52nd

Petersen Asphalt Research Conference

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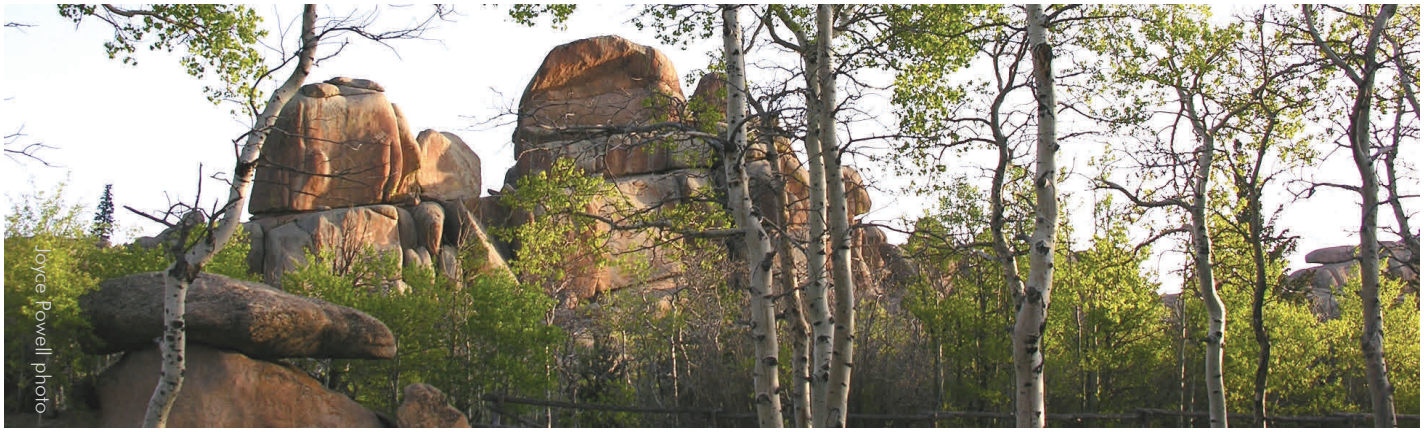

July 13-15, 2015 Laramie, Wyoming

PROGRAM & ABSTRACTS

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Petersen Asphalt Research Conference

Organized by Western Research Institute

University of Wyoming Conference Center • July 13-15, 2015 • Laramie, Wyoming

Monday, July 13

7:30 am	Registration—Pick up conference materials	Hilton Garden Inn and UW Conference Center
8:00-8:10	Welcome and Opening Remarks	Jean-Pascal Planche and Stephen Salmans

SESSION 1 Session Chair: Will Grimes

8:10-8:45	Investigation of the Microstructure of Bitumen – Key for the Understanding of Properties and Prediction of Performance	Hartmut Fischer, Bert Dillingh, and Steven Mookhoek *TNO*
8:45-9:20	Effect of Fatty Acids and Triglycerides on Bitumen and on Mixtures of Asphaltenes and Wax	Salomé dos Santos and Manfred N. Partl *EMPA, Swiss Federal Laboratories for Materials Science and Technology*
9:20-9:55	An Empirical Examination of the Moderating Impact of Maximum Bee Length on the Relationship between Stiffness and Fracture Energy	Elham Fini, Daniel Oldham, and Mahour Parast *North Carolina A&T State University*
9:55-10:10	Break	
10:10-10:45	The Effect of Bio-derived/Chemical Additives on the Stripping Resistance of Warm and Hot Mix Asphalt	Joseph H. Podolsky, Ashley Buss, Grace Mercado, Jesse Studer, R. Christopher Williams, and Eric W. Cochran *Iowa State University*
10:45-11:20	Use of SBS Emulsion to Formulate Polymer Modified Asphalt and Asphalt Emulsions	Jianming Wei *China University of Petroleum*, Lizhi Wang *Shandong Jianzhu University*, Jijiang Chen *Shandong Dashan Road & Bridge Engr. Co. Ltd*, and Raj Dongre *Dongre Laboratory Services Inc.*

Monday, July 13, continued

11:20-11:55	Dynamic Asymmetry in Polymer Modified Bitumen: A Viscoelastic Model for Phase Separation	Jiqing Zhu and Niki Kringos *KTH Royal Institute of Technology*
11:55-12:55	Lunch	

SESSION 2 Session Chair: Alec Cookman

12:55-1:30	Relationship of Recycled Tire Rubber Binder Properties to Mix Performance	John D'Angelo *D'Angelo Consulting, LLC*; and Gaylon Baumgardner, Trey Jorden, and Mike Hemsley *Paragon Technical Services*
1:30-2:05	Engineered Crumb Rubber (ECR) for Improved Performance	Raj Dongre *DLSI*
2:05-2:40	Polymer Modification of Asphalt with Devulcanized Rubbers	Chandrasekaran Pillai and Hari Chandra *Full Circle Technologies*
2:40-2:55	Break	
2:55-3:30	Quantifying the Influence of REOB Asphalt Pavement Materials' Performance	Nelson Gibson and Terry Arnold *Turner-Fairbank Highway Research Center*. Presented by Adrian Andriescu *SES Group & Associates, LLC*
3:30-4:05	The Use of VTAE as a Recycling Agent in RAS Mixes	John D'Angelo *D'Angelo Consulting, LLC*; Ken Gryzbowski and Sara Alzate *PRI*; and Al Palmer *Safety-Kleen*
4:05-4:40	Investigation of Oil-Asphalt Blending Mechanisms and its Effect on Binder Characteristics	Amir Golalipour *Engineering & Software Consultants, Inc.*, and Gina Paroline *Anton Paar USA*
4:40-5:15	Rejuvenation vs. Softening: Critical Analysis of the Reversal of the Aging Impact on Thermo-Rheological and Damage Resistance Properties through Use of Recycling Agents	Hassan Tabatabaee and Todd Kurth *Cargill Industrial Specialties*

