Petersen Asphalt Research Conference
Since 1964

50th

Hosted by Western Research Institute
July 15-17, 2013 • Laramie, Wyoming
Memories of the Past

By J. Claine Petersen, WRI – Retired

In 1963, the US Bureau of Mines Research Center, which specialized in crude oil and shale oil studies, was successful in getting a funding line for asphalt research in Laramie. (The Bureau of Mines was the predecessor of what would become Western Research Institute.) Work began with a small group of three researchers, and I was recruited from the DuPont Experimental Station in Wilmington, Delaware, as project leader, arriving at the center in 1964.

The department head at the Laramie Center, seeking to expose his “green” crew to some seasoned asphalts researchers, arranged to have the Laramie group meet as observers at the project review meeting at the University of Montana. The primary intent was to take advantage of experienced input from the National Cooperative Highway Research Program (NCHRP) project’s advisory committee. The advisory committee consisted of five well-known authorities that included Woodrow (Woody) Halstead and Robert (Bob) Schmidt and Vyt Puzinauskas—well-known peers in the asphalt research community.

The next year, the Laramie group reciprocated and invited the Montana group to hold their NCHRP advisory meeting with the group in Laramie. Thus, all benefited from the advice and feedback from this advisory committee. When the NCHRP program at Montana ended, our group at Laramie invited the members of the original NCHRP advisory committee to meet once a year with us to review the progress of our research program, which now had about five researchers—the advisory committee personnel getting the benefit of results from our current research while the Laramie group received useful advice, knowledge and feedback from them.

At this point, the Laramie group also began to invite selected researchers from highway departments, academia and industry to meet with us to get valuable feedback regarding our work and to help them keep focused on the needs of the nation’s road builders. It was also hoped that those invited to participate would
also benefit from the knowledge and skills being developed at Laramie.

For years, the Laramie meeting was more or less a closed annual meeting between our research team and this group of invited industry, academic and highway research peers. At first, we met for a couple of days around the long table in the old log annex building (now gone), which stood just west of the current WRI building. The format was very informal, with each researcher going into his current research in detail with accompanying discussion and input from the experts. Often a half-day might be spent in detailed discussion of the work of one of the researchers.

It also became traditional to spend one evening visiting the Snowy Range, west of Laramie, and to follow that with a steak dinner at the celebrated “Pat Selve’s” Old Corral in Centennial. The old restaurant building burned down years ago, but it was famous for its walls laden with antiques of the early west and for its huge beefsteaks. When the group was smaller in the 1960s and 1970s, this evening in Centennial was an anticipated ritual, which was later replaced with the mid-meeting banquet.

After-dinner activities at the old Corral might include the likes of Arnold Hoiberg dancing in his cowboy boots while Don Saylak played his accordion, which he had brought with him. Lots of fun and camaraderie was had by all.

As the Laramie group became more well known, individuals with research related to that going on in Laramie would ask if they could meet with us. Also, the Laramie group began to invite individuals whose research complemented ours to meet with us on the basis of mutual benefit. Thus, while still an invitational meeting, the group began to grow to 10 to 20 persons. Interested researchers continued to ask if they could be invited. By the late 1970s the meeting had grown to more than 30 people, and the format took on pre-scheduled presentations.

Jon Epps presents using an overhead projector at the 1980 meeting.

1982 conference participants.
We needed to decide whether to keep the meeting by invitation or to open it up as a public meeting. A decision was made to go public, and annual meeting attendance grew to about 75. However, when the Strategic Highway Research Program (SHRP) came into being in the late 1980s, with Laramie being the contractor for the SHRP fundamental research on asphalt composition and physical properties, meeting participation quickly grew to over 100, where it has remained until the present 50th anniversary in 2013.

The meeting was known as the Laramie Asphalt Research Meeting until I retired in 1990, at which time the powers that be decided to rename the meeting the Petersen Asphalt Research Conference. I was responsible for organizing the meetings until I retired, and Ray Robertson then took over the meetings until he retired a few years ago.

The Laramie research conference has been unique, and in my opinion, valuable in that it has always had the policy of no published papers. This has allowed presenters to give advance information on their research and get valuable input and critique prior to later publication. This format allows discussion and speculation that is valuable to not only the presenter but also the meeting participants.

On a personal note, it has been a great honor, privilege and the source of pleasant reflection to have been associated with the many meeting participants over the past 50 years.
Monday, July 15

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

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

**SESSION 1  Session Chair: Ray Robertson, WRI-retired**

8:15-8:45  Evaluating a New Setup for Rheological Testing of Ground Tire Rubber Modified Binders
Joerg Laeuger  
*Anton Paar Germany*

8:45-9:15  Evaluation of Recycled Tire (RTR) Rubber modified Binders to typical Polymer Modified binders for Performance Specification
John D’Angelo  
*D’Angelo Consulting, LLC*;  
and Gaylon Baumgardner  
*Paragon Technical Services*

9:15-9:45  Rheological Insights on the Delay of Top-Down Cracking with Fine Mix Overlay
Nelson Gibson  
*FHWA*;  
and Adrian Andriescu and  
Susan Needham  
*SES Group & Associates, LLC*

9:45-10:00  Break
### Monday, July 15, continued

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<td>David A. Anderson Consultant; Jean-Pascal Planche and Mike Farrar Western Research Institute</td>
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<td>Testing Method to Determine the Three-Point Bending Strength of Asphalt Binders</td>
<td>Augusto Cannone Falchetto Braunschweig University of Technology; Mugurel I. Turos and Mihai O. Marasteanu University of Minnesota</td>
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<td>The Effect of Thermal History on BBR Test Results</td>
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<td>A Simple Test to Determine Workability of Warm Mix Asphalt – Progress Report</td>
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**SESSION 2**

*Session Chair: Gayle King, GHK, Inc.*

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<td>Application of the Diffusion Mechanism to Healing of Asphalt Binder Cracked Surface in the Dynamic Shear Rheometer</td>
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<td>2:30-3:00</td>
<td>A Micro-Mechanical Model for Asphalt Mastic Modulus based on Physico-Chemical Interaction</td>
<td>Shane Underwood Arizona State University; Y. Richard Kim North Carolina State University</td>
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3:15-3:45 Analysis of Asphalt Binders without Time-Temperature Superposition using Relaxation Computation from Single DSR Isotherms
Ron Glaser, Fred Turner, Jean-Pascal Planche and Steve Salmans
Western Research Institute

3:45-4:15 Frequency Interpretation of Molecular Asphalt Relaxation Processes
Mohammad Masoori and Michael L. Greenfield
University of Rhode Island

4:15-4:45 Mechanistic-Based Constitutive Modeling of Oxidative Aging in Asphalt Concrete Materials
Eisa Rahmani Texas A&M Univ.; Masoud K. Darabi Texas A&M Transportation Institute; Eyad Masad Texas A&M Univ. at Qatar; Dallas Little Texas A&M Univ.; and Rashid K. Abu Al-Rub Masdar Institute of Science and Technology, Abu Dhabi

MONDAY EVENING—Dinner on your own.

