP and RAS. As an improvement, researchers have considered using ΔT_c and other parameters to help differentiate between good and poor performing binders. If successful, ΔT_c should be associated to the compatibility of components within the binder and between virgin and RAP/RAS binders.

The presentation presents data from two investigations. One evaluating mix and binder properties for two binders with similar Performance Grades but having widely different ΔT_c values, and the other evaluating binders extracted from the ongoing RAP/RAS study at Turner-Fairbank Highway Research Center's Pavement Test Facility (PTF). Our goal is to validate the assumption that ΔT_c, phase angle, and other binder parameters are relevant for the mix fatigue performance and is to improve the existing binder selection criteria.

Discussed are the binder rheological parameters ΔT_c, phase angle, and Glover Rowe along with the strain tolerance criteria for fatigue performance in relation with laboratory mix performance. The evolution of the performance parameters during field and laboratory aging and the aging implications for fatigue performance are also presented.

Development of New Performance Indices to Evaluate the Fatigue Performance of Asphalt Binders with Aging

Runhua Zhang, Jo Sias and Eshan Dave
University of New Hampshire

This work presents the development of new fatigue performance indices for asphalt binders based on viscoelastic continuum damage (VECD) theory and failure energy. Five mixtures were subjected to three different aging conditions (short term aging during production, loose mix for 5 and 12 days at 95°C in laboratory), and the corresponding binders were extracted and recovered. The Linear Amplitude Sweep (LAS) test was conducted to measure the fatigue performance of the binders. The traditional performance index from the LAS test, A and B parameters, as well as the Nf versus strain plot are used to evaluate the change of binder fatigue performance with aging. Three new performance indices are developed and used to track the change of binder fatigue properties with aging: Strain Tolerance (eT), Energy to Failure (.f), and Average Reduction in Integrity to Failure (IR). These indices capture the actual failure point and combine the stress and strain history of the material. Compared with the traditional A and B parameters, the new indices show a consistent decrease in the fatigue performance of the binder samples with aging.

Session 3 - Asphalt Aging, Recycling and Rejuvenating

Towards a Better Assessment of Recycling Agents Effects on Bitumen and Asphalt Mix During Hot Recycling

Fayçal Lahjiri, Frédéric Delfosse, Sabine Gazeau and Jacques-Antoine Decamps *(1)*; Anne Dony and Layella Ziyani *(2)*; Virginie Mouillet *(3)*; François Henn *(4)*
(1) Eurovia Management; (2) IRC ESTP; (3) Cerema Méditerranée; (4) Université de Montpellier

In the road industry, the current challenge is to produce asphalt mixtures incorporating higher rates (>50 %) of Reclaimed Asphalt Pavements (RAP) while maintaining the quality of the final mix. The first 100% recycled road on a highway laid by Eurovia in 2018 is an example of this ambition. During its service life the pavement physical properties, i.e. mechanical and durability, change and need to be restored if we want the RAP to be reused. Hence, recycling agents are sometimes employed to "rejuvenate" aged bitumen. In this study, a novel methodology is presented to help better understand the actions of a recycling agent on the bitumen and on the asphalt mix at both unaged and aged states. Although the mechanical features are studied for the different service temperatures, an emphasis is made on low temperatures at which RAP based mixes are more fragile. DSR using 4mm parallel plates for bitumen or TSRST for asphalt mixes are examples of tests offered in this methodology. As far as chemistry is concerned, the recycling agent affinity with bitumen and even aggregates is assessed.

Impact of Rejuvenation: Is Undisturbed Quantification of Bitumen Campatibility and Asphaltene Association Possible?

Hassan Tabatabaee and Tony Sylvester
Cargill Industrial Specialties

"Rejuvenation vs. Softening" has become terms commonly adopted by researchers and practitioners in recent years. Many accept that something beyond decrease of modulus should be expected from a "true" rejuvenator, with "compatibilization" often cited as the main differentiating mechanism.
Continuum rheological parameters such as .Tc, Black Space indexes, and mastercurve parameters on one hand, and SARA fraction ratios such as the "Colloidal instability Index" on the other hand, have been used as empirical circumstantial evidence of bitumen compatibility. However solid evidential support through direct measures of asphaltene association, compatibilization, and sol/gel morphology without the complication of solvent disturbance continues to be elusive.

As stakeholders begin the process of creating new specifications for complex binders and rejuvenators, reliable and non-circumstantial measures of bitumen compatibility are becoming an increasingly evident gap in the current state of knowledge and practice. The present study explores the possible routes towards addressing this need through inducement of various fractional instability scenarios in bitumen through oxidation, volatilization, and low temperature physical aging conditioning, and revisiting the role of thermal analysis and solubility equilibriums in assessing asphaltene association in a fresh context.

Effect of Bio-Oils on Binder Extracted from RAP

Robeam Melaku and D.S. Gedafa
University of North Dakota

In this research, EnSolv-EX chemical was used to extract the RAP binder. The extracted RAP binder was recovered using the Abson method. Two types of bio-oils, waste cooking (WCO) and soy oils (SO), were used to modify and reduce the stiffness RAP binder. A dynamic shear rheometer (DSR) was used to determine the rheology of unaged, rolling thin film oven (RTFO)-aged, and pressure aging vessel (PAV)-aged binders (control and modified). Multiple Stress Creep Recovery (MSCR), Linear Amplitude Sweep (LAS), and 4 mm parallel plate geometry tests were conducted to evaluate the rutting, fatigue cracking, and low-temperature cracking performance of the control and modified binders, respectively. The results showed the addition of 15% SO or 15% WCO reduced the RTFO temperature grade of the RAP binder from 82 °C to the PG 58 grade. But the G*/sin (d) value of the unaged modified binders was less than 1 kPa. Replacement of 2.5% and 5% of both bio-oils by the virgin PG 58-28 binder improved the unaged G*/sin (d) value while maintaining the RTFO high-temperature PG of 58°C. All binders except 100% RAP binders passed the fatigue cracking, low-temperature cracking and rutting criteria, and performed better than the control (virgin PG 58-28 binder).

