57th Petersen Asphalt Research Conference

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From Laramie, Wyoming

July 13-14, 2020

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Welcome

Welcome and *Bienvenue!*

. . . . To the 57th Petersen Asphalt Research Conference online! As PARC chairman, I invite you to soak up some electronic hospitality! Instead of gathering in our unique city of Laramie, Wyoming, we are conducting the conference in the new normal. Let this new era of interaction maintain the warm atmosphere of this unique gathering, continue igniting new friendships, exploring cutting edge ideas and discovering new approaches in the constant quest for knowledge and answers. This year's conference, with no question, is prodding us all to think outside the box.

PARC 2020 presenters from across the continent and the globe are ready to share their recent findings, representing a wide cross-section of asphalt/bitumen stakeholders. Scientists, engineers and manufacturers are bringing this research from the lab into production and construction. We hope this work will have significant, long term impacts on essential materials such as roofing and pavement.

"Chemistry Matters" remains the universal focus point, defined by conference founder Dr. Claine Petersen. As THE widely recognized forum for research in progress, PARC 2020 is proud to offer a high number of presentations on Rheological Performance Indices, Plastic Recycling in Pavements, Pavement Recycling and Recycling Agents, Asphalt Mixture Evaluation, Polymer-Modified Asphalts, Advancements in Asphalt Fractions Characterization, Pavement Sealing Materials and the always growing Machine Learning Applications.

More than ever, rapidly changing circumstances around the world drive us toward innovative solutions to address increasingly complicated issues. We find challenges around every corner, triggering the development of relevant models, analytical tools and test methods to meet these needs. Developing cost effective solutions with lower environmental impact addresses continuing concerns at all levels: global, continental, national, regional, local and personal.

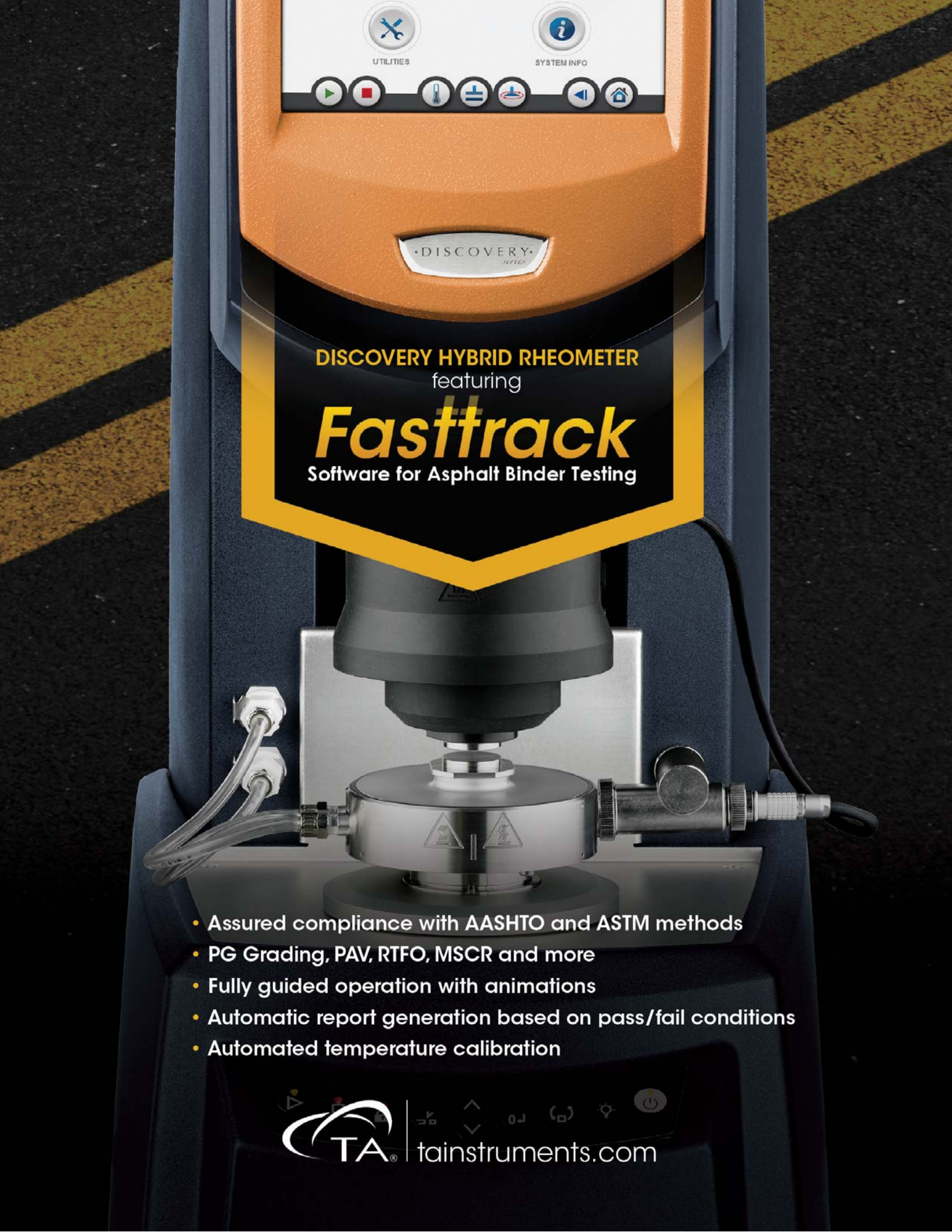
Home to the University of Wyoming, Laramie enjoys an atmosphere of active curiosity. The university motto is "The World Needs More Cowboys". This year's conference offers a range of opportunities to strike out into new territory to bring fresh ideas and innovative solutions to reality.

While PARC 2020 cannot offer its usual western outdoor adventures, we look forward to sharing these with you again soon.

Thank you for attending, and be sure to offer your thanks to all of the sponsors and exhibitors who help make this online conference possible. We are especially interested in your thoughts regarding the 2020 virtual experience. Please be sure to answer the survey that we send after the conference.

Howdy and *Bonjour!* I offer you my personal greeting and look forward to interacting with you during the virtual 2020 Petersen Asphalt Research Conference!