Tuesday, July 16

SESSION 3 Session Chair: Ernie Bastian, FHWA, Retired

8:00-8:30 Application of Asphalt Oxidation Kinetics and Rheology to Rational Pavement Performance Modeling
Ron Glaser, Fred Turner, Steve Salmans, Jenny Loveridge and Jean-Pascal Planche
Western Research Institute

8:30-9:00 Correlation between Rheology and Chemistry of Aged Polymer-Modified Asphalts
Iliya Yut
University of Connecticut

9:00-9:30 Investigation of Mineral Fillers’ Effects on the Oxidative Aging of Asphalt Binders
Raquel Moraes and Hussain Bahia
University of Wisconsin-Madison

9:30-9:45 Break

9:45-10:15 Investigation of Oxidation Parameters in Mixture and Pan-Aged Asphalt Binders
Nathan Morian Nevada DOT/ University of Nevada, Reno; and Elie Y. Hajj and Peter E. Sebaaly
University of Nevada, Reno

10:15-10:45 Exploring the Combined Effects of Asphalt Kinetics, Hardening Susceptibility, Oxygen Diffusivity, Pavement Characteristics, and Climate on Pavement Durability
Charles J. Glover and Yuanchen Cui
Texas A&M University
Tuesday, July 16, continued

10:45-11:15 Effect of Polyphosphoric Acid on Aging Kinetics of Asphalt Binders
Olga Shulga ICL Performance Products; Ken Grzybowski PRI Asphalt Technologies, Inc.; and Rene Maldonado and Henry Romagosa ICL Performance Products

11:15-11:45 Micron-sized Domains in Solution-cast Asphalt Binders Exhibit Significantly Different Mechanical Properties
Xiaokong Yu, Nancy A. Burnham, Rajib B. Mallick and Mingjiang Tao Worcester Polytechnic Institute

11:45-12:45 Lunch

SESSION 4 Session Chair: Gale Page, King of Asphalt Consulting

12:45-1:15 Surface Structuring of Wax in Complex Media
Troy Pauli, R. Will Grimes and James D. Beiswenger Western Research Institute; and Alexander Schmets Delft University of Technology

1:15-1:45 Characterization of Asphalt Binder Microstructure and Chemical Properties using Atomic Force Microscopy Imaging and Indentation Techniques
Rezwan Jahangir, Dallas N. Little and Grover R. Allen Texas A&M University; and Amit Bhasin The University of Texas at Austin

Troy Pauli, Will Grimes and Alec Cookman Western Research Institute; Mengxi Wang and Peng Lu University of Wyoming; and Shin-Che Huang Western Research Institute

2:15-2:45 Field QC/QA Test for Asphalt Binder
Raj Dongre DLSI; Jack Youtcheff and Nelson Gibson FHWA; and John W. Newman LTI

2:45-3:00 Break

3:00-3:30 A Study on Elastomer-HMA Mixture for High-performance Gussasphalt
Zed Liang Canaphalt Ltd.; and Chen Shizhou and Zhang Wen Chongqing Pengfang Group
Tuesday, July 16, continued

3:30-4:00 Recombination of Asphalt with Bio-Asphalt: Binder Formulation and Asphalt Mixes Application
Joana Peralta Iowa State Univ./University of Minho, Portugal; Ka Lai Ng Iowa State Univ.; Hugo M.R.D. Silva University of Minho; R. Christopher Williams Iowa State University; and Ana V.A. Machado University of Minho

4:00-4:30 Binder Rheology: Characterization and Specification
David A. Anderson Consultant and Dr. Geoff Rowe Abatech

6:15 GALA DINNER, University of Wyoming Yellowstone Ballroom (Social Hour 5:30)

Wednesday, July 17

SESSION 5 Session Chair: Jerry Forney, WRI

8:00-8:30 Development of a Carbon-Based Bio-Modifier for Asphalt Cement
Sheng Zhao, Baoshan Huang and Philip Ye University of Tennessee

8:30-9:00 Rubberized Foamed Asphalt Mixtures Using Half-Warm Aggregates
Punith Shivaprasad, David Wingard and Feipeng Xiao Clemson University

9:00-9:30 Understanding Diffusion between Recycled and Virgin Asphalt
Pavel Kriz Imperial Oil Ltd.

9:30-10:00 Evaluation of the Performance Properties of Asphalt Mixes Produced with Re-refined Heavy Vacuum Distillate Bottoms
John D’Angelo Consultant; Ken Grzybowski PRI Asphalt Technologies, Inc.; and Steve Lewis and Rodney Walker Safety-Kleen

10:00-10:15 Break

10:15-10:45 DARWin-ME Value Engineering Design—From Concept to Construction
Raj Dongre DLSI; Bob Kluttz and Hernando Faria Kraton Polymers; and Pablo del Aguila Camineros Consulting

10:45-11:15 Field Performance of RAP/RAS Mixes in Texas
Fujie Zhou Texas Transportation Institute

11:15-11:45 Binder Performance Evaluation of Warm Mix Asphalt
Ashley Buss and R. Christopher Williams Iowa State University

11:45 Closing Remarks
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Evaluating a New Setup for Rheological Testing of Ground Tire Rubber Modified Binders

Joerg Laeuger
Anton Paar Germany

Asphalt binders modified with ground tire rubber (GTR) present several challenges to the rheological testing of these materials. The size of the rubber particles is often too large for standard parallel plate measuring geometries. The use of a cup and bob geometry allows the use of larger measuring gaps. Much effort has been made to optimize the temperature control for standard binder testing. Going to different geometries like cup and bob require the same type of quality in the temperature control. Therefore a new temperature control system for cup and bob geometries has been developed and evaluated. The temperature performance and comparison measurements with standard geometries are presented.

Torsional compliance effects might come into play when stiff samples such as PAV samples are measured in new testing configurations. A comprehensive study of the influence of torsional compliance effects on the rheological data in general and for the cup and bob geometry in particular has been performed and the results obtained show the practicability of the new cup and bob setup for ground tire rubber modified binders.

Evaluation of Recycled Tire (RTR) Rubber Modified Binders to Typical Polymer Modified Binders for Performance Specification

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

The use of recycled tire rubber (RTR) to produce PG modified binders has seen a tremendous increase in interest. Under the current economic conditions it is quite cost effective to produce RTR modified binders that will meet typical extended PG grades and MSCR grades. One major question is, are the RTR modified binders equivalent to typical polymer modified binders currently being used. To evaluate these binders new tools, such as the cup and bob Searle system, have been developed to evaluate the binder properties of RTR modified binders under the AASHTO M 320 and MP 19 specifications.