Evaluation of an Age Retarding Binder Additive Focused on the Re-Aging Rate of the Treated Binder as Measured by Rheological Properties of the Binder at Six Treatment Levels and Four Aging Levels

Gerald Reinke, Seth King and Andrew Hanz *(1)*; Gaylon Baumgardner *(2)*
(1) MTE Services; (2) Paragon Technical Services

Investigation and utilization of recycling/rejuvenating additives, especially bio derived additives, has been a significant effort for 10+ years. Benefits of such additives are obvious assuming the additives alter not only the aged binder's physical properties but also reset the aged binder's aging clock. Most additives soften aged binder, but do not alter the structure of the aged binder as shown by R-Value improvement or improvement in Black Space plots. Our research has shown that sterol in pure or concentrated form substantially retards the re-aging rate of aged binders. Sterol is not a softening additive, it does however, when added to a binder alone or in combination with softening additives retard the re-aging rate of the final blend. We show how dosage rate impacts re-aging of binder and explore explanations of how the sterol functions in the binder. Laboratory aged binder was dosed at six sterol concentrations and aged through 60 PAV hours. Results were evaluated to explain how sterol functions to retard binder aging as manifested by bulk rheological data, and changes in the rate at which asphaltenes and carbonyl content increased with re-aging. A re-aging-rejuvenated binder when paved being subjected to further aging.

Evaluation of an Age Retarding Additive Focused on Change in SARA Fractions, Carbonyl Content and Atomic Force Microscopy Properties Due to Re-Aging of the Age Retarding Additive Treated Binder

Gerald Reinke, Seth King and Andrew Hanz *(1)*; Gaylon Baumgardner *(2)*
(1) MTE Services; (2) Paragon Technical Services

Investigation and utilization of recycling/rejuvenating additives, especially bio derived additives, has been a significant industry effort for 10+ years. Benefits of such additives are obvious assuming the additives alter not only the aged binder's physical properties but also reset the aged binder's re-aging clock. Most additives soften aged binder, but do not alter the structure of the aged binder as shown by R-Value improvement, and changes in asphaltenes and carbonyls Our research has shown that sterol in pure or concentrated form substantially retards the re-aging rate of aged binders. Sterol does not reverse aging, we don't believe this is possible, but sterol does appear to alter the internal structure of the binder when initially blended and continues to do so in a dose response manner when re-aging occurs. Investigations of sterol interaction with binder were conducted using a laboratory aged binder dosed at six sterol concentrations and aged through 60 PAV hours. We explore the interrelationships between compositional properties through Iatroscan testing, chemical oxidative changes using FTIR and changes at the molecular level using Atomic Force Microscopy. A re-aging-rejuvenated binder when paved being subjected to further aging.

Asphalt Binder Laboratory Short-Term Aging: Effective Parameters and New Protocol for Testing

Hamzeh Haghshenas, Robert Rea and Dale Byre *(1)*; Davoud Haghshenas *(2)*; Gerald Reinke *(3);* Martins Zaumanis *(4)*
(1) Nebraska Department of Transportation; (2) Amirkabir University of Technology; (3) MTE Services; (4) Swiss Federal Laboratories for Materials Science and Technology

This study aims to address the effect of time, temperature, airflow rate, and weight of asphalt binder on the laboratory short-term aging and propose an alternative protocol that can reduce the aging time and resolve some of the current short-term aging protocol shortcomings. In the first part of this study, two asphalt binders were examined in Rolling Thin Film Oven (RTFO) at different combinations of the above-mentioned test parameters. The high-end continuous grade and carbonyl index were considered as the two responses for quantification and qualification of aging. The statistical analysis showed that the first order terms of time, temperature, and weight as well as their interactive terms were statistically significant. However, the effect of airflow rate was insignificant. Based on the findings of the first part of study, an alternative protocol was proposed. This protocol was then validated to determine its applicability for different types of binders including one unmodified and three modified ones. According to the obtained rheological properties and chemical characteristics, it was shown that the proposed laboratory short-term aging protocol not only can reduce the aging time of the conventional protocol, but also that it is applicable to both neat and polymer-modified modern asphalt binders.

A Simple Test for Quality Control of RAP Piles - Progress Report

David Mensching and Jack Youtcheff *(1)*; Raj Dongre *(2)*; Xinjun 'Sean' Li and Adrian Andriescu *(3)*
(1) Federal Highway Administration; (2) Dongre Laboratory Services' (3) SES Group

Many State DOTs currently require that contractors characterize the quality and consistency of their RAP pile by chemically extracting the binder from the RAP (TCE or Toluene is generally used) and determining a simple absolute viscosity value or a PG grade. Ten samples from the RAP pile are typically used. The PG or viscosity data are then evaluated to assess the consistency and quality of the RAP pile. The solvents used to extract binder from RAP are now being restricted due to environmental and health concerns. FHWA is looking for an alternative to chemical extraction. Last year at PARC, capability of the DWT test to characterize uncompacted (loose) RAP samples was introduced. Only limited data were shown at that time. A total of 38 RAP samples have now been successfully tested using the DWT. The tests were carried out at four temperatures with two replicates at each temperature.

