51st Petersen Asphalt Research Conference

Asphalt Spoken Here

July 14-16, 2014    Laramie, Wyoming
51st Petersen Asphalt Research Conference

University of Wyoming Conference Center
July 14-16, 2014     Laramie, Wyoming

Organized by Western Research Institute

Monday, July 14

7:30 AM    Registration—Pick up conference materials    Hilton Garden Inn and UW Conference Center

8:00-8:15  Welcome and Opening Remarks    Jean-Pascal Planche, Don Collins, and Stephen Salmans

8:15-8:45  Opening Plenary Speaker    William A. Gern, Vice President, Research and Economic Development, University of Wyoming

SESSION 1  Session Chair: Shin-Che Huang, WRI

8:45-9:15  Characterizing Blending Efficiency of Recycled Asphalt Shingles (RAS) and Virgin Binders    Sheng Zhao and Baoshan Huang, University of Tennessee–Knoxville

9:15-9:45  Comparison of Asphalt Cement Acceptance Methodologies for Provincial Highways in Ontario    Alexander Brown, Asphalt Institute

9:45-10:05 Break


10:35-11:05 Hydrothermal Liquefaction as a Route to Transform Microalgae Residues in Bio-Asphalt    Emmanuel Chailleux, IFSTTAR; C. Queffélec, CEISAM; M. Audo, IFSTTAR; M. Paraschiv and M. Tazerout, EMN; J. Legrand, GEPEA; O. Lépine, Algosource; and B. Bujoli, CEISAM

11:05-11:35 Feasibility Study of Performance Grading Particulate Asphalt Rubber Binders    Sallie Houston, VSS International
### Monday, July 14, continued

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<td>Thermo-mechanical Behaviour of Mixtures Containing Bio-binders</td>
<td>Simon Pouget Eiffage</td>
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**SESSION 2**  
Session Chair: James Beiswenger, WRI

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<td>Evaluation of Performance Properties of Asphalt Mixes Containing RAP Produced with Re-refined Heavy Vacuum Distillate Bottoms Modified Binder</td>
<td>John D’ Angelo D’Angelo Consulting, LLC; Ken Grzybowski and Christine Feaster, EIT PRI Asphalt Technologies, Inc.; and Mark Bouldin and Steve Lewis Safety-Kleen</td>
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<td>Effect of Mineral Filler on Molecular Size Distribution of Asphalts during Aging Process</td>
<td>Raquel Moraes and Hussain Bahia University of Wisconsin-Madison</td>
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<td>Asphalt Diffusion</td>
<td>Pavel Kriz Sarnia Research Centre, Imperial Oil Ltd.</td>
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<td>Towards Simplified Measurements of Oxygen Diffusion Depth in Mixtures: Comparison of Slice-by-Slice Total Air Void Measurements to X-Ray CT Scans</td>
<td>Avery A. Rose Texas A&amp;M University; Edith Arambula Texas A&amp;M Transportation Institute; and Tanner Howell and Charles J. Glover Texas A&amp;M University</td>
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<td>3:30-4:00</td>
<td>Investigation of Aggregate Adhesion and Mixture Characteristics on the Hardening Susceptibility of Asphalt Binders</td>
<td>Nathan Morian Nevada DOT/ Western Regional Superpave Center; and Zia Alavi and Elie Hajj University of Nevada-Reno</td>
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<td>4:00-4:30</td>
<td>Chemical-Mechanical Analysis of Multi-aged Bituminous Binder</td>
<td>Laurent Porot and Pieter Eduard Arizona Chemical, Almere the Netherlands</td>
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<td>4:30-5:00</td>
<td>Correlations of Asphalt Chemical and Rheological Properties with Oxidation Behavior and Crack Survey Data</td>
<td>Ron Glaser, Ryan Boysen, Steve Salmans and Thomas F. Turner Western Research Institute</td>
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**MONDAY EVENING**—*Dinner on your own.*
**Tuesday, July 15**

**SESSION 3  Session Chair: Fred Turner, WRI**

8:00-8:30  Application of Pressure Differential Scanning Calorimetry Methods to the Study of Asphalt Oxidation Kinetics  
Thomas F. Turner and Ron Glaser  
Western Research Institute

8:30-9:00  Every Pavement Can Be a Test Section: Comparing Mature Pavement Age-Related Distress to Binder Oxidation and Hardening and Projecting Future Performance  
Yuanchen Cui and Charles J. Glover  
Texas A&M University

9:00-9:30  Laboratory and Field Performance of Dry-Process Crumb Rubber Mixes  
Redmond Clark  
Asphalt Plus and Raj Dongre  
DLSI

9:30-10:00  Investigation of Suitable Testing Method for GTR Modified Asphalt Binder  
Amir Golalipour  
Anton Paar USA and Tobias Nill  
Anton Paar Germany

10:00-10:20  Break

10:20-11:10  Evaluation of Testing Variability from Variations to Testing Geometries for Recycled Tire Rubber  
Gaylon Baumgardner  
Paragon Technical Services, and John D’Angelo  
D’Angelo Consulting, LLC

11:10-11:40  Rheological Comparison of Crumb Rubber Modified Asphalts Using Two Different Gap Geometries  
Ka Lai Ng and R. Christopher Williams  
Iowa State University

11:40-12:10  Evaluation of a 100% RAP Recycling Project in Fort Wayne, Indiana  
Geoffrey M. Rowe, John Barry and Ken Crawford  
Abatech Inc.

12:10-1:15  Lunch

**SESSION 4  Session Chair: Will Grimes, WRI**

1:15-1:45  Modelling of Asphalt Binder DSR and BBR Rheological Data Using Huet Model and Cole-Cole and Black Space Plots  
Jean-Claude Carret University of Lyon, ENTPE, France; Mihai O. Marasteanu University of Minnesota; and Augusto Cannone Falchetto and Michael P. Wistuba  
Braunschweig Univ. of Technology, Germany
Tuesday, July 15, continued

1:45-2:15  Recent Developments in Asphalt Binder Linear Amplitude Sweep (LAS) Test  
Bob Kluttz *Kraton Polymers*, Cassie Hintz *NCSU*, Sebastiań Puchalski *Kraton Polymers*, and Adrian Andriescu *SES Group & Associates, LLC*

2:15-2:45  ABlaos - Asphalt Binder Large Amplitude Oscillatory Shear  
Michael J. Farrar, Jean-Pascal Planche, Alec Otto Cookman, and Steve Salmans *Western Research Institute*

2:45-3:00  Break

3:00-3:30  Establishing a Protocol for High Stiffness DSR Rheological Measurements  
David A. Anderson *Consultant*, Michael J. Farrar *WRI*, Gerald Reinke *MTE Services Inc.*, Mike Anderson *Asphalt Institute*, Gaylon Baumgardner *Paragon Technical Services, Inc.*, and Matthew Corrigan *FHWA*