This study is evaluating binder modified with multiple RTR sizes and percentages. Sizes such as 60, 30 and 20 mesh RTR are blended with neat binders at zero, 5, 10, 15 and 20 percent to produce modified binders. The properties of the blends are being evaluate using both parallel plate and cup and bob geometries and M 320 and MP19 specifications against typical SBS modified binders. These blends will see further testing in asphalt mixtures to look at performance properties and make comparisons of these properties.
Rheological Insights on the Delay of Top-Down Cracking with Fine Mix Overlay

Nelson Gibson (1); and Adrian Andriescu and Susan Needham (2)
(1) Federal Highway Administration, Turner Fairbank Highway Research Center; (2) SES Group & Associates, LLC, Turner Fairbank Highway Research Center

The results from the use of fine mix overlay to delay top down cracking are reported. Three of the 6 inch high pavements (lanes 8, 9 and 10) containing Control, Air-Blown and Styrene Butadiene Styrene (SBS) binders at Turner Fairbank Accelerated Loading Facility (ALF) were milled over half of their length and 1 inch of 4.75 Nominal Maximum Aggregate Size (NMAS) overlay was added on top. Full scale accelerated loading and aging was utilized to compare the fatigue cracking performance for four combinations of the resulting pavements: with and without 4.75 NMAS treatment, each with and without aging. Previous investigations into the rheological parameters of the extracted binders from natural and accelerated aged pavements have indicated that the aging intensity and hence the fatigue performance vary with the asphalt binder type and with the distance from the surface. Small quantities of binders extracted from drilled bit mix powders obtained from top and bottom of the overlay and control pavements (aged and unaged) have been tested in DSR. Among the rheological parameters, the DSR function $G'/\eta'/G'$ of the extracted or laboratory aged binders was used to quantify the aging progression of full scale accelerated loading pavements and allowed a comparison with the delay in top-down cracking fatigue performance with fine mix overlay.

Determination of DSR Test Specimen Thermal Equilibrium Time

Dr. David A. Anderson (1); and Jean-Pascal Planche and Mike Farrar (2)
(1) Consultant; (2) Western Research Institute

The rheological properties of asphalt binders are highly temperature dependent. Reproducible and repeatable test measurements can be obtained only if the temperature of the test specimen is well-known and controlled. Previous studies have shown that the time required to obtain thermal equilibrium is a function of rheometer design, test temperature, plate dimensions, and the environmental system used to control the test temperature. The time to thermal equilibrium is also potentially affected by steric and physical hardening in the asphalt binder. A comprehensive testing program was conducted using rheometers with different temperature control systems, multiple test temperatures and three plate sizes. Three asphalt binders and the polymer typically used as a reference fluid were included in the study. A protocol for defining the onset of thermal equilibrium based on a continuous measurement of $|G'|$ is described along with a proposed measurement window. The results of the study suggest that the current wait time after the DSR indicates the test temperature should be shortened considerably. The importance of thermal equilibrium when tests are conducted using temperature sweeps or extended isothermal conditions is discussed.

Thank you, Sunday reception sponsors.
Testing Method to Determine the Three-Point Bending Strength of Asphalt Binders

Augusto Cannone Falchetto (1); and Mugurel I. Turos and Mihai O. Marasteanu (2)
(1) Braunschweig University of Technology, Germany, formerly at University of Minnesota; (2) University of Minnesota

Currently, asphalt binder low temperature behavior is characterized using the Bending Beam Rheometer (BBR) for creep tests and the Direct Tension Tester (DTT) for strength measurements. In this study, the possibility of obtaining asphalt binder bending strength is investigated, and a new test method to determine asphalt binder flexural strength at low temperature is presented. Three-point bend strength tests are performed through a modified Bending Beam Rheometer (BBR), capable of applying loads at different rates using three different cooling media: ethanol, potassium acetate and air. Similar strength values are obtained in air and potassium acetate and significantly lower values are measured in ethanol. BBR strength in air is next compared with strength values obtained from Direct Tension Tester (DTT) in potassium acetate. Based on histogram testing and size effect theory for quasibrittle materials it is demonstrated that BBR and DTT strength measurements are similar indicating that strength histogram is capable of identifying the specific brittle or quasibrittle failure distribution of plain and modified asphalt binders.

The Effect of Thermal History on BBR Test Results

Dr. David A. Anderson (1) and Yang Liu (2)
(1) Consultant; (2) West Region CDM Smith

At the lower range of their service temperatures asphalt binders exhibit a reversible increase in stiffness when held under isothermal conditions. This behavior is called physical aging. This increase in stiffness is a function of the isothermal storage temperature relative to the binder glass transition temperature, storage time, and binder source. Failure to account for the physical hardening of asphalt binders can have a dramatic effect on test repeatability. Although the increase stiffness resulting from physical hardening can be equal to the increase in stiffness that occurs after many years of field exposure the effects of physical hardening on-field performance are little-researched and poorly understood. When testing asphalt binders in the BBR, DSR, or DTT the test specimen is typically quenched from room temperature to the test temperature. The effect of slow cooling versus quenching on the stiffness and m-value measured in the BBR was investigated in this study. Filled and unfilled asphalt binders were tested after slow cooling and quenching and the test results were compared relative to the glass transition temperature. The study showed that the two cooling protocols yield nearly identical test results.
A Simple Test to Determine Workability of Warm Mix Asphalt – Progress Report

Raj Dongre and Eugeni Morari (1); and Roger Pyle (2)
(1) DLSI; (2) Pine Instruments

A simple test method, called the Dongre Workability Test (DWT), was developed to determine the workability of mixes using the Superpave Gyratory Compactor (SGC). Several WMA technologies and polymer modified hot mixes (both lab and field produced) were tested using this method. It was found that the new method provides reasonable estimates of compaction temperatures (and/or Workability) for PMAs and WMAs. Initial findings were discussed last year (2012) at the Peterson conference.

Ruggedness testing was completed for the DWT. It was found that rodding with a round tipped rod was required to produce repeatable results. Specimen mass was also found to be mildly significant at one of the evaluation temperatures. Within-lab repeatability was also estimated and found to be 15% at d2s level. The Bailey mix design method was also evaluated and a proposal to implement the DWT was presented to the ETG in Raleigh. This presentation discusses the progress on development and ASTM standardization of the DWT.

SESSION 2

Detection of the Proportion of Polymer-modified Asphalt Binder Placed on Field for Quality Assurance Purpose

Yuhong Wang, PhD, PE (Kentucky) and Zhen Leng, Ph.D.
Hong Kong Polytechnic University

In many regions and countries, highway agencies are interested in verifying the types of asphalt binders placed on roads for quality assurance purpose. Particularly, as PG-graded, polymer-modified binders are increasingly used, they are interested in validating if contractors replace the PG binder, or a portion of it, with cheaper one that contains no or less polymers. This research investigated and compared various test methods for such purpose. Pavements were built with conventional binder without polymer, 30% of conventional binder with 70% of polymer-modified binder, 15% of conventional binder with 85% of polymer-modified binder, and 100% of polymer-modified binder. The mixture production and construction process were carefully designed to simulate what a dishonest contractor would do in committing such a fraud. The evaluated test methods include indirect tensile strength (ITS) and indirect tensile stiffness modulus (ITSM) of field cores, various indicators (G*, phase angle, pass/fail temperature, etc.) from DSR tests of extracted binders, FTIR, and others. Statistical methods to make an inference from small sample size were also examined. It was found that samples made of different proportions of polymer-modified asphalt can be differentiated by ITS, phase angle, and FTIR, out of which FTIR appears to be the most promising.
Cohesion, Fracture and the Vialit Cohesion Pendulum as a Tool for Asphalt Evaluation

Geoffrey M. Rowe (1), Christopher Ericson (2), and Andrew Cooper (3)
(1) Abatech; (2) Rutgers; (3) Cox and Sons

The Vialit Cohesion Pendulum has been used for many years in Europe as a tool for assessing modified binders with a particular emphasis on chip seals/surfacing dressing applications. The cohesion measured in this device has been considered as an indicator of quality of the base bitumen and subsequent polymer formulation. This test demonstrates a transition between brittle and ductile failure of binder systems. When a test of this kind is compared to other binder tests it is possible to deduce the impact that high rate of loading has on the test results. Data will be presented from a series of tests conducted on SHRP core asphalts and these will be compared to direct tension tests and master curves developed with the same binders. A discussion will follow on how the fracture of asphalt binder and mix is both rate and temperature dependent and that this parameter always needs that consideration to truly evaluate the meaning of test data. A test of this nature, while founded partly on an empirical data base of use can be better explained and understood with the consideration of speed of loading and temperature effects this allowing translation of fracture temperatures at one condition to those at another.

