25 WRI 1983-2008

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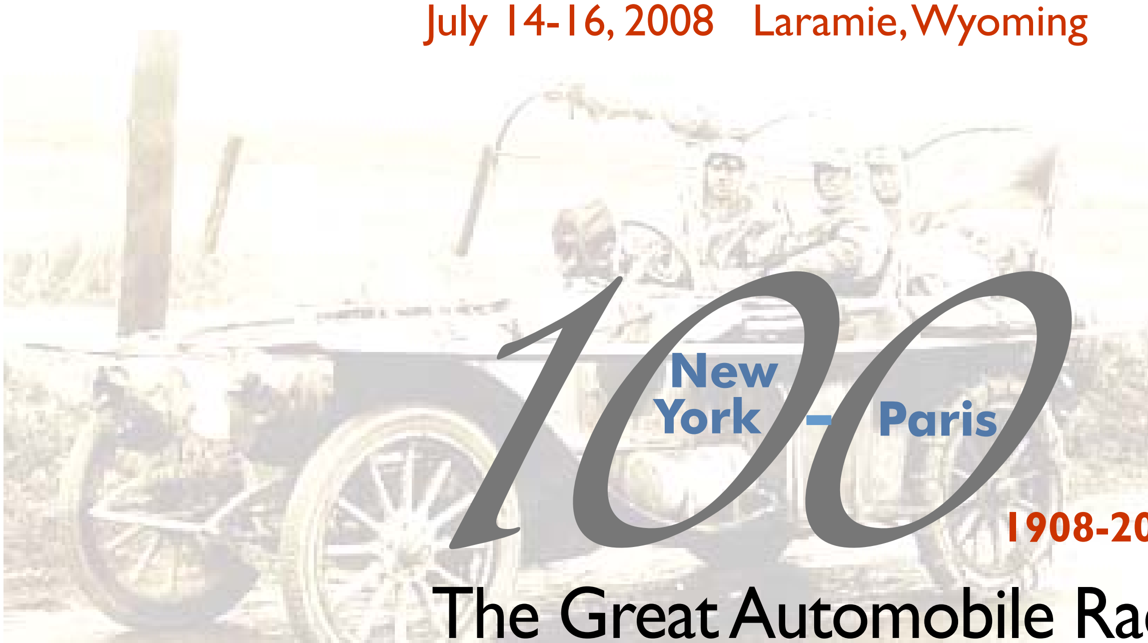
# Petersen Asphalt Research Conference

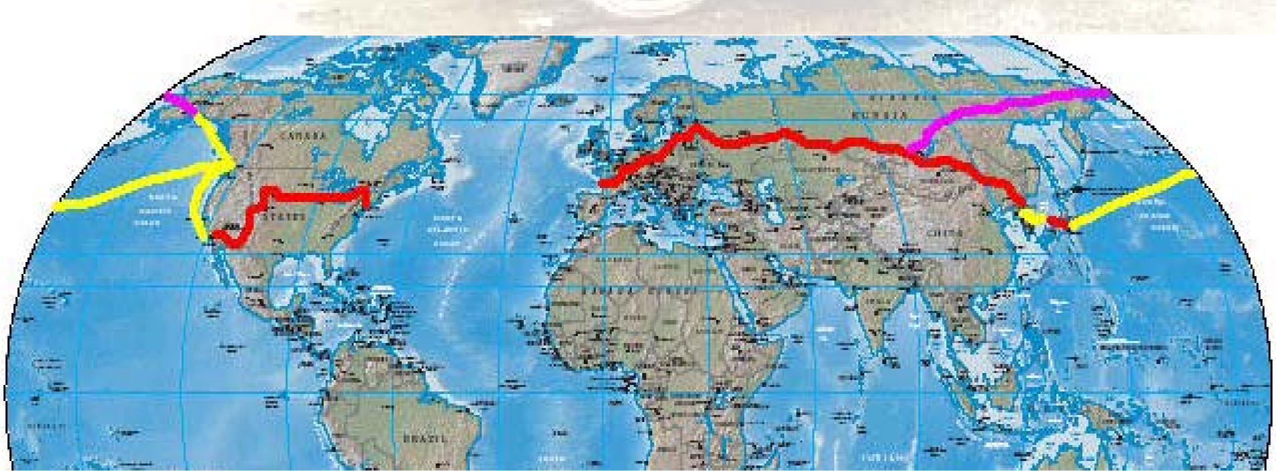
*Organized by Western Research Institute*

July 14-16, 2008 Laramie, Wyoming



100 New York – Paris 1908-2008

## The Great Automobile Race



Organized by

# WESTERN RESEARCH INSTITUTE

in cooperation with the

# FEDERAL HIGHWAY ADMINISTRATION

Washakie Center Rendezvous Room
University of Wyoming

Laramie, Wyoming
July 14-16

IMPORTANT: UW parking permits are available at the registration desks of the Hampton Inn, the AmericInn and the Baymont Inn & Suites.

