55th Petersen Asphalt Research Conference

University of Wyoming
Gateway Center
and
Hilton Garden Inn

Laramie, Wyoming

July 15-18, 2018

www.petersenasphaltconference.org

Presented by Western Research INSTITUTE

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Welcome

Howdy and Bonjour!

Welcome to the 55th Petersen Asphalt Research Conference!
As the PARC conference chairman, it is my immense privilege to offer you the high plains hospitality of Laramie, Wyoming.

In the rapidly changing world of asphalt research, regular sharing of our knowledge and discoveries has become even more important. Scientific inquiry provides answers that have long term impacts on the performance of some of our most vital everyday products, such as roofs and highways.

Advances in crude oil production, extraction processes, use of modifiers and increased rates of recycling drive us to new approaches. The development of relevant models, analytical tools and test methods has become the key to ensuring a consistently high quality of asphalt materials. Solutions are directed toward finding cost effective answers with a lower impact on the environment. These changes are challenging but also serve as triggers for innovation.

As THE widely recognized forum for new ideas in asphalt, PARC has always been particularly interested in the presentation of research in progress. Professional interaction furthers this research and offers fresh perspectives to both presenters and conference participants.

Founded by Dr. Claine Petersen, the primary focus for this conference has always been "Chemistry matters". In this spirit, you are invited to participate in these themes: Asphalt Binder Chemistry and Analysis, Asphalt Material Physical Evaluation, Asphalt Modification and Recycling. Chemistry-related papers at this year's conference and in future years will be offered to authors to be published in Energy and Fuels.

This inquisitive approach has led to a record number of 2018 presentations from around the world, representing a wide cross-section of asphalt stakeholders. Together for a few days, we have a unique opportunity as international colleagues to explore both fundamental and cutting edge asphalt research. In this setting, we look for innovative and applicable solutions to our most difficult real world problems.

As always in Wyoming, visitors experience the friendly western hospitality. Home to the University of Wyoming, Laramie enjoys an atmosphere of curiosity and a quest for increased knowledge. Surrounded by majestic mountains at the eastern edge of the Rockies, you are in a rare and beautiful location. Nearby adventures await you in every direction. I encourage you to take advantage of activities organized for you during the conference, or strike out on your own.

Whether you traveled from the next town or the farthest continent, you'll have a great time at the PARC. Thank you for attending, and be sure to offer your thanks to all our sponsors and exhibitors.

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

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- Solids Mix testing for Research, Fatigue, and Accumulated Strain
- Emulsion stability, particle sizing, and viscosity profiling
- 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...

Thank You to Our 2018 PARC Exhibitors

Please visit their booths in the lobby of the Gateway Center

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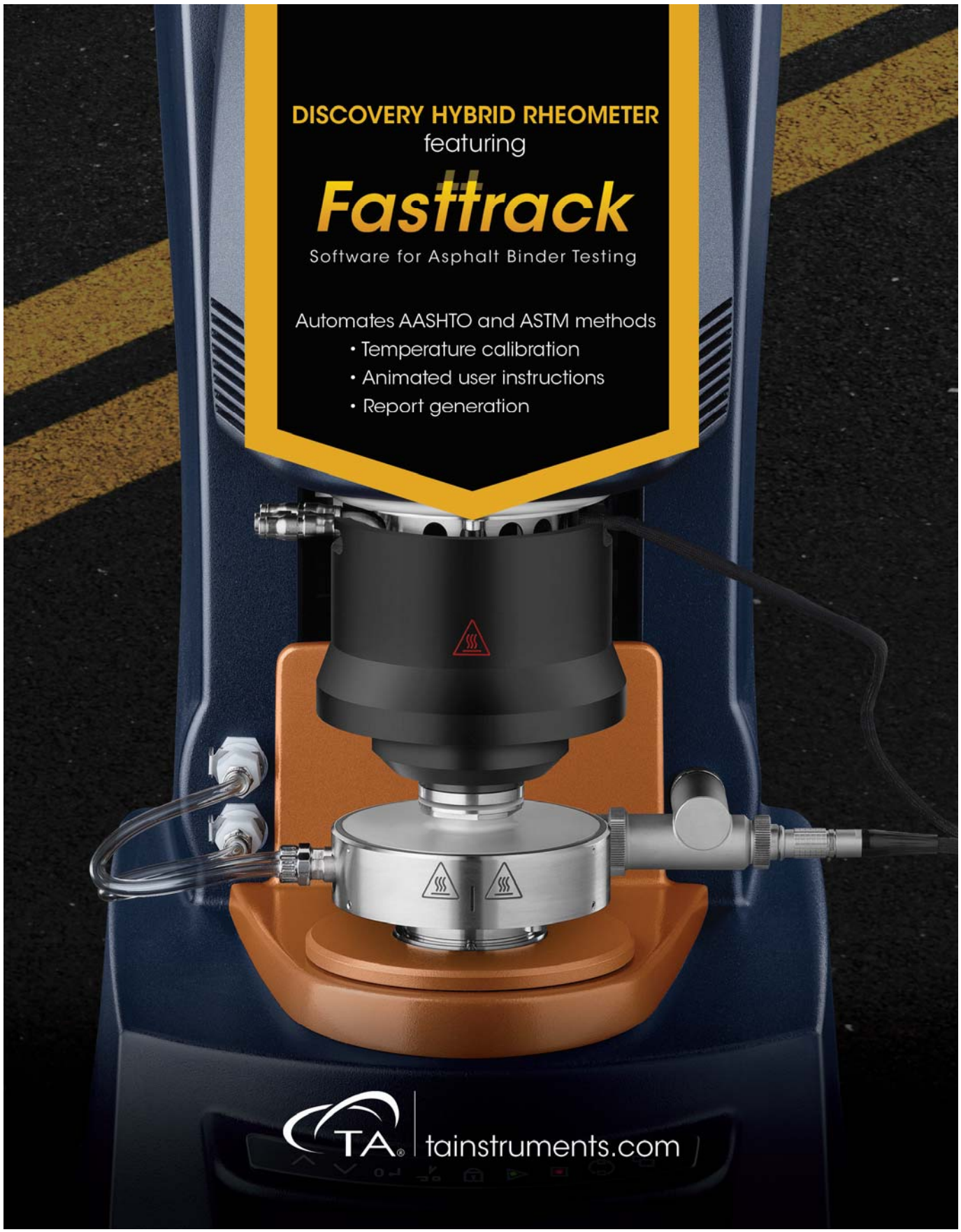
The Association of Modified Asphalt Producers

Full page advertisements included in this program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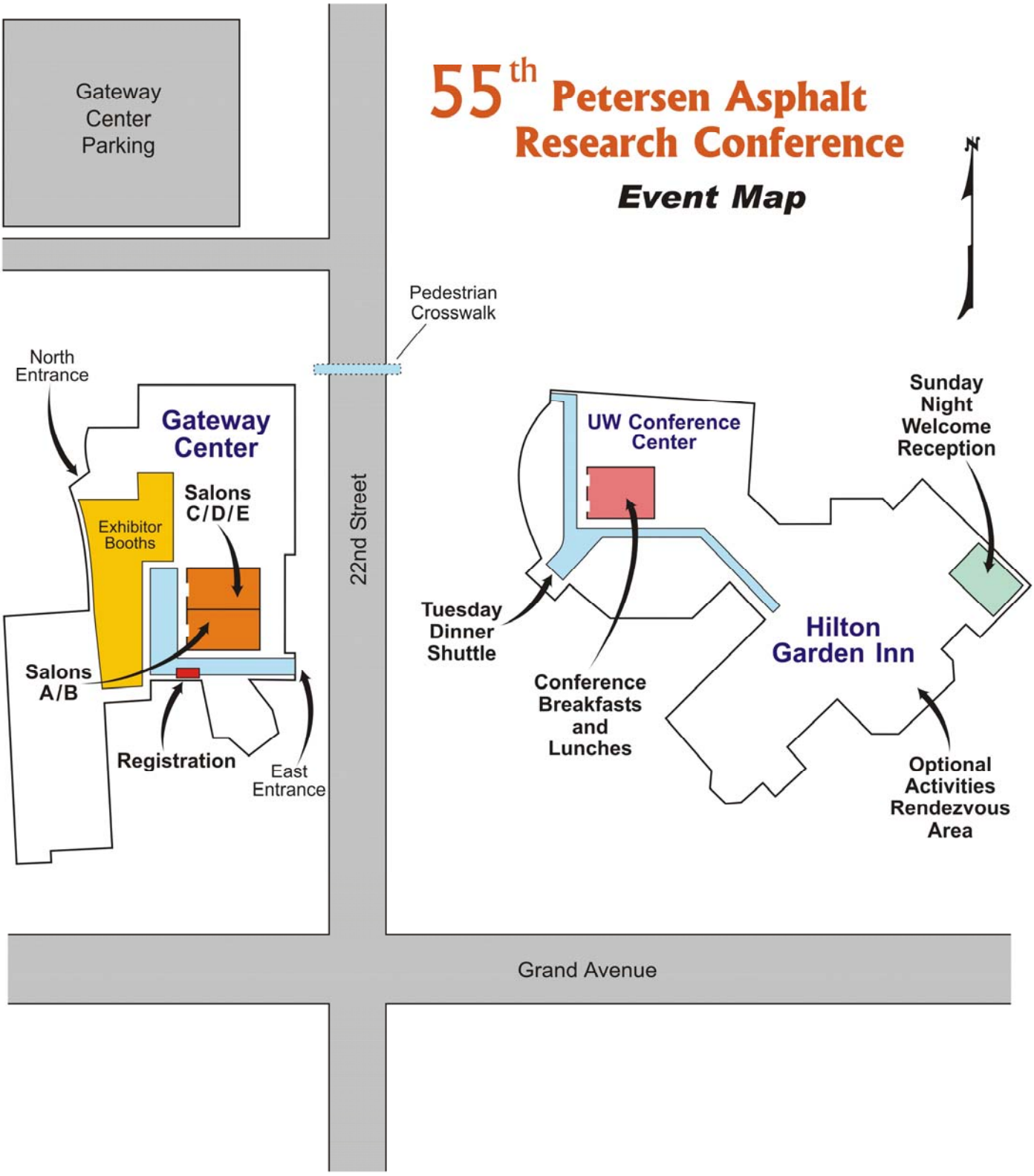
55th Petersen Asphalt Research Conference

Event Map



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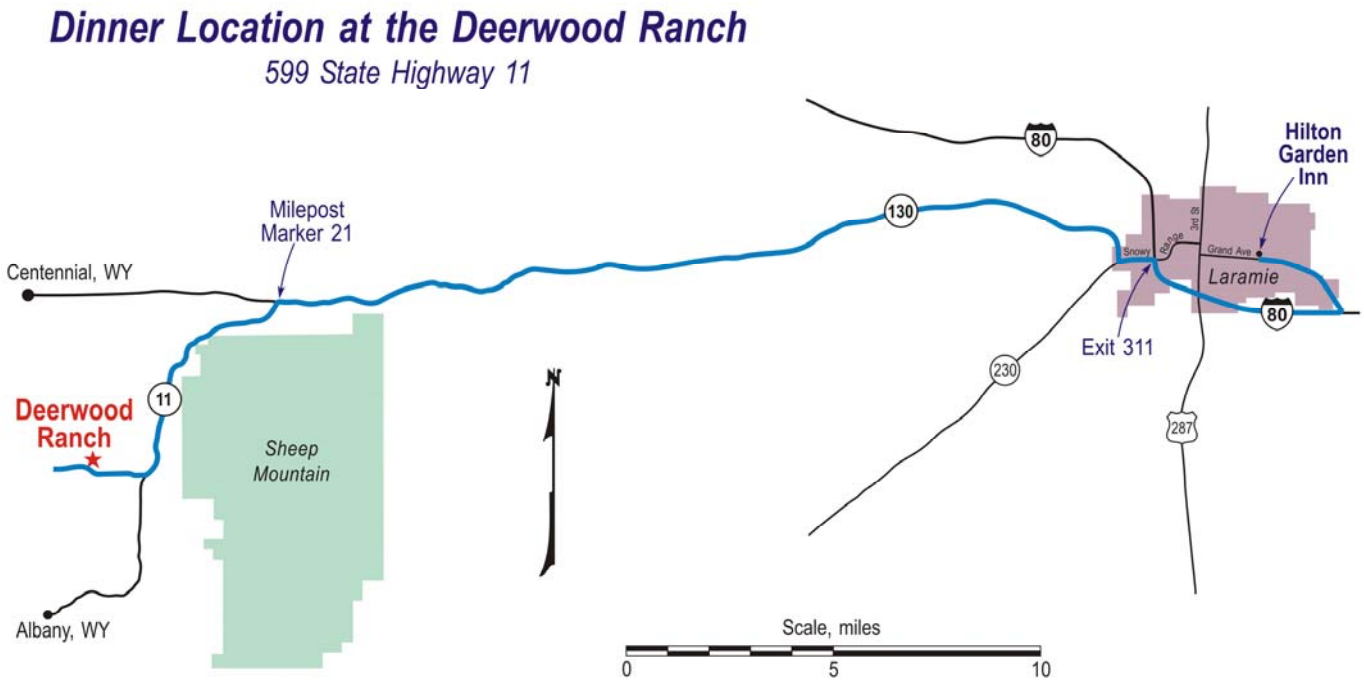
Conference Dinner

Tuesday Evening - July 17, 2018

Deerwood Ranch & Wild Horse Eco Sanctuary
599 State Hwy 11 Laramie, WY 82070

Nestled between Sheep Mountain and the town of Centennial in the Snowy Range mountains is Deerwood Ranch, the very first BLM Certified Wild Horse Eco Sanctuary. It is a family owned operation that has been an active cattle ranch for 30 years. And now, it is a place where the landowners are also taking care of the wild horses that roam the area, and you are invited to share it with the horses for an evening.