MONDAY EVENING—*Dinner on your own.*

Tuesday, July 14

SESSION 3 **Session Chair: Ron Glaser**

8:00-8:35 am	Modification of the Rolling Thin Film Oven (RTFO) Test for Realistic Short-Term Aging of the Asphalt Rubber Binders	Mohammad Zia Alavi, Xai Lao, David Jones, and John T. Harvey *University of California Pavement Research Center*
8:35-9:10	Use of a Total Air Void Diffusion Depth to Improve Pavement Oxidation Modeling with Field Validation	Avery Rose *Texas A&M University*; Edith Arambula *Texas Transportation Institute*; and Guanlan Liu and Charles J. Glover *Texas A&M University*
9:10-9:45	Extended Testing Conditions for the Evaluation of Water Sensitivity of HMA Mixes	Geoffrey M. Rowe *Abatech*; and Ajay Ranka, Moulik Ranka, Doug Zuberer, and Jerry Thayer *Zydex*
9:45-10:00	Break	
10:00-10:35	Physical and Chemical Changes of Asphalt Binders in Long-life Asphalt Pavements	Yuhong Wang *Hong Kong Polytechnic University*
10:35-11:10	Applications of Portable Infrared Spectroscopy to Asphalt Products: Progress Report Card	Iliya Yut and Delmar Salomon *Pavement Preservation Systems LLC*
11:10-11:45	Oxidation of Asphalt Binders Modified with Polyphosphoric Acid	Giovanni Onnembo *Innophos*; and Ron Glaser, Fred Turner, and Jean-Pascal Planche *Western Research Institute*
11:45-12:45	Lunch	

SESSION 4 **Session Chair: Mike Farrar**

12:45-1:20	Impact of the Bitumen Quality on the Asphalt Mixes Performances	F. Delfosse, I. Drouadaine, S. Faucon-Dumont, and S. Largeaud *Eurovia Research Centre*; B. Eckmann *Eurovia Technical Department*; and J. P. Planche, F. Turner, and R. Glaser *Western Research Institute*

Tuesday, July 14, continued

1:20-1:55	Using Chemometrics to Understand Asphalt Composition-Structure-Properties Relationships	Ron Glaser, Fred Turner, and Jean-Pascal Planche *Western Research Institute*; and Frédéric Delfosse, Ivan Drouadaine, and Sabine Largeaud *Eurovia Research Centre*
1:55-2:30	Advanced Techniques in the Low-temperature Rheological Analysis of Bitumen	Olli-Ville Laukkanen *University of Massachusetts Amherst / Aalto University*; H. Henning Winter *University of Massachusetts Amherst*; and Hilde Soenen *Nynas NV*
2:30-2:45	Break	
2:45-3:20	Asphalt Binder Testing Protocol for Dynamic Shear Rheometer	David A. Anderson *Consultant*, Michael J. Farrar *Western Research Institute*, Andrew Hanz *MTE Services, Inc.*, and Sonia Serna *Paragon Technical Services*
3:20-3:55	Applying the Glover-Rowe Parameter to Evaluate Low Temperature Performance of Hot Mix Asphalt LTPP Sections	David J. Mensching *FHWA*; Christopher D. Jacques and Jo Sias Daniel *University of New Hampshire*
3:55-4:30	Predicting Repeated Creep-recovery Behavior of Bituminous Binders from Small-amplitude Oscillatory Shear (SAOS) Data	Olli-Ville Laukkanen *Univ. University of Massachusetts Amherst / Aalto University*; H. Henning Winter *University of Massachusetts Amherst*
4:30-5:05	Relaxation and Linear Visco-elastic Binder Properties and Asphalt Pavement Cracking	Geoffrey M. Rowe and Mark J. Sharrock *Abatech*

Social Hour and Dinner at the University of Wyoming Marian H. Rochelle Gateway Center — just across the street from the conference center

Wednesday, July 15

SESSION 5 **Session Chair: Jeramie Adams**

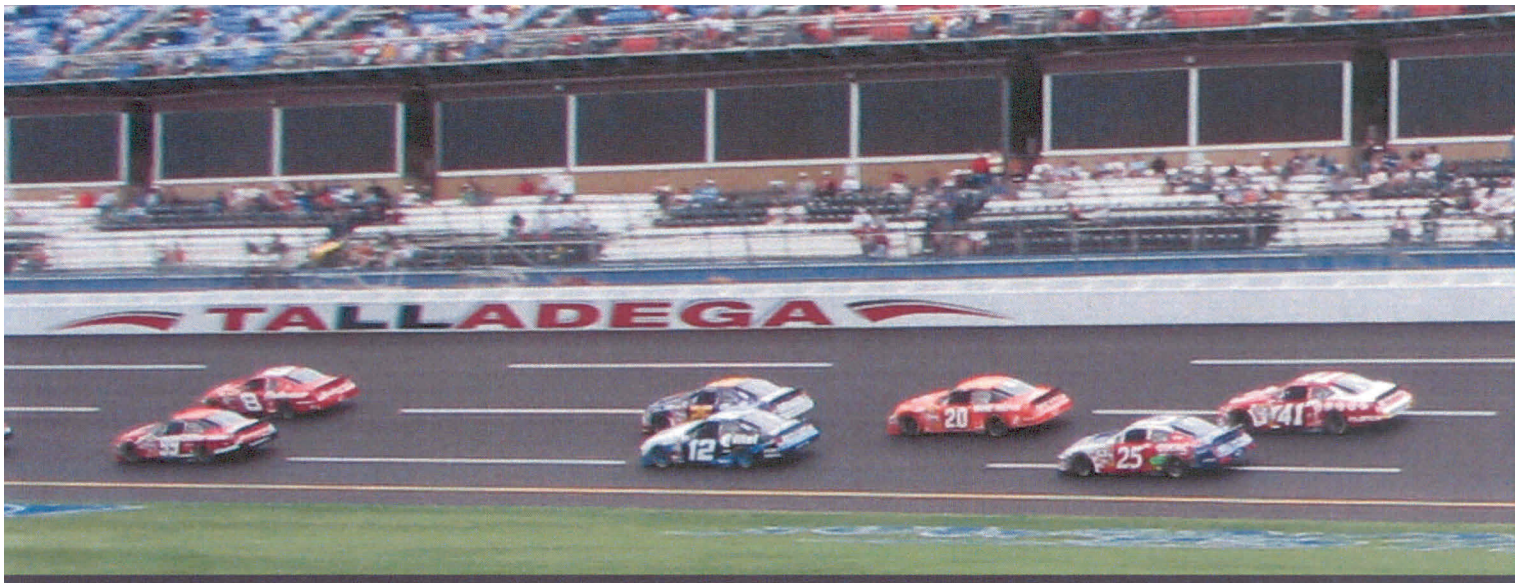
8:00-8:35 am	Evaluating Changes in Performance-Related Properties of Conventional Asphalt Binder after Blending with Different Amounts of Age-Hardened Rubberized Binder	Shawn S. Hung, M. Zia Alavi, and David Jones *University of California Pavement Research Center*
8:35-9:10	Crack Monitoring Results from the 2011 Binder Initiatives in Ontario	Alexander (Sandy) Brown *Asphalt Institute*
9:10-9:45	Proposing a Solvent-Free Approach to Evaluate the Properties of Blended Binders in Mixtures with High Amounts of Recycled Asphalt Pavement (RAP) and Recycled Asphalt Shingles (RAS)	Yuan He, Zia Alavi, and John T. Harvey *University of California Pavement Research Center*
9:45-10:05	Break	
10:05-10:40	Use of Performance Based Testing for High RAP Mix Design and Production Monitoring	Andrew Hanz *MTE Services Inc.*; Erv Dukatz *Mathy Construction*; and Gerald Reinke *MTE Services Inc*
10:40-11:15	Binder Quality Control Test Method (QC Test) – Progress Report	Raj Dongre *DLSI* and Jack Youtcheff *FHWA*
11:15-11:50	Investigation of Warm Mix Asphalt Additives Using the Science of Tribology to Explain Improvements in Mixture Compaction	Sebastian Puchalski *Kraton Polymers* and Hussain U. Bahia *University of Wisconsin, Madison*
11:50-noon	Closing Remarks	

Tuesday Evening Dinner

at the University of Wyoming
Marian H. Rochelle Gateway Center

5:30 Social Hour (Cash Bar)
6:45 Dinner

Options for special diets available—please inquire at registration table.