## *Monday, July 14*

| | | |
|---|---|---|
| 7:30 AM | **Registration**—Pick up conference materials, including UW Parking Permit. | Washakie Center Rendezvous Room |
| 8:15 | **Welcome and Opening Remarks** | Steve Salmans and Don Collins *Western Research Institute* |
| **SESSION I** | **Session Chair—John Schabron, Western Research Institute** | |
| 8:30-9:05 | A Generalized Logistic Function to describe the Master Curve Stiffness Properties of Binder Mastics and Mixtures | Geoffrey M. Rowe *Abatech Inc.*; Gaylon Baumgardner *Paragon Technical Services*; Mark J. Sharrock *Abatech International, Nottingham, UK* |
| 9:05-9:40 | Practical Use of VECD Analysis in Pavement Design | M. Emin Kutay *SES Group & Associates;* Nelson Gibson *FHWA;* Raj Dongré *DLSI;* and Jack Youtcheff *FHWA* |
| 9:40-10:00 | BREAK | |

*Monday, July 14, continued*

| | | |
|---|---|---|
| 10:00-10:35 | Forward and Inverse Self-Consistent Micromechanics Model of an Asphalt Concrete Mixture | Rong Luo and Robert L. Lytton<br>*Texas A&M University* |
| 10:35-11:10 | Modeling Pavement Temperature History for Pavement Performance Prediction | Rongbin Han, Xin Jin and Charles J. Glover<br>*Texas A&M University* |
| 11:10-11:45 | Preliminary Infrared and Rheological Correlations in Asphalt Binders | Ron Glaser<br>*Western Research Institute* |
| 11:45-1:00 | LUNCH | |

**SESSION 2 Session Chair—Eric Kalberer, Western Research Institute**

| | | |
|---|---|---|
| 1:00-1:35 | Bailey Method vs Rational Aggregate 'Packing' Method in Asphalt Mix Design – Advanced Testing and Data Simulation Analysis | Daniel Opacic<br>*Asphalt Consultant*<br>*Copenhagen* |
| 1:35-2:10 | Visco-Elastic Analysis to Determine Mixing and Compaction Temperatures of Asphalt Mixes | John Casola<br>*Malvern Instruments* |
| 2:10-2:45 | Rheological Properties of WMA Additives and Anti-stripping Agent Modified Performance Grade Binder | Zahid Hossain, Dharamveer Singh, Aravinda Buddhala, Musharraf Zaman and Edgar O'Rear<br>*University of Oklahoma* |
| 2:45-3:05 | BREAK | |
| 3:05-3:40 | Phase Angle Determination and Interrelationships within Bituminous Materials | Geoffrey M. Rowe<br>*Abatech Inc.* |
| 3:40-4:15 | Fundamental Asphalt Characteristics in Relation to Pavement Performance | Shin-Che Huang<br>P. M. Harnsberger, M. J. Farrar, T. F. Turner, R. W. Grimes, Stephen L. Salmans and R. E. Robertson<br>*Western Research Institute* |
| 4:15-4:50 | Hot-Mix Asphalt Underlayment Trackbeds -- Long-Term Materials Evaluation | Jerry G. Rose<br>*University of Kentucky* |

MONDAY EVENING—*Dinner on your own*

## *Tuesday, July 15*

| **SESSION 3** | **Session Chair—Shin-Che Huang, Western Research Institute** | |
|---|---|---|
| 8:00-8:35 am | On-Column Precipitation and Re-dissolution Technique for Separation of Asphaltenes and Waxes in Asphalt Binders | John F. Schabron<br>Joseph F. Rovani, Jr. and<br>Mark Sanderson<br>*Western Research Institute* |
| 8:35-9:10 | Analysis of Flow Number Data from Field Hot-Mix Asphalt Samples Using the AMPT | Raj Dongré<br>*Dongré Laboratory Services Inc.*;<br>John D'Angelo<br>*Federal Highway Administration* |
| 9:10-9:45 | Field Validation of Ontario's New Asphalt Binder Specification Tests (LS-299 and LS-308) | Simon Hesp<br>Abdolrasoul Soleimani and<br>Sathish Subramani<br>*Queen's University, Ontario*;<br>Ted Phillips, Dale Smith,<br>Pamela Marks and Kai Tam<br>*Ontario Ministry of Transportation* |
| 9:45-10:05 | BREAK | |
| 10:05-10:40 | Determination of Low-Temperature Properties of Asphalt using Dynamic Shear Rheometry | Changping Sui<br>*Western Research Institute* |
| 10:40-11:15 | Low-Temperature Cracking Specification Revisited — Impact of Binder Aging Protocols | Raj Dongré<br>*Dongré Laboratory Services Inc.*;<br>Mihai Marasteanu<br>*University of Minnesota* |
| 11:15-11:50 | Physical Hardening of Asphalt Binders – Causes and Consequences | Pavel Kriz, Jiri Stastna and<br>Ludo Zanzotto<br>*University of Calgary* |
| 11:50-1:15 | LUNCH<br>***The Great New York-to-Paris Automobile Race of 1908*** | Chavawn Kelley<br>*Western Research Institute* |