Application of the Diffusion Mechanism to Healing of Asphalt Binder Cracked Surface in the Dynamic Shear Rheometer

Hassan A. Tabatabaee, Farhad Yousefi Rad and Hussain U. Bahia (1); and Arianna Stimilli (2)
(1) University of Wisconsin Madison; (2) Università Politecnica delle Marche

Although multiple mechanisms have been attributed to the healing phenomenon in damaged asphalt binders, molecular diffusion across cracked surfaces in the binder is believed by many researchers to be ultimately responsible for long term recovery of micro cracks. The present study used a Dynamic Shear Rheometer (DSR) to investigate the healing phenomenon in a number of asphalt binders with varying degrees of modification and aging, through subjecting samples to a “fatigue-healing-re-fatigue test” (FHRT) procedure. Using recent findings to associate fatigue damage to sample surface reduction in the DSR, the rate of cracked surface recovery was calculated during the healing process and used to derive a diffusion rate parameter through application of a modified “Fick’s Law” equation.

Results showed that due to the interdependency between viscosity of the diffusion medium and diffusion rate, increasing stiffness through reducing temperature, or through oxidative aging, decreased the diffusion coefficient, leading to lower healing rates. Furthermore, higher polymer content was shown to decrease the diffusion coefficient and healing rate. The proposed healing analysis procedure through application of the diffusion framework to cracked surface recovery in the DSR was found to be a promising method for assessment of healing potential of asphalt binders.
A Micro-Mechanical Model for Asphalt Mastic Modulus based on Physico-Chemical Interaction

Shane Underwood (1) and Y. Richard Kim (2)
(1) Arizona State University; (2) North Carolina State University

Many existing formulations for predicting the stiffening effects of graded elastic particulate inclusions (aggregates) at moderate and high concentrations in a viscoelastic matrix (asphalt) exist. These functions encompass dilute, micro-mechanical, and phenomenological solutions. Work by the current authors as well others shows that each model produces unsatisfactory results in both the qualitative and quantitative nature of their predictions. In this research, a model to account for the physico-chemical interactions is developed and applied to predict the stiffening of asphalt mastics across a broad range of volumetric concentrations. Temperature and frequency sweep experiments (10 – 54°C and 14 – 0.1 Hz) have been performed on mastics from two different material sources and at particle concentrations ranging from 10% to 60% by volume. The experimental results are analyzed using 12 different micro-mechanical formulations before an alternative formulation is developed that recognizes the asphalt mastic as a three phase composite; adsorbed asphalt, un-adsorbed asphalt, and aggregate particles. This model is found to capably predict the qualitative and quantitative effects of particles up to a concentration of approximately 40%. At higher concentrations percolation of the microstructure is believed to occur, which requires the incorporation of other mechanical concepts into the micromechanical formulation.

Analysis of Asphalt Binders without Time-Temperature Superposition using Relaxation Computation from Single DSR Isotherms

Ron Glaser, Fred Turner, Jean-Pascal Planche and Steve Salmans
Western Research Institute

The conversion of dynamic rheometric data to the time domain relaxation function can be accomplished through a number of algorithms, most of them describing the relaxation function as Prony series and fitting storage or loss modulus data to the Prony series. These approaches require experimentally measured phase angles to compute loss or storage moduli from the complex modulus data. Consequently, measurement errors propagate into the determined relaxation function. Linear viscoelastic theory is briefly reviewed to demonstrate that non-linear regression methods can be employed to fit the Prony series coefficients directly to the complex modulus, avoiding any need for phase angle measurements and perhaps providing an alternative to suspect phase angle measurements. The ill-posed nature of this problem is somewhat mitigated using a distribution function to constrain the Prony series coefficients and minimize the number of fit parameters. Our method of using a presupposed Prony series distribution function produces consistent changes in master curve model parameters as a function of temperature. This would preferred to shifting when the time-temperature regime for application of the measurements falls outside the ranges actually measured. Example calculation results are shown for real data collected from asphalt binders.
**Frequency Interpretation of Molecular Asphalt Relaxation Processes**

Mohammad Masoori and Michael L. Greenfield  
*University of Rhode Island, Dept. of Chemical Engineering*

Molecular simulations of asphalts provide a route to infer how the actions of individual molecules contribute to the nanoscale mechanical behavior of a model system under well defined conditions. Results from equilibrium molecular dynamics simulations of a system whose composition was tuned to resemble AAA-1 asphalt have been interpreted by converting the stress relaxation modulus $G(t)$ to the complex modulus $|G^*|$ and phase angle delta. Systems 400, 443, and 533 K (127, 170, 260 C) show a similar phase angle peak at very high frequency, with the slope of the less-high-frequency side of the peak increasing with temperature. The slope of $|G^*|$ with frequency shows an opposite temperature dependence, with a faster rise with frequency at higher temperature. A van Gurp-Palmen plot of $|G^*|$ vs. delta appears to reveal deviations from thermorheological simplicity over this broad temperature range, with non-overlapping results calculated at states that correspond to less high frequencies. A prior AAA-1 model system composed of smaller molecules shows a quantitatively lower complex modulus of qualitatively similar shape. Comparisons between the systems focus on effects of the slower molecule relaxations in the newer system. Implications of the nanoscale results for the behavior of real asphalts at pavement temperatures and frequencies are being pursued.

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**Mechanistic-Based Constitutive Modeling of Oxidative Aging in Asphalt Concrete Materials**

Eisa Rahmani (1), Masoud K. Darabi (2), Eyad Masad (3), Dallas Little (1), and Rashid K. Abu Al-Rub (4)  
(1) Zachry Department of Civil Engineering, Texas A&M University; (2) Texas A&M Transportation Institute, Texas A&M University System; (3) Mechanical Engineering Program, Texas A&M University at Qatar, Doha, Qatar; (4) Masdar Institute of Science and Technology, Abu Dhabi, UAE

Oxidative aging is one of the main factors contributing to fatigue damage of pavements resulting in premature failure of pavement structures. Oxidative aging makes the material more brittle and more prone to damage cracking. This study models the oxidative aging by introducing a physically-based oxidative aging internal state variable. The evolution function for the oxidative aging is a functional of oxygen content which bonds the mechanical behavior to the fundamental processes associated with this mechanism. This paper presents a novel experimental-computational framework to determine the oxygen diffusion of asphalt concrete materials. To characterize the diffusivity, asphalt concrete is viewed as a three-phase composite material. Having the oxygen diffusion of binder and the microstructural characteristics of asphalt concrete, the oxygen diffusion of asphalt concrete materials is determined using computational and statistical methods. Qualitative capabilities of oxidative aging effects on the coupled nonlinear-viscoelastic-viscodynamic response of asphalt concrete are investigated against various loading scenarios such as repeated creep-recovery, constant strain rate in tension, and uniaxial tensile and compression tests. It is shown that the predictions of the aging model are in good agreement with the experimental observations.
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Complete technical support for asphalt/bitumen and related materials and products for domestic and international markets for Paving, Roofing and Industrial.