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



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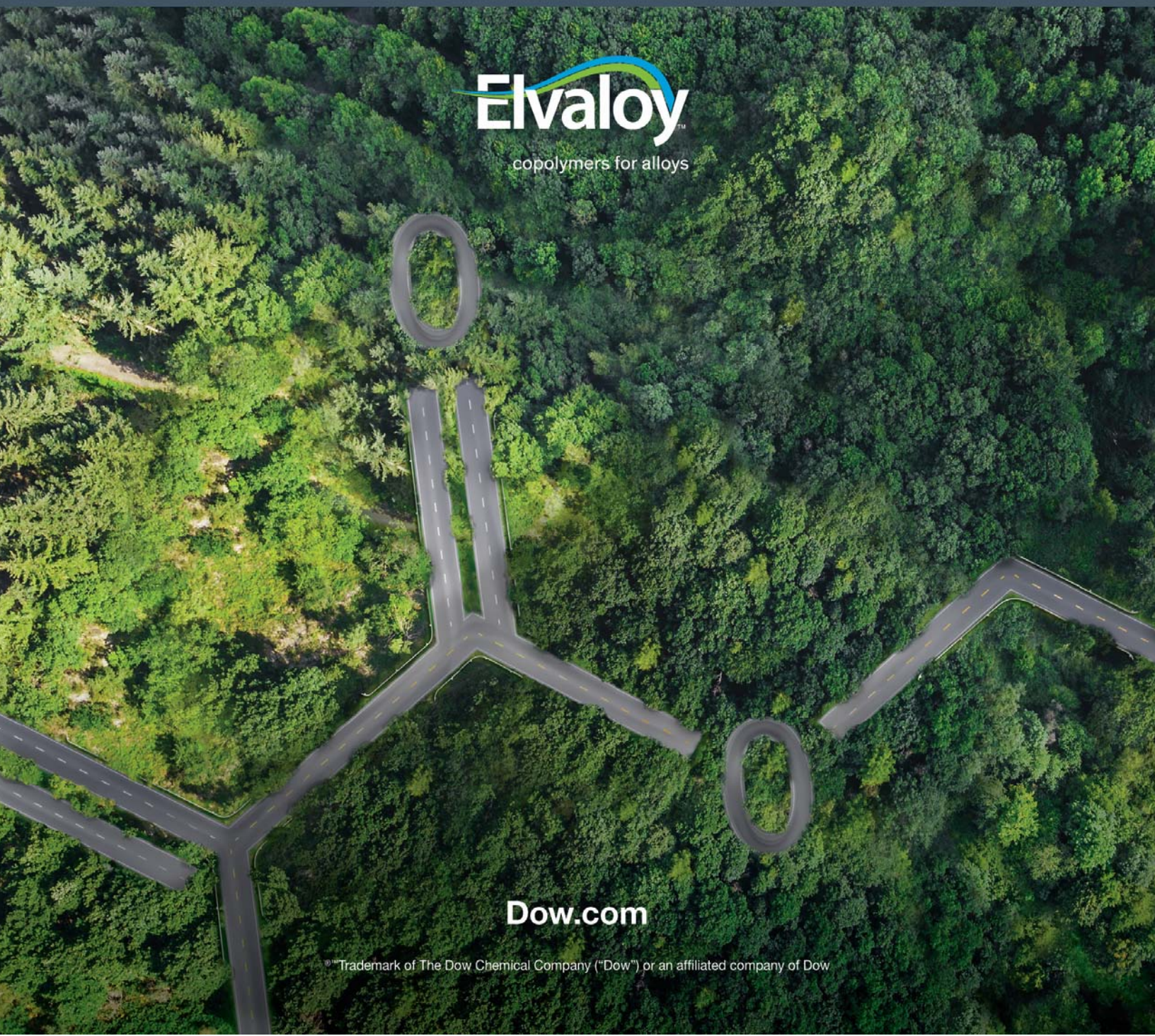

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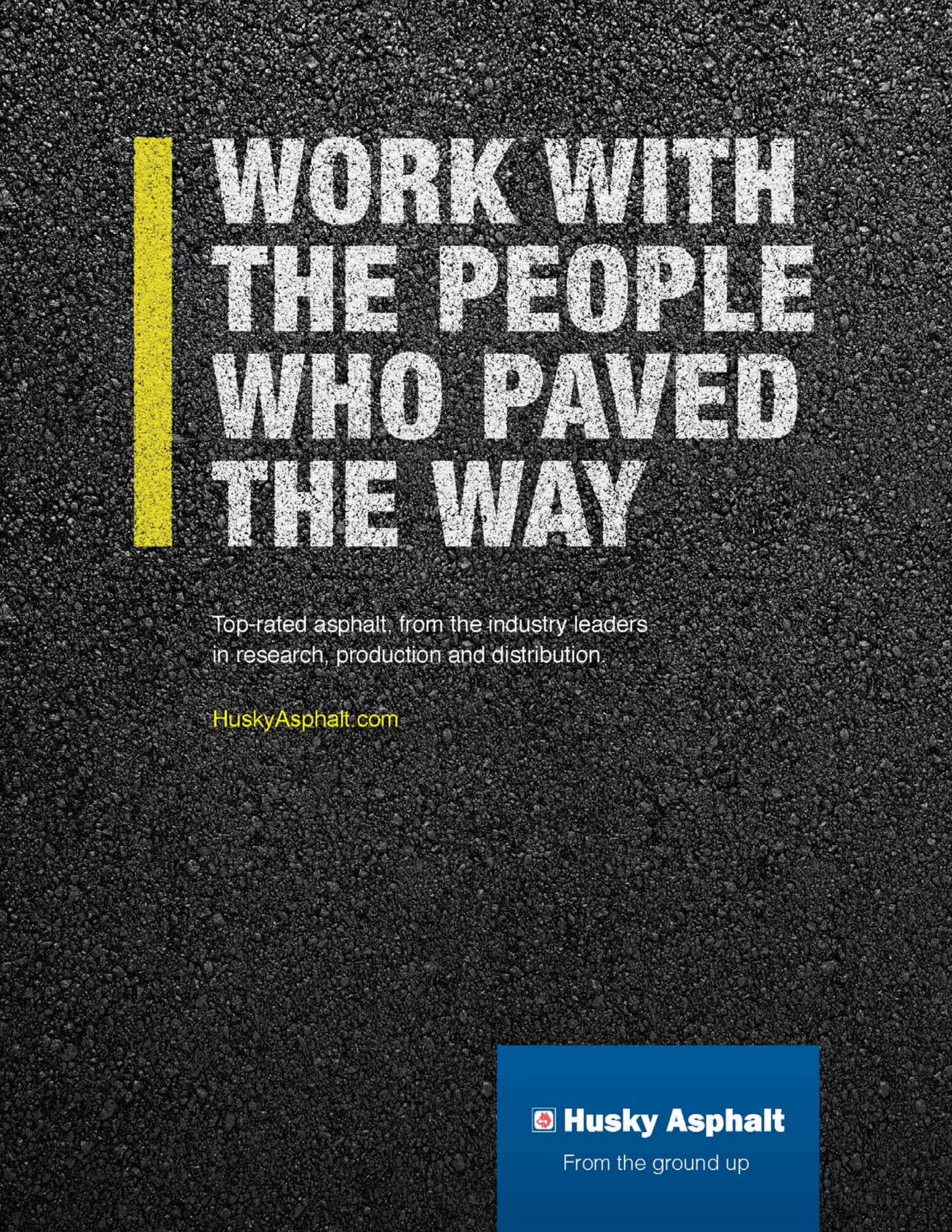
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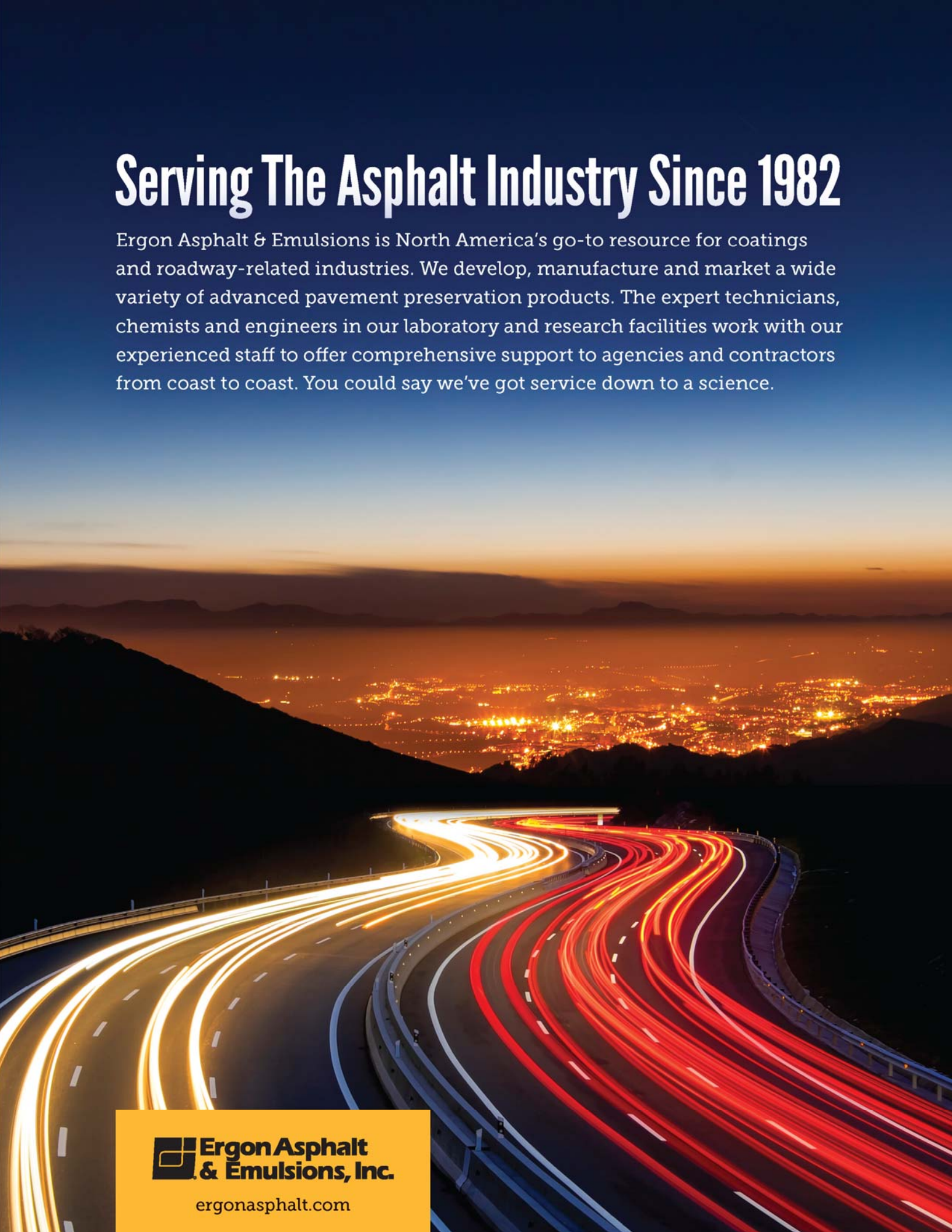