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AAP

Monday, July 13

Session 1

Investigation of the Microstructure of Bitumen – Key for the Understanding of Properties and Prediction of Performance

Hartmut Fischer, Bert Dillingh and Steven Mookhoek
TNO

Bitumen as a natural product is probably one of the oldest binder known and used by mankind and is still used in large quantities in a nearly unlimited number of applications. Although bitumen is a mixture of thousands of compounds, the material shows in general spontaneous structuring on the micro-scale at operational temperatures. This structuring influences the properties and therefore also the performance of the bitumen. Understanding the physico-chemical processes of microstructural formation and evolution has seen an appreciable advance by the application of modern analysis techniques. Especially the application of Scanning Probe Microscopy (SPM) using a wide variety of techniques combined with a number of other analytical methods, resulted in a much better understanding of structuring and dynamics of microstructural changes which bitumen experiences during its operational life time. Knowledge of the structuring processes enables an understanding of the fundamental properties and results in more accurate input for models which aim at performance prediction in multi-scale systems like asphalt roads.

Effect of Fatty Acids and Triglycerides on Bitumen and on Mixtures of Asphaltenes and Wax

Salomé dos Santos and Manfred N. Partl
Empa, Swiss Federal Laboratories for Materials Science and Technology, Dübendorf, Switzerland

Naturally occurring oils can be used as rejuvenators to restore the rheological properties of aged bitumen in the context of recycling of asphalt. Moreover, they could act as bitumen extenders replacing bitumen partially. However, the effect of oils on the phase behavior and microstructures of bitumen has not been systematically studied. Therefore, the effect of oil components such as fatty acids and triglycerides on the molecular assemblies found in bitumen and in mixtures of asphaltenes and wax will be discussed. Some examples of important changes occurring after the addition of oil components are: The size and nature of the microstructures found at the surface of bitumen and asphaltene-wax films depend on the nature and content of the oil components; and crystalline structures change shape and size or are absent. The characteristics of the mixtures and the chemical composition of the microstructures are analyzed in bulk and at the interface with substrates with different surface chemistry, using atomic force, electron and optical microscopies, and spectroscopic techniques.

An Empirical Examination of the Moderating Impact of Maximum Bee Length on the Relationship between Stiffness and Fracture Energy

Elham Fini, Daniel Oldham, and Mahour Parast
North Carolina A&T State University

Oxidative aging in asphalt has been linked to pavement distresses and premature cracking. While there has been several research on improving properties of aged asphalt in RAP and RAS using various modifiers, most of these modifiers are mainly softeners that reduce the overall stiffness of aged asphalt without restoring its chemical and molecular conformation. Reducing stiffness may not be adequate to fully restore mechanical and morphological properties, which control fracture resistance of aged asphalt. Since asphalt fracture properties highly impact cracking in pavement, asphalt fracture properties should be considered when examining the feasibility and effectiveness of rejuvenating aged asphalt.

In this paper, we investigate the moderating effect of maximum bee length on the relationship between stiffness and fracture energy, using a specific bio-rejuvenator (produced from swine manure) which was introduced (at different dosages) to a lab produced RAP to restore its properties to the counterpart un-aged asphalt. Morphological and mechanical properties were studied utilizing an atomic force microscope and rheometer. The study results showed that specific dosage of a bio-rejuvenator could be applied to restore properties of aged asphalts. In addition, it was found that bee length has a moderating role on the relationship between fracture energy and stiffness.

The Effect of Bio-derived/Chemical Additives on the Stripping Resistance of Warm and Hot Mix Asphalt

Joseph H. Podolsky, Ashley Buss, Grace Mercado, Jesse Studer, R. Christopher Williams, and Eric W. Cochran
Iowa State University

Past research with isosorbide distillation bottoms (IDB) a recently derived warm mix asphalt additive co-produced from the conversion of sorbitol to isosorbide has showed that there was improvement in low temperature binder performance using the bending beam rheometer (BBR). Due to this observation it is hypothesized that softening could be occurring at high temperatures decreasing the resistance to stripping for the warm mix asphalt (WMA) mixtures modified with bio-derived/chemical additives as compared to a hot mix control. The effects of IDB as well as several new bio-derived material additives with similar properties to IDB were examined for binders (Montana-PG 58-28, and Montana-PG 64-28 polymer modified with 1.5% SBS). To determine if IDB or any of the new bio-derived materials are viable WMA additives in terms of stripping resistance at high temperatures, four groups were used for comparison: two control groups, each one mixed and compacted at different temperatures), and two commercially available WMA additives derived from forest products; FP 1 additive, and FP 2 additive. The test used to examine stripping resistance at high temperature was the Hamburg Wheel Tracking Device, while binder performance at high temperatures used the MSCR with RTFO aged material.

Use of SBS Emulsion to Formulate Polymer Modified Asphalt and Asphalt Emulsions

Jianming Wei (1), Lizhi Wang (2), Jijiang Chen (3), and Raj Dongre (4)
(1) China University of Petroleum; (2) Shandong Jianzhu University; (3) Shandong Dashan Road & Bridge Engineering Co. Ltd; (4) Dongre Laboratory Services Inc.

The conventional formulation of SBS modified binders and emulsions make use of polymer in solid pellet or powder form. When SBS pellets are used it is necessary to optimize high shear blending time and temperature to produce modified asphalts with optimum properties and stability. Depending on the base asphalt compatibility temperatures as high as 200°C may be required along with significantly long shearing times. Even higher temperatures (up to 220°C) maybe employed when producing concentrated blends of SBS modified asphalts. The prolonged exposure to high temperature and long blending times may cause degradation of SBS as well as aging of the base asphalt.