Data analysis indicates that the repeatability of the test is generally lower than 10% and may be successfully used to assess the quality of a RAP pile. To validate this finding, ten RAP samples were obtained from a RAP pile maintained by a local Virginia contractor. A new concept was developed by which blend charts are created using the DWT value of the virgin mix and the uncompacted RAP sample at various RAP contents. Preliminary analysis of the blend chart analysis of FHWA ALF RAP/RAS experiment shows that blend charts may be successfully used to determine blend ratios without having to chemically extract the RAP binder. The findings from the data analysis of the 38 RAP samples tested using the DWT will be discussed in this presentation. The results of the ten RAP pile consistency samples will also be summarized. The blend chart concept and data analysis results will be presented and the implications will be discussed.

Assessing the Effect of Rejuvenators on the Glass Transition Temperature, Crossover Temperature, and Intermediate Region Temperature Range (TIR) of Reclaimed Asphalt

Mohamed Elkashef, David Jones and John Harvey *(1)*; Michael Elwardany and Jean-Pascal Planche *(2)*
(1) University of California Pavement Research Center; (2) Western Research Institute

Rejuvenators are used to restore the properties of reclaimed asphalt pavement (RAP) binders through restoring the balance between the asphaltenes and maltenes fractions. Numerous studies have examined the relationship between the rheological and chemical changes in asphalt binders with aging and rejuvenation. To characterize the binders' rheology, temperature-frequency sweep testing can be conducted over a wide range of temperatures and frequencies. Master curves or isochronal plots, obtained from temperature-frequency testing results, can be used to understand transitions in behavior between the near glassy, intermediate, and terminal viscoelastic regions. The critical low temperatures measured using a bending beam rheometer (BBR) and the intermediate temperature obtained using a dynamic shear rheometer (DSR) can provide an insight into these regions. In this study, aged RAP binders were rejuvenated using a bio-based and an aromatic extract petroleum based rejuvenator. The rheological properties of the control and rejuvenated RAP binders were determined at different aging conditions, namely unaged, RTFO-aged, 20-hr and 40-hour PAV-aged. Attenuated total reflection Fourier transform infrared (ATR-FTIR) technique was used to measure the evolution of the carbonyl and sulfoxide indices with aging. The rheological results were analyzed to determine the intermediate region temperature range (TIR) of the binders and correlate it with the critical temperatures. The changes in the rheological properties with aging were also correlated with the FTIR results. Differential scanning calorimetry (DSC) testing was conducted to verify the glass transition temperature. Using the constructed isochronal plots, the effect of the different rejuvenators on TIR, glass transition temperature, crossover temperature, and ΔTc parameter was assessed at different aging stages.

Reclaimed Asphalt Pavement Binders: Chemical Analysis

Richard Taylor *(1)*; Dawid D'Melo and Preetika Rastogi *(2)*
(1) Shell International Petroleum; (2) Shell India Markets

The use of reclaimed asphalt pavements (RAP) in road networks is a key component of the circularity of the asphalt industry. There is a wide variation in the concentration of RAP which is used to make a fresh pavement as well as the methods used to accomplish this. Whilst bitumen has a certain degree of chemical variation and complexity, this is compounded with RAP binders. The understanding of RAP binder chemistry, coupled with insights of what drives bitumen and hence asphalt performance is critical in using the correct concentrations and methodologies to design asphalt pavements, achieving the best performance from the pavements.

The current study compares the chemistries of RAP binders obtained from roads from four geographies with different service lives, traffic densities and climatic conditions. The use of RAP binders in blends with conventional paving grade materials indicated the potential for the resultant mixtures to have a higher degree of physical hardening over time.

Significant differences in the composition, elemental makeup and rheological characteristics demonstrate the complexity associated with RAP binders and indicates the potential challenges of optimizing RAP usage to obtain the best performance from RAP containing pavements.

Effects of Different Chemical Components of Rejuvenating/Recycling Agents on the Restoration of Chemical and Physical Properties of Aged Asphalt Binders

Huachun Zhai, Alejandro Rosales, Elena Hubert and Joe Blake *(1)*; Brody Young *(2)*
(1) Idaho Asphalt Supply; (2) Peak Asphalt

When using RAP in HMA, the goal of determine binder replacement percentage is to regain the physical or rheological properties of the aged asphalt in the RAP through the usage of blending chart. The restoration of chemical components in the RAP binder is not considered. In this study, the restoration of both chemical and physical properties of aged asphalt binders were investigated. Two base asphalts, PG58-28 and PG70-28, were aged through 40 hrs PAV test to similar the aged binders in RAP. Soft Asphalt and four different kinds of Rejuvenating and Recycle Agents (RA (Aromatic Oil Based), RP (Paraffinic Oil Based), RP (Naphthenic Oil Based) and RV (Vegetable Oil Based)) were used to blend with the aged binders to achieve the same values of the unaged base asphalt on the following properties: 1) PG HT, 2) PG LT and 3) Asphaltene + Resin Content. SARA tests were performed to analyze the chemical components of different blends. Different rheological tests such as rotation viscosity, frequency sweep at different temperatures, stress sweep, true PG grades and .Tc were used to determine the changes of physical properties. The relationship between chemical and physical properties of these blends were investigated.