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- 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
Application of Asphalt Oxidation Kinetics and Rheology to Rational Pavement Performance Modeling
Ron Glaser, Fred Turner, Steve Salmans, Jenny Loveridge and Jean-Pascal Planche
Western Research Institute

Recent research at Western Research Institute has produced significant advances in our understanding of asphalt binder oxidation and how oxidation affects changes in the dynamic shear rheometer (DSR) master curve shapes. These advancements suggest that simple, short term testing of asphalt binders may be possible to make rational consideration of binder design an integral part of the pavement design process. Our reaction kinetics model, derived from the Petersen dula reaction mechanism, shows a temperature dependence as expressed by the Arrhenius equation is identical for over 30 binders. Consequently, oxidation kinetics can be obtained without testing over a range of temperatures. A simple log-linear empirical relationship was found for correlating the extent of oxidation to master curve changes, so oxidation testing at two extents of reaction, with supporting rheological analysis, is sufficient to obtain the master curve and relaxation function as a Prony spectrum. High pressure oxidation data examined to date indicates a universal pressure correction may pertain, making accelerated oxidation for practical reasons useful. Laboratory and data analysis steps are described to produce master curves at arbitrary aging times to determine current specification quantities and Prony series for input into pavement performance models.

Correlation between Rheology and Chemistry of Aged Polymer-Modified Asphalts
Iliya Yut, Ph.D.
Assistant Professor in Residence Civil and Environmental Engineering Department,
University of Connecticut

There has been increase in using polymers for asphalt production to reduce temperature susceptibility of asphalt and improve its fatigue resistance. This study targeted investigation of correlation between chemical and rheological changes in polymer-modified asphalts (PMA) aged using standardized Rolling Thin Film Oven and Pressurized Aging Vessel procedures. Viscosity measurements on base and modified asphalt samples before and after aging were conducted in Dynamic Shear Rheometer (DSR), whereas changes in asphalt chemical composition due to aging were elucidated from their Fourier Transform infrared spectra obtained in Attenuate Total Reflection (ATR) mode. The analysis of variance in DSR and ATR measurements revealed that severity of aging procedure affected PMA viscosity greater than polymer composition and concentration did. Furthermore, it was possible to predict dynamic shear modulus of PMA at a given temperature and aging test severity from relative content of oxidized functional groups and polymer composition elucidated from ATR spectrum.
Investigation of Mineral Fillers’ Effects on the Oxidative Aging of Asphalt Binders

Raquel Moraes and Hussain Bahia
University of Wisconsin-Madison

Asphalt ages through oxidation, changing its chemical composition. In most laboratory aging studies and in current specifications, asphalt binders are aged alone while in actual pavements asphalts are almost always in contact with mineral surface. Therefore, it is not clear if testing aged asphalt alone is adequate to predict mix performance; because of apparent mitigating and/or catalytic effect that mineral surface may have on aging. In this study, effects of mineral fillers on oxidative aging of asphalt is investigated by means of aging mastics (asphalt and fillers) and measuring changes in stiffness, glass transition temperature (Tg), and coefficient of thermal contraction. Testing matrix included aging evaluation of mastics presenting different fillers content, mineralogy, and fillers’ surface area. Results showed that low temperature behavior of aged mastic can be modified by controlling filler concentration and type. Fillers acts as an agent adsorbing heavy fractions of asphalt, therefore, reducing stiffness and shifting Tg temperature. Results give insight on how to proportion filler concentration, and possibly type, to reduce impact on oxidative aging and improve service life of pavements. Also, simple framework is provided to use existing laboratory aging procedures for estimating aging rates of mastics typically used in paving or roofing practice.

Investigation of Oxidation Parameters in Mixture and Pan-Aged Asphalt Binders

Nathan Morian (1,2), Elie Y. Hajj (2), and Peter E. Sebaaly (2)
(1) Nevada Department of Transportation; (2) University of Nevada, Reno

Ongoing research as part of the Asphalt Research Consortium continues to investigate the influence of mixture parameters and aggregate on the oxidative aging of asphalt binders. This study continues the effort to quantify the influences of mixture components as they alter the measured rate of oxidization of asphalt binders as compared to more standard procedures of pan aging in forced draft ovens.

Consideration of measured mix properties as a function of aging for mixtures produced with the same asphalt binders suggests quantifiable influences of certain mixture characteristics. Measured dynamic modulus (E*) results provide for comparisons of mixture and binder stiffness measures as a function of binder oxidation determined by Fourier Transform-Infrared Spectroscopy (FT-IR) at multiple levels of aging temperature and duration. Additional considerations with the Uniaxial Thermal Stress and Strain Test (UTSST) over the same aging conditions yield further information regarding differential aging between pan-aged and mixture aged binders.

Exploration of oxidation rates of pan-aged and mixture-aged asphalt binders provide insight into the complex interactions of the aging process of asphalt mixtures which ultimately affect the overall durability and longevity of asphalt mixtures along with the properties of those mixtures years into their in-service life.
Exploring the Combined Effects of Asphalt Kinetics, Hardening Susceptibility, Oxygen Diffusivity, Pavement Characteristics, and Climate on Pavement Durability

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

Over the years, we have explored the various factors that affect the oxidation and hardening rates of asphalt materials in pavements and their impact on pavement performance. The most recent contribution is an accelerated method (four days) for determining oxidation kinetics parameters using the PAV apparatus (PARC July 2011). This method, which combines asphalt experimental measurements with pavement modeling, allows comparisons of asphalt durability in pavements in different climates. Data have now been obtained on over 30 asphalt materials, providing a good sense of the range of kinetics and hardening parameters and asphalt diffusivities for both modified and unmodified materials.

Recent observations using computational comparisons of pavement oxidation show differences in oxidation rates that arise from the multiple and coupled effects of kinetics parameters, diffusion resistance, climate (Texas versus Minnesota, e.g.), depth below the pavement surface and pavement characteristics such as air voids and fatigue resistance. These factors result in a wide range in the progression of oxidative hardening in pavements and should be considered in the design of asphalt pavements. The PAV accelerated method for kinetics parameter determinations, coupled with pavement oxidation simulation, provide a fundamentals-based comparison of asphalts for such a design component.

Effect of Polyphosphoric Acid on Aging Kinetics of Asphalt Binders

Olga Shulga (1), Ken Grzybowski (2), Rene Maldonado (1) and Henry Romagosa (1)
(1) ICL Performance Products; (2) PRI Asphalt Technologies, Inc.