With plenty of amenities, the ranch will provide an evening for you to remember. In the spirit of the "Wyoming West", participants and guests will enjoy hayride tours to visit the wild horses currently at the sanctuary, followed by a cash bar cocktail hour. After a cowboy dinner of brisket, chicken and all the fixins, you may never want to leave. Plan to sit back, stay awhile, and enjoy the beautiful sunset over the mountains.



Directions to Deerwood Ranch from Hilton Garden Inn

- From Hilton Garden Inn travel east on Grand Avenue 2.3 miles to Interstate 80
- West on Interstate 80 towards Rawlins, WY approx. 5 miles to Exit 311 (Snowy Range Road)
- Left on Snowy Range Road and travel west 0.8 miles to State Highway 130
- Right on Highway 130 towards Centennial, WY and travel west approx. 21 miles to Highway 11
- Left on Highway 11 towards Albany, WY approx. 6 miles to Deerwood Ranch Road
- Right on Deerwood Ranch Road approx 1.5 miles to Deerwood Ranch


20th AMAP ANNIVERSARY
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or visit our website www.modifiedasphalt.org

Conference Agenda

Sunday, July 15

6:00 p.m.	Welcome Reception *(Pick up conference materials for preregistered participants only)*	Hilton Garden Inn

Monday, July 16

7:00-8:00 a.m.	***Breakfast - UW Conference Center at Hilton Garden Inn***	
7:30 a.m.	Registration *(Pick up conference materials)*	University of Wyoming Gateway Center
8:00-8:30	Welcome and Opening Remarks **Salons A / B**	Jean-Pascal Planche and Joe Rovani *Western Research Institute*
8:30-9:00	The Strategic Asphalt Research (STAR) Symposium: Outcome and Path Forward **Salons A / B**	Steve Buckner *Flint Hills Resources*

Session 1 - Asphalt Binder Chemistry - Analysis

Salons A / B

Session Chair: Ryan Boysen, Lead Scientist, Western Research Institute

9:00-9:30	Diagnostic Techniques for Various Refining Processes, Waxes and Modifiers	Michael Elwardany, Jeramie Adams and Jean-Pascal Planche *Western Research Institute*
9:30-10:00	REOB Detection with Handheld X-ray Fluorescence Instrument	Fujie Zhou and Pravat Karki *Texas A&M Transportation Institute*
10:00-10:30	***Break***	

Monday, July 16 (Continued)

10:30-11:00	Asphaltenes: Characterisation of Asphaltenes Formed on Ageing	Dawid D'Melo and Rohit Gupta *Shell India Markets Ltd.* Richard Taylor *Shell International Petroleum Co.*
11:00-11:30	Use of Ion-Mobility-Mass Spectrometry Comparisons to Evaluate Binder Aging	Ashley Buss, Nacu Hernandez and Eric Cochran *Iowa State University* Andrew Hanz and Mary Ryan *Mathy Construction*
11:30-12:00	Comparison of Chemical and Microstructural Properties of Virgin and RAP Binders and Their SARA Fractions	Peter Mikhailenko and Hassan Baaj *University of Waterloo, Canada*
12:00-12:30	SAR-AD Innovations and Next-Gen Developments	Jeramie Adams, Joe Rovani, Ryan Boysen and Jean-Pascal Planche *Western Research Institute*

12:30-1:30 ***Lunch - UW Conference Center at Hilton Garden Inn***

1:30-5:00 ***Parallel Sessions***

Session 2 - Asphalt Material Physical Evaluation - Binder Testing
Salons A / B

Session 3 - Asphalt Modification
Salons C / D / E

Monday, July 16 (Continued)

Session 2 - Asphalt Material Physical Evaluation - Binder Testing

Salons A / B

Session Chair: Amir Golalipour, Ph.D., Project Engineer, FHWA/ESC Inc.

1:30-2:00	Utah Replaces the Direct Tension Test with the ΔT_{cr} Parameter	Howard Anderson *Utah Dept. of Transportation* Raj Dongre *Dongre Laboratory Services* Jack Youtcheff *Federal Highway Administration*
2:00-2:30	Specifying PAV Pan Levelness and Warpage	David Anderson and Saman Barzegari *Penn State University*
2:30-3:00	Recent Findings Affecting Results AASHTO T 302, Standard Test Method for Polymer Content of Polymer Modified Asphalt	Ken Grzybowski *PRI Asphalt Technologies* Gaylon Baumgardner *Ergon* Robert Kluttz *Kraton Polymers*
3:00-3:30	***Break***	
3:30-4:00	Evaluation of MSCR Jnr diff Determination and Effects on Performance	John D'Angelo *D'Angelo Consulting* Gaylon Baumgardner, Trey Jordan, Codrin Daranga and Mike Hemsley *Paragon Technical Services*
4:00-4:30	Measuring the Yield Stress of Asphalt Binders and Emulsion Residue	David Anderson, Noah Wakeman and Saman Barzegari *Penn State University*
4:30-5:00	Fatigue and Healing Performance of Neat and Modified Asphalt Binders	Chao Wang and Wei Xie *Beijing University of Technology*

Monday, July 16 (Continued)

Session 3 - Asphalt Modification

Salons C / D / E

Session Chair: Ramil Mercado, Asphalt Technology Manager, Research & Development, GAF

1:30-2:00	Recent Advances in the Modification of Asphalt Mixtures with Hydrated Lime	Didier Lesueur *Lhoist, France*
2:00-2:30	Use of TPU as Bitumen Modifier: Compatibility and Morphology Relationship	Raïssa Gallu, Françoise Mechin and Jean-François Gerard *INSA Lyon* Florent Dalmas and Laurent Chazeau *Matéis* Frédéric Loup, François Olard and Florent Schrevel *Eiffage* Rémi Perrin, Christine Robach, Audrey Arnaud and Stéphanie Laurichesse *Soprema*
2:30-3:00	Use of Agent to Increase Efficiency of Styrene-Butadiene-Styrene Block Copolymers in Asphalt Modification	Austin Hohmann, Conglin Chen, Nacu Herandez, Chris Williams and Eric Cochran *Iowa State University*
3:00-3:30	***Break***	
3:30-4:00	New Effective Cross-Linking Agent for Polymer Modified Asphalt (PMA)	Mohammed Memon *Capital Resin Corporation*
4:00-4:30	Trans-octanamer (TOR) in Road Construction - Make Good Things Better	Frank Lindner *Evonik Resource Efficiency GmbH* Ankur Kant *Evonik Corporation*
4:30-5:00	FTIR Characterized Diffusion of Molecular Species within Asphalt Films that are Semi-Submerged in Water	Mathew Peavy, Nibert Saltibus and Darren Williams *Sam Houston State University*

Tuesday, July 17

7:00-8:00 a.m. ***Breakfast - UW Conference Center at Hilton Garden Inn***

Session 2 - Asphalt Material Physical Evaluation - Binder Testing (Continued)

Salons A / B

Session Chair: Pavel Kriz, Americas Asphalt Technical Leader, Imperial Oil (ExxonMobil)

8:00-8:30	A Simple Test Method for Asphalt Binder Fatigue Specification	Raj Dongre *Dongre Lab Services* Adrian Andriescu *SES Group & Associates* Jack Youtcheff *Federal Highway Administration*
8:30-9:00	Study to Evaluate ΔT_c Cracking Criteria and the Relation Between Binder Low Temp and Environmental Temperatures	John D'Angelo *D'Angelo Consulting* Gaylon Baumgardner, Trey Jordan, Codrin Daranga and Mike Hemsley *Paragon Technical Services*
9:00-9:30	Obtaining Creep Compliance from Flexural Strength Test on Asphalt Binders	Tianhao Yan, Mugurel Turos and Mihai Marasteanu *University of Minnesota* Dave Van Deusen *Minnesota Department of Transportation*
9:30-10:00	Developing Suitable Test Procedure for Testing GTR-Modified Asphalt Binder	Amir Golalipour *Engineering & Software Consultants* David Mensching and Matthew Corrigan *Federal Highway Administration*

10:00-10:30 ***Break***

Tuesday, July 17

7:00-8:00 a.m. ***Breakfast - UW Conference Center at Hilton Garden Inn***

Session 3 - Asphalt Modification (Continued)

Salons C / D / E

Session Chair: Lorena Garcia Cucalon, Asphalt Research Scientist, TAMKO Building Products

8:00-8:30	Effects of Different Modifiers and REOB on the ΔT_c of PG Binders	Alejandro Rosales and Huachun Zhai *Idaho Asphalt Supply* Brody Young *Peak Asphalt*
8:30-9:00	RET-based Polymer Modifiers for Concentrates and Fast Blending	C.J. DuBois *E. I. du Pont de Nemours and Co.* Hayley Brown, Jong-Young Lee and Cristina Serrat *The Dow Chemical Company*
9:00-9:30	Impact of Various Crumb Rubber Modifications on Asphalt Binder and Mixture Properties	William Daly, Sreelatha Balamurugan and Ioan Negulescu *Louisiana State University* Louay Mohammad, Samuel Cooper III and Samuel Cooper Jr. *Louisiana Transportation Research Center, LSU* Gaylon Baumgardner *Paragon Technical Services*
9:30-10:00	Ground Tire Rubber Modification for Decreased Asphalt Separation	Nacu Hernandez, Brittany Hallmark, Chris Williams and Eric Cochran *Iowa State University*

10:00-10:30 ***Break***

Tuesday, July 17 (Continued)

10:30-5:00 ***Parallel Sessions***

Session 4 - Asphalt Material Physical Evaluation - Mixture and Pavement
Salons A / B

Session 5 - Asphalt Recycling
Salons C / D / E

Session 4 - Asphalt Material Physical Evaluation - Mixture and Pavement

Salons A / B
Session Chair: Pavel Kriz, Americas Asphalt Technical Leader, Imperial Oil (ExxonMobil)

10:30-11:00	Factors Affecting Coefficient of Thermal Expansion (CTE) and Low Temperature Cracking Performance of Asphalt Mixture	Sang Soo Kim *Ohio University* Moses Akentuna *Louisiana State University*
11:00-11:30	Tailoring a New Laboratory Methodology for Stripping Resistance Evaluation of Asphalt Materials	Justine Vinet *Eurovia Management, IFSTTAR* Vincent Gaudefroy and Emmanuel Chailleux *IFSTTAR* Frédéric Delfosse *Eurovia Management* Everett Crews *Ingevity Corporation*
11:30-12:00	A Simple Test for Quality Control of RAP Piles	Raj Dongre *Dongre Laboratory Services* Sean (Xinjun) Li and Adrian Andriescu *SES Group & Associates* Jack Youtcheff *Federal Highway Administration*

12:00-1:00 ***Lunch - UW Conference Center at Hilton Garden Inn***

Tuesday, July 17 (Continued)

Session 5 - Asphalt Recycling

Salons C / D / E

Session Chair: Lorena Garcia Cucalon, Asphalt Research Scientist, TAMKO Building Products

10:30-11:00	Investigation of High RAP/RAS Binder Performance	Amir Golalipour and Chuck Paugh *Engineering & Software Consultants* David Mensching *Federal Highway Administration*
11:00-11:30	Changes in the Chemical Composition of Virgin Asphalt and RAP Extracted Binder Used for a High Volume High RAP Mix Design Due to the Addition of a Soybean Derived Chemical Additive	Joseph Podolsky, Barrie Saw, Zahra Sotoodeh-Nia, Nacu Hernandez, Benjamin Empric, Fang-Yi Lin, R. Christopher Williams and Eric Cochran *Iowa State University*
11:30-12:00	Recycling Between 40 and 70% of Mixes: From Laboratory Testing to the MURE National Project Demonstrators	Jean-Eric Poirier *Colas* Simon Pouget *Eiffage* Ivan Drouadaine and Stephané Faucon-Dumont *Eurovia Management* Cédric Sauzéat, Hervé Di Benedetto and Alvaro Pedraza *Ecole Nationale des Travaux Publics de l'Etat* Virginie Mouillet, Cerema DeTerMEd and Brice Delaporte *IREX* Vincent Gaudefroy and Sabine Vassaux *IFSTTAR*
12:00-1:00	***Lunch - UW Conference Center at Hilton Garden Inn***	

Tuesday, July 17 (Continued)

Session 4 - Asphalt Material Physical Evaluation - Mixture and Pavement (Continued)

Salons A / B

Session Chair: Mike Anderson, Director of Research and Laboratory Services, Asphalt Institute

1:00-1:30	Evaluation of Binder and Mix Properties of High RAP Mix with Soft Asphalt Binder	John D'Angelo *D'Angelo Consulting* Brett Lambden *Husky Energy* Raj Dongre *Dongre Laboratory Services*
1:30-2:00	Moving Towards a Performance-Related Specification for Asphalt Pavement	David Mensching and Richard Duval *Federal Highway Administration*
2:00-2:30	A Study on Practicality and Variability of Semi Circular Beam (SCB) Test	Faramarz Safazadeh, Pedro Romero, Abu Sufian Mohammad Asib and Shauling Bao *University of Utah*
2:30-3:00	Accurate Modeling and Optimization of Permanent Deformation in Asphalt Pavement via the Application of Principal Component Analysis	Parnian Ghasemi, Derrick Rollins and R. Christopher Williams *Iowa State University* Mohamad Aslani *Florida State University*
3:00-3:30	***Break***	