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57th Petersen Asphalt Research Conference

Conference Agenda

Monday, July 13

7:45-8:00	Welcome and Opening Remarks	Jean-Pascal Planche, Joe Rovani & Michael Elwardany *Western Research Institute*

Session 1 - Rheological Performance Indices

8:00-8:30	Investigation of Physical Hardening Impact on the Loss of Low-Temperature Performance Grade and Delta Tc in Asphalt Binders	Adrian Andriescu *SES Group & Associates* Amir Golalipour & Varun Veginati *ESC Inc.* David Mensching & Jack Youtcheff *Federal Highway Administration*
8:30-9:00	Fundamental and Empirical Relationships Between Binder Cracking Indicators	Ramez Hajj *University of Illinois at Urbana-Champaign*
9:00-9:30	A Tale of Two Deltas: Universal Approach to Evaluate Asphalt Binder Resistance to Thermally-Induced Surface Deterioration	Michael Elwardany & Jean-Pascal Planche *Western Research Institute* Gayle King *GHK, Inc.*

Session 2 - Plastic Recycling in Pavements

9:30-10:00	Key Learnings on Field Asphalt Pavement Trials Containing Recycled Plastic	Fabricio Arteaga, Claudia Hernandez & Cristina Serrat *The DOW Chemical Company*
10:00-10:30	***Break*** ***BASF Exhibitor Video and Chat***	

Monday, July 13 (Continued)

10:30-11:00	Life-Cycle Assessment of Asphalt Pavements with Recycled Plastics	Milena Rangelov, Heather Dylla & Nadaraja Sivaneswaran *Federal Highway Administration*
11:00-11:30	Novel Polyolefin Waxes from Recycled Plastic Feedstocks Improve the Performance and Sustainability of Asphalt Formulations	John Almey & Domenic Di Mondo *GreenMantra Technologies*
11:30-12:00	Impact of Recycled Polyethylene Particle Size on Interaction with Ground Tire Rubber in Terms of Storage Stability and Mechanical Properties	Helmut Leodarta & William Buttlar *University of Missouri Columbia*
12:00-1:00	***Lunch*** ***Exhibitor Videos and Chat***	

Session 3 - Pavement Recycling and Recycling Agents

1:00-1:30	Evaluation of Aging Hardening on Reclaimed Asphalt Pavement Binder Containing Rejuvenators	Yanlong Liang, Mohamed Elkashef, David Jones & John Harvey *University of California Davis*
1:30-2:00	Application of Machine Learning in Identification of Rejuvenated Asphalt Binders	Parnian Ghasemi, Joseph Podolsky, Austin Hohmann, Michael Forrester, Nacu Hernandez, R. Chris Williams & Eric Cochran *Iowa State University*
2:00-2:30	Coal Additives for Paving Industry and Asphalt Recycling	Devang Khambhati, Jeramie Adams, Nicholas Bolton & Joe Rovani *Western Research Institute* Paul Behrens *University of Wyoming School of Energy Resources*

Monday, July 13 (Continued)

Session 4 - Asphalt Mixture Evaluation

2:30-3:00	Post-Production Asphalt Mix Performance Testing in Ontario	Seyed Tabib, Imran Bashir & Gelu Vasiliu *The Ministry of Transportation of Ontario*
3:00-3:30	***Break*** ***Dow Exhibitor Video and Chat***	
3:30-4:00	Asphalt Materials and Characterization for Airport Pavements	Navneet Garg *National Airport Pavements & Materials Research Center*
4:00-4:30	Evaluation of Asphalt Mixture Performance Using Different Cracking and Durability Tests	Amir Golalipour & Varun Veginati *ESC Inc.* David Mensching *Federal Highway Administration*
4:30-5:00	Assessment of the NCHRP 1-52 Top-Down Cracking Model on a Full-Scale Pavement Test Section	Regis Carvalho *SES/Oaken Consult* Raj Dongre *Dongre Laboratory Services* Jack Youtcheff & David Mensching *Federal Highway Administration*
5:00-5:30	Quantum Modeling of the Effects of Hydrated Lime (Calcium Hydroxide) as a Filler in Bituminous Materials	Javier Grajales Saavedra, Lisa Pérez, A. Paul Schwab & Dallas Little *Texas A&M University*
5:30-6:00	Laboratory and Field Investigation of Engineered Crumb Rubber Modified Asphalt Binders and Mixtures	Punyaslok Rath, Behnam Jahangiri, Hamed Majidifard, Shishi Chen & William Buttlar *University of Missouri Columbia*
6:00	***Exhibitor Videos and Chat***	

Tuesday, July 14

Session 5 - Polymer-Modified Asphalts

8:00-8:30	RILEM TC 272 PIM TG1: Glass Transition in Complex Bituminous Binders	Panos Apostolidis *TU Delft* Laurent Porot *Kraton Polymers* Michael Elwardany *Western Research Institute* Stefan Vansteenkiste *Belgian Road Research Centre* Emmanuel Chailleux *Université Gustave Eiffel*
8:30-9:00	Rheological and Microstructural Assessment of Complex Bituminous Binders	Sayeda Nahar *TNO, Delft* Laurent Porot *Kraton Polymers* Panos Apostolidis *TU Delft* Emmanuel Chailleux *Université Gustave Eiffel*
9:00-9:30	The Expansion of UTI While Maintaining Workable Viscosity Using Isocyanate and SBS Modifiers	Brian Orr, Bernie Malonson, Daniel Navarre, Ryan Thomas & Joshua Compeau *BASF Corporation*
9:30-10:00	Relating Performance Parameters to Asphalt Chemical Composition	Bill Winniford, Hayley Brown, C.J. DuBois, Wenzhao Yang, Jeff Sweeney, Tony Gies, Junho Jeon, Dan Baugh III & Praveen Boopalachandran *The Dow Chemical Company*
10:00-10:30	***Break*** ***NETZSCH Exhibitor Video and Chat***	

Tuesday, July 14 (Continued)

10:30-11:00	Exploration of Curing Characteristics for Diluted Epoxy-Modified Asphalt	Raj Dongre *Dongre Laboratory Services* Adrian Andriescu, Amir Golalipour & Varun Veginati *SES Group* David Mensching & Jack Youtcheff *Federal Highway Administration*