Session 4 - Asphalt Emulsions

What is a "Mix-in-Place" Mixing Grade Emulsion?

Dennis Krivohlavek
ButaChem

Since the beginning of emulsion usage in the asphalt industry there has been a need for an emulsion that will quickly coat typical hot mix aggregate gradations plus break, set and cure to traffic in about the same time it takes hot mix asphalt. Until now, such an emulsion has eluded the industry.

The "Mix-in-Place" or "MiP" emulsion is designed to work with typical dense or open graded mix design aggregates common to the road construction industry. MiP emulsions will also perform with single size aggregates. This offers new methods and advantages for Chip Seal applications.

Another distinctive advantage of the MiP emulsion is that various structural additives may be added to the mix. Structural additives most common to the industry would be GTR or fibers. As emulsions are water based, a MiP emulsion can be used with higher additives amounts than normal to hot mix applications.

MiP emulsions control their break, set and cure by the use of a "Break Control Agent" ("BCA") with the primary emulsion. The BCA can be added either before or after the primary emulsion is applied to the aggregate.

Determining the Quality of Asphalt Emulsions by Size and Zeta Potential

Ragy Ragheb, Kiwan Park, Ulf Nobbmann and John Casola
Malvern Panalytical

Asphalt binder emulsions have proven to be an environmentally friendly, energy efficient, and cost-effective alternative to hot asphalt binder mixtures(1). They are typically composed of bitumen, water, and an emulsifying agent or surfactant and must give the required stability and application characteristics for optimum performance. For example, the structural layers must have adequate mechanical properties to make them less susceptible to early-life damage. Two tools highlighted in this work are size and zeta potential as measured by laser diffraction and light scattering. Laser diffraction has a range of 10nm to 3500 microns and Dynamic light scattering has a range of 0.3nm to 10 microns. Size will help determine the distribution and consistency of your asphalt emulsion. Electrophoretic light scattering can also measure zeta potential which is another key metric for the colloidal stability of asphalt emulsions. Zeta potential can also be used to note any compositional differences between emulsions in terms of the sign and magnitude of any electric charge.

Reference: (1) www.asphaltmagazine.com

Zeta Potential as a Measure of Asphalt Emulsion Stability

Irvin Pinto and Ashley Buss
Iowa State University

Asphalt emulsions are becoming popular in pavement preservation techniques due to lower application temperatures and easier handling and storage. Asphalt emulsion stability is an important parameter while deciding the type of emulsion to be used for a specific pavement preservation treatment. The stability of asphalt emulsions, being essentially suspensions of charged asphalt particles in an electrolyte solution are governed by zeta potential, which is essentially the potential difference between the charged particles on the asphalt droplet surface and the oppositely charged ions in solution. This study will consist of two phases, namely determining the reactivity of asphalt emulsions, aggregates and mineral fillers, and finding the point of zero zeta potential by titrating an emulsion with a solution containing aggregate fines. The study will observe the effect of various formulation parameters on the zeta potential of quick setting asphalt emulsions and determine the point of zero zeta potential for each formulation with aggregates of varying reactivity. This study aims to introduce the parameter of zeta potential into the design process of slurry treatments and help improve the selection process and field performance of quick setting asphalt emulsions.

Session 5 - Asphalt Mastic, Mixture and Pavement Analysis

Application of Artificial Intelligence for Design and Construction of Pavements

Raj Dongre
Dongre Laboratory Services

In the current version 2.5.4 of AASHTOWare MEPDG software the dynamic modulus of hot-mix asphalt is predicted using the Witczak model (Nationally Calibrated) for Level 3 analysis. The Witczak model requires mix gradation, volumetrics, and binder rheology (Viscosity or G* and phase angle at various temperatures and frequencies) inputs. The output from this model predicts the E* values at the temperature and frequency of input. The Witzcak model does a decent job of prediction of hot-mix E*. The predictive capability of the Witczak model, however, needs to be improved from the current R^2 of 0.8 in arithmetic space and 0.9 in log space. The 20% error in prediction may cause unacceptable error in prediction of performance as compared with performance predicted using measured E* of Level 1. An enhanced E* prediction model based on Artificial Neural Network (DLSI-ANN) was developed. The DLSI-ANN model uses advanced machine learning concepts and uses the same input parameters as that of latest Witczak model. The ANN model is capable of using both binder viscosity or G* and phase angle inputs. The proposed ANN model has an added advantage of the ability to learn from additional data as it becomes available. This implies that in the future as more E* data from diverse sources is added to the training data of the ANN model it will improve further. The DLSI-ANN training database contains more than 30,000 datapoints collected from various sources including FHWA dataset and from literature where available. The new DLSI-ANN model was used with the original 7400 data points from the Witczak database. The results of the validation are shown below.
This presentation discusses the implementation of such a model to everyday use for quality control during paving. The current state of the art application of AI technology being used in the paving industry will also be highlighted along with its implications to the future of pavement research.