Tuesday, July 17 (Continued)

Session 5 - Asphalt Recycling (Continued)

Salons C / D / E

Session Chair: Dr. Julia Faeth, Advanced Engineer R&D, Owens Corning

1:00-1:30	High RAP Recycling (50%) Facilitated with Bio Material Addition as Part of BioRePavation Project: Test Sections, Field Sampling and Lab Results	Ryan Boysen and Jean-Pascal Planche *Western Research Institute* Emmanuel Chailleux, Erika Bessmann and Juliette Blanca *IFSTTAR* Laurent Porot *Kraton Polymers* R. Christopher Williams and Zahra Sootoodeh-Nia *Iowa State University* Simone Pouget and Françoise Olard *Eiffage* Davide Lo Presti and Ana Jimenez del Barco Carrion *University of Nottingham*
1:30-2:00	Toward the Development of Performance-Related Specification for Bio-Rejuvenators	Fujie Zhou and Pravat Karki *Texas A&M Transportation Institute*
2:00-2:30	Thermal Properties of Rejuvenators and Their Impact on the Low Temperature Performance of Rejuvenated Binders	Mohamed Elkashef, David Jones and John Harvey *University of California, Davis* R. Christopher Williams *Iowa State University*
2:30-3:00	Production of a Cold Mix Using 100% of Milled Material (R.A.P.) with Cold Rejuvenator	Barry Nunez *Infratest* Lorenzo Sangalli *Greenpave Technology*
3:00-3:30	***Break***	

Tuesday, July 17 (Continued)

Session 4 - Asphalt Material Physical Evaluation - Mixture and Pavement (Continued)

Salons A / B

3:30-4:00	An Electrical Resistance Measurement for Moisture Content Evaluation in Asphalt Emulsion Applications	Miguel Montoya and John Haddock *Purdue University*
4:00-4:30	Use of Artificial Intelligence in the Asphalt Industry	Raj Dongre *Dongre Laboratory Services*
4:30-5:00	Post-Production Asphalt Mix Performance Testing in Ontario	Seyed Tabib, Imran Bashir and Pamela Marks *Ministry of Transportation of Ontario*

Tuesday Evening Dinner

Deerwood Ranch

6:00 Social Hour (Cash Bar)

7:00 Dinner

Shuttles Leave at 5:30 p.m. from
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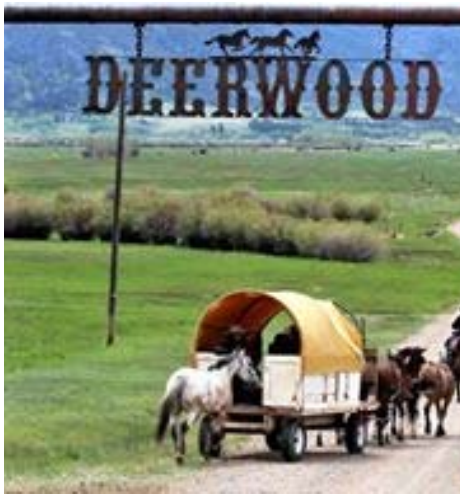


For more information and map with directions to Deerwood Ranch see Page 3 of program

Tuesday, July 17 (Continued)

Session 5 - Asphalt Recycling (Continued)

Salons C / D / E

3:30-4:00	Performance-Engineered Mix Design Methodology for Rejuvenated High-Recycled HMA	Hassan Tabatabaee and Tony Sylvester *Cargill Industrial Specialties*
4:00-4:30	Impact of Silo Storage Time on Blending Between RAP and Virgin Binders in High RAP Content Asphalt Mixes	Payman Pirzadeh, Pavel Kriz and Daniel Grant *Imperial Oil* Hawraa Kadhim, Peter Mikhailenko and Hassan Baaj *University of Waterloo, Canada*
4:30-5:00	Effect of RAP and Aging on Low Temperature Performance of Asphalt Materials	Abu Sufian Mohammad Asib, Pedro Romero and Faramarz Safazadeh *University of Utah*

Tuesday Evening Dinner

Deerwood Ranch

6:00 Social Hour (Cash Bar)

7:00 Dinner

Shuttles Leave at 5:30 p.m. from
UW Conference Center at Hilton Garden Inn

For more information and map with directions to Deerwood Ranch, see Page 3 of program

Wednesday, July 18

7:00-8:00 a.m. ***Breakfast - UW Conference Center at Hilton Garden Inn***

Session 6 - Asphalt Binder Chemistry - Aging

Salons A / B

Session Chair: Jean-Eric Poirier, Senior Scientist, Colas

8:00-8:30	Effect of Oxidation on Stripping Potential of Binder-Aggregate Interfaces	Alejandra Baldi, José Aguiar-Moya and Luis Loría-Salazar *Lanamme, University of Costa Rica*
8:30-9:00	Investigation of Aging Evolution at the Surface of Asphalt Binder Specimen Using a Novel Aging Procedure and AFM Micromechanical Characterization	Meng Xu *Harbon Institute of Technology/ University of Minnesota* Junyan Yi, Zhongshi Pei and Decheng Feng *Harbon Institute of Technology* Mihai Marasteanu *University of Minnesota*
9:00-9:30	Investigation of the Effect of Aging Temperatures on Rheological Properties of Asphalt Binder Based on BBR and AFM	Ashley Buss *Iowa State University* Augusto Cannone Falchetto, Di Wang and Chiara Riccardi *Technische Universität, Braunschweig, Germany*
9:30-10:00	Oxidative and Thermoreversible Aging Effects on Performance-Based Rheological Properties of Six Latin American Asphalt Binders	Alejandra Baldi-Sevilla, José Aguiar-Moya and Luis Loría-Salazar *Lanamme, University of Costa Rica* Max Berkowitz, Matthew Filipovich and Simon Hesp *Queens University*

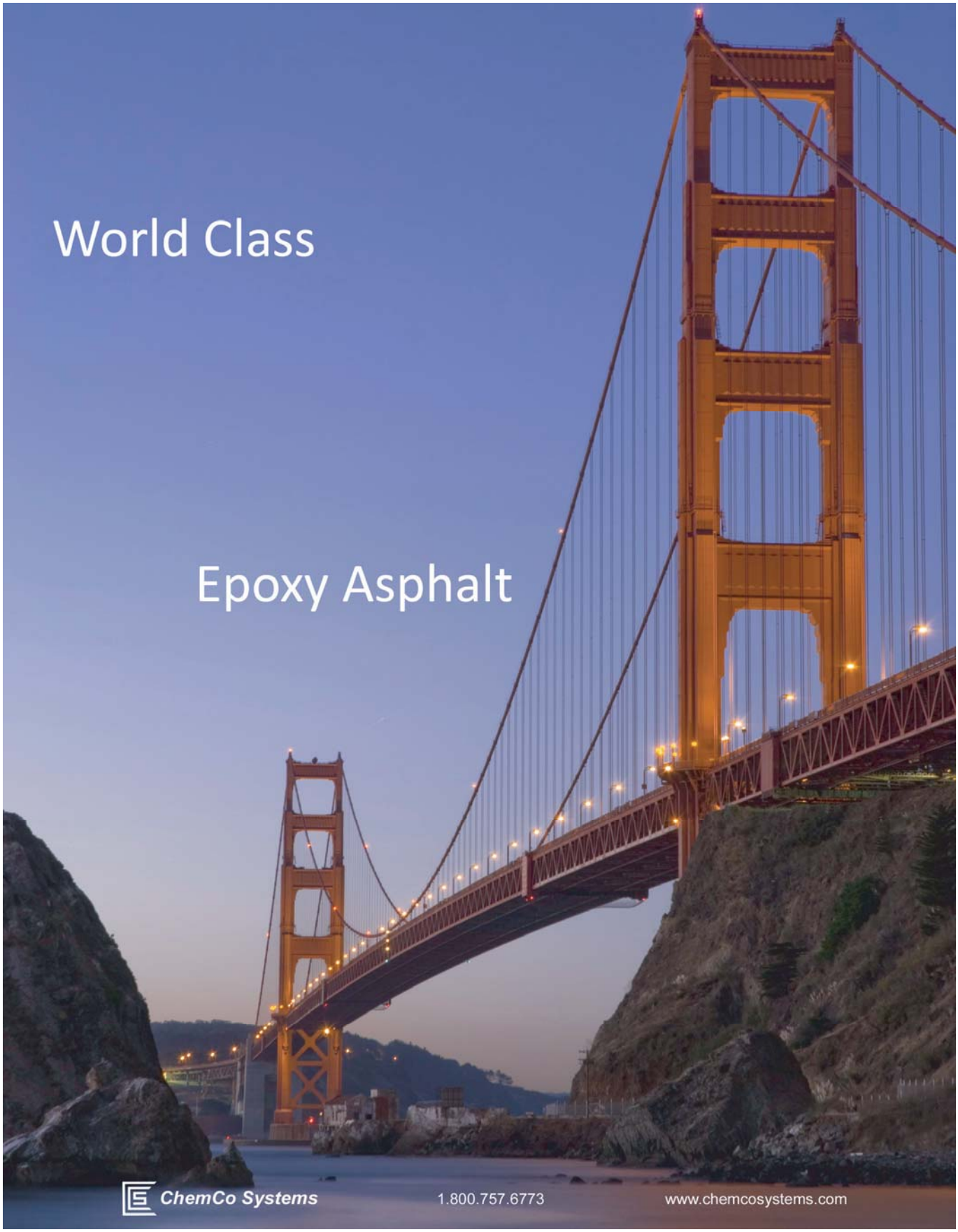
10:00-10:30 ***Break***

Wednesday, July 18 (Continued)

Session 6 - Asphalt Binder Chemistry - Aging (Continued)

Salons A / B

10:30-11:00	Kinetic Study on Laboratory and Field Oxidation of Asphalt	Alejandra Baldi, José Aguiar-Moya and Luis Loría-Salazar *Lanamme, University of Costa Rica*
11:00-11:30	Effect of Aggregates Petrology on the Age Hardening of Asphalt Cement	Hassan Baaj, Yashar Azimi Alamdary and Sarbjot Singh *University of Waterloo, Canada*
11:30-12:00	Microstructure and Chemical Analysis of Asphalt Binders Aged in the Presence of Moisture	Ilaria Menapace, Wubulikasimu Yiming and Eyad Masad *Texas A&M University at Qatar*
12:00-12:10	***Closing Remarks***	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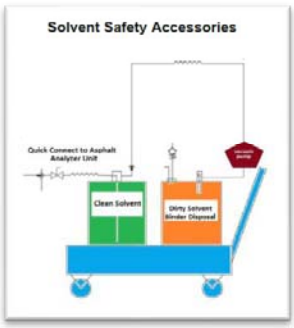
DOTs and construction materials laboratories across the country are embracing a safer, more productive and accurate way to perform solvent extractions. The InfraTest *Asphalt Analyzer™* provides an automated and enclosed method of performing solvent extractions to verify asphalt content on bituminous mixture, and rubber-modified bituminous mixtures.

Since 1997, the infraTest's Asphalt Analyzer has been extensively used throughout Europe for the extraction and determination of binder content, including rubber-modified bituminous mixtures, using non-flammable solvents like trichloroethylene. This is the only allowed extraction method in most of Europe due to very rigorous chlorinated solvent use restrictions. InfraTest's new ground tire rubber model, Rubber Analyzer, is equipped with a second solvent circuit allowing for the extraction of rubber particles in modified asphalt mixtures. For the first time, contractors, DOTs and researchers are able to accurately quantify the amount of rubber within the mix.

HOW ACCURATE ARE INFRATEST ASPHALT ANALYZER ASPHALT CONTENT TEST RESULTS?

A recently published Wisconsin Highway Research Program (WHRP)[1] study on asphalt extraction methods found that the automated solvent extraction method using infraTest Asphalt Analyzer "has the lowest standard deviations, of all of the test procedures evaluated, for tests conducted within a lab and between labs". Other test procedures evaluated included ignition oven, centrifuge and reflux methods. While Iowa DOT also evaluated the performance of the Asphalt Analyzer against other extraction methods. The report published by the Iowa DOT[2].