Polyphosphoric acid (PPA) is widely used asphalt modifier to improve the properties of neat asphalt binders when added at low concentrations. Since PPA acts to stiffen the binder, there has been a concern that PPA also accelerates oxidative aging of asphalt. The purpose of this study was to evaluate the effect of PPA on the aging kinetics of asphalt binder. We used extended PAV aging at various times followed by determination of carbonyl contents and PG grade after each aging period. PAV material containing the binder modified with 1% PPA was investigated by DSR and BBR and showed that such binder has wider Effective Temperature Range, compared to control without PPA. The binder with 1% PPA exhibits improved high temperature stiffness. After 60 hours of PAV aging, the low temperature properties of the PPA modified binder are comparable to those of the original, unaged binder. The control binder without PPA exhibited expected changes due to oxidative aging, proportionate to PAV exposure time. The rate of carbonyl formation was approximately 12% slower for PPA-containing binder than the control without PPA. These improvements strongly suggest that the use of PPA improves a binder’s resistance to oxidative aging.
Micron-sized Domains in Solution-cast Asphalt Binders Exhibit Significantly Different Mechanical Properties

Xiaokong Yu (1), Nancy A. Burnham (2), Rajib B. Mallick (1), and Mingjiang Tao (1)
Worcester Polytechnic Institute: (1) Department of Civil and Environmental Engineering, (2) Physics and Biomedical Engineering Departments

Asphalt binder, also called bitumen, is one of the primary construction materials for pavements around the world. The binder consisting of large numbers of different organic hydrocarbons acts as a glue bonding the aggregates together, thus, its mechanical properties (e.g., adhesion, stiffness and viscosity) affect significantly the overall pavement performance. Better understanding of the relationship between binders’ chemical and mechanical properties can help improve binders’ quality. In this study, atomic force microscope was applied to characterize the adhesion and viscoelasticity of solution-cast binder thin films at room temperature. Adhesion was extracted from force curves, while stiffness, damping, and loss tangent of the binder were derived from oscillation equations. Results indicate that two different domains in topographic image possess different adhesion, stiffness, damping and loss tangent: domains with large phase angle are more adhesive, less stiff and more lossy, having a larger loss tangent; on the contrary, domains with small phase angle were less adhesive, stiffer and less lossy, having a smaller loss tangent. The different mechanical properties between these two domains might be attributed to their chemical composition differences, which provides a promising approach to establishing the chemical-physical link for asphalt binders and will eventually help build more sustainable pavements.
SESSION 4

Surface Structuring of Wax in Complex Media
Troy Pauli, R. Will Grimes and James D. Beiswenger (1); and Alexander Schmets (2)
(1) Western Research Institute; (2) Delft University of Technology, Delft, The Netherlands

Several investigators over the past sixteen years have considered the nature of surface structuring in asphalt bitumen, commonly identified by atomic force microscopy. Recently it has been suggested that the interaction between non-polar constituents present in asphalt, including crystallizing paraffin waxes, are responsible for surface microstructures, originally reported by Loeber [1996]. Pauli et al. [2011] specifically concluded that the interactions between crystallizing paraffin waxes and the remaining non-wax asphalt components are responsible for much of the structuring, including bee-structures. To date, a plausible mechanism to explain the physico-chemical manifestation of this type of surface structuring in asphalts has yet to be presented. In this paper a theory is presented which explains the physicochemical nature of surface structuring in asphalts and asphalt fractions based on investigations of simpler material systems reported in the literature pertaining to paraffin and polymer crystallization. Experimental results obtained over the past several years by our group are presented in support of the theory presented.

Characterization of Asphalt Binder Microstructure and Chemical Properties using Atomic Force Microscopy Imaging and Indentation Techniques
Rezwan Jahangir, Dallas N. Little and Grover R. Allen (1); and Amit Bhasin (2)
(1) Texas A&M University; (2) The University of Texas at Austin

The study of asphalt binder microstructure is evolving into an area of primary interest and of high importance in fundamental and developmental research in asphalt technology. The atomic force microscope (AFM) has become a useful tool to effectively visualize the microstructure of asphalt binder and determine the effects of aging, temperature, and chemical modifiers. AFM indentation has been successfully used by researchers to quantitatively determine nano-scale localized elastic, and time dependent viscoelastic responses. In this work the microstructure of asphalt binder is examined using both AFM imaging and indentation techniques. Here AFM imaging is used to analyze the microstructure of bitumen, looking closely at phases that are present, and also using AFM indentation (with the same tip) to analyze their mechanical properties and comparing these properties among binders with different chemistries and compositions. Chemical properties of the different phases are examined using functionalized AFM tips. A numerical study is also performed in order to minimize the errors obtained during the indentation process. Through the numerical study, a better approximation of the realistic tip shape is presented and the data obtained through experimentation is analyzed to obtain binder viscoelastic properties. Extension of this characterization work to address the impact of phase distributions and phase properties on deformation and crack initiation/propagation are discussed as part of an experimental approach that applies mechanical loading to the thin film of binder imaged under the AFM.
Adherence Energy of Asphalt Thin-Films Measured by Force-Displacement Atomic Force Microscopy (FD-AFM)

Troy Pauli, Will Grimes and Alec Cookman (1); Mengxi Wang and Peng Lu (2); and Shin-Che Huang (1)
(1) Western Research Institute; (2) University of Wyoming

Viscoelastic materials exhibit rate and temperature dependent behavior in terms of stress/strain response and fracture. As a representative class of materials, rate-dependant fracture should be expected for bituminous asphalt binders in pavements structures. As such, preliminary results are reported regarding studies using atomic force microscopy (AFM) to determine rate and temperature dependent adhesive fracture in bitumen thin-films. The present AFM technique involves creating then fracturing a micro adhesive contact between a bitumen thin-film and glass micro-bead by application of a direct tensile force to the contact at various rates and temperatures. The mechanical work required to fracture this micro contact is measured as a function of temperature and separation rate. Results of this study show that fracture energy of bitumen films are rate and temperature dependant, exhibiting plastic flow dissipation for ambient and lower temperatures but simple capillary flow for temperatures above ambient constituting a viscous to viscoelastic transition in adhesive behavior.

Field QC/QA Test for Asphalt Binder

Raj Dongre (1); Jack Youtcheff and Nelson Gibson (2); and John W. Newman (3)
(1) DLSI; (2) FHWA; (3) LTI

FHWA along with Laser Technology Inc. (LTI) of Norristown PA has developed a QC/QA test method for asphalt binders. This method is easy to operate and provides a quick turnaround time for QC/QA results. This device uses an air jet to produce creep and recovery loading. The resulting deformation is measured using a method that is based on Laser technology. At last year’s Petersen Conference data from a working prototype of the QC/QA field test was used to demonstrate the feasibility of such a test method. A first article version of the QC/QA device has now been developed by Laser Technologies Inc. (LTI). Further testing was conducted at FHWA and LTI using the working prototype to further evaluate the technology and to study the long term steric hardening behavior of unaged and RTFO aged asphalt binders. This presentation will discuss the status of the ongoing QC/QA test method development under taken by FHWA and LTI.