Formulations were developed using SBS emulsion to modify regular and concentrated polymer modified binders. Two base asphalts were used. Blending time and temperature studies were conducted to optimize the blends. PG grading, MSCR, Fluorescence micrographs, and TGA were obtained.

Comparison between asphalts modified using the conventional SBS modification methods and the newly developed formulation based on SBS emulsion revealed the following. The polymer modified asphalts produced using SBS emulsion consumed less energy to produce. There was less degradation of the polymer and the polymer modified asphalt showed less aging. The new process variables were found to be simple enough for large scale production and does not require complicated SBS modification plants with high shear mills. Concentrated blends of SBS modified asphalts are also easier to produce with less impact on the final blend.

Dynamic Asymmetry in Polymer Modified Bitumen: A Viscoelastic Model for Phase Separation

Jiqing Zhu and Niki Kringos
Department of Civil and Architectural Engineering, KTH Royal Institute of Technology

Polymer modified bitumen (PMB) has been widely used in many countries, but some challenges still exist. One of the common problems is the storage instability of the final PMB products, which is believed to have a close relationship with the phase separation process in PMB. Based on the pseudo-binary structure of PMB as a blend, the dynamic asymmetry between polymer and bitumen may have significant effects on the phase separation process. Dynamic asymmetry means the different dynamics for the two components of a binary mixture (one slow component and one fast component). For blends, its physical origin is mainly the large difference in the glass transition temperature between the two components. Some previous literature showed the possible effects of dynamic asymmetry on the phase separation process in some PMBs. So it is hypothesized that phase separation in these PMBs can be described by a viscoelastic phase separation model, although more work still needs to be done to confirm this. By assuming composition-dependent mobility and/or additional internal stress sources, the effects of dynamic asymmetry can be introduced into the model. In this, the composition-dependency of mobility and stress-diffusion coupling are expected to play key roles in the model.

Session 2

Relationship of Recycled Tire Rubber Binder Properties to Mix Performance

John D'Angelo (1); and Gaylon Baumgardner, Trey Jorden, and Mike Hemsley (2)
(1) D'Angelo Consulting, LLC; (2) Paragon Technical Services

Over the past few years significant work has been done to evaluate recycled tire rubber modified binders using the Superpave Performance Grading binder system. This has include variations to the testing geometries and fixtures to try and improve the relationship of test results to bulk binder properties. A major question that still exists is will the binder properties relate to asphalt mixture properties. In this study mixes were prepared using recycled tire rubber modified binders using various rubber sizes and percentages. The mix properties such as flow number, dynamic modulus and Hamburg Wheel tracking were determined for comparison to binder properties of the various rubber blends. The comparisons will be used to determine is the measured recycled tire rubber binder properties using the PG system relate to the mix properties. Additionally this study will provide insight into the effect of recycled tire rubber size on mix properties and possible field performance.

Engineered Crumb Rubber (ECR) for Improved Performance

Raj Dongre
DLSI

Crumb rubber modified asphalt mixes are being increasingly specified in the world. Several studies have shown that it can perform relatively well when used properly. It is cheaper than traditional polymer modified mixes and is considered a 'Green' technology due to its recycled origins. To obtain performance comparable to the traditional polymer modified bitumen (SBS, TER, etc) many user agencies around the world are requiring that the crumb rubber modified bitumen (for both wet and dry mix methods) satisfy the m-value and MSCR (Jnr, %recovery, and Jnr diff) specification developed in the United States. In the wet method these requirements can only be satisfied by producing hybrid binders which are a combination of polymer (usually SBS) and crumb rubber pre-blended with bitumen. An even easier method has recently been developed. In this method the crumb rubber is pre coated with proprietary polymers that allow the mixes and bitumen to satisfy the m-value and MSCR requirement. This new crumb rubber called Engineered Crumb Rubber (ECR) can be blended in low shear directly to the hot unmodified bitumen (163^{o}C or 325^{o}F) then added to the mix as usual.

Several ECR materials were made and tested for PG grading and mix properties such as rutting and fatigue. This paper discusses the use and characteristics of ECR and ECR modified CRM binders.

Polymer Modification of Asphalt with Devulcanized Rubbers

Chandrasekaran Pillai and Hari Chandra
Full Circle Technologies

Devulcanized rubbers (DVR) made from used tires and tire curing bladders were tested in asphalt modification as substitute for traditional polymers. The DVR processed well in dissolving and remaining in suspension in asphalt. Extensive laboratory evaluations for use as pavement binders, both on their own and in combination with thermoplastic olefins, show promise. The findings are presented in this paper.

Quantifying the Influence of REOB Asphalt Pavement Materials' Performance

Nelson Gibson and Terry Arnold (1) – presented by Adrian Andriescu (2)
(1) Turner-Fairbank Highway Research Center; (2) SES Group & Associates, LLC

The use of Recycled Engine Oil Bottoms (REOB) as a softening agent by asphalt suppliers to formulate PG graded asphalt binders has attracted significant attention in recent years. However, the effect of REOB on the performance of mixtures is not well understood by most engineers and technologists. Researchers at the FHWA, Turner Fairbank-Highway Research Center have developed an XRF-based test method to identify the presence and approximate quantity of REOB in asphalt binders and are gathering field performance of binders found to be formulated with this additive. To advance an understanding of the performance of REOB, a suite of binder and mix tests were conducted with asphalt materials containing 0%, 2.5%, 6% and 15% concentrations of REOB. All four binders met PG58-28 grading. The test results for the various binders and mixtures were analyzed and compared at low, intermediate and high temperatures and at various levels of aging. Among the parameters investigated for binders include delta T critic (∆Tcr), the difference between the low temperature critical specification temperature for m and S values, rheological index (R), strain tolerance as measured with the CTOD, and fatigue life as determined using the linear amplitude sweep test (LAST). Laboratory made mixtures were tested for fatigue life, moisture damage, indirect tension strength and low temperature performance (TSRST). While high concentrations of REOB are consistent with loss of strength and performance in binder and mixes, lower REOB concentrations have yielded mixed results.

The Use of VTAE as a Recycling Agent in RAS Mixes

John D'Angelo (1); Ken Gryzbowski and Sara Alzate (2); and Al Palmer (3)
(1) D'Angelo Consulting, LLC; (2) PRI; (3) Safety-Kleen

Over the past several years the use of recycled asphalt shingles (RAS) in asphalt mixers has increased tremendously. The primary reason is the high binder content in the RAS material. The RAS binder is typically an air-blown asphalt binder that has been aged on a home roof for many years. This makes the RAS binder extremely hard. To be able to use the RAS binder in an asphalt mixture it is very common to use some type of recycling agent. The recycling agent softens the RAS binder restoring, to some extent, the binder properties.