"Evaluation of the infraTest Asphalt Analyzer for Performing Extractions on Recycled Asphalt Materials" acknowledges, "Two advantages of the Asphalt Analyzer were the reduced technician time needed to complete the extraction and the reduced time from the start of the test to obtaining the final test results. The T164 test took from 2.5 to 3 hours per extraction where the technician was constantly adding solvent or transferring solvent to the second centrifuge to filter the fines. Afterwards the aggregate was washed over the #200 sieve and then dried. The Asphalt Analyzer process saved overall about 1.5 hours of staff time per extraction. With the Asphalt Analyzer, the unit was loaded and left to do the cleaning and filtering while the technician was free to perform other tasks. The unit dried the sample and at that point the sample was ready for gradation, absorption, and specific gravity testing. The Asphalt Analyzer procedure allowed for quicker turnaround of test results. A Risk Assessment showed that the Asphalt Analyzer scored in the low risk range since the Analyzer reduced the time and volume of solution needed while running the test, providing further exposure risk reduction. It is concluded that the machine can provide superior **risk controls, leading to improved health and safety conditions.**"

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Session 1 - Asphalt Binder Chemistry - Analysis

Diagnostic Techniques for Various Refining Processes, Waxes and Modifiers

Michael Elwardany, Jeramie Adams and Jean-Pascal Planche
Western Research Institute

The way of producing asphalt binder has significantly changed since the SHRP Superpave days due to a number of economic, technical, and environmental reasons. The oil world has changed, refining has had to adapt and so have the asphalt suppliers. More blends of crude oils and refining streams, more additives from various origins are being used, and even more are under development. Considering asphalt as a straight run vacuum residue made out of a single crude is now the exception. Most of the aforementioned changes can enhance binder properties when they are designed and controlled well. However, some of these changes trigger concerns about the quality and consistency of the delivered asphalt binder, especially as current specifications appear insufficient to ensure satisfactory field performance of the end products.
Asphalt Industry Research Consortium was launched in 2015 to help the eight industry partners who positively responded, perform chemo-mechanical characterization of 52 binders. The utilized diagnostic techniques include, but are not limited to, chemical/compositional characterization: SAR-ADTM, FT-IR, and Waxphaltene Determinator, microstructural evaluation: GPC/SEC, rheological investigation: Black Space plots, and thermal analysis: DSC. Results demonstrated that multiple diagnostic techniques were instrumental to detect various refining processes, different types of waxes and binder modifiers.

REOB Detection with Handheld X-ray Fluorescence Instrument

Fujie Zhou and Pravat Karki
Texas A&M Transportation Institute

Re-refined engine oil bottom (REOB) has been used to modify asphalt binders for a long time. Recent studies revealed that pavements constructed with REOB-modified binders cracked much faster than those constructed with binders containing no REOB. Therefore, some state transportation agencies enforced a complete ban while others set an upper limit in its use. To implement these measures, there is a need of a well-verified, cost friendly test method to estimate REOB contents in binders. This paper presents a simple method that fulfills this objective. The method involves the measurement of element concentrations in an unknown sample using a handheld X-ray fluorescence (XRF) instrument, the identification of the most likely sources of this sample using normalized sulfur-versus-vanadium concentration plot, and the estimation of REOB content in the sample using the calibration curves of zinc, calcium and molybdenum elements. Researchers developed and verified this method using 384 calibration and 24 verification samples. Test results show the proposed method can quantify REOB content in binders with reasonable accuracy. Test results also show that this portable XRF-based REOB estimation method is as effective as a benchtop XRF-based method.

Asphaltenes: Characterisation of Asphaltenes Formed on Ageing

Dawid D'Melo and Rohit Gupta *(1)*; Richard Taylor *(2)*
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The impact of asphaltenes and asphaltene chemistry, reflected by the various sub-fractions in the asphaltene determinator, on bitumen properties has been investigated and discussed previously. It is known that asphaltenes are formed during chemical ageing of bitumen. These asphaltenes formed on chemical ageing were characterised with respect to chemical composition, solubility based on asphaltene determinator and molecular ordering. It was seen that the newly formed asphaltenes are more aliphatic and contain higher concentrations of heteroatoms, compared to asphaltenes already present in the bitumen. The newly formed asphaltenes do not form as well defined structures as those already present in the bitumen, possibly, due to the higher aliphatic nature of the molecules. The investigations of the chemistry and behaviour of asphaltenes formed on chemical ageing are important as they will contribute to the behaviour of bitumen in pavements. A deeper insights into the compositional and behavioural changes of the bitumen will allow for a fit for purpose bitumen to be supplied for pavements.

Use of Ion-Mobility-Mass Spectrometry Comparisons to Evaluate Binder Aging

Ashley Buss, Nacu Hernandez and Eric Cochran *(1);* Andrew Hanz and Mary Ryan *(2)*
(1) Iowa State University; (2) Mathy Construction

Advances in ion mobility-mass spectrometry (IM-MS) have made MS analysis a viable tool for chemical characterization of "everyday" complex fluids. Testing can be performed efficiently with higher repetitions and the use of software has streamlined comparison between samples. In this study, two binders (PG 64-22 and a PG 58-28 with 25% recovered shingles) were tested in a Waters Synapt G2 IM-MS with an atmospheric solids analysis probe at five aging states: original binder, rolling thin film oven-aged, 20-hour pressure aging vessel (PAV), 40-hour PAV, and 60-hour PAV aged. From IM-MS testing, each sample's mass to charge ratio and drift time spectra were developed. The spectra at each aging state was compared to map the changes in the asphalt sample as a function of drift time and molecular weight. Observations show molecular weight changes continue to happen in the PG 64-22 binder at each stage in the aging process; indicating molecular weight changes continue to occur in the sample after 20, 40 and 60 hours of PAV aging. In contrast, the PG 58-28 binder with 25% recycled shingles binder shows almost no additional molecular weight changes or ion drift changes in the spectra after only 20 hours of PAV aging.

Comparison of Chemical and Microstructural Properties of Virgin and RAP Binders and Their SARA Fractions

Peter Mikhailenko and Hassan Baaj
University of Waterloo, Canada

The chemical properties and microstructural features of two straight run virgin asphalt binders (PG 52-34 and 58-28), a RAP binder as well as their corresponding SARA fractions were examined. The chemical properties were examined using Fourier Transform Infrared Spectrometry (FTIR-ATR). The RAP binder showed a Significant increase in the indices of the carbonyl (IC=O) and sulfoxide (IS=O) functional groups compared to the virgin binders. Examining the corresponding SARA fractions revealed that the increases in the carbonyl index of RAP relative to the virgin binders were mainly found in the resins and asphaltene fractions, while the increase in sulfoxide index is mainly found in the asphaltenes fraction. The microstructural features of the binders were examined using Environmental Scanning Electron Microscopy (ESEM). The fibril microstructure of the virgin binders was found to be relatively sparse. On the other hand, this microstructure was not visible in the RAP binder, possibly due to the severity of the aging. The ESEM observation of the resins and naphthene aromatics fractions did not reveal a fibril microstructure as it did in the binders.

SAR-AD Innovations and Next-Gen Developments

Jeramie Adams, Joe Rovani, Ryan Boysen and Jean-Pascal Planche
Western Research Institute

Model compounds can be used to identify molecular classes of compounds in the SAR-AD separation. Key molecular features of model compounds cause molecules to report to the different chromatographic saturates, aromatics and resins fractions. The saturates fraction is shown to contain saturated hydrocarbons ranging from linear to cyclic species containing several naphthenic rings; the advanced aromatics separation produces three different fractions which are based upon the number of fused aromatic rings; and the resins fraction contains a variety of molecules which are highly influenced by heteroatoms and the different types of functional groups for the different heteroatoms. As with most things with petroleum, these fractions are not necessarily 100% clean cut points. For example, the size, geometry, and location of aliphatic side chains can result in steric hindrance causing molecules to report to different fractions. Similarly, different types of functional groups, within a heteroatom class, can change where the molecules will report.
Current developmental activities directed at a second-generation SAR-AD will also be introduced in this presentation. Methodology innovations including multi-dimensional separations and advanced detection techniques are presently being explored as next-generation SAR-AD platforms.

Session 2 - Asphalt Material Physical Evaluation - Binder Testing

Utah Replaces the Direct Tension Test with the ΔT_{cr} Parameter

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When implementing the PG grading system, UDOT included the DTT test, which was developed by SHRP. Utah is the only state that explicitly requires failure strength (4 MPa) and failure strain (1.5%) as part of the PG binder specification. After more than a decade of experience with the DTT, engineers have observed that thermal cracking is substantially reduced for UDOT HMA projects.
Although UDOT is satisfied with the DTT specification, the existing test equipment is no longer being supported by the original manufacturer (Instron) due to lack of demand for the procedure. Alternative equipment is also not available at a reasonable cost. To address this issue UDOT along with the request of UAPA (Utah Asphalt Pavement Association) decided to eliminate the DTT test and replace it with the newly developed ΔT_{cr} requirement, 20 hour PAV. UDOT met with each of its binder suppliers to discuss its intention. The use of a 40 hour PAV was viewed as unacceptable because it delayed test results too much for the industry. UDOT suppliers supported the ΔT_{cr} concept with an adjustment to the Elastic Recovery (ER) specification that fit UDOT data. All of the supplier were asked to test their binders and provide a proposed spec limit that would meet their materials. We came up with a minimum -1.0 value with a compliance limit of -2.0 before penalties applied. These values have been consistent with six months of test results from our Central Lab, using the additional BBR test at 6^{o}C colder.
The UDOT binder database containing PG grade verification data as well as DTT data was analyzed to determine the impact of eliminating the DTT. UDOT engineers wanted to make sure that as a result of eliminating the DTT the binder quality (source and formulations) remained unchanged. In addition to the data from UDOT, results from a comprehensive study of BBR data from more that 20 State DOTs conducted by the research team at TFHRC (FHWA) was also studied.
ΔT_{cr} values were estimated for the historical data and it was found that ΔT_{cr} alone may not be enough to guarantee continuation of existing binder supply. Data analysis showed that if a limit is also placed on the minimum S(60) value of BBR creep stiffness, DTT may be eliminated without causing significant thermal cracking problems. The new UDOT Binder specification is now being implemented. The criteria requires a bottom limit on S(60) of 150 MPa and a top limit on S(60) of 300 MPa in addition to the ΔT_{cr} (min. -1.0 degree) and ER (80% for UTI below 98 and 85% for UTI of 98). During our implementation period, one year, we will allow the contractor to dispute test results using the previous specification.

Specifying PAV Pan Levelness and Warpage

David Anderson and Saman Barzegari
Penn State University

Changes in the rheological properties that occur in an asphalt binder during a Pressure Aging Vessel (PAV) conditioning cycle depend upon the nature of the binder, the pressure and temperature inside the vessel, the conditioning time, and the uniformity and average thickness of the binder film. Thickness variations in the binder film can be affected by the levelness of the supports upon which the PAV pans are placed, the design of the supports, and the flatness of the PAV pans. There is no well-accepted procedure for verifying the levelness of the supports upon which the PAV pans are placed or the flatness of the pans, both of which can cause variations in the thickness of the binder film. Further, there is no well-accepted tolerance limits for pan flatness or levelness of the pan supports. These issues are addressed by the experiment plan followed in this study. The results of the extensive round robin for PAV residue measured by five laboratories using different pans supports and degrees of support levelness is reported and compared to values predicted from profiles of the pans and the non-linear variation of the properties with film thickness. Recommendations for specifying pan warpage and support levelness are given.

Recent Findings Affecting Results AASHTO T 302, Standard Test Method for Polymer Content of Polymer Modified Asphalt

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Review of the polymer modified asphalt binders used for HMA and the determination of SBS content by AASHTO T 302. Polymer modified asphalt produced today routinely use co-modifiers, crosslinking and extender technologies. The use of these technologies can affect the accurate determination of the SBS content using the current T 302 test method. Unless the PMA's formulas are known in advance, and proper calibration curves are developed, the polymer content determined by T 302 may not reflect the actual content. These results may impact specification compliance and subsequent acceptance or rejection. The current test method requires updating and refinement to provide accurate results with today's PMA formulations.

Evaluation of MSCR Jnr diff Determination and Effects on Performance

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

The Multi Stress Creep and Recovery (MSCR) test is being implemented by many highway agencies. The MSCR test includes an evaluation of the change in compliance Jnr between low stress level and higher stress level 0.1kPa and 3.2kPa Jnr diff. This criterion was included to determine if the binder may be overly sensitive to stress. With implementation of the specification there have been issues with binders using soft base asphalt and higher polymer contents showing high stress sensitivity which causes specification failure.
This study has two phases. The first is to evaluate alternate criteria for evaluation of stress sensitivity. Alternate low stress levels were evaluated to determine where the deviation from the linear range were evaluated to reduce the issue with very small compliance values. The second is to evaluate stress sensitivity and mixture performance. Binders with different polymer formulations were developed to provide various Jnr diff values and internal structures which were used in an asphalt mix to determine rutting potential.

Measuring the Yield Stress of Asphalt Binders and Emulsion Residue

David Anderson, Noah Wakeman and Saman Barzegari
Penn State University

Very little research has been conducted on the yield stress of asphalt binders and emulsion residue. Work performed by the research team shows that the yield stress of these materials at the upper range of service temperatures is a function of both time and temperature. Measured values of yield stress for these materials may be very small and difficult to measure and the measured values are dependent upon the method of measurement. For a material to have a true yield stress it must have an infinite viscosity of zero shear stress. A variety of different methods are used by rheologists to measure yield stress of rheological materials including: model fitting of dynamic viscosity data, stress growth, analysis of stress or strain ramps, oscillatory amplitude sweeps, multiple sweep tests, and incremental sweeps. Measurements on a series of asphalt binders and asphalt emulsions to include polymer modified binders and high float emulsions are presented and compared.

Fatigue and Healing Performance of Neat and Modified Asphalt Binders

Chao Wang and Wei Xie
Beijing University of Technology

The objectives of this paper are to estimate the fatigue and healing characteristics of asphalt binder by newly developed linear amplitude sweep (LAS) and LAS-based Healing (LASH) protocols. Three neat asphalt binders (Pen-30, Pen-50 and Pen-70) with distinguished penetration grades and one more SBS modified binder are selected for this study. Experimental results indicate that the SBS binder has advanced fatigue resistance among all tested binders and the softer neat binder with a higher penetration grade generally displays a relatively better fatigue performance. The fatigue failure occurrence is a significant threshold for healing potential comparison. The rate of healing results demonstrate the best healing potential of Pen-70 binder in pre-failure conditions followed by the SBS binder, Pen-50 and Pen-30 binders, however, the SBS binder presents better healing performance than Pen-70 binder in post-failure condition. The combined use of LAS and LASH tests is recommended for effectively distinguish and design the fatigue-healing performance of neat and modified asphalt binders.