3:30-4:00  Interrelationships in Rheological Parameters  
Geoffrey M. Rowe *Abatech Inc.*

4:00-4:30  Switchable-Hydrophilicity Solvent Technology for Extraction of Asphalt Binder from Recycled Asphalt Shingles  
Joe Rovani *Western Research Institute*, David Haedt *ASPEXT*, James Lockhart *NORAM Engineering and Constructors*, Ira Wolf *BC Research*, and Lowy Gunnewick *Switchable Solutions, Inc.*

Tuesday Evening Dinner  
at the  
Snowy Range Ski Area

5:00 Buses leave the conference center
5:45 Social Hour (Cash Bar)
6:45 Dinner

Options for special diets available—please inquire at registration table.
Wednesday, July 16

SESSION 5  Session Chair: Mike Farrar, WRI

8:00-8:30  Evaluation of Methodologies for Crossover Modulus Determination  Shane Underwood, Arizona State University; Michael Farrar, Western Research Institute; and Y. Richard Kim and Cassie Hintz, North Carolina State University

8:30-9:00  Investigations towards Understanding of Coalescence in Bitumen Emulsions for Cold Asphalts  Abdullah Khan, KTH Royal Institute of Technology, Per Redelius, NYNAS Bitumen AB, and Niki Kringos, KTH Royal Institute of Technology

9:00-9:30  Development of a High Modulus Binder in Brazil  Alexander Vivoni, Carlos Herrmann, and Carlos Junqueira, Petrobras Distribuidora; and Luis Herrmann, Petrobras Research Center

9:30-10:00  A Review of Field Trials Using Composite Layered Pavement Preservation Technologies  Gary Houston and Sallie Houston, VSS International

10:00-10:20  Break

10:20-10:50  Comparative Performance of Bio-based/Chemical Additives in Warm Mix Asphalt at Low Temperature  Joseph Podolsky and R. Christopher Williams, Iowa State University

10:50-11:20  The Morphological and Property Changes of Asphalt Microstructure after Short-term and Long-term Aging  Yuhong Wang, Hong Kong Polytechnic University and Xin Yu, Hohai University, China


11:50  Closing Remarks

Dr. William A. Gern
As Vice President for Research and Economic Development at the University of Wyoming (UW), Dr. Gern has worked with UW’s seven colleges to develop research and technology development programs and has led UW’s outreach programs to integrate research, technology transfer and economic development. With a PhD in biology, he has conducted research on environmental effects on aquatic life, including those associated with acid precipitation. He has won many teaching awards and is on the board of directors of the EPSCoR (Experimental Program to Stimulate Competitive Research) States Coalition, the Wyoming Industrial Development Corporation, the Ruckelshaus Institute for Environment and Natural Resources, and Western Research Institute.
Traditionally treated as a waste material, waste asphalt shingles may be utilized in asphalt paving mixtures as recycled asphalt shingle (RAS). However, since the asphalt binder from RAS is extremely stiff compared to regular asphalt binder, insufficient blending of the aged and virgin binders may occur in RAS mixtures during mixing, thus compromising the long-term performance and shortening the pavement service life. Up to date, there has been limited research addressing this problem. In the present study, methods for characterizing blending efficiency of RAS and virgin binders were explored. Gel permeation chromatography (GPC) was utilized to characterize binders extracted and recovered from selected aggregates so as to qualitatively and quantitatively investigate the degree of RAS binder rejuvenation during mixing. In addition, atomic force microscopy (AFM) was adopted to directly observe the blending in terms of microstructures. It was found that GPC was capable of characterizing and quantifying the RAS binder rejuvenation during mixing. Mixing time and RAS content effectively affected the rejuvenation, while mixing temperature in selected range and virgin aggregate size showed little effect. The microstructural observation indicated that virgin and RAS binders were more likely to be ‘mixing’ rather than ‘blending’.
Comparison of Asphalt Cement Acceptance Methodologies for Provincial Highways in Ontario

Alexander Brown
Asphalt Institute

The use of the Double Edged Notch Tension (DENT) test for acceptance has been the source of considerable technical debate between industry and provincial authorities in Ontario. In 2010, the MTO–OHMPA Binder Task Group agreed that the issue could not be resolved by technical debate. Accordingly, MTO and industry partnered on a unique trial to evaluate the effect of four different approaches to acceptance on full MTO contracts with additional criteria: using DENT and Extended BBR (ExBBR); using the Recovery portion of the Multiple Stress – Creep Recovery test (MSCR); using 98% reliability for low temperature grading; and, as a control, using only ASSHTO M320 and the Solubility (Ash) test. On all the projects, all of the laboratory testing was carried out on each of the Quality Assurance binder samples taken during the normal course of the project execution. The trial contracts were paved between 2010 and 2013. It is intended that a performance evaluation of the contracts will be performed by the Binder TG on a yearly basis starting in the third year of service. These inspections will start in 2014 and will continue until the sections are 7 to 8 years in age.

This paper summarizes the methodology for the various test procedures. In addition, the results of the laboratory testing carried out on approximately 125 asphalt cement QA samples collected from the 33 contracts are also presented. The differences and similarities of the test results in reference to the acceptance criteria are examined. In addition, changes to the specification for acceptance of asphalt cement on Ontario provincial highways are presented as well as future directions in the research.

Binder Quality Assurance Test Method (QA Test) – Progress Report

Raj Dongre (1); and Jack Youtcheff, Adrian Andriescu, and Nelson Gibson (2)
(1) DLSI; (2) Federal Highway Administration

An innovative, simple, and easy-to-use test method for Quality Assurance of asphalt binders was developed. This new method, called the binder QA test, uses an air jet to produce indentation loading. A laser deflectometer installed coaxially to the air jet is used to measure the resulting deflection from the indentation. The QA test is conducted under stress control at an air pressure of 15 psi and test temperature of 77°F (25°C). The test protocol is similar to the traditional Penetration test (ASTM D5) except instead of the penetration needle an air jet is used with a loading time of 15s and recovery time of 60s under no load. Unlike the Penetration Test, the QA test measures both the loading and recovery characteristics of a binder. The complete creep-recovery curve is measured and stored. The measurement of recovery properties allows for successful testing of both unmodified and polymer modified binders.

Several PG graded asphalt binders were tested with and without modifiers. Modifiers included polymers as well as Recycled Engine Oil Bottoms (REOB). Several modifier contents were tested using this device. Penetration graded asphalt binders obtained from Europe were also evaluated using the test. It was found that the QA test was able to distinguish between the various PG grades and Penetration graded binders and produced rankings similar to the PG and Pen grading systems. It was also found that the results were able to discriminate between the various type and content of the modifiers used. This implies that the QA test may be used to assure that during production the asphalt binder supplied is within the requirements specified by the user during the design process.