Session 6 - Advancements in Asphalt Fractions Characterization

11:00-11:30	Impact of Aging on Polarity Fractions of Asphalt Binders	Johannes Mirwald, Stefan Werkovits, Ingrid Camargo, Daniel Maschauer, Bernhard Hofko & Hinrich Grothe *TU Vienna*
11:30-12:00	Redefining the Colloidal Instability Index for Paving-Grade Asphalts	Michael Elwardany, Jeramie Adams, Joe Rovani & Jean-Pascal Planche *Western Research Institute*
12:00-1:00	***Lunch*** ***Exhibitor Videos and Chat***	

Tuesday, July 14 (Continued)

1:00-1:30	Effect of Colloidal Index Variation on Chemical-Rheological-Mechanical Properties of Asphalt Binders Modified by Recycling Agents Under Different Aging Conditions	Hamzeh Haghshenas *University of Nebraska Lincoln* Robert Rea *Nebraska DOT* Gerald Reinke *MTE Services* Martins Zaumanis *Swiss Federal Laboratories for Materials Science & Technology*
1:30-2:00	Advancements in SAR-AD Capabilities and Applications	Joe Rovani, Jeramie Adams, Seth Bassham, Nicholas Bolton, Michael Elwardany & Jean-Pascal Planche *Western Research Institute*

Session 7 - Pavement Sealing Materials

2:00-2:30	The Effect of Zeta Potential on the Cohesive Strength of Slurry Seals	Irvin Pinto & Ashley Buss *Iowa State University*
2:30-3:00	Field Study Evaluation of Soybean Oil Derived Additives Used in a Bio-Cutback and Bio-Fog Seal for Brittle HMA	Maxwell Staver, Joseph Podolsky, Theodore Huisman, R. Chris Williams, Irvin Pinto & Ashley Buss *Iowa State University*
3:00-3:30	***Break*** ***TA Instruments Exhibitor Video and Chat***	

Tuesday, July 14 (Continued)

Session 8 - Machine Learning Applications

3:30-4:00	Deep Learning Approach for Automatic Pavement Distresses Detection Using Google-Map Images	Hamed Majidifard, Yaw Adu-Gyamfi & William Buttlar *University of Missouri*
4:00-4:30	From PG Grade to Pavement Performance - A Virtual Research Project	Raj Dongre *Dongre Laboratory Services* Jack Youtcheff *Federal Highway Administration*
4:30-5:00	Machine Learning-Based Prediction Models for Performance of Asphalt Mixtures	Hamed Majidifard, Behnam Jahangiri, Punyaslok Rath & William Buttlar *University of Missouri* Amir Alavi *University of Pittsburgh*
5:00-5:15	***Closing Remarks***	

Professional Development Hours (PDH's)

16 PDH's will be provided to registered participants upon request after the conference.

Session 1 - Rheological Performance Indices

Investigation of Physical Hardening Impact on the Loss of Low-Temperature Performance Grade and Delta Tc in Asphalt Binders

Adrian Andriescu *(1)*; Amir Golalipour and Varun Veginati *(2)*; David Mensching and Jack Youtcheff *(3)*
(1) SES Group & Associates; (2) ESC Inc.; (3) Federal Highway Administration

Delta Tc (.Tc) has been identified as an important parameter related to asphalt binder durability and a threshold of -5°C has been proposed as a block (age-related) cracking criterion at 40 h conditioning in the pressure aging vessel (PAV). Research done at the Federal Highway Administration (FHWA) and in other asphalt laboratories suggests that .Tc becomes more negative with extended PAV aging and some modifiers are strengthening this tendency. There are also strong indications that physical hardening of the binders that manifests at temperatures below or around the glass transition temperature (Tg) has a significant influence on the binder and mixture low temperature performance. A loss (increase) in low-temperature performance grade (LTPG) of a grade or more signals that the binder may not be able to handle long spells of low temperatures and may be prone to cracking. Both parameters are determined at low temperatures, where stiffness and relaxation properties of materials can have substantial variations in time (of loading or conditioning). This study investigates the impact of physical hardening on .Tc and the loss of LTPG for a variety of PAV or field aged binders. This effort is meant to improve the existing binder selection criteria and to understand the relationship between these two material properties.

Fundamental and Empirical Relationships Between Binder Cracking Indicators

Ramez Hajj
University of Illinois at Urbana-Champaign

In the last few years, many rheological parameters have been developed which are suggested to have a relationship with the cracking resistance of the binder. Although these parameters are often obtained at either intermediate or low temperature, and correlated to a specific type of cracking, a prevailing theory indicates that "a crack is a crack" and a cracking parameter should relate to all types of cracking and cracking temperatures. This theory is furthered by the popular Black Space analysis, which is independent of temperature. In the present study, the fundamental relationship between two of the predominant novel cracking parameters- the Glover-Rowe parameter and .Tc- were examined in black space, which indicated a fundamental discrepancy between these two parameters. Further analysis was performed by curating data from previous studies, which revealed that although individual studies show a link between these parameters, overall the relationship is not particularly strong, but not opposite as the Black Space analysis indicated. Therefore, it is postulated that temperature dependency plays a significant role in ranking these parameters across a wider range of binders, calling into question the use of temperature-independent analysis. An argument for nonlinear cracking parameters is therefore presented.

A Tale of Two Deltas: Universal Approach to Evaluate Asphalt Binder Resistance to Thermally-Induced Surface Deterioration

Michael Elwardany and Jean-Pascal Planche *(1)*; Gayle King *(2)*
(1) Western Research Institute; (2) GHK, Inc.

Asphalt binder production and formulation has significantly changed since the development of Superpave Performance-Grade system because of economic, technical, and environmental reasons. Superpave specifications address binder properties that may lead to rutting, transverse cracking, and fatigue damage with varying degrees of success. However, aged-induced surface distresses have become the main challenge for many highway agencies. Thermally-induced surface deterioration appears in the form of traditional transverse cracking, block cracking, raveling, or accelerating damage at construction joints. Transverse cracking requires external restraint to impose tensile stresses on the asphalt mixture as it cools. This study proposed a second model for "Internal Restraint" damage mechanism, which creates localized tensile stresses in the mastic due to its differential contraction with the surrounding aggregate as pavement surface cools. This study evaluates the limitations of the linear viscoelastic (LVE) rheological indices, such as .Tc, R-value, and G-R parameters, and the ability of the Asphalt Binder Cracking Device (ABCD) failure test to overcome these limitations. ABCD is particularly appropriate to ranking binder performance because the measured cracking temperature (Tcr) depends upon binder LVE properties, failure strength, coefficient of thermal contraction, and cooling rate. The proposed parameter (.Tf = Tc(S=300 MPa) from BBR - Tcr from ABCD) effectively gives credit to well-formulated and compatible polymer-modified binders that may increase binder strength and strain tolerance. .Tc and .Tf are complementary and they should be considered to rank binder performance and durability. This proposed new analysis approach can be applied universally regardless of binder composition.

Keywords: asphalt durability, polymer-modified asphalt, rheological surrogates, cracking index, .Tc parameter, .Tf parameter, asphalt binder cracking device (ABCD), Coefficient of Thermal Contraction (CTC).

Session 2 - Plastic Recycling in Pavements

Key Learnings on Field Asphalt Pavement Trials Containing Recycled Plastic

Fabricio Arteaga, Claudia Hernandez and Cristina Serrat
The Dow Chemical Company

If post-consumer recycled (PCR) plastic could be used to deliver improved performance for asphalt pavements and at the same time reduce the waste footprint with potential cost benefits, the overall gains for the environment and both, the asphalt and the plastics industries would be significant. Recycled Polymer Modified Asphalt (RPMA) could take pavement into a new direction by adding post-consumer recyclate content, typically polyethylene-rich compositions. This could be beneficial, particularly in Mexico, where only 38% of the 400,000 km of road infrastructure is paved, and only less than 10% of flexible packaging gets recycled. This study presents three demonstration projects completed in Mexico in which LLDPE-rich PCR, equivalent to 1MM units of flexible packages (2500 kg), was successfully incorporated into asphalt binders through formulating blends with a Reactive Elastomeric Terpolymer (RET). These roads (combined 5 Km in total) made with PCR + RET met the performance specifications, based on AASHTO M350, for a PG 76-16V modified asphalt binder.