A Simple Test Method for Asphalt Binder Fatigue Specification

Raj Dongre *(1)*; Adrian Andriescu *(2)*; Jack Youtcheff *(3)*
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The contribution of asphalt binder properties to fatigue behavior of hot-mix asphalt pavements is a subject of current research (e.g. NCHRP 9-59 and 9-60). New tests and parameters are being proposed to determine the impact of asphalt binder characteristics to fatigue distress in pavements. The research team at TFHRC is evaluating creep and recovery characteristics of asphalt binders using the DSR test to address this distress. Two test protocols conducted at 25°C are being evaluated. The first, called Multiple Time Creep Recovery (MTCR) characterizes the time dependent behavior of asphalt binders. In MTCR a set of four loading and recovery times are used at a single stress level. The second protocol called the Multiple Stress Creep Recovery is used to determine non-linearity or stress dependence of the viscoelastic properties of asphalt binder. In MSCR a set of four stress levels are used at a single loading and recovery time.
A total of 24 asphalt binders with known fatigue performance were selected for this study. MTCR and MSCR tests were performed on unaged, RTFO and PAV aged conditions for all binders tested. Traditional G* and phase angle data was also measured at 25°C for all binders. Preliminary results suggest that asphalt binders are not stress dependent under the test conditions of MSCR in this study. So MSCR testing may not be necessary for fatigue characterization. The MTCR data for binders, however, shows differences in linear viscoelastic properties at 25°C.
In this presentation, the results from these two approaches to asphalt binder fatigue testing will be discussed. Implications of not finding stress dependence will also be examined. Based on data analysis from this study a strawman specification criterion for binders will be proposed to estimate the contribution of binder properties towards fatigue distress in hot-mix pavements.

Study to Evaluate ΔT_c Cracking Criteria and the Relation Between Binder Low Temp and Environmental Temperatures

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

While there has been good correlation with ΔT_c and pavement cracking each of these limited sections were in climates where the binder low temperature grade was close to the actual climate temperature. One question to be address is if the binder low temperature grade is below the climate temperature is there some strength reserve in the binder because it is actually used in a warmer climate.
A second question is if polymer in the binder will mitigate some of the cracking potential of the binder even with less ideal ΔT_c values. This experimental plan is intended to provide some insights into these questions. The study used 6 binders, 4 polymer modified and 2 neat. The neat binders had good and poor ΔT_c values and were used as the base for the polymer modified binders at 2 polymer levels. The binders were used in an asphalt mixture to evaluate cracking potential. Extensive mixture and binder testing was conducted to determine differences in the cracking potential of the various binders and mixes at different temperatures.

Obtaining Creep Compliance from Flexural Strength Test on Asphalt Binders

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Good resistance to low-temperature cracking is a critical requirement for asphalt binders. In order to investigate low-temperature behavior of asphalt binders, two test methods were developed during the Strategic Highway Program (SHRP): the Bending Beam Rheometer (BBR) and the Direct Tension Test (DTT). Many agencies use only the results of the BBR creep test to grade asphalt binders due to the high cost of the DTT instrument and complex sample preparation. The research group at University of Minnesota has recently developed a BBR strength test to obtain failure properties, similar to DTT. Through experimental work performed on a set of binders, it is demonstrated that the failure properties of binders with similar creep stiffness and m-values can be significantly different. Using linear viscoelasticity concepts, it is shown that creep compliance results can be used to predict stress-strain curves obtained in the strength test. It is also shown that by performing strength test at a reduced loading rate, it is possible to predict creep compliance and therefore, obtain creep stiffness and m-value.

Developing Suitable Test Procedure for Testing GTR-Modified Asphalt Binder

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(1) Engineering & Software Consultants; (2) Federal Highway Administration

Increasing traffic demands on asphalt pavements in recent decades has led to the evaluation, development, and use of a wide range of modifiers which enhance the performance of the base asphalt binder and consequently the pavement. One modifier used historically is ground tire rubber (GTR). Recently this material regained significant attention due to economic and environmental influences, new usage methods, and newly improved material evaluation methods.
This study addresses some of the primary topics of discussion about GTR-modified binder usage and evaluation methods. Introducing new GTR materials with larger particles and higher percentages have brought concerns about suitable test methods to characterize these materials. Detailed binder testing has indicated that current Superpave test methods are inadequate to capture rheological behavior of GTR-modified binders. Due to presence of large particles in binder, there could be an interaction of the modifier particles with the testing plates which has significant effects on test results. Therefore, this study focuses on the evaluation of concentric cylindric geometry usage for testing field and laboratory prepared GTR-modified asphalt. Different steps taken in developing the new testing procedure are discussed as well as information regarding implementation process for concentric cylinder testing geometry.

Session 3 - Asphalt Modification

Recent Advances in the Modification of Asphalt Mixtures with Hydrated Lime

Didier Lesueur
Lhoist, France

Although known for a long time, hydrated lime (HL) still attracts a strong technical interest as an asphalt additive. This presentation reviews the current knowledge on the topic, illustrating first its 3 main functionalities: (1) reducing moisture damage, (2) slowing down binder aging and (3) stiffening the mastic more than other mineral fillers above room temperature. Our current understanding of the physico-chemical origins of these effects are described, highlighting the relevant properties of the HL for each of these functionalities. In addition, gaps in knowledge are discussed in the light of recent results, covering (1) the resistance of mixes to freeze-thaw damage, (2) a simple test methods to assess binder aging in the presence of fillers and (3) the role of the filler on the mechanical properties of corresponding asphalt mixtures.

Use of TPU as Bitumen Modifier: Compatibility and Morphology Relationship

Raïssa Gallu, Françoise Mechin and Jean-François Gerard *(1)*; Florent Dalmas and Laurent Chazeau *(2)*; Frédéric Loup, François Olard and Florent Schrevel *(3)*; Rémi Perrin, Christine Robach, Audrey Arnaud and Stéphanie Laurichesse
(1) INSA Lyon; (2) Matéis; (3) Eiffage; (4) Soprema

Styrene-butadiene-styrene (SBS) block copolymers are currently used in bitumen modification for road pavements and waterproofing membranes, because of their good compatibility with bitumen. Nevertheless, these polymers show weak resistances to ultraviolet (UV) light, and therefore give poor aging resistance to the bitumen materials. To overcome this drawbacks, thermoplastic polyurethanes (TPU) are used in the present study because of their good durability and better resistance to UV light compared to SBS. Furthermore, the modular structure of the polyurethane polymers can allow screening a wide range of chemical structures for the TPU and studying their compatibility with the bitumen matrix. This study aims to find a relationship between polymer microstructure and compatibility mechanism with bitumen by means of solubility, multi-scale microstructure and thermo-mechanical properties using rheology and microscopy analyses.
To do so, we studied the influence of TPU content in the binder, as well as the amount of hard blocks or nature of the blocks. The phase inversion where the bituminous continuous matrix change to a polymer rich continuous phase occurs close to 13wt% polymer. Increasing hard blocks amount in the TPU leads to binders with various mechanical properties.

Use of Agent to Increase Efficiency of Styrene-Butadiene-Styrene Block Copolymers in Asphalt Modification

Austin Hohmann, Conglin Chen, Nacu Herandez, R. Chris Williams and Eric Cochran
Iowa State University

Over the past century various products have saturated the asphalt marketplace due to their potential to bring binder enhancements and economic opportunities. Currently, one of the most commonly used materials in the asphalt modification industry are Styrene - Butadiene - Styrene (SBS) block copolymers. SBS polymers, a type of thermoplastic elastomer, help increase the asphalt s performance grade and aid in the elastic recovery of asphalt binders. To help with the increasing costs and price volatility of SBS materials, we have developed an agent that when blended into the asphalt, decreases the amount of polymer needed while maintaining the rheological properties of the modified asphalt. Additionally, this agent has the versatility of being blended with the binder at lower temperature reducing operational costs.

New Effective Cross-Linking Agent for Polymer Modified Asphalt (PMA)

Mohammed Memon
Capital Resin Corporation

A New Cross-Linking Agent was developed to make PMA using asphalt obtained from high, medium and low sulfur crude oil. Use of this new Cross-Linking Agent showed storage stable PMA, improved elasticity (MSCR), using AASHTO T-350 and PG Plus properties. The Elasticity so obtained with this new cross-linking system was between 91-95% for a PMA having PG-76-22 and or PG-76-28. Stability/separation was confirmed through AASHTO PP5-93 as well as, fluorescent microscopic technique, the separation with different asphalts showing between 2.5-4.5%. The Fluorescent Microscope showed that proper networking had been achieved and there is no more butadiene double bond of Styrene Buta-Diene Styrene (SBS) was left over. A new carrier type of system containing aliphatic hydroline (non-carcinogen material) was used to carry this new cross-linking system for the interaction between asphalt and polymer (SBS) molecule. This kind of innovative cross-linking system is going through the Friedel-Craft type reaction and also the reaction between the SBS with the asphalt molecule. This cross-linking agent has trace amount of catalyst and is acting as a bridge between SBS and asphalt molecule. The main reason for achieving this high elasticity by MSCR is due to proper networking between asphalt and SBS molecule.

Trans-octanamer (TOR) in Road Construction - Make Good Things Better

Frank Lindner *(1)*; Ankur Kant *(2)*
(1) Evonik Resource Efficiency GmbH; (2) Evonik Corporation

VESTENAMER trans-polyoctenamer (TOR) has an over 30 years of track-record as a processing additive in the Asphalt industry. TOR helps reduce stickness, improve rutting resistance, and reduce cracks. In addition, use of TOR helps improve storage stability and pumpability of rubberized asphalt. This paper explores positive impact of TOR on the mixing and the processing of rubberized asphalt-binder and hot-mix asphalt. The speech addresses to all participants who would like to run a state-of-the-art performance in asphalt products with an easy processing, competitive costs, in a sense of a circular economy.

FTIR Characterized Diffusion of Molecular Species within Asphalt Films that are Semi Submerged in Water

Mathew Peavy, Nibert Saltibus and Darren Williams
Sam Houston State University

The incompatibility between asphalt and water is well known, but the changes to asphalt induced by water may not nearly as well be understood. Using FTIR spectroscopy, the diffusion of molecular species through asphalt may be traced. Eleven PG 64-22 asphalt samples were semi-submerged one inch in deionized water in sealed containers for 2 to 32 days. The samples were then sectioned from the top to bottom and left to right in an approximate 4mm by 4mm diagonal grip. The samples from the grid were analyzed with an attenuated total reflectance attachment on an FTIR spectrometer at 4 wave number resolution. The resulting spectra were compared intra-sample from top to bottom and by sub-sample location to other aged samples. Preliminary analysis indicates a relative concentration decrease in aromatic ketones and ethers, as sampling moved toward the air/water interface section of a sample from the top and bottom. There was also an increase in relative concentration of aromatic ketones and ethers as the samples were aged. It is unclear if these changes in relative concentration are the result of chemical reactions induced by aging or are caused by diffusion within the asphalt. Additional analysis of the asphalt samples is needed to conclusively determine the cause.

Effects of Different Modifiers and REOB on the ΔT_c of PG Binders

Alejandro Rosales and Huachun Zhai *(1)*; Brody Young *(2)*
(1) Idaho Asphalt Supply; (2) Peak Asphalt

To understand the effect of different modifiers on the ΔT_c value of asphalt binders and determine the effect of REOB on the ΔT_c values, three different modifiers (SBS, Polyethylene and PPA) were used to modify PG58-28 with different dosages of REOB (0, 3 and 8%). Three different percentages of modifiers were also selected (0%, low and high). The final modified asphalt binders were aged at two different PAV conditions (20 hrs and 40 hrs). ΔT_c values were determined based on the BBR results at different temperatures of these aged binders. To understand the relationship between ΔT_c and the cracking resistance, ductility at 15°C were also tested at different conditions to correlate with the ΔT_c values.

RET-based Polymer Modifiers for Concentrates and Fast Blending

C.J. DuBois *(1)*; Hayley Brown, Jong-Young Lee and Cristina Serrat *(2)*
(1) E. I. du Pont de Nemours and Co.; (2) The Dow Chemical Company

A new class of Reactive Elastomeric Terpolymers (RET) has been developed for applications in polymer modified asphalt (PMA). This technology addresses preparation of PMA concentrates, which upon letdown and treatment with polyphosphoric acid (PPA) or other co-reactant can meet various Performance and Multi-Stress Creep Recovery Grades. Incorporation speed of the polymer into the asphalt, evolution of properties over the course of the RET chemical cross-linking reaction with the asphalt matrix, and preliminary testing information will also be discussed.