Possible implementation of the QA test method developed in this study include quick and easy determination of asphalt tank contamination issues, value engineering projects, and during polymer modified binder formulation studies.

At last year’s Petersen conference, a demonstration of the QA test method was presented. This year the progress towards development, implications and implementation of the binder QA test will be presented.
Hydrothermal Liquefaction as a Route to Transform Microalgae Residues in Bio-Asphalt

Emmanuel Chailleux (1), C. Queffélec (2), M. Audo (1), M. Paraschiv (3), M. Tazerout (3), J. Legrand (4), O. Lépine (5), and B. Bujoli (2)
(1) IFSTTAR; (2) CEISAM; (3) EMN; (4) GEPEA; (5) Algosource

The worldwide petroleum production doesn’t increase anymore. In that context, refining strategies are changing: for example, high molecular fractions can be cracked into lighter fuel fractions and consequently, in the future, it could be difficult to answer to the worldwide needs in asphalt. To avoid this problem, some biomass-based binders have been developed. They are generally based on a mixture between a vegetable oil, like rapeseed oil, a natural or modified vegetable resin and a synthetic polymer in order to adjust the rheological properties. The weak point of those alternative binders is that edible oil is used. Therefore, it has been decided to investigate the potential of a new promising biomass, microalgae, which don’t compete with human feeding.

Microalgae are already studied for bioenergy, cosmetics, nutraceuticals or animal feeding. For economic and ecological reasons, the by-products resulting from the microalgae industries have to be valorized. Consequently, we propose to study the potential of using those by-products as binder for aggregates.

To achieve this goal, two processes have been studied. First, extraction steps have been performed as an exploratory, descriptive study. The oil extracted has been characterized from a chemical and a mechanical point of view, and showed an interesting asphalt-like behaviour. The comparison of rheological and chemical analyses allows highlighting a relationship between the thermo-dependent behaviour of the oily extracts and the presence of some specific chemical species. Nevertheless, to reach an economic viability, all fractions of the new microalgae industry must be valorized (proteins, lipids, polysaccharides), so that the “algo-refinery” concept is achieved. The second study focused on a new promising solvent-free method to valorize all the fractions in the microalgae, not only the lipid fraction: the hydrothermal liquefaction. This process allowed recovering around 54% of a hydrophobic material. This material is made of a mix between solid residues and bio-oil (the bio-crude), which ratio depends on the experimental conditions (temperature, atmosphere). The process parameters allow to control bio-crude rheological behavior to reach the one of petroleum bitumen.

Feasibility Study of Performance Grading Particulate Asphalt Rubber Binders

Sallie Houston
Technical Manager, VSS International

There is increased interest in performance based testing of ground tire rubber (GTR) modified asphalt versus the current empirical testing such as rotational viscosity at 190°C. There is an effort in AASHTO committee recommending a 2mm gap on the Dynamic Sheer Rheometer (DSR) for GTR modified binders containing particles 0.6 millimeter and smaller. There are several state agencies that have incorporated this modification into their specifications.

This study includes GTR modified binders with larger particle sizes of 0.6 to 1.4 millimeter using existing specifications and a modified 3mm gap for both high temperature and intermediate temperatures on the DSR. The Pacific Coast Conference on Asphalt Specifications (PCCAS) Round Robin Committee has completed Phase One of a feasibility study of full Performance Grading using one GTR modified binder. This study included 10 laboratories representing states, industry and academia in the western United States.

Using ASTM standards for performing inter-laboratory studies the data show strong agreement of variance in inter and intra lab data and strongly indicate feasibility of the test method. PCCAS is implementing Phase Two of the study which will involve the development of a precision and bias statement through a round robin using multiple GTR modified binders.
PRI Asphalt Technologies Inc. is a fully accredited, independent third-party technical services laboratory with locations in Tampa, FL and Munster, IN (Chicago area).

Complete technical support for asphalt/bitumen and related materials and products for domestic and international markets for Paving, Roofing and Industrial.

**Staff and Facilities:** Over 40 technicians, scientists, and engineers trained in more than 600 Federal, State, ASTM, AASHTO, and International (IP, EN, BS, GOST, and others) test methods and specifications, and maintain certifications through NICET, NETTCP, AI/NBTC, and various professional associations and agencies. Combined facilities encompass over 60,000 ft.² and housing state-of-the-art testing and evaluation equipment.

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- **Adhesives**  
  Pavement Markers  
  Roofing Products
- **Aggregates & Soils**  
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  Mineral Aggregates & Fillers: particle size, Surface area, etc.
- **Asphalts/Bitumen**  
  Conventional, SUPERPAVE™  
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- **Crack & Loop Sealants**  
  Hot and/or Cold-Applied
- **Crude Oils**  
  Asphalt/Bitumen Characterizations  
  Analysis  
  Atmospheric/Vacuum Distillations
- **Cutbacks**  
  All Types, plus cutback-based products
- **Emulsions**  
  All Types, Pilot Mill for R&D
- **Forensic/Product Failure Investigations**  
  LEED Product Certifications
  Litigation Support
  Mix Designs  
  Marshall, SP, HMA, CIR, FDR, Micro, Slurry, RAP, RAS
  Modifiers/Polymers  
  Elastomers, Plasticizers, Reactants
  Pavement Field Services  
  FDR, Profilograph
  Pavement Performance Properties  
  All
  Pavement Preservation & Maintenance  
  Micro/Slurry/Chip Sealer-CIR/FDR/Thin lifts, Rejuvenator Sealers
  Petroleum Coke  
  Characterization, QC, QA
  RAP & RAS  
  Characterization
  Referee Testing
  Release Agents
  Roofing - Complete Composition & Performance Properties  
  Accelerated Weathering  
  Evaluation & Characterization of all raw materials  
  Fluxes, Oxidation
  Stripping Paints
  Sustainable Materials
Thermo-mechanical Behaviour of Mixtures Containing Bio-binders

Simon Pouget
Eiffage

The objective of the presented study is to develop an approach to assess the linear viscoelastic (LVE) properties and the low-temperature behaviour during thermal ageing of semi-coarse asphalt concrete (SCAC) containing bio-binders. The investigation is part of a wider ongoing research project in EIFFAGETravaux Publics Research Center. Tension/compression complex modulus tests, direct tensile strength tests at low temperatures and thermal stress-restrained specimen tests were performed on SCAC, containing three different clear binders. The first one is a reference petroleum-based clear binder, the two others are bio-binders, manufactured from renewable raw materials and fit in with the ideas of sustainable development. The analogical LVE 2S2P1D model (2 springs, 2 parabolic elements, 1 dashpot) was used to fit experimental data for the three mixtures. This method seems to be very relevant to compare rheological properties of mixtures made with bio-binders, for which evolution of low-temperature behaviour with ageing is very discriminatory.