In this study Vacuum Tower Asphalt Extender (VTAE), the residue from the used motor oil re-refining process, was used as a recycling agent in asphalt mixes produced with RAS. A Dolomitic Limestone mix containing 5% RAS had 8, 16 and 20% VTAE added as a component of the virgin asphalt binder. The binder for the various mixes was extracted and tested using the PG system. Additionally mix properties were tested to evaluate performance properties such as, rutting, moisture damage, fatigue cracking and low temperature cracking.

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Ken Grzybowski, President
kgrzybowski@priasphalt.com
Laci Tiarks-Martin, Director
ltiarks@priasphalt.com

PRI Construction Materials Technologies
Brad Grzybowski, Managing Director
bgrzybowski@pricmt.com

Munster: 219-595-3433; 219-924-7762 Fax
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Investigation of Oil-Asphalt Blending Mechanisms and its Effect on Binder Characteristics

Amir Golalipour, Ph.D. (1) and Gina Paroline (2)
(1) Engineering and Software Consultants, Inc. ; (2) Anton Paar USA

Recently wide ranges of oil based modifications (oil extenders and rejuvenators) have been introduced to improve asphalt binder performance, especially at the low service temperatures. Although in many other fields the importance of blending procedure is recognized, for blending of oil in asphalt binder, the blending procedure is rarely considered as a factor. The type of liquid in liquid blending process, "distributive" or "dispersive", can have critical implications on the optimum blending conditions needed to achieve maximum effectiveness and miscibility in the blend.

The present study focuses on further exploration of the mechanism of oil modification of asphalts through various blending procedures, and its implications for low temperature performance of oil modified asphalt binders. Blend miscibility is assessed in terms of changes in glass transition properties by Calorimetry tests (DSC). Also, gel permeation chromatography (GPC) is used to investigate the miscibility of blends. The results demonstrate different degrees of miscibility between the binder and the oil modifiers depending on blending procedure used. Furthermore, rheological properties of different asphalt blends are explored at wide range of temperatures using DSR and BBR. The investigation of characteristic effects of oil modification is extended to possible modification of aging susceptibility in this study.

Rejuvenation vs. Softening: Critical Analysis of the Reversal of the Aging Impact on Thermo-Rheological and Damage Resistance Properties through Use of Recycling Agents

Hassan Tabatabaee and Todd Kurth
Cargill Industrial Specialties

The increasing incorporation of highly oxidized asphalt material into pavements has increased the need for effective recycling agents. Thus assessment of the differences between various approaches to "rejuvenation" in terms of the reversal of the detrimental effect of aging on the performance properties is more important than ever.

The present study uses a number of analytical, thermo-rheological, and damage characterization procedures to compare the impact of "Softeners", which supplement the solvent fraction of the asphalt colloidal structure, to "rejuvenating" additives designed to disrupt the association of polar structures formed by aging. Although both approaches result in an apparent reduction in modulus, important differences in the type of viscoelastic response was observed by analyzing the thermo-rheological parameters derived from modeling the master curve and Black Space Analysis.

Finally, a Linear Amplitude Sweep (LAS) analysis was carried out on the aged and treated samples, immediately followed by an isothermal "healing" period during which the gradual modulus recovery is monitored through low amplitude sinusoidal loading, and ultimately a second Linear Amplitude Sweep application to assess the rate of recovery of damage resistance. The "healing" potential was significantly higher when using rejuvenators designed for disrupting the association of the oxidative aging products.

Tuesday, July 14

Session 3

Modification of the Rolling Thin Film Oven (RTFO) Test for Realistic Short-Term Aging of the Asphalt Rubber Binders

Mohammad Zia Alavi, Xai Lao, David Jones, and John T. Harvey
University of California Pavement Research Center (UCPRC)

This study proposed and assessed increasing both the testing temperature and the amount of binder sample in each bottle as practical approaches to facilitate RTFO testing of asphalt rubber binders that is more representative of plant and field conditions. Asphalt rubber binders are typically heated to between 190°C and 220°C when mixed with aggregate and consequently the RTFO testing temperature, which is set at 163°C for testing conventional binders, needs to be increased accordingly for asphalt rubber binders. Moreover, asphalt rubber binders typically contain between 18 and 22 percent rubber by mass of binder and using the same quantity of binder as that used for testing conventional binders (35 g) effectively reduces the quantity of actual binder tested given that the rubber particles are not fully digested. Based on preliminary results of rheological tests on various laboratory prepared asphalt rubber binders, it is recommended that the RTFO testing temperature is increased to 190°C and that the sample size is adjusted according to the percentage of rubber particles added so that 35 g of base binder is tested. For a binder containing 20 percent rubber by mass of binder, a 45 g sample would be required.

Use of a Total Air Void Diffusion Depth to Improve Pavement Oxidation Modeling with Field Validation

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

Recent efforts relating pavement failure to binder oxidation and hardening have resulted in 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 as a function of time, depth, and geographic location. A key model parameter is the binder "diffusion depth," the ratio of binder volume to accessible air void (AAV) surface area. Previously, AAVs have been identified using x-ray CT image analysis to identify air voids with connected paths to the pavement surface. Length-scale comparison of x ray CT resolution and oxygen mean free path casts doubt on the approach.

In the herein reported work, nine field cores, from four Texas locations, are analyzed to compare variation over depth of total air voids (TAVs), AAVs (i.e. x-ray CT identified AAVs), and oxidation. TAV and AAV variation with depth is generally similar; nevertheless, two cores have especially low AAV content in their lower slices. Oxidation in these lower slices is not correspondingly low. Combined, these data suggest development of a new diffusion depth based on TAVs. Modeling using a TAV diffusion depth provides superior oxidation predictions. Results imply nearly complete oxygen accessibility to pavement air voids.

Extended Testing Conditions for the Evaluation of Water Sensitivity of HMA Mixes

Geoffrey M. Rowe (1); and Ajay Ranka, Moulik Ranka, Doug Zuberer, and Jerry Thayer (2)
(1)Abatech; (2) Zydex

During the SHRP project it was noted that "almost perfect agreement" existed between predictions made by the A -002A research team and the immersion wheel tracking test extended wheel tracking test. The test procedure implemented in this work involved a 6-day 60C conditioning period. In the development of this method in the early 1990s it was noted that this extended conditioning time was needed to fully capture the expected performance on site. More recently, work has been conducted using a more extreme conditioning in the MIST device with higher temperatures. Results obtained for two additives used show comparable behavior even when condition at temperatures as high as 90C. The need for high temperatures is postulated as being a substitute for the extended times that has been used in earlier work and it would be reasonable to assume that time and temperature effects must be interrelated via Arrhenius type relationships. Test results from extended tests using an organosilane technology will be presented based upon several years of use since the introduction of this technology in North America approximately 6-years ago in commercial projects. The need to evaluate materials with longer conditioning and/or more extreme conditioning is discussed.