Life-Cycle Assessment of Asphalt Pavements with Recycled Plastics

Milena Rangelov, Heather Dylla and Nadarajah Sivaneswaran
Federal Highway Administration

Because of the massive global production and use, the amounts of waste plastics are rapidly increasing. Chinese ban on imported plastic waste and other legislative initiatives created an impetus to improve recycling capabilities worldwide. Due to high available amounts of plastics, possibilities of re-utilization in products other than virgin plastics are sought after. One such practice could be the use of recycled plastics in asphalt mixtures. Research to-date primarily investigated the feasibility of recycled plastics use in asphalt in terms of the impact on mechanical performance, the suitability of different plastics types, and recommended dosages. Although environmental benefits are often mentioned as a core motivation of this practice, the evaluation of environmental impacts is lacking in the literature. To address the identified gap, this study uses a life cycle assessment (LCA) methodology to evaluate the environmental impacts of the inclusion of recycled plastics in asphalt pavements for cradle-to-grave scope. Tradeoffs between environmental and other aspects of asphalt mixture performance throughout the life cycle are evaluated to demonstrate data-driven mixture selection. The results of this study elucidate the suitability of recycled plastics in asphalt pavements specific to different scenarios and can meaningfully inform specifications, policy, and potential legislation.

Novel Polyolefin Waxes from Recycled Plastic Feedstocks Improve the Performance and Sustainability of Asphalt Formulations

John Almey and Domenic Di Mondo
GreenMantra Technologies

There is significant interest to increase both the performance and sustainability profile of asphalt formulations. GreenMantra's technology transforms recycled plastics into specialty polyolefin waxes that are particularly effective in modifying asphalt binder to improve thermal stability and offer a broader operating window. Recent application data validates these materials can be used in two avenues to increase the sustainability profile of asphalt while maintaining or exceeding desired performance parameters.

These specialty waxes are designed for straight addition to enable "grade-bumping." Results show that a low-level addition improves binder stiffness, significantly raising upper temperature grades with negligible impact on lower temperature grade. Because these materials are derived from 100% recycled plastic, formulators add 2-3% recycled plastic content and simultaneously expand the asphalt temperature grade.

Furthermore, these novel waxes can be used to increase the storage stability of TBGTR modified asphalt. A third-party lab validated the materials significantly improve stiffness and % recovery of a TBGTR blend and minimize separation of the GTR from the asphalt matrix, demonstrating these novel waxes enable higher recycled content when used in conjunction with GTR to boost asphalt performance.

Impact of Recycled Polyethylene Particle Size on Interaction with Ground Tire Rubber in Terms of Storage Stability and Mechanical Properties

Helmut Leodarta and William Buttlar
University of Missouri Columbia

The reutilization of waste plastic in asphalt binder has become a popular field of research inquiry in the field of asphalt paving . The motivating factors behind this surge in research activity include reducing the environmental impact of waste plastic, along with realizing potential economic savings and investigating effects on mechanical properties. Polyethylene (PE) is the most abundant recycled plastic, and has been used on a number of early recycled plastic studies worldwide. However, PE-modified binders are known to create challenges with respect to storage stability, due to its higher density as compared to binder, and its non-polarity and inert nature. The addition of Ground Tire Rubber (GTR) as second modifier has been shown to improve the storage stability of PE-modified binder. Chemical compatibilizers usually require long blending times in order to fully react PE with asphalt binder. GTR has the potential advantage of lowering materials costs, due to shorter blending times and additional costs savings realized by employing a second recycled material. The current study examines the interaction between GTR and PE, along with the impact of PE particle size with respect to storage stability. PE powder and ~5 mm PE pellets were investigated in trials with and without GTR. The cigar tube test was used for sample conditioning, and DSR frequency sweeps were conducted to evaluate the storage stability of the various PE-GTR combinations. In addition, High Temperature Performance Grading (PG-HT), viscosity and MSCR testing were carried out to further investigate the effects of different PE-GTR recycling combinations on binder physical properties.

Session 3 - Pavement Recycling and Recycling Agents

Evaluation of Aging Hardening on Reclaimed Asphalt Pavement Binder Containing Rejuvenators

Yanlong Liang, Mohamed Elkashef, David Jones and John Harvey
University of California Davis

Reclaimed asphalt pavement (RAP) has been recycled to reuse the aggregates in paving applications for decades. A primary concern regarding the application of RAP is the advised impact of its oxidative-aged binder. Rejuvenators are, therefore, added to those RAP binders to partially recover aged binders to a less aged status. Rejuvenator rebalances the proportion of light-oily components and heavy aging products in the RAP binder, resulting in a reduction of the aging hardening effect. This study investigates the change of chemical components and physical properties of rejuvenated RAP binder along with different aging protocols. The chemical components are measured by Fourier transform infrared spectroscopy, and the physical properties are obtained from frequency sweep tests using a dynamic modulus rheometer. It is found that rejuvenators decrease the carbonyl components and binder viscosities in RAP binders. After rolling thin film oven test and pressure aging vessel test, carbonyl components and binder viscosities increase in rejuvenated RAP binders. A linear correlation between logarithm viscosity and carbonyl component exists at various temperatures and frequencies. The slope of this linearity is capable of tracking the aging hardening in rejuvenated RAP binders.

Application of Machine Learning in Identification of Rejuvenated Asphalt Binders

Parnian Ghasemi, Joseph Podolsky, Austin Hohmann, Michael Forrester, Nacu Hernandez, R. Chris Williams and Eric Cochran
Iowa State University

Rejuvenators which are used to improve fatigue and low temperature behavior of asphalt binder, vary significantly in their physical properties and chemical compositions. The interactions between rejuvenators and base binder and their impacts on asphalt rheology are complicated. Moreover, the complicated asphalt chemistry adds to the complexity of the problem of finding the correlation between chemical and rheological properties of modified binders. In this study nine modified binders are produced using three rejuvenators and three different binders. The short and long-term aging are simulated in the lab and the rheological properties of the control and rejuvenated binders are assessed. To separate the asphalt binder fractions, SARA fractionation process is conducted. An identification framework for asphalt is established through Small Angle X-ray Scattering (SAXS) and Ion Mobility Mass Spectrometry (IMMS). The identification framework is achieved by analyzing the elastic scattering behavior of X-rays traveling through the asphalt binder fractions (obtained from SAXS), as well as analyzing the chemical composition and molecular structure of the asphalt binders obtained from IMMS. Using the developed framework, the proper material composition of the rejuvenator which is compatible with different base asphalt binders and the optimum dosage of the bio-rejuvenator will be determined.

Coal Additives for Paving Industry and Asphalt Recycling

Devang Khambhati, Jeramie Adams, Nicholas Bolton and Joe Rovani *(1)*; Paul Behrens *(2)*
(1) Western Research Institute; (2) University of Wyoming School of Energy Resources

Coal is an inexpensive, abundant and domestic feedstock, which is facing headwinds for its usage as a fuel due to climate change and competition from intermittent renewable energy. Revenue from coal is very important for coal rich state economies, such as Wyoming. Coal has tremendous potential to be used as feedstock for different materials and chemicals ranging from bulk commodities to specialty chemicals. Due to its high volume, the asphalt paving industry is an attractive outlet for coal products. Coal tar pitches were used in the past for road pavement, but due to the very high concentration of carcinogenic polycyclicaromatic hydrocarbons (PAH), its usage was banned in most of the world. New methods have been developed to extract coal with very low amounts of PAH. Subbituminous Powder River Basin coal and solvent extracts from it have high amount of oxygen, primarily phenolic groups, which makes them very attractive for different chemistries to tune properties and engineer in desired properties. Chemical modified coal and solvent extracts were engineered to make them compatible with petroleum asphalt and show promise for modifying the PG as well as recycling agents. Recycling agents derived from coal and solvent extracts using amine chemistry can lower both the upper PG and lower PG significantly as well as having a positive effect on ΔTc.