Session 2

Evaluation of Performance Properties of Asphalt Mixes Containing RAP Produced with Re-refined Heavy Vacuum Distillate Bottoms Modified Binder

John D’Angelo (1); Ken Grzybowski and Christine Feaster, EIT (2); and Mark Bouldin and Steve Lewis (3)
(1) D’Angelo Consulting, LLC; (2) PRI Asphalt Technologies, Inc.; (3) Safety-Kleen

Asphalt mixtures are increasingly incorporating recycled asphalt pavement (RAP) and/or recycled asphalt shingles (RAS) as a means to control costs, provide sustainability, and conserve resources. These mixes, similar to conventional mixes, must perform to the same standards. The mixes must exhibit long life, low and high temperature properties and distresses of cracking, moisture damage and raveling. The inclusion of RAP and/or RAS provides new and different concerns in asphalt binder selection. To compensate for the aged asphalts in the RAP and RAS and assure required mix performance, lower temperature PGs or modifying a PG with recycling or softening agents are used.

Re-refined Heavy Vacuum Distillate Bottoms (RHVDB) or residue from re-refining of selected used engine oils has been used to improve low temperature properties (crack and aging resistance) of asphalt binders and the resultant conventional mix. Two previous papers have shown binders modified with RHVDB exhibit improved properties as a function of dosage and the beneficial impacts on performance properties in mixes without RAP or RAS.

Questions are: Will the use of RHVDB modified binder improve pavement performance incorporating RAP and/or RAS and potentially provide a means for more use?

In this study, an in-depth evaluation was performed to determine performance characteristics of asphalt mixtures with 20% RAP using PG binders with and without (Control) RHVDB. The comparative performance characterization evaluated an array properties both before and after accelerated weathering. The study provides an extensive evaluation of the effects of RHVDB modification on initial and aged (simulates 10-15 years) mix performance.
Effect of Mineral Filler on Molecular Size Distribution of Asphalts during Aging Process

Raquel Moraes and Hussain Bahia
University of Wisconsin-Madison

Asphalt binders are used in conjunction with mineral aggregates in pavements and roofing (i.e. asphalt mastics). Current aging specification tests are only conducted on binder phase. Therefore, interactions between binders and mineral fillers and effect on oxidative aging process is of concern. In this study, an experimental testing matrix was performed to account for different chemical and physical conditions in asphalt mastics. Viscoelastic master-curve of aged mastics showed that presence of filler during aging resulted in a reversal of master-curve slope change observed during individual aging of base binder. A method to characterize behavior of mastics with aging was found to be through monitoring its G* aging index (ratio of complex modulus before and after aging). Results clearly indicate that fillers can significantly change effect of oxidative aging of binders. Gel Permeation Chromatography (GPC) results supported mentioned findings regarding G* changes, as presence of mineral filler appears to decelerate rate of production of larger molecular size oxidation products in binder phase of mastics. Implication of this finding is that molecular size distribution of asphalts, which is a controlling factor in mechanical and thermo-volumetric behavior, can be engineered by proper design of mastic phase. It is concluded that by selecting a proper type and concentration of filler, aging of pavement or roofing shingle, and consequently durability and performance can be controlled.

Asphalt Diffusion

Pavel Kriz
Sarnia Research Centre, Imperial Oil Ltd.

Use of recycled asphalt pavement (RAP) is beneficial to both road owners and builders as it allows for significant raw material cost reduction, while potentially maintaining expected pavement service life. RAP contains significantly aged (harder) asphalt binder. Therefore a softer virgin binder may be required, namely at high RAP concentration, to soften the RAP binder and ensure an adequate road performance. Appropriate blending between the binders in the mix is essential to ensure resistance from pavement moisture damage and permanent deformation, and adequate low temperature performance. There is currently little understanding to what extent and at what rate the RAP and virgin binder blend during mix production, placement and compaction.

The diffusion kinetics between RAP and virgin binders is of interest in this study. A previously developed testing protocol which uses dynamic shear rheometer to determine diffusion coefficient is employed. Study outcomes are utilized to simulate binder diffusion during typical temperatures and residence times observed for HMA and WMA production and placement. Based on the model developed here guidance on proper mixing times and temperatures to practitioners is provided.
Towards Simplified Measurements of Oxygen Diffusion Depth in Mixtures: Comparison of Slice-by-Slice Total Air Void Measurements to X-Ray CT Scans

Avery A. Rose (1), Edith Arambula (2), Tanner Howell (1), and Charles J. Glover (1)
(1) Artie McFerrin Department of Chemical Engineering, Texas A&M University;
(2) Texas A&M Transportation Institute

Recent efforts towards relating pavement failure to binder oxidation and hardening have resulted in the development of a pavement oxidation model. This model uses binder oxidation kinetics and hardening parameters, together with readily available climate data, to estimate binder oxidation and hardening in pavements as a function of time, depth, and geographic location. A key parameter of this model is the binder “diffusion depth,” the ratio of the binder content to the accessible air voids (AAV) surface area. One method of estimating the AAV and their surface area is via x-ray CT scans.

Towards an alternate methodology, we have measured total air voids (TAV) of core slices and compared the results to x-ray CT. The cores were cut into multiple slices, nominally 0.4 in thick. Because of the small size of core specimens compared to sizes specified by the standard volumetric procedures, techniques were evaluated for their accuracy and precision: a vacuum drying machine was used to provide improved precision and speed of drying between elements of the process; alternative methods for measuring bulk and theoretical maximum specific gravities were compared; variation of estimated TAV with depth was compared to x-ray CT data. Further evaluation continues with the objective of estimating the diffusion depth.

Investigation of Aggregate Adhesion and Mixture Characteristics on the Hardening Susceptibility of Asphalt Binders

Nathan Morian (1); and Zia Alavi and Elie Hajj (2)
(1) Nevada Dept. of Transportation/Western Regional Superpave Center; (2) University of Nevada-Reno

An investigation into the oxidation properties of mixture-aged asphalt binders contrasted between mixtures composed of multiple aggregate sources and the corresponding pan-aged binders with special attention given to the chemical interaction between aggregates and binders. Oxidation kinetics were determined through Fourier-transform infrared spectroscopy techniques, which were combined with shear modulus master curves of the asphalt binders to determine the hardening susceptibility relationships. The hardening susceptibility parameters were utilized to investigate the influence of the varied aggregate sources as well as several aspects of the mixture characteristics, e.g. air void level, asphalt binder content, and qualitative gradation. An evaluation of the asphalt-aggregate interaction was performed utilizing a modified SARA analysis to quantify the adsorption characteristics of the respective mixtures. Further evaluation of the low-temperature properties of the evaluated mixtures were also conducted utilizing the proposed Uniaxial Thermal Stress and Strain Test (UTSST) with respect to the same oxidative aging levels. The characterization resulting from the UTSST testing provided additional measures of not only the increased stiffness of the oxidized mixtures, and also provided information regarding the balance between the reduction of the viscous properties (i.e. flexibility) and increased brittleness of the mixtures.
Chemical-Mechanical Analysis of Multi-aged Bituminous Binder

Laurent Porot and Pieter Eduard

Arizona Chemical, Almere the Netherlands

Paving asphalt material may be seen as a living in that the behavior of the material changes over time thus affecting the end performance of the pavement. This change occurs primarily through oxidation thus modifying the chemical structure of the binder. As a consequence, the mechanical properties of the binder are affected, becoming harder and more brittle. Will these changes last forever or will they reach, to a certain extent, some degree of stabilization?