Physical and Chemical Interaction Mechanism Between Asphalt and Aggregate in Asphalt Mastic

Jing Ding and Benjamin Shane Underwood
North Carolina State University

The current state of the art in asphalt binder to mixture numerical and micromechanical modeling usually simplifies the contact behavior between asphalt and aggregate, which greatly limits engineer's ability to adequately understand and design the best possibly performing mixtures. This study examines the physical and chemical mechanisms that occur at the interface of asphalt and aggregate filler in order to more completely interpret the rheology of asphalt mastic. Asphalt mastics, blends of filler sized particles and binder, of limestone, granite, mica and fused silica at filler contents of 10%, 20%, 40% by volume are fabricated and their complex shear modulus across temperatures and frequencies are measured. The physical mechanisms are characterized using the filler particle shape, size distribution, surface area, specific gravity, and Rigden's voids. The chemical mechanisms are characterized by the filler chemical composition and the adsorption isotherm using X-Ray diffraction and a spectrophotometer. The results demonstrate that the mastic rheology ranking is consistent with the aggregate affinity to asphalt, which is mica > limestone > granite ~ fused silica. A covariate matrix and factor analysis are also conducted, and three underlying factors are extracted to combine the physical and chemical stiffening effect in asphalt mastic.

Improving the Durability of Asphalt Mixtures with Hydrated Lime: Field Results from Recent French Sections

Didier Lesueur and P. Métais *(1)*; P. Pibis *(2)*; S. El-Bédoui *(3)*; H. Ruat *(4)*; S. Bouron and F. Hammoum *(5)*
(1) Lhoist; (2) Vosges Dept.; (3) Cerema; (4) North-West Road Admin.; (5) IFSTTAR

Although known for a long time, hydrated lime (HL) still attracts a strong technical interest as an asphalt additive. This presentation describes recent field results obtained in France in two different contexts:

- First, we describe the 7-yrs experience obtained on 20 sections with and without HL in the mountainous Vosges department. This eastern part of France is characterized by cold winters and significant elevation, making it a pretty challenging environment for asphalt mixtures. The types of mixtures were essentially semi-dense Asphalt Concrete (French BBSG). The results after 7-yrs of monitoring are described.

- Second, we describe the 5-yrs experience obtained on 5 sections with and without HL in the oceanic climate of Highway A84 in Normandy. The types of mixtures were also semi-dense Asphalt Concrete (French BBSG) and a thorough testing program was established from the beginning. The results after 5-yrs of monitoring are described. As a result, the results allow quantifying the impact of HL in terms of durability improvement.

Laboratory Evaluation of Moisture Damage and Impact of Additivation

Frédéric Delfosse and Justine Vinet *(1)*; Vincent Gaudefroy and Emmanuel Chailleux *(2)*; Everett Crews (3)
(1) Eurovia Management; (2) IFSTTAR; (3) Ingevity

Performance of pavement materials overtime are lowered under mechanical and environmental loadings. Among influent factors, water appears to be one of the major element leading to deterioration of the material cohesion. Numerous tests in the world are available to evaluate moisture damage in laboratory. However, most of them show poor correlation with field performances. A fundamental understanding is still needed to predict and prevent its effects.

Stripping is defined as the debonding of the bitumen on aggregate surface. It could be one of the road pavement materials moisture damage mechanisms in presence of water. An experimental method was used to characterize the stripping kinetic using a model bitumen/aggregate interface.

Additionally, standardized laboratory tests were carried out on loose and compacted mixes. Experimental procedures vary from one to another regarding conditioning process and mechanical loading types. Advantages and limits of these test methods are exposed. Different moisture damage mechanism have been identified using the acquired knowledge from the stripping evaluation on model system.

This work also allow to evaluate the discriminating power of test methods. It allows to select the most relevant one able to evaluate several parameters, in particular the chemical bitumen additivation.

Use of Boil Test to Determine Type and Optimum Antistrip Additive Content for Asphalt Mixtures

Shivpal Yadav, Zahra Tayebali and Akhtarhusein Tayebali *(1)*; Abhilash Kusam *(2);* Andrew LaCroix *(3)*
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Moisture damage in asphalt concrete mixtures has been a major problem for decades. The use of antistrip additives can significantly reduce moisture damage, specifically stripping (loss of adhesive bonds between asphalt and aggregate) in asphalt mixtures. A simple test method to evaluate moisture damage is the boil test (ASTM D3625). The drawback of this test method is that it is a visually subjective test method. However, the boil test results can be quantified with the help of a color measuring device, such as a colorimeter. Percentage Stripping or moisture damage in asphalt mixture can be determined by using a color measuring device after the boil test.

This presentation provides results of boil tests performed on various asphalt mixtures prepared with three different aggregates sources, each with three different antistrip additives with additive content ranging from 0% to 1% by weight of asphalt binder. A color measuring device was used to determine percent stripping. The optimum antistrip additive content for a given asphalt aggregate mixture was determined using relative reduction in percentage stripping. This method is helpful in selecting a more cost-effective antistrip additive and conducting a more effective and efficient quality control testing of plant-produced asphalt mixtures.

Assessment and Implementation of Low Temperature Mixture Cracking Criteria for Iowa

Joyce Wairimu Kamau, Christopher Williams and Joseph Podolsky
Iowa State University

Low temperature cracking is one of the distresses common in northern US climate. It is caused by thermal stress buildup in pavements due to low temperature and often a large sudden drop of temperatures resulting in cracking. This increases the maintenance costs of the pavements and often reduces pavement life. This research assesses the low-temperature cracking resistance of asphalt mixtures used by correlating the laboratory results with field performance. The disk-shaped compact tension (DCT) and semi-circular bend tests (SCB) are used to evaluate mixes. The five mixes have a void ratio average of 6.5% and fracture energy ranging from 240-540kj and depend upon the materials in the mix. Performance criteria for the DCT and SCB tests are provided identifying critical low temperature cracking of asphalt mixtures.