A Study on Elastomer-HMA Mixture for High-performance Gussasphalt

Zed Liang (1); and Chen Shizhou and Zhang Wen (2)
(1) Canaphalt Ltd., Richmond Hill, ON Canada; (2) Chongqing Pengfang Group, China

Gussasphalt because of its superior performance has been widely used in large and medium-sized bridges, especially in large-span steel bridge deck. However, with conventional Gussasphalt materials, producing a highly durable surface on steel bridge decks or some asphalt paving sections under heavy duty traffic loading and/or due to serious climate variation is still a technical challenge today.

This study provides a basic mode for the research and development of high-performance Gussasphalt by incorporating a reactive SBS based formulation package (or a value-added SBS material) into HMA mixtures. This work evaluates the effects of DIRECT blend of the value-added SBS with the HMA on the workability and performance based on Gussasphalt application.

The results indicate that a unique/direct mixture of the value-added SBS, straight asphalt and mineral aggregates is established to be sufficiently fluid and uniform at high temperature to be poured into place, which can also satisfy performance criteria for Gussasphalt in terms of both high service temperature modulus and low temperature flexibility.
Recombination of Asphalt with Bio-Asphalt: Binder Formulation and Asphalt Mixes Application

Joana Peralta (1,2), Ka Lai Ng (1), Hugo M.R.D. Silva (2), R. Christopher Williams (1); and Ana V.A. Machado (3)
(1) Iowa State University, Dept. of Civil, Construction and Environmental Engineering; (2) University of Minho, Campus of Azurêm, Dept. of Civil Engineering, Guimarães, Portugal; (3) University of Minho, Campus of Azurêm, Dept. of Polymer Engineering, Guimarães, Portugal

Bio-oil derived from fast pyrolysis is a viscoelastic material, mainly a product of the recycling of waste materials. After a heat treatment, it presents viscosity similar to conventional asphalts. These two characteristics indicate that this could be a good material to replace asphalt. Although, bio-oil showed very good high temperature performance, the same was not observed at low temperatures. In order to improve the performance of bio-oil, it was hypothesized that the addition of ground tire rubber (GTR) would change its rheology, making it suitable binder in a greater range of ambient temperatures. Therefore, a GTR modified bio-oil was produced (bio-binder), and blended with a PG64-22 asphalt binder. The binders were aged and storage stability tests were performed. The binders were tested by means of Fourier Transform Infrared Spectroscopy (FTIR), Dynamic Shear Rheometer (DSR), to obtain the materials master curves and grades. Additionally, it was necessary to assess the behavior of this material in an asphalt mixture, specially, in regards to moisture susceptibility, fatigue cracking, and low temperature fracture resistance as well as modulus testing. Therefore asphalt mixes were produced and tested for the aforementioned performance characteristics. The results showed that this material can perform as well or better than conventional asphalts over a large range of temperatures.

Binder Rheology: Characterization and Specification

Dr. David A. Anderson (1) and Dr. Geoff Rowe (2)
(1) Consultant; (2) Abatech

A dramatically new approach to the testing and specification of asphalt binders was developed as part of the Strategic Highway Research Program (SHRP). Developed for plain asphalt binders, it was based upon fundamental material properties that are related rationally to fundamental mixture properties and hence, pavement performance. The basic assumption was that the quality of an asphalt binder is reflected in its rheological properties and that its rheological properties can be defined by a relaxation spectrum. The relaxation spectrum is defined by an R parameter which dictates the shape of the relaxation spectrum and the master curve. In time and in order to “sell” the new specification it was revised to include point properties at the lower, intermediate, and upper service temperatures. In spite of this evolution, the specification provides a reliable indicator of the performance-related behavior of laboratory mixtures. However, when applied to modified asphalt binders or to the prediction of field performance reliability is no longer ensured. As a consequence, a plethora of new empirical test methods are being proposed for specification use. The efficacy of these empirical test methods is reviewed and the need for a more rational evolution of binder test methods and specifications is discussed.
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Development of a Carbon-Based Bio-Modifier for Asphalt Cement

Sheng Zhao, Baoshan Huang and Philip Ye
University of Tennessee

Every year, 500-550 million tons of asphalt paving mixtures are placed in the U.S., which contains around 30 million tons of petroleum based asphalt binder. Only if a small fraction of asphalt binder to be replaced by bio-asphalt (or bio-modifier) derived from biomass, significant reduction in the consumption of crude oil, and appreciable utilization of otherwise wasted resources can be expected. In the present work, residues derived from biomass obtained through different types of vacuum pyrolysis were tested as bio-modifier for asphalt binder. A commercially available activated carbon sample was utilized for comparison purposes. All the carbonaceous materials were incorporated into one commonly used asphalt binder in the U.S. at different concentrations in order to obtain the optimal content. The samples prepared were tested in the laboratory for their rheological characteristics, rutting, fatigue and low temperature performance properties. Pyrolysis temperature, pyrolysis type and particle sizes of the bio-modifier were evaluated as the factors of interest. It was found that rutting resistance of the binder was increased by adding all the matrix of the bio-modifiers. Fatigue property was improved with the addition of bio-modifiers with finer particle obtained from slow pyrolysis. The maximum low temperature cracking resistance would be obtained at 5% bio-modifier concentration.

Rubberized Foamed Asphalt Mixtures Using Half-Warm Aggregates

Punith Shivaprasad, David Wingard and Feipeng Xiao
Clemson University, Glenn Department of Civil Engineering

Over the last few years as environmental criteria becoming stricter and stricter, new technologies have been introduced in the asphalt industry that allow producing asphalt mixtures at moderated mixing temperatures commonly referred to as warm mix asphalt or half-warm mix asphalt (HWMA). The objective of the present study was to investigate the influence of compaction temperatures on performance characteristics including dynamic modulus (DM), phase angle, E* Ratio, moisture sensitivity, rutting resistance of HWMA mixtures using regular (PG 64-22), and terminal blended (TB) polymerized binder. All the mixtures using TB binders showed better wet ITS values. Mixtures using neat PG 64-22 binders compacted below 85°C were found to be susceptible to moisture induced damage. From the moisture sensitivity perspective, it is recommended to use higher compaction temperatures ranging between 95°C and 85°C, when using HWMA mixtures containing half warm aggregates. DM tests were sensitive to the small change in asphalt binder contents used in HWMA. For most cases as the compaction temperature increased, the |E*| values of the HWMA mixtures increased. The observed |E*| values from the present study for HWMA were comparatively lower than HMA this is a result of less aging because of reduced mixing and compaction temperatures.
Understanding Diffusion between Recycled and Virgin Asphalt

Pavel Kriz
Imperial Oil Ltd.

An important factor for asphalt grade selection at a given RAP level is the extent of blending between RAP and virgin binders during HMA production. Appropriate blending between the binders is essential to ensure resistance from pavement moisture damage and permanent deformation, and low temperature performance. Developing a better understanding of the blending kinetics and its impact on blended binder rheology is the focus of the current work. Mixing of virgin and RAP binders in a hot mix plant is a function of the shear mixing energy and the diffusion rate between asphalt binders. Initially, the diffusion kinetics between various RAP and virgin binders has been studied. A unique testing protocol using a DSR was developed to study diffusion through viscosity increase. The viscosity increase results from the process where two, initially separated layers of RAP and virgin binders are progressively blended by diffusion. A model was developed to calculate diffusion coefficients from viscosity data, and it was utilized to simulate diffusion during typical temperatures and residence times observed for HMA production and placement. This presentation will detail initial work to provide insight into the extent of blending between RAP and virgin binder that occurs during hot mix production.