Physical and Chemical Changes of Asphalt Binders in Long-life Asphalt Pavements

Yuhong Wang
Hong Kong Polytechnic University

Understanding asphalt binder aging in long-life pavements is critically important for rational pavement design and construction practices. Using binder test data obtained at various times from a heavily trafficked 36-year-old asphalt pavement, the study examined the evolution of binder aging as well as variations in aging severity with pavement depth and cross-sectional location. Asphalt consistency, ductility, and temperature sensitivity were used to assess the states and effects of binder aging. In addition, relationships between the rheological and chemical properties of the binders were investigated.

It was found that asphalt binders continuously and severely age over time, regardless of the location in the pavement structure. Test data also revealed that mixture type and pavement depth have significant effects on binder aging, but the effect of cross-sectional location is insignificant. Binder aging variations with pavement depth can be attributed to temperature and oxygen content variations in the pavement structure. The rheological properties were found to be well related to asphaltenes content and ketone formation. The dynamic rheological properties measured in the oscillation shear test apparently can be well explained by the micromechanical models that describe colloidal suspension.

Applications of Portable Infrared Spectroscopy to Asphalt Products: Progress Report Card

Iliya Yut and Delmar Salomon
Pavement Preservation Systems, LLC

Quality control of composition and fingerprinting of asphalt products continue to be crucial for ensuring an adequate performance and durability of asphalt pavements. Most recent phase of SHRP 2 R06B study targeted in-situ pilot implementation of portable FTIR technology to detect excessive oxidation in asphalt as measured directly on solid samples retrieved from pavement surface. Since first presented in Laramie in 2010, a significant progress has been made in using portable ATR and DRIFT devices, particularly, in identifying polymers in in-service pavements and measuring oxidation and moisture content in RAP stockpiles. This presentation reports results from in-situ ATR and DRIFT measurements on polymer-modified mixes and RAP from Connecticut, Maine, Ontario, and Idaho.

Oxidation of Asphalt Binders Modified with Polyphosphoric Acid

Giovanni Onnembo (1), and Ron Glaser, Fred Turner, and Jean-Pascal Planche (2)
(1) Innophos Inc.; (2) Western Research Institute

A small aging study has been conducted to determine whether PPA significantly influences oxidation rates in PPA -modified binders. Two bitumens were treated with PPA and oxidized as thin films at 70°C for up to 8 weeks along with the untreated control materials. Oxygen uptake was determined by transmission Fourier-transform infrared spectroscopy for each material, and the rates of reaction of the treated and untreated bitumens are compared. Diffusivity differences were investigated by oxidation under the same conditions with thicker films. Molecular weight changes were explored with size exclusion chromatography. The changes in rheological properties were examined using dynamic shear rheometry with 4 mm plates. The results indicate that PPA alters the oxidation reaction mechanism somewhat. However, the influence of PPA modification on overall oxidation severity is small for conditions relevant to pavement aging.

Session 4

Impact of the Bitumen Quality on the Asphalt Mixes Performances

F. Delfosse, I. Drouadaine, S. Faucon-Dumont, and S. Largeaud (1); B. Eckmann (2); and J. P. Planche, F. Turner, and R. Glaser (3)
(1) Eurovia Research Centre; (2) Eurovia Technical Department; (3) Western Research Institute

French and European refining is currently in a phase of rationalization and search for maximum flexibility in crude supplies. For users of bitumen, this creates concerns about the quality and consistency of products delivered, especially as the European standard EN 12591 appears to them as insufficient to ensure satisfactory performance of the finished products, particularly in case of specialty products such as high modulus asphalt, polymer modified bitumen, and bitumen emulsions.

In this context, the search for correlations between the bitumen properties and the performance of the finished product is more relevant than ever. The study presented here is focused on asphalt mixes. It was based on a standard design, but with two different types of aggregates. After a preliminary selection, 8 bitumen (20/30, 35/50 and 50/70) were selected. The characterization of asphalt mixes covers all the usual characteristics (stiffness modulus, resistance to rutting and fatigue, resistance to thermal cracking, water sensibility). The characterization of binders, besides conventional testing, focuses on the rheological properties (DSR, MSCR, and BBR tests) but also on compositional analysis, including infra-red spectroscopy and SARA analysis. These tests were performed on the original binders, on the RTFOT aged binders as well as on the binders recovered from asphalt mixes.

This project was conducted as a collaboration between Eurovia and the Western Research Institute (WRI) who performed the compositional analysis of binders, including the SAR-AD™, the WRI improved SARA separation technique and the chemometrics analysis using the WRI developed ExpliFit™ software.

Using Chemometrics to Understand Asphalt Composition-Structure-Properties Relationships

Ron Glaser, Fred Turner, and Jean-Pascal Planche (1); and Frédéric Delfosse, Ivan Drouadaine, and Sabine Largeaud (2)
(1) Western Research Institute; (2) Eurovia Research Centre

This presentation provides possible conceptual interpretations of multivariable correlations of chemical composition measurements to mechanical properties for asphalts. The data have been obtained in the course of Eurovia's finger print project. Eight binders were examined as received, after rolling thin film oven treatment, and after extraction from pavement mix samples. The asphalt binder chemical characteristics were determined from mid infra-spectra, SAR-AD and SEC measurements. A large suite of mechanical properties were also measured including, but not limited to, Penetration, Ring and Ball, ABCD cracking Temperature and Stress, and extensive DSR measurements. Most of the calibration quality correlations contain significant measurements that can be explained with conceptual ideas of molecular mobility and consistent with micro-structure as a temperature sensitive nano-scale suspension with a peptizing region consisting of a solubility gradient. It is thought that the results of these empirical correlation models can be used to enhance formulation of first principle fundamentally based mathematical descriptions of the relationships between asphalt binder composition and mechanical behavior.

Advanced Techniques in the Low-temperature Rheological Analysis of Bitumen

Olli-Ville Laukkanen (1), H. Henning Winter (2), and Hilde Soenen (3)
(1) University of Massachusetts Amherst / Aalto University; (2)University of Massachusetts Amherst; (3) Nynas NV

The thermal cracking performance of asphalt pavements is largely governed by binder properties. Therefore, it is important to thoroughly analyze the low-temperature viscoelastic properties of bitumen. Recently, a robust technique for measuring these properties with small amounts of material has been developed. This test method, often referred to as 4-mm DSR, uses 4-mm diameter parallel plate geometry on a dynamic shear rheometer (DSR) with torsional instrument compliance corrections. However, mainly because of the newness of this test protocol, the techniques used to analyze 4-mm DSR data are still not fully developed.