Freezing Damage in Asphalt Paving Mixture Saturated with Water-$CaCl_2$ Solutions

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Ohio University

Freezing and thawing of water in asphalt mixture is one of the main causes for the failures in asphalt pavements. In this paper, the ice expansion pressure of frozen water-$CaCl_2$ solution in an instrumented open metal tube was measured as low as -60C. Expansion of asphalt mixtures that were moisture-conditioned with various saturation and $CaCl_2$ concentration levels was also measured using Ohio CTE Device (OCD). Indirect tensile strength (ITS) was used to measure the level of damage caused by freeze-thaw conditioning.

Freezing of water developed up to 2800 psi pressure in an one inch diameter steel tube with one open end. As the temperature decreased, the ice pressure gradually decreased due to large CTE of ice, reaching zero pressure between -50C and -60C. As $CaCl_2$ concentration increased, the peak pressure drastically reduced, having near zero pressure with 10% $CaCl_2$ concentration. Freezing of 100% moisture saturated asphalt mixture showed up to 600 microstrain expansion. As the saturation level decreased or the $CaCl_2$ concentration increased, the magnitude of OCD expansion decreased, having near zero OCD expansion for the mix with fully saturated with 10% $CaCl_2$ solution. ITS of freeze-thaw conditioned mixes decreased as the saturation level increased or the $CaCl_2$ concentration decreased.

A Contribution to Understanding the Thermo-Mechanical Behavior of Partially Saturated Asphalt Concrete Under Freezing Condition

Ferhat Hammoum, Olivier Chupin, Jean-Michel Piau and Thang Van Vu *(1)*; Didier Lesueur *(2)*
(1) IFSTTAR; (2) Lhoist

Development of potholes occurring in bituminous pavements was observed during winters over short time laps. This led us to seek for a specific mechanism of degradation of asphalt concrete (AC) layers, related to the behavior of partially saturated AC subjected to freeze. Two types of laboratory tests were performed under traction free and restrained strain conditions to study the behavior of AC. These tests showed the development of large swelling strains or stresses induced by the phase change of pore water into ice. Additional tests using Magnetic Resonance Imagery allowed us to visualize this phenomenon in AC. Based on these tests, we developed a thermo-viscoelastic constitutive law including phase change for partially saturated AC. A numerical program was implemented to introduce this law in structural calculations; this program handles the coupling between mechanics and the heat equation, also taking into account the phase change through the latent heat of crystallization of pore water. After validating the software, this numerical tool was utilized to compute the response of bilayer bituminous structures representative of the upper layers. The results obtained show the development of high frost-induced pull-out stresses located at the interface between the layers, likely to explain the formation of potholes.

Binder and Mix Performance Testing for Cracking: The Effect of Aging

John D'Angelo *(1)*; Gaylon Baumgardner, Codrin Daranga, Trey Jordan and Mike Hemsley *(2)*
(1) D'Angelo Consulting; (2) Paragon Technical Services

Cracking has become the predominant distress affecting pavement performance in the US. Over the past several years several new binder cracking properties have been evaluated. These include items like .Tc, Glover-Rowe, Cross-over Temperature, Cross-over Modulus and Rheological Index. In addition to the binder properties several mix tests have been developed to evaluate cracking. This includes testing at both intermediate and low temperature. The most used of these mix tests are the Illinois Flexibility Test, the Texas Overlay test and the Axial Fatigue test. While most of the binder properties are determined on conditioned sample to simulate long term aging the mix tests are typically run on sample that are only conditioned to simulate short term aging.

This study is evaluating the variations in results between the binder and mix properties and recommendations on cracking potential. The criteria for the binder and mix in both the short term and long term aging condition are being evaluated. Comparisons of the short term aged against long term aged properties for both the binder and mix will be evaluated. This will be used to better understand if testing of short term aged mix results can be correlated with binder results.

Use of Void Reducing Asphalt Membrane (VRAM) to Improve the Performance of the HMA Longitudinal Joint

Joyce Wairimu Kamau, Christopher Williams and Joseph Podolsky
Iowa State University

Density and air voids of asphalt affects the durability of asphalt pavement. Longitudinal joints of the pavement do not receive compaction of the same magnitude as that of mat center section for a multitude of reasons and hence have lower density thus higher air voids and can cause water infiltration causing moisture induced damage to the pavement and reducing pavement life. The use of Void Reducing Asphalt Membrane (VRAM) has been recommended and used at longitudinal joints of asphalt pavements as a remedy to achieve higher density and reduce deterioration at the longitudinal joint. The composition is applied below a hot mix asphalt layer, and it migrates into hot mix asphalt to filling 50-70% of the voids. This research is evaluating how it increases density and improves performance. Sections with and without VRAM were constructed for comparisons. Field core were collected and volumetric data were determined and low-temperature fracture testing was done using the disk compact tension (DCT) and semi-circular bend (SCB) tests, and falling head permeability was used. It was found out that the pavement with VRAM will have lower permeability, higher bond energy, and higher fracture energy than the pavement sections without VRAM.

Session 6 - Polymer– and/or Rubber-Modified Asphalts

Faster PMA Processing

Dennis Krivohlavek
ButaChem

Efficiencies in processing SBS can be obtained by lowering SBS melt times and increasing the speed of cross linking SBS into the asphalt. These two goals are achieved by more efficient mixing and utilization of the cross linking agent.