Among other techniques, infra-red spectrometry is a useful tool to address the change in oxidation through sulfoxide and carbonyl index. The hardening of the mechanical properties can be observed with fundamental rheological analysis using DSR. While these tools are widely used to demonstrate aging, there is limited work on very long term aging. This presentation shows the results of a multi aging study whereby binder samples underwent excessive aging – 5 cycles using PAV – and were then analyzed by FTIR and DSR. One point of interest is a trend between the increase in the carbonyl index and the change in cross-over parameters. It may open the door towards more qualitative and quantitative characterization of the degree and phenomena of aging.

Correlations of Asphalt Chemical and Rheological Properties with Oxidation Behavior and Crack Survey Data

Ron Glaser, Ryan Boysen, Steve Salmans and Thomas F. Turner

Western Research Institute

Preliminary investigations into understanding the role of functional groups and solubility in determining the rheological properties of fresh and aged asphalts are presented. SARA fractions are used to provide solubility defined fraction information and Fast Fourier Transform Infrared spectroscopy is used to provide functional group information. Calorimetric data is also studied. The rheological properties are obtained from Dynamic Shear Rheometry. This presentation describes efforts to find how chemical methods may be employed to better understand asphalt behavior and to provide simpler chemo metric measurements to replace more expensive physical testing. Additional correlations of rheological and chemical measurements with field site crack survey data are also presented.

An autumn ride in Banff National Park, Alberta, Canada.
Session 3

Application of Pressure Differential Scanning Calorimetry Methods to the Study of Asphalt Oxidation Kinetics

Thomas F. Turner and Ron Glaser
Western Research Institute

Several asphalt binders were oxidized over a range of pressure and temperature to investigate the possibilities of measuring asphalt binder oxidation uptake potential in a rapid, practical manner using pressurized differential scanning calorimetry (PDSC). Oxidation rates, monitored as exotherms, at these extremely accelerated conditions were found to behave differently than expected based upon previous lower severity studies. The previously derived WRI rate model does not explain this behavior. The model was modified to include secondary reactions that are less important under milder conditions. After exploring a variety of possible mechanisms, one was found that matches the behavior well over a wide range of temperature and pressure conditions. The material property (reactive material content) required to describe behavior under pavement aging conditions appears to be obtainable from fits to the data with this modified model. In addition, empirical correlations using the oxidation onset temperature work reasonably well for estimating the source-dependant reactive-material term in the simpler low severity oxidation model, suggesting that a rapid, inexpensive test could be designed that measures oxidation susceptibility for binders and produces fundamental kinetics for advanced pavement performance models as well. This work also provides additional insight into asphalt oxidation in the mix plant and placement environment.

Every Pavement Can Be a Test Section: Comparing Mature Pavement Age-Related Distress to Binder Oxidation and Hardening and Projecting Future Performance

Yuanchen Cui and Charles J. Glover
Artie McFerrin Department of Chemical Engineering, Texas A&M University

Although pavement test sections are designed to track and investigate the progressive loss of pavement durability, ultimately the effort is very problematic. The cost of such tests, coupled with complications that produce a low conversion of test sites to conclusive results, and the time to observe a site to maturity, provide a very low return on investment.

A long-term (25 year) research program supported in large part by the Texas DOT has produced a comprehensive fundamental foundation that enables a significant increase in the efficiency and effectiveness of using field data to understand the progression of age-related pavement failure. This foundation includes an improved understanding of binder oxidation kinetics and hardening, an ability to model the progression of binder oxidation in pavements for specific climates and specific binders, and an improved understanding of the impact of binder oxidative hardening on mixture properties and durability.

Using this foundation, an “every-pavement-is-a-test-section” strategy has been developed. Such a strategy focuses on mature pavements that exhibit a specific type of distress (fatigue cracking, e.g.) and via these fundamentals, probes the role of the progression of binder oxidation and hardening leading to that failure and then projects its role in future performance. Original materials are not needed for this forensics investigation.
**Laboratory and Field Performance of Dry-Process Crumb Rubber Mixes**

Redmond Clark (1) and Raj Dongre (2)

*(1) Asphalt Plus; (2) DLSI*

State and federal highway agencies are under increasing pressure to manage asphalt pavements at progressively lower life-cycle costs. The use of crumb rubber as an additive to binder is a known method to elevate binder performance grading with ancillary benefits, including improved traction, better surface drainage of water and reduced traffic noise volumes. Addition of rubber to binder at asphalt terminals – often called terminal blend - is convenient, addition rates are readily monitored and quality control can be managed by existing DOT systems. But this method has two significant drawbacks: settlement of rubber during transport and handling, and cost. Extensive laboratory and field work with the NCAT, several universities, the State of GA and the FHWA have allowed identification of an alternative method for adding rubber to hot and warm mix asphalt: plant blend, plant mix or the “dry process.” This involves the addition of engineered crumb rubber through the RAP collar during the production of hot and warm mix asphalt. Almost a decade’s experience on state and federal highway systems has demonstrated that rubberized asphalt produced through use of plant blend is an effective and very cost effective replacement for terminal blend.

The authors discuss process engineering of the plant mix process, and they share test and field data from a range of plant mix projects. Special attention is paid to strict quality control systems that ensure proper addition rates and field verification. The potential for improved life cycle costs is also discussed.

**Investigation of Suitable Testing Method for GTR Modified Asphalt Binder**

Amir Golalipour (1) and Tobias Nill (2)

*(1) Anton Paar USA; (2) Anton Paar Germany*

A concept with growing popularity in many parts of the world is the addition of recycled ground tire rubber (GTR) to the asphalt binder. However, modification with GTR has not been accepted nationally and several highway agencies remain skeptical. This skepticism is sustained by the variability in current methods of use associated with GTR modification. Therefore, this study focused on the evaluation of using different test methods to characterize GTR modified asphalt binders’ viscoelastic properties.