This paper introduces tools for analyzing the rheological data produced by the 4-mm DSR method. The construction of master curves using the time-temperature superposition (TTS) principle and the use of vertical (modulus) shifts therein are discussed. The temperature dependence of horizontal shift factors is modeled using the Kaelble-WLF equation. Further, the relaxation time spectrum of bitumen is calculated from dynamic data measured over a wide range of frequencies and temperatures. Some concepts adopted from the glass rheology are also discussed. Finally, the use of time-resolved rheometry (TRR) combined with the time-aging time superposition analysis in the characterization of physical aging in bitumen is demonstrated.

Asphalt Binder Testing Protocol for Dynamic Shear Rheometer

David A. Anderson (1), Michael J. Farrar (2), Andrew Hanz (3), and Sonia Serna (4)
(1) Consultant; (2) Western Research Institute; (3) MTE Services, Inc.; (4) Paragon Technical Services

Test results obtained for asphalt binders using the Dynamic Shear Rheometer (DSR) can be significantly affected by testing protocol. This is true for data used for sell-purchase specifications where accuracy and precision are important as well as for research applications, especially in the generation of mastercurves where systematic errors can lead to issues of interpretation. Adapting the 4-mm parallel plate to the low temperature-high modulus region places additional demands on specimen preparation, asphalt binder-test plate adhesion, physical hardening and thermal equilibrium. The results of a series of multi-laboratory experiments directed at these issues and conducted in large part as contributions to the Federal Highway Administration (FHWA) Asphalt Binder Expert Task Group (ETG), are discussed. The thermal equilibrium criterion established for 8-mm and 25-mm parallel plate was applied to the 4-mm plate and the results compared. Two 4-mm specimen preparation protocols that give adequate binder-plate adhesion were finalized and the study also afforded an opportunity to evaluate physical hardening during low temperature DSR testing.

Applying the Glover-Rowe Parameter to Evaluate Low Temperature Performance of Hot Mix Asphalt LTPP Sections

David J. Mensching (1); and Christopher D. Jacques and Jo Sias Daniel (2)
(1) National Research Council Postdoctoral Research Associate, FHWA; (2) University of New Hampshire

Four Long-Term Pavement Performance (LTPP) projects with hot mix asphalt were evaluated using three proposed indicators for low temperature cracking resistance. The primary objectives were to: compare ways to combine stiffness and relaxation properties as it relates to cracking correlation; assess data collection schemes in the LTPP relating to the analysis methods; and provide agencies with information to develop approaches for cataloging binders and performance. The Superpave low temperature specification was compared with the recently developed Glover-Rowe parameter to relate laboratory-measured properties to field cracking. Complex modulus and phase angle master curves were constructed to plot binder properties in Black Space. Results show the Superpave specification was able to capture both sections where cracking coincided with test data obtained within a reasonable amount of time from field measurement, while the Glover-Rowe parameter detected one of these sections. However, the available LTPP data was not ideal for Glover-Rowe analysis, where frequency sweeps at several temperatures are desired. The information presented is particularly relevant as tighter budgets delay maintenance and rehabilitation, exposing pavements to extensive aging.

Predicting Repeated Creep-recovery Behavior of Bituminous Binders from Small-amplitude Oscillatory Shear (SAOS) Data

Olli-Ville Laukkanen (1) and H. Henning Winter (2)
(1) University of Massachusetts Amherst/Aalto University; (2) University of Massachusetts Amherst

The high-temperature rutting resistance of bituminous binders is often characterized by performing subsequent creep-recovery experiments on a dynamic shear rheometer (DSR). The objective of this study is to use small-amplitude oscillatory shear (SAOS) data to predict strain accumulation in various unmodified and modified bituminous binders under repeated creep-recovery loading. In the majority of the experiments the creep stress was selected to be so low that the strain response remained in the linear viscoelastic (LVE) regime. In parallel to the repeated creep-recovery experiments, this study uses the retardation time spectrum, measured over a wide range of frequencies and temperatures in SAOS, to predict the creep-recovery response. Using the Boltzmann superposition principle (BSP), the stress in a sequence of creep-recovery loadings can be predicted as linear superposition of individual creep-recovery tests provided that the memorized strain does not exceed a critical value. It was observed that the LVE creep-recovery predictions are very accurate for the unmodified binders and also fairly accurate ($\leq$ 20% relative error) for the modified ones. The importance of the low-frequency/high-temperature SAOS data in the prediction of long-term creep and elastic recoil is demonstrated. The non-recoverable creep-compliance (Jnr) at 3.2 kPa is also fairly accurately predicted by the model.

Relaxation and Linear Visco-elastic Binder Properties and Asphalt Pavement Cracking

Geoffrey M. Rowe and Mark J. Sharrock
Abatech

The Strategic Highway Research Program (SHRP) resulted in test parameters implemented in Superpave™ which are based upon linear visco-elastic measurements, for example G*/sin delta, G*.sin delta, S(t), and m(t). The last three of these are used to define fatigue and thermal cracking. In addition, the SHRP research workers developed the Christensen-Anderson binder model, defining the R value (rheological index) and cross-over frequency. The R value is related to the relaxation properties of the binder. More recently, other test parameters have been proposed for cracking evaluation such as the Glover-Rowe parameter (G*.cos(delta).cos(delta)/sin(delta)), the difference between Tcrit from S(t) & m(t) (delta Tc), and the visco-elastic transition temperature (TVET and G*VET). All of these test parameters are measured in the linear visco-elastic region. This paper demonstrates how these model parameters can be interrelated through an understanding of the linear visco-elastic properties and how a simple understanding of a few key asphalt binder parameters can be used to estimate other parameters. Data will be presented that demonstrates how these parameters correlate to cracking behavior.

Wednesday, July 15

Session 5

Evaluating Changes in Performance-Related Properties of Conventional Asphalt Binder after Blending with Different Amounts of Age-Hardened Rubberized Binder

Shawn S. Hung, M. Zia Alavi, and David Jones
University of California Pavement Research Center (UC Davis)

In California, rubberized asphalt pavements has been widely used over the past two decades for both environmental and performance benefits. As these rubberized pavements reach the end of their design lives, they are being milled off and the millings will be added to recycled asphalt pavement (RAP) stockpiles. Considering more and more Rubberized RAP (R-RAP) to be generated, the goal of this research is to investigate the effects of aged asphalt rubber, in existing R-RAP, on the performance-related properties of conventional asphalt binder. Simulated rubberized RAP binder were prepared by aging asphalt rubber binder in a pressure aging vessel (2.10 MPa) for 40 hours at 100°C, and they were then blended with a PG64-16 virgin binder at three binder replacement percentages (15, 25, and 40). The properties of blended binders were measured at high and low in-service temperatures using a dynamic shear rheometer and a bending beam rheometer. For high temperature, asphalt binder shear stiffness increased and phase angle decreased with increasing R-RAP binder content. For low temperature, slight reductions were observed in creep stiffness and m-value of binder with increasing R-RAP content. This research will continue to evaluate the performance properties of mixtures containing different amounts of R-RAP.