Session 4 - Asphalt Mixture Evaluation

Post-Production Asphalt Mix Performance Testing in Ontario

Seyed Tabib, Imran Bashir and Gelu Vasiliu
The Ministry of Transportation of Ontario

The Ministry of Transportation of Ontario (MTO) uses a PG plus specification to mitigate premature pavement cracking. Due to complex nature of the various asphalt mixture components and binder additives, testing the tank asphalt cement (AC) alone may not be sufficient and there is a need for testing post-production products for acceptance.

The 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 (i.e., to achieve a balance between resistance to cracking and rutting). Loose asphalt mix and pavement cores were collected and tested from various paving contracts using the following tests:

- Flexibility Index Test (FIT)
- Disk-Shaped Compact Tension (DC(T)) test
- Hamburg Wheel Tracking (HWT) test
- Grading of Recovered AC

Work to date has revealed that, in general, these tests were able to differentiate asphalt mixes based on PGAC, asphalt mix type, and presence of RAP.

MTO has also evaluated cores taken from good and poor performing pavements 5-13 years old using FIT and DC(T) tests and obtained reasonable results. Both recovered AC grading and mix performance tests are considered effective tools in evaluating pavement performance.

This presentation will provide an overview of the test procedure, results, and preliminary threshold values for acceptance of post-production asphalt mixes.

Asphalt Materials and Characterization for Airport Pavements

Navneet Garg
National Airport Pavements & Materials Research Center

Evolution of commercial aircraft traffic in recent years, in terms of increasing traffic volumes, emergence of new aircraft, new and more complex landing gear configurations, higher wheel loadings and contact pressures, presents a major challenge for airport pavement stakeholders. Extensive research efforts are in progress to develop high-performance materials to withstand these increased wheel loads and tire pressures. The HMA mix design for commercial airports in the United States of America is performed as per guidelines set forth in the FAA AC 150/5370-10, Item P-401. A 75-blow Marshall mix design criterion is used for pavements designed for aircraft gross weights in excess of 60,000 lb (27.2 tonnes) and tire pressures exceeding 100 psi (0.69 MPa). The advisory circular also allows the use of Superpave mix design technology. Research is in progress at Federal Aviation Administration's (FAA) National Airport Pavement & Materials Research Center (NAPMRC) and National Airport Pavement Test Facility (NAPTF) to evaluate new asphalt material technologies such as Warm Mix Asphalt (WMA), use of recycled asphalt pavement (RAP) in HMA, develop performance tests for acceptance of P401 HMA, develop models to characterize the non-linear visco-elastic/visco-plastic behavior of HMA, and design of long lasting asphalt pavements. This presentation will summarize results from research conducted at FAA's accelerated pavement test facilities.

Evaluation of Asphalt Mixture Performance Using Different Cracking and Durability Tests

Amir Golalipour and Varun Veginati *(1)*; David Mensching *(2)*
(1) ESC Inc.; (2) Federal Highway Administration

In the asphalt materials community, the most critical research need is centered on a paradigm shift in mixture design from the volumetric process of the previous 20-plus years to an optimization procedure based on laboratory -measured mechanical properties. This study is focused on advancing the state of understanding with respect to intermediate temperature cracking tests. The materials included are plant-mixed, laboratory-compacted specimens reheated from the 2013 Accelerated Loading Facility study on reclaimed asphalt pavement/reclaimed asphalt shingle (RAP/RAS) materials. Six commonly discussed cracking performance tests (Asphalt Mixture Performance Tester (AMPT) Cyclic Fatigue, Cantabro, Illinois Flexibility Index Test (I-FIT), Indirect Tensile Cracking (IDEAL-CT), Nflex, and Texas overlay) were selected to support the objective of evaluation of different cracking tests. Test results were analyzed to compare differences between the cracking tests. In addition, statistical analysis was conducted to assess the separation among materials (lanes) for each cracking test. Cyclic fatigue and IDEAL-CT tests showed the most promising results. The materials ranking from these two tests matched well with ALF field performance. Furthermore, both of them showed reasonable variability of test data and they were successful in differentiating between different materials.

Assessment of the NCHRP 1-52 Top-Down Cracking Model on a Full-Scale Pavement Test Section

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Recently, a new top-down cracking model for asphalt pavements has been introduced as part of the NCHRP 1-52 Project. This model is designed to be implemented in the AASHTOWare Pavement ME Design software. An updated version of the software, that incorporates the top-down cracking model, is being beta tested.
In this study, the existing cracking data collected at the Pavement Testing Facility (PTF) located at Turner-Fairbank Highway Research Center is being used to evaluate the NCHRP 1-52 top-down cracking model. Inspection of cores from the wheel path edges and other locations has suggested that both top-down and bottom-up cracking contribute to the total cracking obtained at the various projects at the PTF. The total cracking measured is manually separated between top-down and bottom-up, following the procedure described in the NCHRP 1-52 report to characterize crack depth and severity based on surface observations. Using the new beta version of Pavement ME, top-down cracking predictions are compared with measured field cracking performance. The characterization procedure and the NCHRP 1-52 top-down cracking model predictions are discussed.

Quantum Modeling of the Effects of Hydrated Lime (Calcium Hydroxide) as a Filler in Bituminous Materials

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Petersen and several exemplary researchers at WRI demonstrated the beneficial impact of hydrated lime as a mineral filler in bituminous mixtures. Although experimental evidence supports the proposed rheological and chemical changes enhancing the overall durability, the reaction between bitumen moieties and hydrated lime has not been fully investigated at the atomic scale. In this study, quantum molecular modeling techniques were implemented to explore possible mechanisms of resistance to deterioration due to moisture. The interaction between hydrated lime and key molecular building blocks of bitumen was modeled using density functional theory (DFT). The energies of dissociation were calculated and the nature of the bonds characterized. Hydrated lime was found to be capable of reacting with specific functional groups in bitumen moieties and develop strong, water-resistant complexes. Among the functional groups investigated, carboxylic acids were found to be preferential reaction sites between hydrated lime and bitumen moieties. In contrast, analogs of other common fillers such as quartz and calcite were predicted to be unable to chemically react effectively with the bitumen in presence of water.

Laboratory and Field Investigation of Engineered Crumb Rubber Modified Asphalt Binders and Mixtures

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Pre-treatment of crumb rubber is emerging as a popular method to incorporate rubber particles in asphalt mixtures. An Engineered Crumb Rubber (ECR) has been recently used recently by many agencies in pavement construction, including Illinois State Toll Highway Authority (ISTHA). This relatively new dry-process GTR approach utilized rubber particles measuring 400-600 microns in diameter (minus #30 mesh), coated with a non-elastomeric liquid and was added directly to aggregates without any change in aggregate gradation (called dry-hybrid process). In this study, the impacts of ECR modification were investigated in terms of binder properties measured by DSR, MSCR, BBR, and RV. Additionally, mixture properties measured by Disk-shaped Compact Tension (DC(T)) test. Illinois Flexibility Index Test (IFIT), and IDEAL-CT test were evaluated. Following observations were noted with ECR-modification: a) Two-grade bump on high temperature PG with 10% modification by weight of binder, b) improvement in non-recoverable compliance in MSCR test indicated higher rut resistance, c) increase in DC(T) fracture energy at low temperatures, d) improvement in rut depth, e) decrease in flexibility index and CT-index. Lastly, field performance of an ECR-section located in Chicago, IL, supported the lab findings in terms of excellent crack and rut resistance of the mixture.