Using new GTR materials with larger particles and higher percentages have brought the concerns about suitable method to test these materials considering current Superpave methods. This study investigates the variability in properties as the testing geometries changes and the potential for new test procedure development. Unmodified neat binder and different GTR modified neat binder (10% GTR) with multiple mesh sizes was tested with different methods. Each binder was first characterized using current Superpave procedures and then tested using cylindrical geometry (Bob & Cup fixture). Detailed binder testing indicates that current Superpave test methods are not adequate to capture the rheological behaviour of GTR modified binders; meanwhile the cylindrical system was able to capture rheological properties of GTR modified binders successfully at wide range of temperatures.
Evaluation of Testing Variability from Variations to Testing Geometries for Recycled Tire Rubber

Gaylon Baumgardner (1) and John D’Angelo (2)
(1) Paragon Technical Services; (2) D’Angelo Consulting, LLC

The use of recycled tire rubber (RTR) as an asphalt binder modifier has grown over the past several years. This increased use is driven by cost. With asphalt binder and polymer costs’ raising the use of RTR becomes much more cost effective. One major issue still to be addressed is testing of the RTR modified binder.

RTR is a particulate material added to the asphalt binder. The current Superpave testing procedures and specification do not allow particulate modified binders. Several studies are under way to develop procedures for testing these binders such as increasing the gap size in DSR parallel plate testing and the new cup and bob geometries. This study evaluates the variability of the modifications of the parallel plate and cup and bob geometries to the current DSR tests on typical asphalt and RTR binders. Additionally, evaluations of intermediate temperature DSR testing of RTR binders using torsion bar testing compared to larger gap settings on the DSR is evaluated.

Rheological Comparison of Crumb Rubber Modified Asphalts Using Two Different Gap Geometries

Ka Lai Ng and R. Christopher Williams
Iowa State University

Crumb rubber is mostly used to improve the rheological characteristics of asphalt binders, due to its elastomeric characteristics and thus improve mix performance. However, it is suspected that the swelled crumb rubber particles depending upon the crumb rubber grind size can interfere in the assessment of the rheological properties of the modified asphalts due to the gap in the plate-plate geometry used during the testing procedures, which is a gap of 1 mm in the Dynamic Shear Rheometer (DSR). Some researchers have proposed to increase the gap geometry to 2 mm to avoid the interference of the crumb rubber particles with the plates of the DSR. The objective of this experiment is to determine if the results obtained using these two different gaps are any different amongst them. For this, four different rubber modified binders have been studied; the unaged and rolling thin film oven aged materials of these binders were tested using the DSR equipment at the two gap geometries. The continuous performance grading of the binders were determined, and master curves were constructed from the DSR results. The preliminary results showed that the continuous performance grading of the binders’ materials using 2 mm gap geometry were on average 2 degrees higher than using a 1 mm gap geometry.
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Evaluation of a 100% RAP Recycling Project in Fort Wayne, Indiana

Geoffrey M. Rowe, John Barry and Ken Crawford
Abatech Inc.

A project site investigation involving a 100% RAP recycling has been evaluated to determine the performance differences with a control section, located in Fort Wayne, Indiana, one year after construction. The analysis involved cutting cores from the surface and determining recovered binder properties and mixture physical properties. Binder properties included standard PG grading in accordance with AASHTO M320 and the development of full master curves over the range of temperatures -30 to +80°C. From the master curve analysis was conducted to look at parameters such as cross-over frequency, rheology index and visco-elastic transition temperature. The data from this testing has been used in a manner to judge the effectiveness of a recycling oil, particularly when inspecting the relationship between cross-over frequency and rheological index.

Mixture testing included evaluation of strength properties by conducting tests in bending beam rheometers and the development of mixture master curves. The mixture data provided a method of judging the effectiveness of the modification and recycling process on the expected long term mixture performance. The tensile stress at failure data showed that the level of compaction achieved on site for the control and recycled mixtures was the major controlling influence on the performance. Torsion bar rheology on thin sections provided data for the master curve analysis of the mixtures. The master analysis of the mixtures demonstrated that at lower temperatures the material behaved as a thermo-rheologically simple material whereas at higher temperatures used in the tested the material started to behave in a more complex manner.

The pavement laid at this location will be subjected to a long term monitoring program to continue to evaluate the change in material properties over time. At the current time little difference is seen in the performance of the 100% RAP section compared to the control section, which provides significant support for continuing the effort to develop technologies for high percentage RAP recycling projects.

Session 4

Modelling of Asphalt Binder DSR and BBR Rheological Data Using Huet Model and Cole-Cole and Black Space Plots

Jean-Claude Carret (1), Mihai O. Marasteanu (2), Augusto Cannone Falchetto (3) and Michael P. Wistuba (3)
(1) University of Lyon, ENTPE, Vaulx en Velin, FRANCE; (2) University of Minnesota; (3) Braunschweig University of Technology, Braunschweig, Germany

One of the simplest continuous spectrum models used to characterize asphalt materials was proposed by Huet in 1963. The model consists of two parabolic elements, characterized by power-law creep behavior, and one spring; over the years, the model was further improved with additional parameters (Huet-Sayegh, 2S2P1D) to fit experimental data obtained over a wide range of temperatures. Huet model is, however, the only model that has expressions for both complex modulus and creep compliance, and presents the advantage of connecting asphalt binder BBR and DSR rheological data through the use of the same model parameters.

In previous studies, it was found that Huet model could fit reasonably well experimental results obtained from creep and complex modulus tests on asphalt binders when restrictions are imposed on the model parameters. In this study, additional tools, such as Cole-Cole plots and Black space, are used to obtain some of the Huet model parameters prior to fitting the model. This approach reduces the number of fitted model parameters and significantly reduces the errors associated with fitting models with large number of parameters.
Fatigue resistance is a key performance characteristic of asphalt mixes. Asphalt binder plays an important role in fatigue damage but to date there is no widely accepted binder test for fatigue resistance. Over the years, several variants of oscillatory shear “torture tests” have been evaluated and the latest version of the Linear Amplitude Sweep (LAS) test continues to show promise. The LAS protocol is particularly interesting as it combines rheological characterization by frequency sweep and damage development by strain sweep. The Simplified Viscoelastic Continuum Damage model (S-VECD) allows prediction of asphalt binder fatigue life under a range of conditions versus providing a single parameter.