## *Tuesday, July 15, continued*

| SESSION 4 | Session Chair—Bill Tuminello, Western Research Institute | |
|---|---|---|
| 1:15-1:50 | Historical and Current Rheological Binder Characterization vs. Binder Performance | David Anderson *Consultant;* Geoffrey M. Rowe *Abatech Inc.* |
| 1:50-2:25 | Utilization of Bio-Oil Fractions as an Asphalt Additive | R. Christopher Williams, Justinus Satrio, Margorie Rover, Robert C. Brown, Ryan Shropshire, and Shang Tang *Iowa State University* |
| 2:25-3:00 | Induced Oxidation of SBS Modified Asphalt Cements | Ionela Glover, William Daly and Ioan Negulescu *Louisiana State University*; Louay Mohammad *LSU/LTRC*; Christopher Abadie *LTRC*; Raphael Cueto *LSU* |
| 3:00-3:20 | BREAK | |
| 3:20-3:55 | Recent Developments in Sulfur-Extended Asphalt Technology | Imants Deme, Mark Bouldin and Norman Pugh *Shell Sulfur Solutions* |
| 3:55-4:30 | Effect of SBS Dispersion and Other Additives in PMA Binders on MSCR Test Results | Raj Dongré *Dongré Laboratory Services Inc.*; John D'Angelo *Federal Highway Administration* |

**Conference Dinner at Laramie Plains Museum**
Social Hour 5:30-6:30, Dinner Served at 6:30 pm

## *Wednesday, July 16*

| SESSION 5 | Session Chair—Changping Sui, Western Research Institute | |
|---|---|---|
| 8:00-8:35 | Modeling the Response of Polymer-Modified Asphalt Binders under Monotonic Shear Loading | Carl M. Johnson and Codrin Daranga *University of Wisconsin-Madison* |

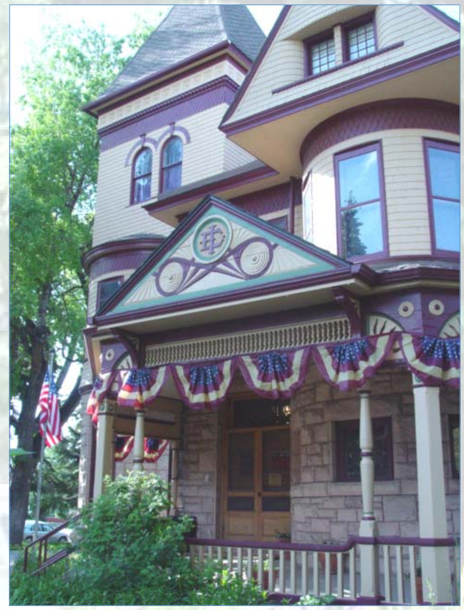
## Tuesday Evening

## CONFERENCE DINNER

### Ivinson Mansion, 603 Ivinson Avenue

Social Hour and
Ivinson Mansion Tours 5:30
Dinner 6:30

The Laramie Plains Museum is housed in the Victorian mansion built by Laramie town father, Edward Ivinson.



| | | |
|---|---|---|
| 8:35-9:10 | Effect of Temperature on the Moisture Susceptibility of Hot-Mix Asphalt | Pedro Romero *University of Utah*; Kevin VanFrank *Utah Dept. of Transportation*; Jason Nielson *University of Utah* |
| 9:10-9:45 | Update on TFHRC Research: The Effect of Moisture on HMA Mixes Modified with Phosphoric Acid | Terry Arnold, *FHWA*; Susan Needham *SES Group & Associates, LLC* |
| 9:45-10:05 | BREAK | |
| 10:05-10:40 | Polyphosphoric Acid (PPA) Modified Asphalt Binders: Factors of Influence on Rheological Properties | Cristian Clopotel and Codrin Daranga *University of Wisconsin-Madison* |
| 10:40-11:15 | Polyphosporic Acid Modified Asphalt in Conjunction with Lime as an Antistripping agent: Performances of Asphalt Mixes used in MN Road Pavement Test Track—Preliminary Results | JV Martin *Innophos*; G. Reinke *MTE*; T. Clyne *Minnesota Dept. of Transportation*; D. Fee *ICL-Performance Products* |
| 11:15 | CLOSING REMARKS | |

## Acknowledgement

*Western Research Institute expresses*
*Thanks and appreciation to the*
*Federal Highway Administration*
*for its long-term support of much of the*
*research that is reported at the*
*Petersen Asphalt Research Conference.*