Impact of Various Crumb Rubber Modifications on Asphalt Binder and Mixture Properties

William Daly, Sreelatha Balamurugan and Ioan Negulescu *(1)*; Louay Mohammad, Samuel Cooper III and Samuel Cooper Jr. *(2)*; Gaylon Baumgardner (3)
(1) Louisiana State University; (2) Louisiana Transportation Research Center; (3) Paragon Technical Services

Blending virgin asphalt binder with ambient or cryogenic ground crumb rubbers along with additional modifiers to produce sustainable asphalt mixtures was studied. The modifiers evaluated include E-rubber (free flowing rubber pellets), SBS, sulfur, and R-polymer (reactive polymer polyolefin blend coated micronized rubber particle). Thermogravimetric analysis was used to determine the natural rubber to synthetic rubber ratio in the ground tire rubbers. The impact of 170°C and 190°C blending temperatures on the properties of the modified asphalt binders was determined. Gel Permeation Chromatography (GPC) was used to investigate changes occurring in the asphalt binder on blending with rubber/modifier. All of the binder blends were evaluated using MSCR and standard SHRP rheometer testing. Mixtures prepared from modified binders were characterized using Semi Circular Bend (SCB) at intermediate temperature and Hamburg wheel tracking (LWT) tests. Addition of elastomeric high molecular weight polymer additives improved MSCR test results of binder blends. The presence of high molecular weight elastomeric species in asphalt binder blends appears necessary to obtain acceptable intermediate temperature cracking performance. Presence of crumb rubber in asphalt binder contributed to the increase in percent high molecular weight species that provided an enhanced mixture rut resistance.

Ground Tire Rubber Modification for Decreased Asphalt Separation

Nacu Hernandez, Brittany Hallmark, R. Chris Williams and Eric Cochran
Iowa State University

Asphalt covers 94% of paved roads in the US, many improvements have been made to increase its durability and viscoelastic performance, for example: addition of styrene-butadiene based polymers, addition of ground tire rubber, etc. The addition of ground tire rubber (GTR) has proven to be a cost-effective way to improve the resilience of the road as well as its viscoelastic properties. However, it has not been widely adopted as it has a higher density when compared to asphalt (1.1 gm/cm^3 vs 1.03 gm/cm^3), causing it to settle to the bottom of the asphalt mix if not continuously stirred. We have developed a method to modify the density of the GTR before it is mixed in the asphalt, thus mitigating the settling of GTR particles in the asphalt mixture. Preliminary Storage Stability (ASTM D6930 – 10) and Softening Point (Ring-and-Ball Apparatus) (ASTM D 36-0) results have shown less than 0.5^{o}C difference between the top and the bottom sections.

Session 4 - Asphalt Material Physical Evaluation - Mixture and Pavement

Factors Affecting Coefficient of Thermal Expansion (CTE) and Low Temperature Cracking Performance of Asphalt Mixture

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While rheological and strength/fracture properties of asphalt binder are generally considered to have a major influence on the low temperature performance of asphalt mixtures, other factors and mixture properties also contribute to the low temperature cracking phenomena. Various asphalt mixtures were prepared in the laboratory using Superpave gyratory compactor to determine the effects of binder content, compaction effort, aggregate coefficients of thermal expansion/contraction (CTE), aggregate size, use of recycled materials, mixture aging, and mixture type on mixture CTE and the low temperature performance of asphalt mixture. CTE and the low temperature performance of each mixture were determined using the Ohio asphalt mixture CTE device and the Asphalt Concrete Cracking Device (ACCD), respectively. Test results showed that compaction effort, aggregate CTE, aggregate size, use of recycled materials, mixture aging, mixture type were all found to have a significant effect on asphalt mixture CTE and low temperature performance of asphalt mixtures. For dense graded asphalt mixture, the coarse aggregate fraction had significantly larger effects on the mixture CTE and the ACCD cracking temperature than the fine aggregate fraction. Binder content, however, did not show significant effects on the low temperature performance.

Tailoring a New Laboratory Methodology for Stripping Resistance Evaluation of Asphalt Materials

Justine Vinet *(1)*; Vincent Gaudefroy and Emmanuel Chailleux *(2)*; Frédéric Delfosse *(3)*; Everett Crews *(4)*
(1)Eurovia Management, IFSTTAR; (2) IFSTTAR; (3) Eurovia Management; (4) Ingevity Corporation

Moisture damage induces loss of bond between asphalt and aggregate. This stripping effect still needed to be fully understood to enable paving technologists to improve moisture resistance. In the present multi-scale study, influence of key parameters on the stripping kinetics is assessed. At the first fundamental scale, a time-lapse image analysis method was developed to quantify the dewetting kinetics. This method is based on the observation of precisely applied bitumen droplets on highly polished aggregates during immersion in water. The surface areas of the receding bitumen droplets for different bitumen-aggregate pairs are measured and used to rank materials. Results of this fundamental analyses are compared to the second scale standardized test results (rolling bottle tests) and to the third scale standardized test results (lab-compacted paving mixtures). Results highlighted the influence of water temperature during immersion on dewetting kinetic. For each scale, different families are identified according to their resistance to moisture damage. Classifications are similar between time-lapse method and rolling bottle test but are not correlated with those of tests on compacted sample. Differences can be attributed to the nature of the stress applied (time, loading type) that could mobilize (or not) the bond according to the scale studied.

A Simple Test for Quality Control of RAP Piles

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

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 is then evaluated to assess the consistency and quality of the RAP pile. The use of solvents needed to extract binder from RAP are now being restricted due to environmental and health concerns. FHWA is looking for an alternative to chemical extraction. The research team at Turner Fairbanks Highway Research Center (TFHRC) is evaluating the Dongre Workability Test (DWT) as a potential characterization tool for RAP. The DWT RAP QA Test is being developed to implement a quick and easy test that may be used by State DOT's and paving contractors to assess the quality of RAP available in a RAP pile. The variability of the RAP in the pile may also be measured using this test. Previous work on DWT development for hot-mix asphalt has shown the potential of the DWT test and the DWT value determined from that test to be used as a QA index. The ultimate outcome of present study is to produce a new DWT test protocol and parameter that may be used to assess RAP quality and variability in a Pile.

In this study, RAP obtained from five States were tested. These RAP samples represent the softest RAP (PG 70-22) to hardest RAP (PG 90-22 and higher) and in between. For example, RAP from Idaho and Washington State will represent soft RAPs and those from Arizona and Nevada may provide some of the hardest RAP available. DWT tests were conducted on these RAP samples at the current test rate of 0.05 mm/min at 4 temperatures. Data to date shows that the DWT test method in its current format may be successfully used to characterize RAP quality and RAP pile consistency. It was also found that the variability of DWT test results (as determined by testing two replicates per test condition) may also be an indicator of RAP quality and consistency.

In this presentation, the results of the RAP quality assessment study using the DWT test will be discussed. The RAP Quality Index parameter will allow the user to estimate the amount of RAP that may be safe to use in a given hot-mix without affecting field performance.

Evaluation of Binder and Mix Properties of High RAP Mix with Soft Asphalt Binder

John D'Angelo *(1)*; Brett Lambden *(2)*; Raj Dongre *(3)*
(1) D'Angelo Consulting; (2) Husky Energy; (3) Dongre Laboratory Services

In an effort to be more environmentally friendly many highway agencies and contractors are looking for ways to increase the amount of Recycled Asphalt Pavement (RAP) they can use in production of new asphalt mix. High quality softer asphalt binder is ideally suited to address the needs of the highway agencies and contractors to increase the use of RAP.

The use of RAP in new asphalt mixtures will increase its high temperature stiffness. While this is good for rut resistance, the blending of the RAP binder with new binder will also affect the intermediate and low temperature cracking properties of the mixture. High RAP mixtures have been known to show increased fatigue and low temperature cracking. Using a high quality soft asphalt binder in the mix is likely to mitigate some of the negative effects of the RAP binder on the fatigue and low temperature cracking on the roadway. This study was undertaken to demonstrate the improved fatigue and low temperature mix properties of high RAP mixes using high quality Husky asphalt binder. Both binder and mixture testing were undertaken to evaluate the cracking properties of the of the high RAP mix.

Moving Towards a Performance-Related Specification for Asphalt Pavement

David Mensching and Richard Duval
Federal Highway Administration

In the present-day infrastructure environment, owners are urged to optimize monetary resources and minimize disruption to the traveling public. Asphalt mixture producers have shown interest in providing innovative mixtures to meet these owner priorities. This study explains an approach that will encourage innovation from pavement design through asset management and performance monitoring: performance-related specifications (PRS). A PRS requires characterization and prediction of pavement life to establish a comparison between as-designed and as-constructed asphalt pavements. The approach featured in this work utilizes a performance-engineered mixture design (PEMD) procedure predicated on bulk testing in the Asphalt Mixture Performance Tester (AMPT) to better understand fundamental rutting and cracking resistance properties. This information is then compared to an as-built pavement evaluation procedure using volumetric properties in the short-term and laboratory performance testing in the intermediate-term. Through use of the FlexMAT™ and FlexPAVE™ systems, a user can seamlessly analyze AMPT data and predict the life of a pavement system given certain distress and damage thresholds. This presentation will elaborate on the PRS framework, highlight a PEMD case study, relay the overall status of the effort to-date, and identify gaps for future research.

A Study on Practicality and Variability of Semi Circular Beam (SCB) Test

Faramarz Safazadeh, Pedro Romero, Abu Sufian Mohammad Asib and Shauling Bao
University of Utah

Fatigue cracking is a prominent distress in flexible pavements caused by repeated traffic loading or temperature differences. Fatigue is a complex phenomenon and one way to deal with this distress is to evaluate fracture resistance. Semi-Circular Bending Beam Test (SCB) was proposed to determine the crack resistance and crack growth rate of bituminous mixtures and become more popular due to its simplicity in terms of specimen preparation using the SGC (SuperPave Gyratory Compactor) or coring from the field and testing method. Standard protocols have been developed for different methods such as ASTM D8044-2016, which is more known as the Louisiana method of SCB test, and AASHTO TP124-2016 related to the Illinois flexibility index known as IFIT to determine test procedures such as loading rate, specimen geometry and support conditions to obtain a value for the fracture resistance. UDOT has been trying to address balanced asphalt mixtures in order to reduce premature failures and to improve pavement performance by following the standards. This study investigates the use of the semi-circular bend (SCB) test to predict fatigue resistance of different asphalt mixtures with different sources of aggregate and binders. In addition, assessment of repeatability and reproducibility of the SCB test in Utah is investigated. Statistical analysis of the results shows that if this test is capable of discriminating between different materials in regard of source of binder, aggregates, modifiers, RAP and the effect of aging of HMA kept in silos.

Accurate Modeling and Optimization of Permanent Deformation in Asphalt Pavement via the Application of Principal Component Analysis

Parnian Ghasemi, Derrick Rollins and R. Christopher Williams *(1)*; Mohamad Aslani *(2)*
(1) Iowa State University; (2) Florida State University

Permanent deformation in asphalt pavement is a function of material properties, loading, environmental conditions, and structural design. Developing an accurate predictive model for permanent deformation has some difficulties due to the large number of effective variables and their nonlinear interrelationships. In this research, a laboratory database containing accumulated strain values (output) and material properties (inputs) from several asphalt pavements is used to develop a predictive model for permanent deformation. We first detect the highly correlated inputs and then using Principal Component Analysis (PCA), a set of orthogonal pseudo-inputs is produced. Two predictive models based on the pseudo-inputs are developed using linear regression analysis and Artificial Neural Networks (ANN), and are compared using statistical analysis.
Extrapolation in empirical predictive models is highly risky. To avoid extrapolation, an n-dimensional hyper-space is defined in which the proposed models are allowed to be used. The developed model, along with the defined input space, provides sufficient information for an optimization algorithm which maps the response backward to the input space. The outcome is a set of design parameters leading to the minimal accumulated strain. The obtained optimal design parameters meet current design specifications, and can be used as a first step in pavement design procedure.

An Electrical Resistance Measurement for Moisture Content Evaluation in Asphalt Emulsion Applications

Miguel Montoya and John Haddock
Purdue University

Due to their versatility, asphalt emulsions are one of the most commonly used materials for pavement construction and preservation. An asphalt emulsion is a stable dispersion of asphalt binder droplets in water, which can be pumped, stored and mixed with aggregates at ambient temperatures. At the beginning of an asphalt emulsion application, the asphalt emulsion consists of three basic components, asphalt, water and an emulsifying agent. But after the separation of the water from the asphalt and partial or complete moisture loss, the material residue achieves the adhesive properties of the original base asphalt. Therefore, one inherent concern related to the use of asphalt emulsions is to determine when the material residue has experience enough moisture loss to provide the desired binding properties. This study presents an electrical resistance measurement for moisture content evaluation in asphalt emulsion applications. Field trials studying the relationship between electrical properties, moisture content, and development of mechanical properties are discussed. The implementation of such an approach has a great potential as an early-life performance assessment tool for diverse asphalt emulsion applications.

Use of Artificial Intelligence in the Asphalt Industry

Raj Dongre
Dongre Laboratory Services

Artificial Intelligence (AI) is being used in all industries for data analysis and decision making. A part of AI called Artificial Neural Networks modeling has been used in the past to model asphalt data (mostly hot-mix E* prediction). Recently, an ANN application was developed to predict binder PG grade from a simple creep recovery test known as the Asphalt Binder Quality Test (ABQT). The application is now being evaluated by three State DOTs. Data obtained to date suggests that the ANN application has successfully predicted over 95% of the PG grades accurately.
State DOTs have also expressed interest in having the ability to predict the low temperature continuous PG grade and ΔT_{cr} value from the BBR data collected at only the verification (passing) temperature. Normally, BBR data at both passing and failing temperature are required to determine the low temperature continuous PG grade and ΔT_{cr}. A new application based on ANN was developed to predict the low temperature continuous grade and ΔT_{cr} values from BBR data obtained at the passing temperature. Initial validation effort suggests that the model has a validation accuracy of 97%.
In this presentation the findings from the DOT evaluation of the PG grade model will be discussed. The new BBR model will also be presented along with validation data and implementation plans. Other possibilities for application of AI in the paving industry will also be explored in detail. The difference between AI and ANN will also be examined in general.