In this presentation we will discuss some new ideas and some of the latest work on the LAS test. These include cone-and-plate versus parallel plate geometry, damage/failure mechanisms in specimens, different damage parameters including failure stress, failure strain and failure energy, and equi-stiffness versus equi-thermal testing. We will then correlate the fatigue damage predictions with known field behavior of binders from the ALF II project and the NCAT 2009 pavement cycle. These include binders with a wide range of actual fatigue performance, from poor to excellent, which will demonstrate the efficacy of various test protocols.
ABlaos - Asphalt Binder Large Amplitude Oscillatory Shear

Michael J. Farrar, Jean-Pascal Planche, Alec Otto Cookman, and Steve Salmans
Western Research Institute

Nonlinear mechanical properties play an important role in several asphalt binder tests such as the Linear Amplitude Sweep (LAS) test. The rheological behavior of asphalt binder in the nonlinear regime can be characterized by an oscillatory deformation protocol known as large amplitude oscillatory shear (LAOS). To date, there has been little application of LAOS to characterize the nonlinear viscoelasticity of unmodified and modified asphalt binders. The common practice has been to apply the “viscoelastic moduli” corresponding to the first harmonic Fourier coefficients $G_1'(\omega)$, $G_1''(\omega)$. However, in many cases that can be misleading in describing the nonlinear phenomena. Our approach for this presentation is to demonstrate the application of LAOS within the framework of Lissajous curves. The results suggest that in the nonlinear regime, strain softening and then strain hardening is occurring.

Establishing a Protocol for High Stiffness DSR Rheological Measurements

Dr. David A. Anderson, PE (1), Michael J. Farrar (2), Gerald Reinke (3), Mike Anderson (4), Gaylon Baumgardner (5), and Matthew Corrigan, P.E. (6)
(1) Consultant; (2) Western Research Institute; (3) MTE Services, Inc.; (4) The Asphalt Institute; (5) Paragon Technical Services, Inc.; (6) Federal Highway Administration

Recent work championed by Western Research Institute has shown that when compliance corrections are implemented the useful range of the dynamic shear rheometer can be extended to measurements well below the glass transition temperature. Although a preliminary procedure has been established for making compliance corrections, using the DSR for low-temperature measurements requires modification to the protocols currently used for intermediate and high temperature measurements. The objective of the work reported in this presentation is to establish a testing protocol that can be applied to measurements obtained at extended ranges of stiffness, typically greater than 10 MPa, where particular attention must be given to machine compliance. Of concern is the mounting of the test specimen, appropriate strain levels, instrument resolution, and thermal equilibrium. Laboratory data obtained with instruments representing each of the three major DSR manufacturers are presented. Recommendations are offered with respect to 1) the preparation of the test specimen to include mounting, trimming and bulge formation, 2) the linear region as a function of specimen stiffness evaluated through the roll off of $G^*$ with increasing strain, harmonic analysis, and Lissajous diagrams, and 3) the importance of thermal equilibrium and physical hardening.

Thank you, Sunday reception sponsors.
**Interrelationships in Rheological Parameters**

Geoffrey M. Rowe  
*Abatech Inc.*

The formation of the SHRP test parameters implemented in Superpave where based upon linear visco-elastic measurements, for example $G^*/\sin\delta$, $G^* \sin\delta$, $S(t)$, $m(t)$. More recently other test parameters have been proposed for use such as multi-stress creep recovery test ($J_{nr}$), Glover-Rowe parameter ($G^* \cos^2\sin\delta$), the difference between $T_{crit}$ from $S(t)$ & $m(t)$ ($DT_c$), visco-elastic transition temperature ($T_{VEt}$) and others. Some of the proposed test parameters relate directly to a linear visco-elastic understanding of the binder whereas others parameters can be best described as non-linear parameters. Both non-linear and linear parameters are important for pavement performance and in many cases these are interrelated through an understanding of time and temperature susceptibility of the asphalt binders. In the intermediate to high stiffness range a model such as that developed by Christensen and Anderson (and further developments) enables a good definition of an asphalt binder linear visco-elastic response. The paper will present some limitations on the use of models and discuss some alternate methods to define cold and intermediate temperature properties.

**Switchable-Hydrophilicity Solvent Technology for Extraction of Asphalt Binder from Recycled Asphalt Shingles**

Joe Rovani (1), David Haedt (2), James Lockhart (3), Ira Wolf (4), and Lowy Gunnewiek (5)  
(1) Western Research Institute; (2) ASPEXT; (3) NORAM Engineering and Constructors; (4) BC Research; (5) Switchable Solutions Inc.

A switchable-hydrophilicity solvent (SHS) can interconvert reversibly and repeatedly between two forms, hydrophobic and hydrophilic. Carbon dioxide is the trigger molecule for altering an SHS between its oil-soluble and water-soluble forms. SHS technology has application across several industries for extraction of hydrocarbons from target materials. One such use is for the extraction of asphalt binder from recycled asphalt shingles (RAS) and low-slope roofing waste. Although other solvent extraction techniques have been used in the past to process these materials without causing significant changes in binder rheology, composition, or chemistry; binder extracted from roofing shingles using SHS has not been characterized until the current study described in this presentation. Such characterization is necessary to demonstrate compatibility for downstream uses of the binder and/or to suggest options for modification. A testing protocol was devised to extract asphalt binders from a common sample of shingle waste using both traditional solvent extraction and SHS extraction. The binders were subsequently characterized using a series of analytical techniques. This presentation describes the extraction and testing protocol and provides the comparative results for the two extracted asphalt binders.
Evaluation of Methodologies for Crossover Modulus Determination

Shane Underwood (1); Michael Farrar (2); and Y. Richard Kim and Cassie Hintz (3)
(1) Arizona State University; (2) Western Research Institute; (3) North Carolina State University

As part of efforts in evaluating the long term aging potential of asphalt concrete, NCHRP 9-54 is examining the crossover modulus of asphalt binders. After a review of the literature and discussion with experts it was found that many different methods have been proposed for evaluation of this quantity. While each method shares many of the same basic principles each differs slightly in their implementation and as a result produces results of varying accuracy as a function of data quality. A large database has been assembled with data of varying quality from different testing agencies to evaluate and refine these methods. This presentation will discuss the analytical details of the selected method, its limitations, and possibilities. Alternative methods will also be discussed and assessed for their ability to match experimental data.
Investigations towards Understanding of Coalescence in Bitumen Emulsions for Cold Asphalts

Abdullah Khan (1), Per Redelius (2), and Niki Kringos (1)
(1) KTH Royal Institute of Technology, Sweden; (2) NYNAS Bitumen AB, Nynäshamn, Sweden

Cold mix technology is a technology that is very attractive from an economical start-up costs and an environmental point of view. Sufficient long-term mechanical performance and predictability of material behavior during the construction phase are thereby important challenges. The exact nature of the breaking mechanism of bitumen emulsion is not completely understood today and the adhesion between the binder and the aggregate surface is largely dependent on the process of the water push-out from the mixtures. The objective of this research is to develop understanding of the structural changes during the phase separation and coagulation stages of the emulsion while interacting with the aggregate surface via experimental test designs. For this, wettability of the aggregates with the binder in the presence of the emulsifier, the water and dust is being investigated. Furthermore, the coalescence behavior of bitumen droplets in the emulsion environment is investigated to develop a better control on the right time and location of the build-up of mechanical strength. For these, both binder and aggregate mineral surfaces were investigated for their wettability using a modified Sessile drop method in which temperature and humidity were controlled using a climate chamber. Wettability of bitumen was also analyzed by changing the substrate climate conditions. The experimental work regarding the wetting of stone surface by bitumen was carried out when the stone surface is dry and clean, wet and clean as well as already coated with bitumen layer and water. Moreover, this study was extended with the addition of emulsifier and other additives to water present at the surface of bitumen and stone. Similar kinds of experiments were setup for exploring the coalescence of bitumen drops in air, water and emulsifier with other additives. From the measurements, the bitumen surface was found to be dispersive in nature whereas mostly minerals surfaces were having polar profiles except the plagioclase and calcite where both polar and dispersive interactions seem equally displacement contributions. Furthermore, the effect of emulsifier and the presence of moisture on wetting behavior and coalescence were also investigated.