*Thank you.*

## SESSION 1

### A GENERALIZED LOGISTIC FUNCTION TO DESCRIBE THE MASTER CURVE STIFFNESS PROPERTIES OF BINDER MASTICS AND MIXTURES

Geoffrey M. Rowe (1), Gaylon Baumgardner (2) and Mark J. Sharrock (3)
*(1) President, Abatech Inc., Blooming Glen, PA; (2) Executive VP, Paragon Technical Services; (3) Abatech International, Nottingham, UK*

The generalized logistic curve, also known as Richards' curve is a widely-used and flexible sigmoidal ("S-shaped") function arising in the study of growth modeling. This model has been found to be very suitable for representing the complex modulus mastercurve of unimodal visco-elastic solid materials, five fitting parameters representing; 1) the lower asymptote, 2) the upper asymptote, 3) the abscissa at the steepest point on the curve, 4) the width of the curve, and 5) the ordinate at which the maximum gradient occurs, coincident with the inflection point of the sigmoid. Various forms of this generalized model are allows and discussion is presented how a limiting case results in the generalized Gompertz equation.

The mathematical solutions are applied to various asphalt mastics and binders. Experimentation includes testing with binders and mastics with dynamic shear rheometer, torsion bar, being beam rheometer and a direct tension test. Data is reduced to complex shear modulus. The results for a wide range of material types are combined to produce master curves and compared to analysis with consideration of the symmetrical sigmoidal function used within the ASSHTO MEPEG method.

The analysis shows that for the materials evaluated a generalized model format works very well. In addition, the data shows that the resulting master curves are non-symmetrical about a point of maximum gradient. The modeling of asphalt materials to produce mastercurves is becoming more important in the development of pavement design methods. However, the method being applied uses a symmetrical sigmoidal model which can clearly be shown not to apply for many types of asphalt materials. This paper presents several additional approaches with sigmoidal models which can be assessed within the same mechanistic-empirical framework. This is anticipated to be important as materials containing more modifiers are used and/or the greater use of materials not typical of those used to develop the original sigmoidal model adopted by many researchers.

## PRACTICAL USE OF VECD ANALYSIS IN PAVEMENT DESIGN

M. Emin Kutay (1), Nelson Gibson (2), Raj Dongré (3) and Jack Youtcheff (2)
*(1) SES Group & Associates; (2) FHWA; (3) DLSI*

The Viscoelastic Continuum Damage (VECD) theory has gained wide acceptance in analysis of fatigue characteristics of hot mix asphalt (HMA) pavements. VECD theory is capable of successfully modeling uniaxial behavior of HMA for a variety of temperatures and loading rates. Practical applications of VECD theory have also been proposed by a number of researchers. Furthermore, VECD-based simulations have been shown to produce very good correlation with the field measurements such as the fatigue data from the Accelerated Loading Facility (ALF) at the Turner-Fairbank Highway Research Center (TFHRC). What is needed is a demonstration and discussion of the use of VECD (and possibly VEPCD) for everyday pavement engineering and materials characterization. This presentation demonstrates the possible use of VECD (or VEPCD) in a future version of the Mechanistic Empirical Pavement Design Guide (MEPDG). Simulations are used to show the applicability of VECD based damage calculations for pavement design.

## FORWARD AND INVERSE SELF-CONSISTENT MICROMECHANICS MODEL OF AN ASPHALT CONCRETE MIXTURE

Rong Luo and Robert L. Lytton
*Texas A&M University*

A forward and inverse self-consistent micromechanics model has been developed for the asphalt concrete as a composite material consisting of three components: asphalt binder, aggregate and air. This model has been programmed using MATLAB and been applied to the analysis of the viscoelastic properties of asphalt mixtures at different aging times. The inverse process takes as input the volumetric composition of the mixture and the measured frequency-dependent bulk and shear properties of an asphalt mixture and a binder and extracts from them the bulk and shear properties of the aggregate. The forward process takes as input the frequency-dependent bulk and shear properties of the aggregate and binder and produces the frequency-dependent properties of the asphalt mixture. It has been demonstrated that the forward and inverse operations are in fact the inverse of each other and that the inferred aggregate properties are realistic. This model provides a technique to catalog the properties of aggregate and use them in a computerized determination of the combinations of binders, aggregates and air to produce the desired properties of asphalt mixtures.

## MODELING PAVEMENT TEMPERATURE HISTORY FOR PAVEMENT PERFORMANCE PREDICTION

Rongbin Han, Xin Jin and Charles J. Glover
*Artie McFerrin Department of Chemical Engineering, Texas A&M University*

A key factor that influences asphalt binder behavior and pavement performance is pavement temperature variation with time, depth, and site location. An accurate model is needed for temperature related pavement performance modeling, including calculating binder oxidation. Previous models, though remarkable, are limited either by model accuracy or limited input data availability.