Post-Production Asphalt Mix Performance Testing in Ontario

Seyed Tabib, Imran Bashir and Pamela Marks
Ministry of Transportation of Ontario

The Ministry of Transportation of Ontario (MTO) is evaluating various asphalt mix performance tests with the goal to establish acceptance criteria for post-production asphalt mix that relates to long term pavement performance. MTO intends to use performance tests to achieve a balance between both resistance to cracking and rutting.
As part of our ongoing investigation, loose asphalt mix and pavement cores were collected and tested from various paving contracts. Testing carried out to date includes:
• Semi-Circular Bend (SCB) test
• Disk-shaped Compact Tension (DCT) test
• Hamburg Wheel Tracking test
• Grading of Recovered Asphalt Cement (AC)
Work to date has revealed challenges including labour-intensive sample preparation and high testing variability. Capability of the commercial laboratories to conduct performance tests is also a concern.
MTO will be evaluating cores taken from good and poor performing pavements paved 5-10 years ago using performance tests. We believe that both recovered AC grading and mix performance tests are required in evaluating pavement performance.

Session 5 - Asphalt Recycling

Investigation of High RAP/RAS Binder Performance

Amir Golalipour and Chuck Paugh *(1)*; David Mensching *(2)*
(1) Engineering & Software Consultants; (2) Federal Highway Administration

Economic and environmental demands motivate transportation agencies to increase the amount of reclaimed asphalt pavement (RAP) and recycled asphalt shingles (RAS) used in asphalt pavements. However, mixtures with high recycled materials contents are usually more prone to cracking, raveling, and other durability-related pavement distresses. The use of recycling agents may improve recycled mixture performance, facilitating the inclusion of high recycled materials contents.
In order to provide a long lasting, safe and efficient highway network, the Federal Highway Administration (FHWA) uses the Mobile Asphalt Testing Trailer (MATT) to respond to develop and deploy innovations in the asphalt pavement industry. FHWA's MATT recently participated in projects to characterize the performance of asphalt binders and mixtures containing high percentages of RAP/RAS material. These projects used different percentages of RAP and RAS and multiple asphalt binder grades with and without recycling agents.
The objective of this study is to better understand performance related properties of the high RAP/RAS binders. For some binders, different dosages of recycling agents were used. The rheological properties were characterized using the dynamic shear rheometer (DSR) to run strain or amplitude sweep tests, frequency sweep tests, and multiple stress creep and recovery (MSCR) tests; plus, low temperature characterization using the Asphalt Binder Cracking Device (ABCD) test. Short and long-term aging was also evaluated via rheological indices. Discussions on a blending chart analysis using recycling agents is also provided.

Changes in the Chemical Composition of Virgin Asphalt and RAP Extracted Binder Used for a High Volume High RAP Mix Design Due to the Addition of a Soybean Derived Chemical Additive

Joseph Podolsky, Barrie Saw, Zahra Sotoodeh-Nia, Nacu Hernandez, Benjamin Empric, Fang-Yi Lin, R. Christopher Williams and Eric Cochran
Iowa State University

Recent work has shown that epoxidized plant oil materials work well as rejuvenators in recycled asphalt pavement (RAP). At the end of the 2017 construction season, a field trial mix with 30% RAP (total recycled binder content of 30.3%) was produced and placed in Northwest Iowa on US-18, east of Sheldon, Iowa. The rejuvenator used was epoxidized methyl soyate (EMS), and was used at a rate of 0.125% by total mix weight. The mix design for the control section used a PG 58-34H. Due to Iowa DOT specification (recycled binder content greater than 20%) a grade bump was needed for the binder in the EMS trial section (PG 52-40H). With 0.125% EMS by total mix weight the grade bump was achieved. To better understand the chemistry behind this rheological improvement several chemical characterization methods will be explored (SAXS, IM-MS, FTIR-ATR, Raman Spectroscopy, and others) on SARA fractions of several binders (PG 52-34, RAP, PG 52-34 w/polymer (PG 58-34H), PG 52-34 w/EMS, PG 52-34 w/RAP, RAP w/EMS, PG 58-34H + EMS, PG 58-34H + RAP, PG 52-34 w/EMS + RAP, and PG 58-34H + EMS + RAP).

Recycling Between 40 and 70% of Mixes: From Laboratory Testing to the MURE National Project Demonstrators

Jean-Eric Poirier *(1)*; Simon Pouget *(2)*; Ivan Drouadaine and Stephané Faucon-Dumont *(3)*; Cédric Sauzéat, Hervé Di Benedetto and Alvaro Pedraza *(4)*; Virginie Mouillet, Cerema DeTerMEd and Brice Delaporte *(5)*; Vincent Gaudefroy and Sabine Vassaux *(6)*
(1) Colas; (2) Eiffage; (3) Eurovia Management; (4) Ecole Nationale des Travaux Publics de l'Etat; (5) IREX; (6) IFSTTAR

A collaborative national research project, known as MURE (which stands for the multirecycling of mixes) got under way in France in 2014. Its aim is to demonstrate know-how in the area of high recycling rates coupled with techniques that lower temperatures, and to forecast the consequences of recycling mixes that already contain high proportions of RAP Eight field demonstration sites were created in 2015 and 2016 with either 40 or 70% RAP content. Both hot and warm mixes were manufactured.. Two of the sites (an additive warm mix with 40% RAP rate and a foam warm mix with 70% RAP) were constructed in four stages in order to simulate the construction of a new pavement followed by three recycling operations, i.e. approximately 40 years of service. This presentation will set out the aims of the field demonstration sites. The industrial accelerated ageing method used to simulate 10 or so years of service will be described. Results that demonstrate the ability to forecast the thermoviscoelastic properties of the mixes using the 2S2P1D model will be presented. The rate of mixing between the binder in the RAP and the added asphalt will be addressed.

High RAP Recycling (50%) Facilitated with Bio Material Addition as Part of BioRePavation Project: Test Sections, Field Sampling and Lab Results

Ryan Boysen and Jean-Pascal Planche *(1)*; Emmanuel Chailleux, Erika Bessmann and Juliette Blanca *(2)*; Laurent Porot *(3)*; R. Chris Williams and Zahra Sootoodeh-Nia *(4)*; Simone Pouget and Françoise Olard *(5)*; Davide Lo Presti and Ana Jimenez del Barco Carrion *(6)*
(1) Western Research Institute; (2) IFSTTAR; (3) Kraton Polymers; (4) Iowa State University; (5) Eiffage; (6) University of Nottingham

The European/American call for Innovation in Infrastructures named Infravation awarded the Project BioRepavation to a transatlantic research consortium led by IFSTTAR and including Eiffage TP, Kraton, ISU, the University of Nottingham and WRI. The goal was to demonstrate the feasibility of high RAP recycling using three bio material based solutions to make high performance structural pavement layers.
In a demonstrator at the IFSTTAR accelerated loading facility in France, pavement test sections were built using GB5 type mix designs with 50% RAP and bio-rejuvenators Sylvaroad RP1000, Epoxidized Methyl Soyate, and replacement bio-binder Biophalt. An EME-2 high modulus test section with 20% RAP that is one of the standard high traffic mixes used in Europe was also built as a reference. Both surface and subsurface pavement samples were taken at the time of construction and after 5 months of service from each section using WRI's micro-sampling technique. The extracted and recovered asphalt portion of each sample was tested on the DSR to observe low temperature properties including ΔT_c and infrared spectroscopy to observe possible chemical or physical interactions. These results were compared to laboratory aged samples and the EME control test section.

Toward the Development of Performance-Related Specification for Bio-Rejuvenators

Fujie Zhou and Pravat Karki
Texas A&M Transportation Institute

Recently, a variety of bio-rejuvenators have been developed to address the premature cracking issue of RAP/RAS mixes. However, there is no purchasing specification available for bio-rejuvenators. This paper presents the efforts made toward the development of performance-related specification for bio-rejuvenators. A total of eight bio-rejuvenators were evaluated in this study. Their chemical and rheological properties and aging characteristics were measured. In addition, the effectiveness of the eight bio-rejuvenators in improving low temperature property of (recycled) asphalt binders was investigated. It was found that the chemical property-total fatty acid content is the preferred performance indicator, because (1) the low temperature PG of recycled asphalt binders is controlled primarily by relaxation property; and (2) the total fatty acid content has much better correlation with the m-based low temperature PG, which was verified by mixing pure fatty acid compounds with a virgin PG64-22 binder. The identified performance indicator was further confirmed by testing blends of recycled binder/virgin binder/three bio-rejuvenators. At the end of this paper, a framework of performance-related specification for bio-rejuvenators is proposed.

Thermal Properties of Rejuvenators and Their Impact on the Low Temperature Performance of Rejuvenated Binders

Mohamed Elkashef, David Jones and John Harvey *(1)*; R. Christopher Williams *(2)*
(1) University of California, Davis; (2) Iowa State University

Rejuvenators are added to RAP mixtures to enhance their low temperature and fatigue performance. The effectiveness of a rejuvenator depends on many factors including the rejuvenator's properties as well as the compatibility between the rejuvenator and the base binder. The thermal properties of a rejuvenator can vary greatly based on its chemical composition. This research focuses on understanding the effects of the thermal properties of rejuvenators on the rheological properties of the rejuvenated binders, particularly in relation to the low temperature performance grade. In this research, an extracted RAP binder was blended with two different rejuvenators at a dosage of 10% by weight of the binder. The effect of rejuvenation on the performance grade of the RAP binder was determined. Differential scanning calorimetry (DSC) was used to obtain the crystallization and melting points of the rejuvenators. DSC was also used to assess the change in glass transition temperature of the control base binder and the rejuvenated RAP binder, as well as to identify crystallization and melting events. The results showed that there is a clear relation between the melting and crystallization behavior of the different rejuvenators and their effect on the low temperature performance grade of the RAP binder.

Production of a Cold Mix Using 100% of Milled Material (R.A.P.) with Cold Rejuvenator

Barry Nunez *(1)*; Lorenzo Sangalli *(2)*
(1) Infratest; (2) Greenpave Technology

In cooperation with Polytechnico Milano, Iterchimica has developed a cold binder rejuvenator for Reclaimed Asphalt Pavement (RAP). ITERLENE ACF 1000 HP GREEN, allows the production of cold-mix asphalt for road maintenance and low traffic wearing course or bike paths. This rejuvenator is a cold binder liquid additive free of aromatic oils studied for the production of cold mix asphalt for paving applications.
Several trial sections have been carried out with Milano Municipality with favorable results for cold patching applications and have been entered into the city specifications. Test sections on wearing courses of low traffic road are in progress in Italy and Spain, containing 100% of RAP with a cold binder rejuvenator ITERLENE ACF.
During the study the main aims were to analyze the impact of ITERLENE ACF on the bitumen through the complete analysis of the rheological behavior and the curing effect of the rejuvenator.
The bitumen was obtained through an extraction process of the material treated by rejuvenator with different percentages: 1%, 1,5%, 2% and 3% on the weight of RAP. The binder was tested by the method of Sharp Superpave, through the use of the DSR, PAV, BBR in reference to the AASHTO standard. It was possible to construct master curves and understand the bitumen's behavior to creep. Also we evaluated the impact of ACF on bituminous conglomerates through mechanical performance using two different ways of compactor: impact compactor and gyratory compactor.

Performance-Engineered Mix Design Methodology for Rejuvenated High-Recycled HMA

Hassan Tabatabaee and Tony Sylvester
Cargill Industrial Specialties

While rejuvenating technologies have been utilized in pavement materials at various scales of research for years, in recent years they have emerged as increasingly practical solutions for use in high-recycled pavement applications, offering the potential for high performance combined with environmental and economic sustainability.
Adaptation of rejuvenators in practice requires a working knowledge on the definition "rejuvenation", relevant evaluation criteria available to the practitioner, and perhaps most important: how can Performance-Engineered Mix Design (also known as Balanced Mix Design) be utilized for design of rejuvenated high-performance HMA in which bitumen content is no longer the main design variable?
The present research focuses on answering these questions by proposing the use of rheological parameters derived from the extracted bitumen as the design variable in a Performance-Engineered Mix Design scheme. Examples from a range of durability performance tests including the DCT, IFIT, Beam fatigue, overlay tester, are balanced against rutting performance data from the Hamburg, APA, flow number to demonstrate the feasibility of this concept for development and optimization of high performance rejuvenated high-recycled asphalt pavements.

Impact of Silo Storage Time on Blending Between RAP and Virgin Binders in High RAP Content Asphalt Mixes

Payman Pirzadeh, Pavel Kriz and Daniel Grant *(1)*; Hawraa Kadhim, Peter Mikhailenko and Hassan Baaj *(2)*
(1) Imperial Oil; (2) University of Waterloo, Canada

Reclaimed Asphalt Pavement (RAP) is a major component of hot mix asphalt (HMA) production in asphalt plants. Quality of blending between RAP content and virgin binder can significantly impact HMA properties, and consequently its performance in the field. Blending becomes of more importance when RAP content increases, particularly when softer virgin binder may need to be utilized. Higher treatment temperatures and longer interaction time can help achieving a more homogeneous blend of RAP and virgin binders. Storage silos in asphalt plants can provide a staging phase for improved blending before transporting the HMA to a job site. To further extend understanding from previous laboratory studies on diffusion in binders and mix samples, this field work looks at the impact of silo storage duration on plant-manufactured HMAs for surface and base layers of pavement with RAP contents of 15% and 30%, respectively. HMA samples were collected from asphalt plant silos at different times. Results suggest that there might be an optimum storage period during which maximum blending could be achieved before additional hardening happens.