Session 5 - Polymer-Modified Asphalts

RILEM TC 272 PIM TG1: Glass Transitions in Complex Bituminous Binders

Panos Apostolidis *(1)*; Laurent Porot *(2)*; Michael Elwardany *(3)*; Stefan Vansteenkiste *(4)*; Emmanuel Chailleux *(5)*
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The RILEM TC 272 PIM (Phase and Interphase behaviour of innovative bituminous Materials) – TG1 Binder has initiated an inter-laboratory program investigating the phase and interphase behaviour of bituminous binders. Five laboratories evaluated the low temperature properties of seven standard and complex binders with differential scanning calorimetry (DSC). DSC has been accepted as a powerful tool to evaluate, among others, the glass transitions, Tg, monitoring the endothermic or exothermic heat flow of a material under controlled temperature conditions. There are different ways to run the test, conventional temperature linear-DSC (TL-DSC), and temperature modulation-DSC (TM-DSC). The latter has been proven as an efficient method differentiating the structural relaxation phenomena from the heat capacity. In this study, emphasis was laid on comparing the Tg measured by TL- and TM-DSC improving the interpretation of binder glass transitions. To restrain the scope of this study, two SBS polymer modified binders (PmBs), a commercially available PmB and an highly modified PmB (7.5 % SBS), were evaluated and compared with two neat bituminous binders. It was observed that the modification by 7.5% SBS resulted in a decrease of the Tg. This reduction of Tg reflects the positive influence of SBS at low temperatures.

Rheological and Microstructural Assessment of Complex Bituminous Binders

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In the past years, the use of liquid additives as bitumen modifiers has increased to enhance or adjust the properties of bitumen for wide range of applications. Their molecular composition and mutual interaction result in a specific phase morphology in the binders. Hence, there is a need to evaluate the phase and interphase framework and physical properties of complex binders. The RILEM Technical Committee 272-PIM 'Phase and Interphase behaviour of innovative bituminous Materials', Task Group TG1 investigates the characterization of assessing phase interphase properties of complex bituminous binders. In this framework, three liquid additives have been selected with different viscosity, nature and use. They were blended with base bitumen to achieve similar consistency and the blends were further aged. Physical properties were evaluated through rheology using dynamic shear rheometer (DSR) in a wide range of conditions. The phase morphology was addressed by atomic force microscopy (AFM), differential scanning calorimetry (DSC) techniques. AFM and DSC results, from fresh and aged binders, reveal that each binder display specific phase morphology and glass transition characteristics, manifesting mutual compatibility of the individual binder components. This approach of binder assessment: combining phase characteristics and rheological response can assist material selection to specific applications.

The Expansion of UTI While Maintaining Workable Viscosity Using Isocyanate and SBS Modifiers

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BASF Corporation

In the early 1990s Performance Graded (PG) binder was introduced as a part of the SHRP program. It was then adopted and implemented by the American Association of State and Highway Transportation Officials (AASHTO) in 1999. Since this time production of asphalt binder to meet the initial and expanded PG binder specifications has been conducted using styrene-butadiene-styrene and other limited modifiers. Typically, these modifiers can only be integrated into the binder before storage stability and matrix inversion becomes a problem. Similarly, these materials are primarily used to expand the useful temperature interval (UTI) by a few performance grades. It was noticed in recent experimental studies using isocyanate based modification, that large temperature intervals beyond normal expectations can be reached with no storage stability issues. In this study 2 asphalts were used, with varying levels of SBS, isocyanate-based modification and extender oils to reach extreme levels of useful temperature intervals (x > +4 UTI) while maintaining workable viscosity. Standard PG binder specification testing was used to characterize each modification level. Additionally, MSCR, Elastic Recovery, Ductile properties, and FT-IR characterization were used to further capture the modification level of the asphalt binder.

Relating Performance Parameters to Asphalt Chemical Composition

Bill Winniford, Hayley Brown, D.J. DuBois, Wehzhao Yang, Jeff Sweeney, Tony Gies, Junho Jeon, Dan Baugh III and Praven Boopalachandran
The Dow Chemical Company

Variability in asphalt sourcing and refining procedures results in materials with greatly variable chemical composition, resulting in turn in highly variable performance between asphalts as binders in paving applications. We have previously reported on advances in characterizing asphalts with respect to reactivity, particularly for Reactive Elastomeric Terpolymers (RET). New tools such as ultra-high resolution mass spectrometry can be used to identify specific compounds and functional groups that are present in asphalt but this leads to an enormous amount of data. The ideal measurement techniques are the simplest that predict the performance. We will review our work in evaluating our data sets, comparing chemical composition to performance data.

Exploration of Curing Characteristics for Diluted Epoxy-Modified Asphalt

Raj Dongre *(1)*; Adrian Andriescu, Amir Golalipour and Varun Veginati *(2)*; David Mensching and Jack Youtcheff *(3)*
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FHWA conducted a study of epoxy-modified asphalt (EMA) diluted with two binders of different aging propensities (SHRP asphalts AAD-2 and AAG-2). The exploration was designed to understand the effect of curing rates, as well as long-term post-curing characteristics as a result of isothermal storage of these systems.

Rheological characterization was conducted using AASHTO T 315 and frequency sweep tests in the DSR and the newly developed Asphalt Binder Tester (ABT). DSR test results showed the clear trend of curing time and dilution percentage impact. It was also observed that the parallel plate geometry may not be well-suited to study the higher epoxy percentages due to the thermosetting properties of the EMA. Other researchers have come to the similar conclusion and have used alternate geometries (e.g., torsion bar) for DSR testing. The ABT method was capable of assessing the material for all curing and storage times. Analysis of the ABT data to-date suggests that the binder used as a diluter presents a significant effect on the composite properties. The impact of long-term storage was also found to be dependent on the diluter used.

This presentation discusses the details of the exploratory study to evaluate the curing, aging, and long-term storage characteristics of EMA.

Session 6 - Advancements in Asphalt Fractions Characterization

Impact of Aging on Polarity Fractions of Asphalt Binders

Johannes Mirwald, Stefan Werkovits, Ingrid Camargo, Daniel Maschauer, Bernhard Hofko and Hinrich Grothe
TU Vienna

The service life of a road is determined by the aging behavior of the asphalt binder, as it is the only component of organic nature. Common chemo-mechanical analysis involving dynamic shear rheometer (DSR) and Fourier-Transformation Infrared (FTIR) spectroscopy are capable to capture these changes, but they focus only on the material performances on a composite level. By looking at binder's molecular constituents and how their polarity changes during aging, we analyze aging in terms of molecular chemistry and link it to the binder level.

In this study, various long-term aged (LTA) binders from different crude oil sources were investigated with FTIR spectroscopy, DSR, separated into their four polarity based (SARA) fractions and measured with FTIR spectroscopy subsequently. The results show the same trends on the molecular and the binder level. The most notable changes within the fractions occur in the aromatics, resins and asphaltenes with the formation of carbonyls. The formation of sulfoxides is only found in the resins and asphaltenes. On the basis of this study, we contribute to a more fundamental understanding on how bitumen ages and we translate that knowledge to realistically simulated field aging in the laboratory.

Redefining the Colloidal Instability Index for Paving-Grade Asphalts

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

Asphalt binder production and formulation has significantly changed due to a number of economic, technical, and environmental reasons. Enhanced chemical understanding of asphalt composition and reliable analytical tools are of pragmatic importance. In response to the aforementioned changes, the SAR-ADTM technique was developed combining chromatography separation of the maltenes (SAR) with the solubility separation of asphaltenes (Asphaltene DeterminatorTM-AD) in asphalt binders and hydrocarbon materials in general. SAR-AD separates asphalt binders into the following eight fractions: saturates, three aromatic fractions, resins, and three asphaltenes fractions. This hybrid separation technique was used successfully to diagnose special refining or plant treatments that affect the stability of the colloidal system of asphalts, such as, visbroken/upgraded, air blown, oxidized, polymer modified, and other modified asphalts. The colloidal instability index (CII) is traditionally defined as the ratio between saturates and asphaltenes to the aromatics and resins. In this study, SAR-AD fractions were used to revisit the classical definition of CII for thirty paving-grade asphalts. The Automated Flocculation Titrimeter (AFT) was used to provide a reference measure for the colloidal stability of asphalt binders. The correlation between AFT results and SAR-AD fractions led to redefining the colloidal instability index for paving-grade asphalts. Additionally, this study provided insights on the relationship between the redefined CII and binder rheology.