In this work, an improved one-dimensional mathematical model, coupled with site-specific model parameters and recent improvements in the availability of required input climate data, was used to calculate pavement temperatures nationwide. Required input climatic data are: (in order of importance) solar radiation, air temperature, and wind speed. Hourly solar radiation and daily average wind speed can be obtained directly from existing databases. Hourly air temperatures were imputed from commonly recorded daily maximum and minimum air temperatures. Parameter estimation identified two critical site-specific model parameters: the albedo, the difference between the emissivity and absorption coefficients. The national distribution of these model parameters, optimized at 29 pavement sites based on the average hourly absolute error objective function, appears to correlate with climatic patterns, suggesting interpolating those parameters based on climate. The temperature model, proposed data sources and methods provided calculations that agreed well with experimental measurements.

### PRELIMINARY INFRARED AND RHEOLOGICAL CORRELATIONS IN ASPHALT BINDERS

Ron Glaser
*Western Research Institute*

Traditional research philosophies and analyses have led to fundamental insights into the nature and problems of asphalt material science, and these are continued in our research experimental designs. However, the inclusion of statistical modeling tools into our data analysis skill set shows promise for immediate applications where explanation of the data need not be fundamental and as a starting point for obtaining a deeper understanding of asphalt behavior.

Many useful outcomes are possible using a systematic effort to correlate chemical measurements with material properties in the asphalt industry. Immediately apparent is the economy of using inexpensive, rapid chemical analytical techniques in lieu of expensive physical testing. Considerable cost savings could be realized all across the asphalt industry, from manufacturing and blending process control through design-and-build monitoring and finally, low-cost pavement monitoring so that road repairs can be made “just in time.”

The ability to rapidly estimate rheological properties in asphalt binders from easily obtained Infrared Spectra is the ultimate goal of this research. A computer program was developed to rapidly scan spectra and perform correlations against asphalt properties of interest. Using existing data from previous asphalt aging studies at WRI, a number of interesting relationships have been discovered relating various regions in the IR spectra to asphalt binder oxidation. Preliminary results will be presented.

## SESSION 2

### BAILEY METHOD VERSUS RATIONAL AGGREGATE ‘PACKING’ METHOD IN ASPHALT MIX DESIGN – ADVANCED TESTING AND DATA SIMULATION ANALYSIS

Daniel Opacic
*Asphalt Consultant, Copenhagen*

The ultimate purpose behind performing a volumetric asphalt mix design is the optimum proportioning of the right functional constituents in order to provide optimum or requested performance and cost-effectiveness for the project conditions. In hot-mix asphalt (HMA) layers – both dense and to considerable extent in gap graded - the skeletal aggregate structure functions as a backbone and is crucially responsible for resisting pavement distresses. The Bailey Method is ‘guess & trial’ widely proposed technique for evaluation of ‘packing’ characteristics and aggregate gradation analyses. Less known Rational Asphalt Mix Design Method, originally invented and field validated in the eighties, as refreshed and fully computerized serves now as the powerful tool for reliable TOTAL design. The objective of both methods is to use spatial ‘packing’ concepts and relate them to compaction characteristics and optimum HMA performances.

Advanced Testing and Data Simulation Analyses based on highly correlative regression models indicate that volumetric concentration of stone skeleton at ‘denied’ compaction (VC ss / as max) MUST BE USED as THE BASE for ANY OPTIMUM mix design, constructability evaluation, and meaningful performance related criteria development. Cutting edge technology—ASPHALT EXPERT SYSTEM® optimization software — has been used for data processing and solutions validation.

## VISCO-ELASTIC ANALYSIS TO DETERMINE MIXING AND COMPACTION TEMPERATURES OF ASPHALT MIXES

John Casola
*Malvern Instruments*

This presentation will investigate the rheology of both modified and unmodified asphalt binders to determine reasonable mixing & compaction temperatures. Specifically, the use of an asphalt binder's visco-elastic spectra will be investigated to evaluate differences in binder behavior and how these differences relate to determining the correct temperatures for both mixing and compaction. Rheological data will be presented to explain the controlling mechanism affecting aggregate coating as well as determine the optimum temperature to minimize resistance to compact. Selected excerpts from NCHRP 9-39 will be presented.

## RHEOLOGICAL PROPERTIES OF WMA ADDITIVES AND ANTI-STRIPPING AGENT MODIFIED PERFORMANCE GRADE BINDER

Zahid Hossain and Dharamveer Singh (1); Aravinda Buddhala (2); Musharraf Zaman (3); and Edgar O'Rear (4)
*University of Oklahoma: (1) Doctoral Student, Civil Engineering and Environmental Science; (2) Masters Student, Chemical Engineering; (3) Assoc. Dean for Research, College of Engineering; (4) Professor, Chemical Engineering*