Crack Monitoring Results from the 2011 Binder Initiatives in Ontario

Alexander (Sandy) Brown
Asphalt Institute

Over the last 7 years, Industry and the Ontario Ministry of Transportation collaborated in looking at different testing methodologies for the purchase acceptance of asphalt cement binder. In an initiative to assist Industry in evaluating the different protocols, in 2011 MTO chose a total of 38 contracts representing over 1.2 million tonnes of hot mix to study. Quality Assurance samples of the asphalt cement supplied for these contracts were tested for the following properties: Low Temperature Grade from the standard (M320) 1 hr BBR test; Low Temperature Limiting Grade and Loss from the Extended (72 hr) BBR test; Ash test; Crack Tip Opening Displacement from the DENT test (Ontario procedure); and the Percent Recovery from the MSCR test. The projects were constructed between 2011 and 2014. In 2014, MTO conducted surveys of surface distress on the contracts with their updated ARAN (laser crack measurement). Sixteen of the 38 contracts have been accepted after the 2 year warranty period and the results of the crack monitoring have been evaluated by Industry against the results of the individual tests. Industry's analysis based on preliminary results after the first 3 years of the 8 year initiative indicate that M320 low temperature results show moderate correlation with cracking, ExBBR LTLG and MSCR Percent Recovery show poor correlation with cracking, and ExBBR Loss, Ash and DENT show no correlation to cracking.

Proposing a Solvent-Free Approach to Evaluate the Properties of Blended Binders in Mixtures with High Amounts of Recycled Asphalt Pavement (RAP) and Recycled Asphalt Shingles (RAS)

Yuan He, Zia Alavi, and John T. Harvey
University of California Pavement Research Center

The traditional extraction and recovery approach to evaluate the properties of blended binder in asphalt mixtures has long been criticized for being labor intensive, changing binder rheological and chemical properties, forcing homogenized blending of binders, and causing hazardous material disposal issues. A research being undertaken at the University of California Pavement Research Center (UCPRC) proposes an alternative approach for characterization of blended binder properties by testing asphalt fine aggregate matrix (FAM) using a torsion bar fixture with a dynamic shear rheometer (DSR). The asphalt binder content and the gradation of a FAM must be matched the binder content and gradation for the fine portion of the respective full-graded asphalt mix. In this study, FAM specimens made with different fresh binder grades and sources, various percentages of RAP and RAS have been evaluated. Partially, the effectiveness of rejuvenating agent on restoring the properties of blended binder is also investigated. Generally, complex shear modulus (G*) and relaxation properties of FAM specimens can be measured precisely with DSR torsion bar fixture. Particularly, it has been found that the test is sensitive enough to capture the differences between binder grade, binder source, RAP/RAS content, and presence of rejuvenating agent.

Use of Performance Based Testing for High RAP Mix Design and Production Monitoring

Andrew Hanz (1), Erv Dukatz (2), and Gerald Reinke (1)
(1) MTE Services Inc.; (2) Mathy Construction

In 2014 the Wisconsin Department of Transportation and industry developed a pilot program for HMA with higher recycled asphalt content that required use of performance based test methods during mix design and production. Following the balanced mix design concept mixture tests were selected to address rutting resistance after short term aging and durability after long term aging. Durability tests include the semi-circular bend (SCB) at intermediate temperatures and disc-shaped compact tension (DCT) at low pavement temperatures. Asphalt binder extraction and grading from aged mix was also required. The focus of this presentation is to present the data gathered and to discuss the lessons learned from application of this special provision on STH 77 in Ashland County, WI. Results of asphalt mixture fracture tests and recovered binder grading after 12 and 24 hour loose mix aging will be used to demonstrate the change in properties with aging and to recommend loose mix aging as a viable alternative to the current long term aging protocol in AASHTO R30. High RAM results will also be compared to a conventional mix to assess the impacts of increased recycled binder content on the evolution of binder and mix properties with aging.

Binder Quality Control Test Method (QC Test) – Progress Report

Raj Dongre (1) and Jack Youtcheff (2)
(1) DLSI; (2) FHWA

An innovative, simple, and easy-to-use test method for Quality Control of asphalt binders was developed. This new method, called the binder QC 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^{o}F (25^{o}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.

At last year's Petersen conference, data on modified and unmodified binders for several PGs were presented. Theoretical analysis to determine fundamental rheological properties from the creep recovery data obtained using this test was also discussed. Presented here will be the results of our investigation of crumb rubber modified asphalt binders and hybrid crumb rubber/polymer using the QC test. Also discussed will be a smaller sample size to test emulsion residue that has been developed and a new test protocol by which the stress sensitivity (Jnr difference) of the binders can be assessed. Results from additional applications for CRM binders and emulsion residue testing and the relationship between the MSCR test and the QC test will be discussed in greater detail. The progress towards development, implications and implementation of the binder QC test at selected State DOTs will be presented.

Investigation of Warm Mix Asphalt Additives Using the Science of Tribology to Explain Improvements in Mixture Compaction

Sebastian Puchalski (1) and Hussain U. Bahia (2)
(1) Kraton Polymers; (2) University of Wisconsin, Madison

The science of tribology was used to understand and quantify mechanisms through which Warm Mix Asphalt (WMA) additives can improve compaction process. It has been found that chemical WMA additives are capable of creating boundary lubrication films protecting aggregate particles from direct solid-to-solid contact, hence reducing friction between particles. In this study, new test method was developed to investigate effects of WMA additives on changes in binder boundary lubricating properties. The method utilizes principles of tribology to quantify interactive effect of binder-aggregate system as influenced by WMA additives. New fixture was developed based on pin-on-disk tribological geometry and adapted in Dynamic Shear Rheometer. It can measure coefficient of friction (COF) of aggregate lubricated with asphalt binder at various temperatures. Results show that the developed testing procedure can be used to indicate effect of WMA additive modified binders on improving binder boundary lubrication as compared with control binders. Results also indicate that aggregate mineralogy plays major role on efficiency of WMA additives on lubricating properties. Results are in general agreement with observed effect of WMA additives on mixture volumetrics. Additionally, at high testing temperature (145°C), boundary COF provided explanation for changes in mastic viscosity, which can be correlated with mixture volumetrics. played in the Conference Program.

Notes

Western Research
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3474 North 3rd Street • Laramie, WY 82072
(307) 721-2011 www.westernresearch.org