A new rotor blade / stator is designed for use with a top mounted mixer to complete the assembly. This new assembly and design results in lowering SBS melt times of about 10% to 40%, asphalt and SBS characteristics dependent.

Optionally, this new and highly efficient blade / rotor design can be mounted in-line with the stator.
Some PMA plants are built to use cross link agents that are oil dispersions while others use dry materials. For latex emulsions, water dispersions could be preferred. Befitting any method of introduction would be faster, more efficient reaction times for the same cross link agent.

A bonus would be a cross link agent superior in performance, as determined by physical testing, to the most common cross link agents. Sulfur is the most common cross link agent used in PMA production today. This new cross link agent shows fast reaction speed and superior to sulfur in final PMA properties.

Effect of Polymer Concentration, Cross-Linker Concentration, Blending Temperature and Asphalt Binder on Rheological Properties of Highly Concentrated PMA Made with SBS

Sebastian Puchalski and Marsha Thompson
Kraton Polymers

This work evaluates properties of highly concentrated polymer modified asphalt blends made with a styrene-butadiene block copolymer as applicable to PMA concentrate production or high polymer asphalt production. The factors examined in this work include elemental sulfur cross-linker concentration, polymer concentration, processing temperature and base asphalt properties. Effort has been made to understand how the mentioned factors impact key PMA performance parameters such as time to achieve full blend homogeneity or ability to reduce PMA viscosity, while maximizing the elastomeric response as measured with the MSCR test. The work helps identify potentially optimal conditions leading to a reduction of the PMA gelation risk and maximization of the elastomeric performance.

Characterization of Asphalt Reactivity Using Advanced Mass Spectrometry Techniques in Conjunction with NMR and IR Characterization

William Winniford, Hayley Brown, C.J. DuBois, Tony Gies, Junho Jeon, Dan Baugh III, Anna Leal and Praveen Boopalachandran
Dow

Variability in asphalt sourcing and refining procedures results in materials with greatly variable chemical composition, resulting in turn in highly variable performance between asphalts as binders in paving applications. A variety of polymeric systems including Reactive Elastomeric Terpolymers (RET) have been developed to improve physical properties in asphalt, but it is well known that the variation in asphalt composition affects the performance for many types of PMA. The presence of active hydrogen groups i.e. -OH, -SH, -NH contribute to hydrogen bonding and polarity, impacting physical properties such as solubility and mechanical performance and are also important for RET chemical bonding. However, quantitatively measuring the active hydrogen concentration in asphalts is not straightforward, especially with respect to concentration vs molecular weight or carbon number. Advances in mass resolution for high resolution mass spectrometry make it possible to generate even more accurate Kendrick mass defect plots and van Krevelen plots. While these plots give information about heteroatom distribution in asphalts, there is still a need to distinguish between functional groups that are reactive vs non-reactive. NMR and IR give bulk information about the functionality represented in the SARA fractions.

Rheological Properties of Isocyanate Modified Binders: An Assessment of Rutting and Cracking Potential

Pravat Karki, Edith Arámbula Mercado and David Newcomb
Texas A&M Transportation Institute

The demand for modified binders is increasing but the types of additives currently used to produce most modified binders is limited to non-reactive additives. The production of modified binders using reactive additives has been mostly ignored and the industry has not tapped the benefits of such modification due to the lack of research on the rheological properties of such binders. To address this issue, researchers conducted a study focused on assessing rheological properties of the binders modified with non-reactive and reactive additives. Five binders from different sources and with different performance grades were modified with isocyanate, a reactive liquid chemical, and with styrene-butadiene-styrene (SBS), a non-reactive polymer. Then, researchers conducted the Dynamic Shear Rheometer, the Bending Shear Rheometer, the Multiple Stress Creep Recovery and the Glover-Rowe Damage Parameter to capture their rheological properties. Test results showed that binders modified with isocyanate were equivalent to or better than binders modified with SBS in terms of their rutting and cracking potential. The study suggested that isocyanate could be used as a substitute of non-reactive additives in producing modified binders without compromising properties.

Sustainable Polyolefin Performance Additives for the Modification of Asphalt Binder

John Almey
GreenMantra Technologies

Within the asphalt industry, there is significant consideration given to additives that enhance bitumen performance, while more recently, there has also been an increased interest in using sustainable materials. This is creating an opportunity for many new asphalt binder additives. Here we describe the use of performance enhancing specialty polyolefin additives that have been derived from post industrial and post consumer recycled plastic feedstocks to modify asphalt binder for roads.

GreenMantra Technologies collaborated with third party labs to analyze the performance grade of asphalt binders modified with CERANOVUS A115 Polyethylene and A155 Polypropylene additives according to AASHTO M320 and M332. Further experiments were completed to determine the effects of the additives as a partial offset to SBS modified asphalt binder.

Results showed that straight low level addition of the polymer additives improves the stiffness of the binder, raising the upper temperature grades significantly with negligible impact on the lower temperature grade. When offsetting 1/3 of the SBS in a polymer modified binder, the additives maintained the performance grade, while reducing the viscosity by as much as 30%. These results demonstrate the ability of these additives to improve performance, increase the life cycle and enhance the sustainability of roads.