As the mixing and compaction temperatures are relatively low in Warm Mix Asphalt (WMA), aggregates in the mixture may not be dry enough. The entrapped water in the mixture may cause undesirable stripping in WMA pavements. To reduce such moisture induced damages in WMA pavements, anti-stripping (AS) agents can be added with WMA additives to modify Performance Grade (PG) binders. Keeping this in view, a laboratory study is undertaken to examine the effects of two selected WMA additives and an anti-stripping agent on the rheological properties of a selected PG binder. A PG 64-22 binder is used as a base binder. Sasobit® and Aspha-Min® are used as WMA additives and Adhere HP-Plus® is used as the anti-stripping additive. The optimum percentages of Sasobit® and Aspha-Min® are found to be 1.5% and 6%, respectively, by the weight of the binder. The amount of Adhere HP-Plus® is kept constant at 0.5% by weight of the binder, while the dosages of Sasobit® and Aspha-Min® are varied within a range. The corresponding changes in the rheological properties of the base binder (PG 64-22) are examined. The base and modified binders are tested using a Dynamic Shear Rheometer (DSR) and a Rotational Viscometer (RV) under un-aged and short-term (RTFO)-aged conditions. It is observed that Sasobit® outperforms Aspha-Min® when Adhere HP-Plus® is added to the base binder. It is evident that Sasobit® increases the rutting resistance by as much as 77% at $64^{o}$C. Comparatively, an increase of up to 40% in rutting resistance is observed if the Sasobit® modified binder is further blended with Adhere HP-Plus®. Surface free energy characteristics of the Sasobit® and Aspha-Min® modified binder are examined using dynamic contact angles, due to the addition of Adhere HP-Plus®. The visco-elastic properties being examined in this study are expected to be useful in evaluating the behavior of WMA mixes in rutting.

**PHASE ANGLE DETERMINATION AND INTERRELATIONSHIPS WITHIN BITUMINOUS MATERIALS**

Geoffrey M. Rowe
*President, Abatech Inc.*

The phase angle (d) of bituminous materials is often required when in-sufficient data exists to define this with a high degree of accuracy. In addition, the measurement of d has a higher variability that that associated with the determinations of G* in binders and E* in mixtures. Often historical data consists only as G* versus frequency with no phase angle information. To enable use of these data sets in current analysis requires the d information to be obtained from mathematical and/or predictive procedures.

Phase angle can be calculated from the retardation and relaxation spectra when this is available for a material. The contribution of spectra properties to the complex modulus and phase angle is explained. Work presented in the SHRP-A-369 report showed analysis of mastercurves that can be shown to incorporate a similar relationship between modulus and phase angle. This approach is contrasted to the spectra analysis method.

A strong relationship is found between the log-log gradient of complex modulus versus frequency and phase angle, in data where we do have both complex modulus and phase angle. This data is demonstrated for a wide range of materials that includes non-bituminous and bituminous products. As the log-log gradient varies from 0 to 1, d (radians) varies from 0 to $\pi/2$, if we assume the relation is simply linear, this would result in the phase angle becoming the product of this gradient and $\pi/2$. This is shown to be the same relationship as proposed in the SHRP-A-369 report. On this basis it is concluded it would be reasonable to analyze G* vs. Frequency on this basis and estimate the phase angle. An alternate method of prediction involves an equation which can be used to fit a discrete spectrum, given only G*. The data from this method is also illustrated.

**FUNDAMENTAL ASPHALT CHARACTERISTICS IN RELATION TO PAVEMENT PERFORMANCE**

Shin-Che Huang, P. Michael Harnsberger, Michael J. Farrar, Thomas F. Turner, William Grimes, Stephen L. Salmans and Raymond E. Robertson
*Western Research Institute*

A comparative pavement validation site was constructed in cooperation with state DOT to explore the variations in long-term pavement performance caused by variations in asphalt composition. This site has been and will continue to be monitored for long-term performance. Pavement distress is monitored periodically to identify and quantify the amount of rutting and/or cracking in the pavement. Neat asphalts and asphalts extracted from loose-mix, core samples were evaluated to determine physical and chemical changes occurring in the pavement. The same asphalts were also laboratory aged in the PAV at pavement service temperature for different durations to investigate how laboratory aging correlates to field pavement aging. In addition, each core sample from pavement was sliced into four layers, the top half inch, second half inch, third half inch, and bottom half inch to investigate how pavement depth affects the aging characteristics of asphalt binders. Extensive rheological analyses performed on neat asphalts, laboratory aged asphalts and the asphalt binders extracted from cored samples at different layers showed that there was little variation with respect to their rheological behaviors before field service. However, the four asphalts showed significant differences in terms of aging characteristics after five years in service. In addition, it was found that the top half inch pavement was significantly aged as compared to the underlying layers after five years of pavement service. Moreover, the rheological results indicated that laboratory aged in PAV at 60°C for approximately 500 hours is equivalent to the bottom slice of four year old shoulder pavement for one asphalt. It was also found that the data presented in the "G* versus phase angle" format correlates well with the field pavement cracking performance of the binders in the field validation section.