Evaluation of the Performance Properties of Asphalt Mixes Produced with Re-refined Heavy Vacuum Distillate Bottoms

John D’Angelo (1), Ken Grzybowski (2), and Steve Lewis and Rodney Walker (3)
(1) Consultant; (2) PRI Asphalt Technologies, Inc.; (3) Safety-Kleen

Asphalt mixtures used for paving are required to perform under extreme conditions. At high temperatures when the binder is softer, it must withstand heavy traffic loading to prevent rutting. At low temperatures, it must remain flexible to resist cracking from traffic and thermal stresses. The aggregate structure is a primary performance characteristic for high temperature rutting, but it is the asphalt binder that has a much more critical role when it comes to cracking. Re-refined Heavy Vacuum Distillation Bottoms (RHVDB) or the residue from the re-refining of used engine oil has been used to improve the low temperature properties of asphalt binders in order to improve its cracking response. Previous papers have shown the improved binder properties with the addition of RHVDB, but the question still remains will these materials perform well in a mixture.

In this study, an in-depth evaluation was performed to determine the performance characteristics of asphalt mixtures produced with binders modified with Re-refined Heavy Vacuum Distillation Oil at several different levels. The rutting, fatigue and low temperature properties of the mixtures were evaluated against a control mix produced with unmodified binders. Multiple tests were run to compare the mixtures with RHVDB against the control mix. The study provides an extensive evaluation of the effects of RHVDB modification on mix performance.
DARWin-ME Value Engineering Design – From Concept to Construction

Raj Dongre (1); Bob Kluttz and Hernando Faria (2); and Pablo del Aguila (3)
(1) DLSI; (2) Kraton Polymers; (3) Camineros Consulting

Value engineering is used to design highway pavement structures with reduced thickness of the structural layers. Thickness reduction by as much as two inches for asphalt layer allow for substantial cost savings but require advanced fatigue and rutting characterization of the materials along with rigorous mechanistic – empirical pavement design methods. A project in Peru was selected for implementation of value engineering techniques using asphalt layers made using HiMA technology developed by Kraton Polymers. HiMA (Highly Modified Asphalt) is a polymer-modified asphalt with high SBS loading that gives exceptional fatigue and rutting resistance. This material property improvement is not recognized in the basic mechanistic-empirical damage models so revised calibration coefficients must be determined based on material property tests.

The recently approved AASHTO DARWin-ME software was used to design value engineered pavement layers in Peru. The newly developed S-VECD (Kim et. Al) fatigue characterization technique was used to develop fatigue performance coefficients for HiMA for use in DARWin-ME. Similarly, the latest NCHRP 9-33A Flow Number test protocols were used to develop rutting coefficients. The resulting pavement design performed using DARWin-ME software allowed thickness reductions for the project for an overall higher performance, more cost effective design.

This presentation will describe in detail the process of value engineering developed for the pavement design project in Peru. The advanced fatigue and rutting characterization techniques and their use in the AASHTO DARWin-ME will also be discussed.

Field Performance of RAP/RAS Mixes in Texas

Dr. Fujie Zhou
Texas Transportation Institute

The use of reclaimed asphalt pavement (RAP) and recycled asphalt shingles (RAS) can significantly reduce the increasing cost of hot-mix asphalt paving, conserve energy, and protect the environment. However, the premature cracking problem has been a serious concern. This paper discusses performance of field test sections with RAP/RAS in Texas.

A series of field test sections with RAP/RAS mixes have been constructed around Texas in last 5 years. These field test sections cover different applications of RAP/RAS mixes, such as 1) asphalt overlays vs. new construction, 2) cold weather vs. hot weather, 3) heavy traffic vs. low traffic, 4) thicker vs. thin asphalt layer(s), and 5) virgin mix vs. RAP only (or RAP/RAS). It was found that RAP/RAS mixes can have better or similar performance than virgin mixes if they are well designed with balancing both rutting/moisture damage and cracking requirements. Cracking performance of RAP/RAS mixes is influenced by many factors, such as traffic, climate, existing pavement conditions for asphalt overlays, and pavement structure and layer thickness. It is obvious that a single cracking requirement does not apply to all asphalt overlay applications. Instead, a project-specific service conditions based mix design system should be developed.
**ABSTRACTS**

**Binder Performance Evaluation of Warm Mix Asphalt**  
*Ashley Buss* and R. Christopher Williams  
*Iowa State University, Department of Civil, Construction and Environmental Engineering*

Warm mix asphalt (WMA) has long been hypothesized of having the ability to incorporate higher amounts of recycled asphalt pavement (RAP) than traditional hot mix asphalt (HMA) due the decreased production temperature. Research has shown that during construction, reduction in plant temperatures decrease the aging of the asphalt binder. It is important to determine if the reduction in the continuous asphalt binder grade is still detectable after some time of in-service aging. Three pavements were produced in 2009 having control HMA and experimental WMA test sections. RAP amounts ranged from 17 -20%. Each pavement studied represents one of the three predominate types of WMA additives, chemical modifiers, wax modifiers and foaming process. In 2010, three WMA mixes were constructed containing 20% and 5% RAP as well as a WMA mixture with 0%, 5%, 7% shingles. Virgin binder was collected at construction for each mix and a continuous performance grade was determined. In 2011 cores from all test sections were obtained and binder was extracted and recovered. The continuous binder performance grade was determined for all cores to develop comparisons between the HMA and WMA mixes as well as the recovered binder grade change with various amounts of recycled asphalt materials.

**ALTERNATE**

**Advances in Understanding Asphalt Aging Oxidation During Fundamental Properties 3**  
*Ron Glaser*, Fred Turner, Steve Salmans, Jenny Loveridge and Jean-Pascal Planche  
*Western Research Institute*

The work funded by FHWA under the Fundamental Properties Contract 3 has produced significant advances in our understanding of asphalt binder oxidation and how oxidation affects changes in the dynamic shear rheometer (DSR) master curve shapes. This paper reviews these advances from the perspective of improving rational pavement design. The work indicates that the rate limiting steps in the reaction scheme are very near oxygen attack on a reactive material or materials present in the asphalt. By deriving the rate equations from Petersen’s dual reaction mechanism, a kinetic expression was developed that can explain the behavior of over 30 binders with only one adjustable parameter. The temperature dependence as expressed by the Arrhenius equation is identical for all of these binders, meaning that oxidation kinetics can be obtained without testing over a range of temperatures. A simple log-linear empirical relationship was found for correlating the extent of oxidation to master curve changes, so oxidation testing at two extents of reaction, with supporting rheological analysis, is sufficient to obtain the master curve and relaxation function as a Prony spectrum. High pressure oxidation data examined to date indicates a universal pressure correction may pertain, making accelerated oxidation for practical reasons useful.
A moose showed up for the Petersen Conference dinner at the Snowy Range Ski Area in 2006. No wildlife is expected to attend this year’s event.
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