Impact of High-Polymer Modification on Rheological and Chemical Properties of Asphalt Binders

Robert Kluttz *(1)*; Jhony Habbouche *(2)*; Elie Hajj *(3)*
(1) Kraton Polymers; (2) Virginia Transportation Research Council; (3) University of Nevada, Reno

While several previous studies highlighted the positive impacts of high-polymer (HP) modification on the performance of asphalt mixtures, there is still a serious lack of understanding this impact on the oxidative aging of asphalt binders. The main objective of this study is to assess the long-term aging characteristics of conventionally-modified (PMA) and HP asphalt binders in terms of their rheological and chemical properties. An extended asphalt binder aging experiment was generated and considered multiple combinations of PMA and HP asphalt binders from different sources. Long-term oven-aged and acceleratedly PAV-aged asphalt binders at multiple temperatures and multiple durations were evaluated using the dynamic shear rheometer through full master curve characterization. The Fourier Transform Infrared Spectroscopy was used for characterization of chemical functional groups. The results consistently indicated decreases in the hardening susceptibility based upon low shear viscosity and Glover-Rowe evaluations with the HP modification processes, thus indicating an increased resistance to aging from a physical characteristics standpoint. In addition, the potential of polymer degradation was observed to be minimally present with aging, thus indicating an increased longevity from a chemical characteristics standpoint. Overall, the HP modification is expected to be beneficial to the aging resistance and longevity of asphalt binders.

Evaluation of High Polymer Modified Binders to Improve the Durability of Open-Graded Friction Courses

Edith Arámbula-Mercado and Pravat Karki *(1)*; Silvia Caro, Carlos Rivera Torres and Mauricio Sánchez-Silva *(2)*
(1) Texas A&M Transportation Institute; (2) Uniandes

The use of open-graded friction course (OGFC) mixtures is associated with numerous safety and environmental advantages, but the need to have more cost-effective layers with improved durability is still a challenge. Efforts to prevent raveling in this type of mixture have included enhanced material selection procedures, mix design considerations, and identification of suitable project conditions. Recently, the use of high or heavily polymer-modified (HP) binder, which is produced at a polymer dose modification ranging between 6% and 8% by weight of binder, was explored as an option to improve the raveling resistance of OGFC mixtures. The objective of this project was to evaluate whether the use of an HP binder that satisfied the requirements of FDOT specifications yielded more durable OGFC mixtures than those produced with a control PG 76 22 polymer-modified asphalt (PMA), as well as their cost effectiveness. The project included a comprehensive experimental plan at the binder, mastic, and mixture levels, as well as computational mechanics simulations and life-cycle cost analysis (LCCA). The experimental results showed that the HP binders, mastics, and mixtures had improved cracking performance and durability through aging. Numerical modeling and the LCCA suggested that the HP OGFC mixtures were cost effective.

Understanding the Principals of Storage Stability in Ground Tire Rubber Modified Asphalt

Christopher Williams, Brittany Hallmark-Haack, Nacu Hernandez and Eric Cochran
Iowa State University

Ground tire rubber (GTR) is a cost-effective addititive to asphalt that improves the resilience of the road as well as its viscoelastic properties. However, GTR has not been widely utilized due to separation that occurs if not continuously stirred. Previously, the researchers developed a method to stabilize GTR in asphalt (Hallmark-Haack, 2019). This method compounds GTR and a polymer additive by screw extrusion. Preliminary storage stability (ASTM D6930 – 10), softening point (ASTM D 36 – 0), and separation index (measured by G*/sin(d)) have proved that modified GTR is successfully stable in asphalt. The aim of this research is to further characterize interaction between the GTR and polymer in the compounded pellet (such as rheological properties, SEM, and density). GTR and polymer were compounded using a single screw and a double screw extruder in order to additionally observe performance differences caused by extrusion variables. This characterization will increase understanding of how the GTR and polymer interacts with asphalt to improve storage stability.

Long and Short Term Aging in Asphalt Rubber Binders

Hashim Rizvi
University of California Pavement Research Center

The rolling thin film oven (RTFO, AASHTO T 240) test is known to be problematic for asphalt rubber binders due to the limited rolling action of the binder during the test, and consequent poor distribution and inconsistent film thickness of the binder during aging. The free flow of binder in RTFO during the aging process is critical to achieve homogeneous aging, which prerequisites: pretest coating, appropriate temperature, and sufficient binder quantity. Likewise, conventional PAV process does not ensure full coverage of pans and consistent film thickness. Binder rubber separation and inconsistent film thickness (before and after PAV process) were also observed in most pans. Solutions to the aforementioned problems, in short and long term aging processes, were investigated and presented in this study. Increased temperature and binder quantity, and preheating of the bottles were investigated in short term aging process. Whereas, increased binder quantity and pan heating were investigated in long term aging process. Dynamic Shear Rheometer (DSR), Bending Beam Rheometer (BBR) and Fourier Transform Infrared (FTIR) Spectroscopy were used to compare results to select or reject proposed alterations to the standard test methods.

Notes

Notes

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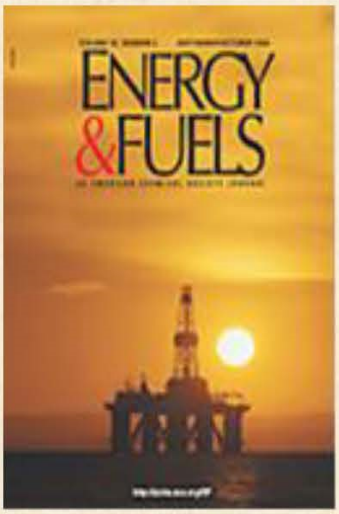

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