### HOT-MIX ASPHALT UNDERLAYMENT TRACKBEDS -- LONG-TERM MATERIALS EVALUATION

Jerry G. Rose
*University of Kentucky*

Railway trackbeds containing a layer of hot-mix asphalt in the substructure are becoming common on heavy-haul freight lines in the United States and high-speed passenger lines in Eurpope and Asia. It is utilized during the rehabilitation of existing trackbeds and the construction of new trackbeds. The primary purposes of the asphalt layer are to provide increased load-carrying capabilities by reducing vertical stress concentrations, reducing and minimizing moisture fluctuations in the underlying subgrade, reducing track deflections, and enhancing the long-term maintenance of desirable track geometric parameters. Prevailing practices for selecting ideal asphalt mix parameters, typical trackbed section designs, and prevalent applications procedurees are presented.

Primary attention is devoted to relating the results of a recent characterization and evaluation program of several asphalt underlayment trackbeds to ascertain the effects of long-term exposure in various trackbed environments relative to performance of the trackbed materials. Asphalt cores and underlying roadbed (subgrade) materials were obtained from existing trackbeds and subjected to various laboratory analyses. The effects of weathering on the properties of the recovered asphalt binders from the insulated trackbed environments and changes in the properties of the subgrade materials were evaluated and are described in detail. These data are compared with typical values for asphalt highway pavements.

## SESSION 3

### ON-COLUMN PRECIPITATION AND RE-DISSOLUTION TECHNIQUE FOR SEPARATION OF ASPHALTENES AND WAXES IN ASPHALT BINDERS

John F. Schabron, Joseph F. Rovani, Jr., and Mark Sanderson
*Western Research Institute*

A new automated separation technique of on-column precipitation and re-dissolution was developed as a new approach for measuring the amounts and distribution profiles of both asphaltene and wax components of asphalt binders. The separation uses a continuous flow system to precipitate and re-dissolve various chemical species from the oil. Milligram quantities of samples are separated in less than an hour. Although high performance liquid chromatography equipment is used, the separation does not involve chromatographic adsorption mechanisms. The separation is conducted using a ground polytetrafluoroethylene (PTFE) packed column, and it is strictly solubility based. The Asphaltene Determinator method involves injection of a solution of asphalt binder in chlorobenzene into a heptane mobile phase, followed by selective dissolution of the precipitated asphaltenes using solvents of increasing polarity: cyclohexane, toluene, and methylene chloride. Another method, the Waxphaltene Determinator, uses methyl ethyl ketone at -20 ºC to precipitate waxes and asphaltenes and asphaltenes together. The precipitated material is re-dissolved in four steps using solvent of increasing polarity at different temperatures: heptane at a -20 ºC, heptane at 60 ºC, toluene at 25 ºC, and methylene chloride at 25 ºC. A preparative Asphaltene Determinator separation was conducted with residua heptane asphaltenes. The separated material was characterized using Fourier transform infrared (FTIR) and ultraviolet/visible absorption spectroscopy. For the Waxphaltene Determinator method, information about the nature of the material under the peaks was obtained by injecting a series of standard materials.

**ANALYSIS OF FLOW NUMBER DATA FROM FIELD HOT-MIX ASPHALT SAMPLES USING THE AMPT**

Raj Dongré (1) and John D'Angelo (2)
*(1) Dongré Laboratory Services Inc.; (2) Federal Highway Administration*

The Asphalt Mix Performance Test (AMPT) was used by the FHWA mobile laboratory to obtain flow number data on samples collected at various pavement construction sites across the USA. Flow number is being studied by many researchers as a criterion to characterize rut resistance of hot-mix asphalt. Flow number is defined as the number of creep and recovery cycles until the tertiary stage of creep is reached. The test is conducted at various high service temperatures according to the climate.

The flow number test is a time consuming test especially for high stiffness binders. It can take as long as four to six hours to reach the tertiary stage to obtain the flow number. In this study other parameters from the flow number test data were studied to determine if the test can be terminated significantly before the tertiary creep is reached without loss of information on rut resistance. Steady state slope was found to be a robust indicator of rut resistance of hot-mix asphalt. The flow number test can now be terminated once the steady state is reached, substantially reducing test time.

This presentation discusses the finding of the flow number data analysis of samples from various field sites conducted by the FHWA.