Effect of Colloidal Index Variation on Chemical-Rheological-Mechanical Properties of Asphalt Binders Modified by Recycling Agents Under Different Aging Conditions

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This research studied the effect of colloidal index (CI) variation on chemical-rheological-mechanical properties of asphalt binders modified by five different classes of recycling agents (i.e., paraffinic oils, aromatic extracts, naphthenic oils, triglycerides/fatty acids, and tall oils) under different aging conditions. For chemical investigation, the asphalt binders were examined using saturates-aromatics-resins-asphaltenes (SARA) and elemental (oxygen) analysis. The low temperature properties (relaxation constant and flexural creep stiffness) of asphalt binders were characterized using bending beam rheometer (BBR). Dynamic shear rheometer (DSR) was employed to evaluate cracking resistance of asphalt binders at mid temperature using Glover-Rowe parameter and rutting performance of asphalt binders at high temperature. It was shown that recycling agents could vary the softening and long-term performance of the blended binders based on their chemical makeup. This chemistry directly affected the binders, the resultant CI, and sometimes produced binder blends that were shown to be unstable and not able to withstand long-term aging. In addition, the results revealed a strong linear correlation between the CI and the chemical-rheological-mechanical properties of all binders in different aging conditions, with the exception of the Glover-Rowe parameter.

Advancements in SAR-AD Capabilities and Applications

Joe Rovani, Jeramie Adams, Seth Bassham, Nicholas Bolton, Michael Elwardany and Jean-Pascal Planche
Western Research Institute

WRI's SAR-AD analytical instrument and methodology is used to separate asphalt binder into eight constituent solubility and polarity-based fractions. Development efforts in past years have focused on optimization of the technique to provide repeatable quantitative fraction contents. More recent efforts have been devoted to understanding the chemistries of the fractions and discriminating differences in chemical compositions within each fraction. New developments utilizing SAR-AD size exclusion, diode-array detection, fluorescence detection, and more efficient column sizes for a variety of visbroken, airblown, modified, and reference binders - with RTFO and PAV-aged counterparts, will be presented.

Session 7 - Pavement Sealing Materials

The Effect of Zeta Potential on the Cohesive Strength of Slurry Seals

Irvin Pinto and Ashley Buss
Iowa State University

Emulsion formulation parameters like pH, the nature of the emulsifier and emulsifier dosage play an important role in the stability of quick setting bituminous emulsions. In order for zeta potential to be introduced as a measurement in the design process of emulsions, it is important to understand how emulsion stability affects emulsion treatment performance. This study will determine the cohesive strength developed at 60 and 90 minutes of curing time by changing the mix design parameters of the slurry seal mix and include the emulsion pH as a variable so that the effect of emulsion reactivity on the cohesive strength of a slurry seal mix can be studied. This research makes use of the zeta potential of the emulsions used in the mix design to determine if the model developed to predict cohesion from the slurry seal mix design parameters is still applicable if emulsion pH is replaced with zeta potential as an independent variable. This research aims to pave the way for future studies to determine the effectiveness of using zeta potential to predict slurry seal performance and the effectiveness of emulsions in the field.

Field Study Evaluation of Soybean Oil Derived Additives Used in a Bio-Cutback and Bio-Fog Seal for Brittle HMA

Maxwell Staver, Joseph Podolsky, Theodore Huisman, R. Chris Williams, Irvin Pinto and Ashley Buss
Iowa State University

Pavement preservation treatments applied before significant deterioration and cracking has occurred can extend the service life of a pavement and reduce future maintenance costs. Rejuvenating materials can help to increase the performance of these preservation treatments. Soybean derived additives have been found to greatly reduce the stiffness of aged and brittle asphalt binders. This report proposes the use of these soybean derived additives to be used in a fog seal emulsion and as a bio-cutback treatment. Cutbacks are not used often due to the environmental hazards of the traditional cutbacks that use kerosene for the solvent. The bio-cutback utilizes a soybean derived oil as the solvent that would greatly reduce the environmental concerns of using a cutback, however the oil does not evaporate away. Instead, the soybean oils diffuse into the aged asphalt and reduce the stiffness. The bio-fog seal utilizes the soybean derived additives in the asphalt phase of the emulsion. This reduces the temperature required to create the emulsion, as well as adds the rejuvenating effect of the soybean oil to the fog seal. The results of an ongoing field study will be presented.

Session 8 - Machine Learning Applications

Deep Learning Approach for Automatic Pavement Distresses Detection Using Google-Map Images

Hamed Majidifard, Yaw Adu-Gyamfi and William Buttlar
University of Missouri

Pavement distress inspections are performed using sophisticated data collection vehicles and/or foot-on-ground surveys. In either approach, the process of distress detection is human-dependent, expensive, inefficient, and/or unsafe. Automated pavement distress detection via road images is still a challenging issue among pavement researchers and computer-vision community. In this study, we extracted 7237 google street-view, manually annotated for classification (nine categories of distress classes). Afterward, YOLO (you look only once) deep learning framework was implemented to train the model using the labeled dataset. Also, U-net based model is developed to quantify the severity of the distresses, and finally, a hybrid model is developed by integrating the YOLO and U-net model to classify the distresses and quantify their severity simultaneously. The output of the distress classification and segmentation models are used to develop a comprehensive pavement condition tool which rates each pavement image according to the type and severity of distress extracted. As a result, we are able to avoid over-dependence on human judgement throughout the pavement condition evaluation process. The outcome of this study could be conveniently employed to evaluate the pavement conditions during its service life and help to make valid decisions for rehabilitation of the roads at the right time.

From PG Grade to Pavement Performance - A Virtual Research Project

Raj Dongre *(1)*; Jack Youtcheff *(2)*
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All State Transportation Agencies (STAs) test asphalt binders to verify PG grade compliance. In determining this compliance, testing is simply conducted at the passing temperature. As a result, the STAs have limited single temperature test data on asphalt binders. New tests and parameters such as the MSCR test and specification, and Delta Tc continue to emerge but not all state STAs are using these.

A research project was designed to determine if a DOT engineer can virtually obtain necessary information from the PG grading compliance data to predict pavement performance without doing a single additional hot-mix or binder test. A second interest was to obtain MSCR and Delta Tc using the same limited PG data.

Artificial Neural Network (ANN) modeling was used to predict MSCR and Delta Tc from the PG grade data. The continuous PG grade was also accurately predicted using ANN models and the PG grade data. Using the ANN predicted data, gradation, and volumetrics information, dynamic modulus (E*) was predicted using a highly accurate ANN model.

This presentation explains in detail the results of the virtual research project and the process used to obtain them. An ANN based software that can predict the MSCR parameters, Delta Tc, and continuous PG grade from PG grade will also be demonstrated. The ability of PG grade data to predict pavement performance using the AASHTOWARE MEPDG will also be examined.

Machine Learning-Based Prediction Models for Performance of Asphalt Mixtures

Hamed Majidifard, Behnam Jahangiri, Punyaslok Rath and William Buttlar *(1)*; Amir Alavi *(2)*
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In this study a prediction tool was developed to predict the performance of asphalt mixture at high and low temperatures. This tool is based on two different prediction models for DC(T) fracture energy and Hamburg wheel track tests. For DC(T) fracture energy model, genetic programming was used to develop the prediction model, and Convolution Neural Network (CNN) was used to train the Hamburg wheel track model on 10,000 data points. A database containing a comprehensive collection of Hamburg and DC(T) tests results were used to develop the machine learning-based prediction models. This tool can be used for pre-design purposes to design an asphalt mixture with balanced performance in rutting and cracking. The models were formulated in terms of typical influencing mixture properties variables such as asphalt binder high-temperature performance grade (PG), mixture type, aggregate size, aggregate gradation, asphalt content, total asphalt binder recycling content and tests parameters like temperature and number of cycles. Models accuracy were assessed through a rigorous validation process and found to be quite acceptable, despite the relatively small size of the training set. Since performing performance tests might be cost-restrictive for some users, using the proposed ML-based models can save time and expense during the material screening phase.