Development of a High Modulus Binder in Brazil

Alexander Vivoni, Carlos Herrmann, and Carlos Junqueira (1); and Luis Herrmann (2)
(1) Petrobras Distribuidora; (2) Petrobras Research Center

The present work describes the development of an asphalt binder for high modulus mixes in Brazil. The CAP AM follows a French based specification on Pen and Softening Point, adapted by a Brazilian contractor. Its special formulation promotes a stiff binder with high fatigue cracking and rutting resistances. The CAP AM is compared to the unmodified AC 15-25 and AC 50-70 binders in three different levels: binder, asphalt mix (HMA), and pavement.

Regarding the binder analysis, it was carried under the AASTHO MP 19-10 specification testing protocol (PG + MSCR), and the Linear Amplitude Sweep test (LAS) for fatigue characterization. In the mix level, mechanical tests were done in order to compare the dynamic modulus, flow number, and fatigue damage characteristics according to the Simplified Viscoelastic Continuum Damage model (S-VECD) of the different binders used. To access the full scale response of the mixes, pavement simulations using finite element analysis with the S-VECD model were made, whose results are being confirmed through a pavement test sections construction and monitoring program. So far, the results have shown that the CAP AM has improved the overall HMA performance, since it has high stiffness associated to very good fatigue and rutting performances.
A Review of Field Trials Using Composite Layered Pavement Preservation Technologies

Gary Houston (1) and Sallie Houston (2)
VSS International (1) Director of Sales, Marketing & Technology, (2) Technical Manager

Over the past several years funding issues have lead some Public Agencies to use composite layer Pavement Preservation techniques on some roadways. This presentation highlights a few such projects that have used double layers of Micro Surfacing, double layers of Micro Surfacing with fibers, three layer systems using Micro Surfacing as a base layer with Hot Asphalt Rubber Chip Seal followed by a top layer of Micro Surfacing, and Cape Seal using cold applied rubberized asphalt emulsion with ground tire rubber chip seal. Some of these techniques have been in service over ten years.

The purpose of this presentation is to highlight some of the unique ways these technologies are being used to address roads that are deteriorated beyond where traditional pavement preservation has been used. It is hoped this will provide a platform for further thought on modeling distressed roads to provide Agencies with the academic background they need to justify using these methodologies. Also, some time is given to highlight the economic and sustainability opportunities these concepts provide.
Comparative Performance of Bio-based/Chemical Additives in Warm Mix Asphalt at Low Temperature

Joseph Podolsky and R. Christopher Williams
Iowa State University, Department of Civil, Construction and Environmental Engineering

Isosorbide Distillation Bottoms (IDB) is a recently bio-derived co-product that has surfactant properties. IDB is produced from the conversion of sorbitol to isosorbide by using sorbitan to perform a dehydration reaction. Sorbitol is produced by hydrogenating the glucose from corn biomass. In previous studies IDB has shown great potential in improving the low temperature performance grade (PG) benefits at an optimum dosage rate of 0.5% by weight of the binder. Due to this observation it is hypothesized that there will be improvement in low temperature performance of WMA when modified with IDB as compared to a control group. The effects of IDB addition to asphalt mix performance at low temperatures were examined for binders (Montana-PG 64-22, and Polymer Modified Montana-PG 70-22, a Montana-PG 64-22 polymer modified with 1.5% SBS). To determine if IDB was a viable WMA additive in terms of mix performance at low temperature, three groups were used for comparison: no additive (control group) and two commercially available WMA additives derived from forest products; FP 1 additive, and FP 2 additive. The test used to examine mix performance at low temperature was the semi-circular bend (SCB) test on aged material, while binder performance at low and high temperatures used the bending beam rheometer (BBR) test with PAV aged material, and the MSCR with RTFO aged material.

The Morphological and Property Changes of Asphalt Microstructure after Short-term and Long-term Aging

Yuhong Wang (1) and Xin Yu (2)
(1) Hong Kong Polytechnic University; (2) Hohai University, China

The engineering properties of asphalt are imparted by the fundamental characteristics of its molecular agglomerates (microstructure). Using asphalts that were artificially aged by RTFO and PAV and that were aged in field conditions for 8 and 36 years, this research studied the morphological and property changes of the microstructures in these asphalts. Transmission electron microscope (TEM) and atomic force microscope (AFM) were used to probe the morphologies and properties of the microstructures. The findings were used to explain the rheological properties of asphalt observed at the macro level. It was found that the microstructures undergo significant changes during the aging process. In particular, the microstructures of the asphalt that was long-term aged in field conditions demonstrate unique and interesting characteristics. It was also found that the microstructures formed by artificial aging are different than those formed by natural aging. The changes in microstructures apparently can explain the rheological property changes of asphalt in different aging status.
Investigating Microstructural Characterization of Different Modified Asphalt Binders by Using Atomic Force Microscopy

Mona Nobakht (1), Pooyan Kabir (1), and Maryam S. Sakhaefifar (2)
Zachry Dept. of Civil Engineering, Texas A&M University (1) Graduate Research Assistant, and (2) Assistant Professor

This study involves evaluating the evolution of rheological and nanorheological properties of two different modified asphalt binder and the control binder through the application of two different test methods, dynamic shear rheometer (DSR) and atomic force microscopy (AFM). Previous research efforts have shown that the rutting parameter used in the performance grade asphalt binder specifications, $|G^*|/\sin \delta$, does not reasonably predict the rutting potential of asphalt mixtures, especially when modified binders are used. Therefore, a number of other parameters, such as the zero shear rate viscosity and the permanent strain accumulated under repeated creep and recovery were investigated here. This study investigates the use of zero shear rate viscosity and of repeated creep permanent strain as potential specification parameters and discusses the importance of temperature susceptibility and of strain tolerance to the rut resistance of asphalt binders. Furthermore, the evolutions of rheological and nanorheological properties have been investigated as the asphalt sample transitions through various degrees or stages of aging. It was observed that certain asphalt chemical parameters have a consistent and measurable effect on bitumen microstructure. The results show the difference between two different modifications and the causes of different behaviors relative to the base binder.
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