Effect of RAP and Aging on Low Temperature Performance of Asphalt Materials

Abu Sufian Mohammad Asib, Pedro Romero and Faramarz Safazadeh
University of Utah

Hot Mix Asphalt (HMA) pavements encounter long-term oxidative aging during their service period. Adding Reclaimed Asphalt Pavement (RAP) to asphalt mixtures further accelerates the stiffening of asphalt concrete during cold weather. This study addresses the effects of RAP and long-term aging of asphalt mixtures using Bending Beam Rheometer (BBR) according to the AASHTO TP125. A PG64-28 binder with two different Superpave© mix designs and materials were used to make all the HMA for this study. HMA mixtures consisting 0% to 35% RAP by the mass of virgin binder were made at 5% intervals and aged at variable aging periods ranging from one day to seven days at 80°C and three to six hours at 135°C. Furthermore, ten BBR specimens from each unaged mixture were put on the roof and tested periodically for last three years. Second phase was collaborated between two labs by testing of plant and field mixtures obtained from various projects which had been contemporarily running in Utah. Comprehensively, the effect of RAP and Aging was investigated for both laboratory and natural aging, and results between labs for plant and field mixtures were compared to see the efficacy of using BBR in Quality Control/Assurance (QC/QA) purposes.

Session 6 - Asphalt Binder Chemistry - Aging

Effect of Oxidation on Stripping Potential of Binder-Aggregate Interfaces

Alejandra Baldi, José Aguiar-Moya and Luis Loría-Salazar
Lanamme, University of Costa Rica

Moisture damage in asphalt pavements is frequently related to stripping processes, which in turn is associated with the quality of the adhesive bond between binder and aggregate. However, the adhesive bond might also be compromised with oxidation, as it chemically transforms the binder. Since asphalt oxidation is an unavoidable process, it is necessary to analyze the changes occurring at the binder-aggregate interface, caused by oxidative aging. Consequently, this study pretends to quantify the effect of oxidation on stripping potential of binder-aggregate interfaces. To achieve this goal, physicochemical parameters such as work of adhesion, work of debonding and energy ratio, were calculated to evaluate stripping potential for 120 asphalt-binder combinations at unaged and oxidized conditions. The results show that changes in stripping potential after oxidation are dependent on the aggregate type and, in the case of modified binders, on the nature and dosage of additive used. Consequently, it is possible to reduce oxidative weakening of binder-aggregate bond by introducing modifiers that increase compatibility between these materials, even in the presence of water.

Investigation of Aging Evolution at the Surface of Asphalt Binder Specimen Using a Novel Aging Procedure and AFM Micromechanical Characterization

Meng Xu *(1)*; Junyan Yi, Zhongshi Pei and Decheng Feng *(2)*; Mihai Marasteanu *(3)*
(1) Harbon Institute of Technology/University of Minnesota; (2) Harbon Institute of Technology; (3) University of Minnesota

In this study, three asphalt binders were aged using an instrument developed in-house that takes into consideration three important factors: heat, ultraviolet radiation, and water. The structure and mechanical properties of the original surface were explored with an optical microscope and atomic force microscopy. The results show that two characteristic regions appear at the surface of the binder samples after aging. The mechanical properties of these two regions were measured using AFM force curve measurements. It was found that the adhesion ability of the aged binder was much less than that of the virgin binder. The hardness and modulus of the aged binder were significantly greater, however, the adhesion ability, hardness and modulus of the valley area were similar to the unaged binder. Based on the results, a possible generation and evolution mechanisms of the aging of the surface of the asphalt binder is presented, which could explain the occurrence of micro-cracks at the surface of asphalt pavements.

Investigation of the Effect of Aging Temperatures on Rheological Properties of Asphalt Binder Based on BBR and AFM

Ashley Buss *(1)*; Augusto Cannone Falchetto, Di Wang and Chiara Riccardi *(2)*
(1) Iowa State University; (2) Technische Universität, Braunschweig, Germany

In this research, the effect of a reduction in aging temperature on the rheological properties of asphalt binders was experimentally investigated. Four 70/100 pen grade virgin binders, which are part of the materials selected by the active RILEM 252-CMB, were used and studied for this purpose. First, the asphalt binders were artificially short-term aged at three different temperatures (123 ºC, 143 ºC, and 163 ºC) and then the standard long-term aging procedure was applied to all materials with the Pressure Aging Vessel (PAV). Then, the low temperature properties were investigated with the Bending Beam Rheometer (BBR) tests on the entire long-term aged asphalt binders. Creep stiffness, S(t), relaxation parameter, m-value, thermal stress and the difference in critical temperature, ΔT_c, were calculated and compared. Next, the microscopic morphology was investigated with the Atomic Force Microscope (AFM) device on virgin and long-term aged binders. BBR results indicate that a reduced aging temperature of 40 ºC can significantly improve the aging properties of asphalt binders at low temperatures. This is confirmed by the bee structure observed with the AFM on virgin and long term aged material showing a progressive increase in the number the bee-structure elements for higher aging temperatures.

Oxidative and Thermoreversible Aging Effects on Performance-Based Rheological Properties of Six Latin American Asphalt Binders

Alejandra Baldi-Sevilla, José Aguiar-Moya and Luis Loría-Salazar *(1)*; Max Berkowitz, Matthew Filipovich and Simon Hesp *(2)*
(1) Lanamme, University of Costa Rica; (2) Queens University

This paper studies the effects of oxidative and thermoreversible aging on intermediate limiting grade temperatures for six asphalt binders that were subjected to several PAV oxidative cycles. Modulated differential scanning calorimetry analysis of the aged materials showed a strong influence of cooling rate on crystalline fractions (C(T)). The dependence of C(T) on cooling rate was accurately modeled with the non-isothermal kinetic theory according to Ozawa. The Ozawa exponent reflects the rate of thermoreversible aging (crystallization, phase transformation and separation, vitrification), and it was found that such exponent differs between binders and increases with PAV aging. Materials that were oxidized for longer periods in the PAV contained higher amounts of polar functionalities and therefore became more prone to thermoreversible aging. Binders were also graded after non-isothermal conditioning in a dynamic shear rheometer (DSR). It was found that complex stiffness and phase angle are strongly affected by the oxidation extent, and the conditioning time in the DSR. Hence, for future intermediate temperature performance grading it is important to take the effects of both oxidative and thermoreversible aging into consideration, since they appear to be of comparable weight.

Kinetic Study on Laboratory and Field Oxidation of Asphalt

Alejandra Baldi, José Aguiar-Moya and Luis Loría-Salazar
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Laboratory and field oxidation of asphalt binders are heterogeneous reactions in which oxygen interacts with the binder molecules. To apply an adequate model to study the formation of functional groups such as carbonyl and sulfoxide with time, a kinetic equation must be selected according to the conditions of the reaction, such as temperature and heterogeneity. Consequently, the Ozawa kinetic model for heterogeneous and isothermal reactions was applied in this paper to samples of binders subjected to two different oxidative conditions: environmental and accelerated in laboratory (PAV). It was found that field oxidation and laboratory oxidation follow the same mechanism, ruled by the diffusion of oxygen molecules into the binder surface. The activation energy for carbonyl and sulfoxide production was found to be different for the aging procedures. The findings serve as starting point to calibrate an aging procedure that better simulates oxidation, as well as to select binders in terms of their oxidation proneness.

Effect of Aggregates Petrology on the Age Hardening of Asphalt Cement

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Aging is a well-known phenomenon for pavement engineers, yet due to complexity in chemical structure of asphalt cement, not understood thoroughly. Accelerated laboratory aging procedures usually consider aggregates as inert material and not sensitive to environmental effects. While in most cases this assumption is not far from the reality. Iron sulfide exist in many aggregate sources in different forms such as pyrite and pyrrhotite. Products of the reactions from such aggregates may have catalytic effect on the aging procedure of asphalt cement.
In this research three different sources of Iron sulfide containing aggregates were selected to produce laboratory mixes and conditioned under moisture and heat alongside Dynamic modulus measurements were performed on all samples and rheological parameters of each were obtained using 2S2P1D model. After each step of conditioning, recovered asphalt was subjected to chemical and rheological analysis. Using 2S2P1D model, rheological parameters were obtained. Carbonyl and sulfoxide indices and the ration between them were also used to investigate the chemical path of reactions.
Results of this study showed that when samples subjected to both heating and moisture, mixes containing iron sulfide minerals, seems to follow somehow a different aging kinetics resulting in meaningful different rheological parameters and chemical indices.

Microstructure and Chemical Analysis of Asphalt Binders Aged in the Presence of Moisture

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This work presents the evolution of the surface microstructure and chemical build-up of asphalt binders aged in an accelerated weathering tester in the presence of UV radiation, heat, oxygen and moisture. Optical photos, Atomic Force Microscopy (AFM), Fourier Transform Infrared (FTIR) and X-ray photoelectron spectroscopy (XPS) were used to analyze the samples. The findings were compared with those obtained on the same binders aged in a similar protocol without moisture. In the aging protocol without moisture, there was a clear trend in the microstructural evolution of the binder surfaces without material loss. In addition, the surface concentration of oxygen, nitrogen and sulfur increased with aging time. In the aging protocol with moisture, parts of the binder were lost as aging proceeded and the microstructure pattern was random. The concentration of the previously mentioned elements increased initially and then remained constant or decreased. This phenomenon is explained with the fact that aging with UV radiation created an aged superficial film, which was water-soluble and was therefore removed by the condensed moisture. Consequentially, new material is continuously exposed to aging and its microstructure is random. This work highlights the importance of an aging protocol that takes into account the presence of moisture.

Notes

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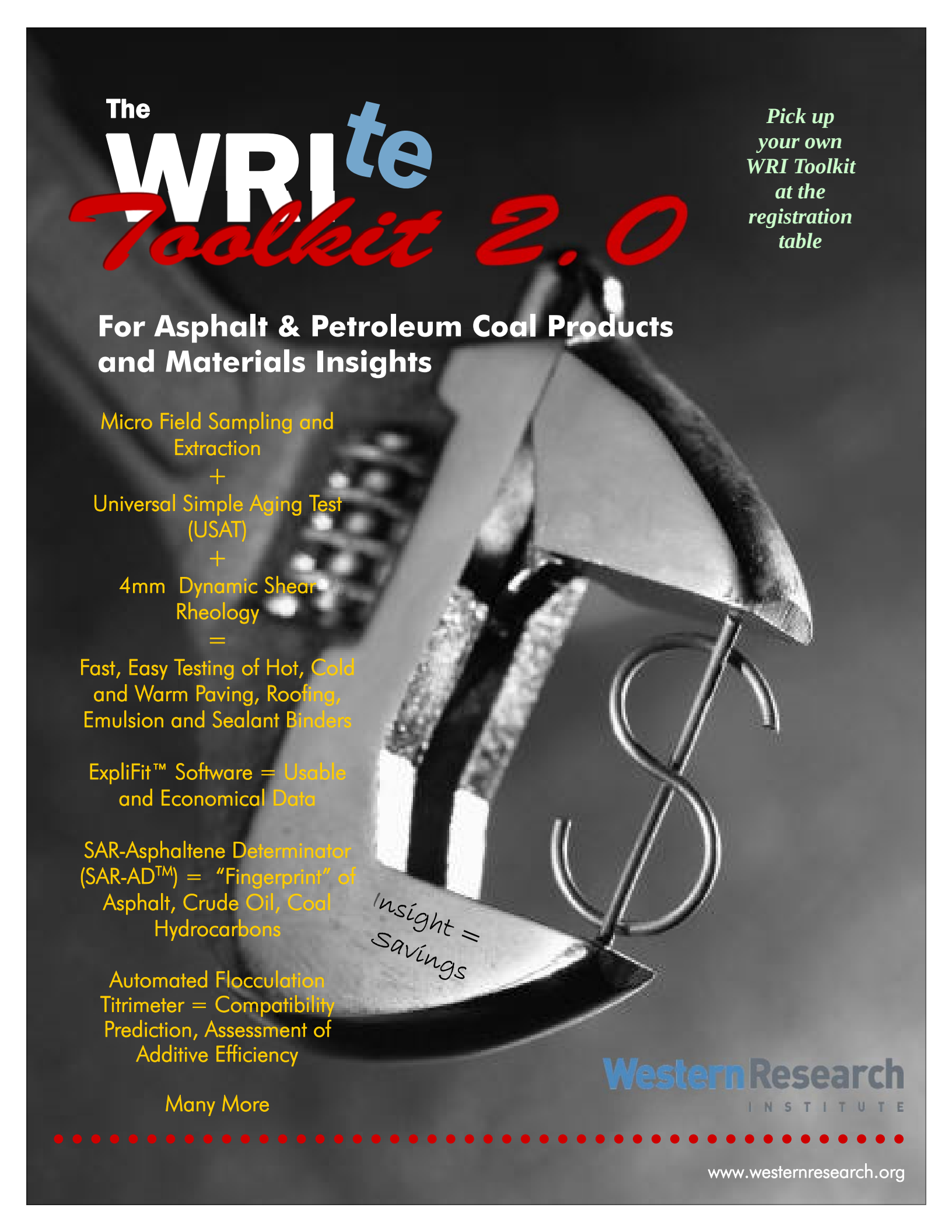

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