**FIELD VALIDATION OF ONTARIO'S NEW ASPHALT BINDER SPECIFICATION TESTS (LS-299 and LS-308)**

Simon Hesp, Abdolrasoul Soleimani and Sathish Subramani (1); and Ted Phillips, Dale Smith, Pamela Marks and Kai Tam (2)
*(1) Queen's University, Kingston, Ontario; (2) Ontario Ministry of Transportation*

This study concerns an investigation into low temperature cracking in 20 eastern and northeastern Ontario pavement contracts aged between 7 and 14 years. Recovered asphalt binders were tested according to extended bending beam rheometer (BBR) and double-edge-notched tension (DENT) protocols. The extended BBR and DENT tests were able to explain vast performance differences with a 95% accuracy (one outlier), which is a significant improvement over the 55% accuracy of the regular BBR specification. Eleven of the contracts showed little or no thermal cracking with joints and shoulders largely unblemished. In contrast, the remaining 9 contracts had cracked prematurely and excessively. Cracks in 5 of the poor performers were sealed in early life yet the pavements have continued to crack unabated. The remaining 4 were beyond repair and will likely have to be completely reconstructed at an early date. The extended BBR test measures limiting temperatures after conditioning for up to 72 hours. The DENT test measures strain tolerance as approximated by the critical crack tip opening displacement. Based on these findings and those of prior studies, the Ontario Ministry of Transportation is looking at how these novel methods can be used to improve pavement performance at an early date.

## DETERMINATION OF LOW-TEMPERATURE PROPERTIES OF ASPHALT USING DYNAMIC SHEAR RHEOLOGY

Changping Sui
*Western Research Institute*

Shear stress relaxation experiments were conducted at temperature as low as -30$^{o}$ C with parallel-plates on a strain-controlled dynamic shear rheometer (ARES). By applying time-temperature superposition, the master curve of the stress relaxation modulus was obtained. The apparent glassy plateau modulus obtained from the master curve is about 5 x $10^{8}$ Pa, which is lower than the literature reported value (about $10^{9}$ Pa). The lower glassy plateau modulus measured from DSR is due to the error caused by the machine compliance issue. The dynamic frequency sweep data have been corrected using the method developed by Schröter et al. [Schröter, K., S. A. Hutcheson, X. Shi, A. Mandanici, and G. B. McKenna, 2006, *J. Chem. Phys*., 125: 214507]. The stress relaxation data will be corrected using a method developed by Hutcheson et al. [Hutcheson, S. A., K. Schröter, X. Shi, A. Mandanici, and G. B. McKenna, submitted to *J. Chem. Phys*., 2007]. The stress relaxation data were also compared with the data converted from the dynamic frequency sweep data and BBR data.

## LOW-TEMPERATURE CRACKING SPECIFICATION REVISITED — IMPACT OF BINDER AGING PROTOCOLS

Raj Dongré (1) and Mihai Marasteanu (2)
*(1) Dongré Laboratory Services Inc.; (2) University of Minnesota*

In-service aging of asphalt pavements gradually embrittle the asphalt binder and asphalt mixtures over time. In the current binder specifications, plant-aging is simulated by the RTFOT, and in-service aging by the PAV. Most of the research on binder aging has been focused on the high temperature properties, such as viscosity, although the detrimental effects of aging occur at intermediate and low service temperatures.The fatigue parameter $|G^*|\sin\delta$, is currently under intense investigation by various researchers. The low-temperature parameters, however, are considered adequate. The low temperature cracking resistance is controlled using the creep stiffness value S(60) and the m-value. The failure (or fracture) properties are also specified using the failure strain and the $T_{cr}$.

This presentation revisits the limiting stiffness performance criterion that has long been shown to be a low temperature performance predictor. The embrittlement observed in the field due to in-service aging is not captured in binder properties measured in either BBR or DTT; the binder appears to toughen as a result of PAV. This is due to the manner in which the aging protocol was developed during Superpave – based solely on the effect of temperature and pressure on the viscosity of the binder. No consideration was given to the effect of aging on failure properties of binders.The consequences of the current Superpave low temperature specification on the binder being produced will be discussed. The theoretical aspects of the m-value and the S(60) will be presented. The other, often neglected, issue of in-situ impact of aging on asphalt mixture mechanical properties will also be discussed.

### PHYSICAL HARDENING OF ASPHALT BINDERS – CAUSES AND CONSEQUENCES

Pavel Kriz, Jiri Stastna and Ludo Zanzotto
*Bituminous Materials Chair, University of Calgary*

Physical hardening of asphalt binders has been already addressed in the literature for several times. Asphalts harden and embrittle if kept at low temperature over period of time. Although there is a controversy to what extend the physical hardening affects the low temperature performance of the pavement, it was shown that the low temperature performance grade determination is affected.

The effect of hardening on the caloric and viscoelastic properties of several asphalt binders was studied by modulated differential scanning calorimetry (MDSC) and by dynamic mechanical analysis (DMA). The effect of time, temperature, oxidation and external stresses on physical hardening was evaluated. The results indicated that there are at least two mechanisms behind the physical hardening – structural relaxation of the glassy state (physical aging) and evolution of the crystalline phase. It was concluded that the physical hardening of asphalts is universal and inevitable process, predominantly dependent on the time and temperature (thermal history) and not on stress induced volume changes or previous deformation history.

## SESSION 4

### HISTORICAL AND CURRENT RHEOLOGICAL BINDER CHARACTERIZATION VS. BINDER PERFORMANCE

Dr. David A. Anderson, P.E. (1) and Dr. Geoffrey M. Rowe (2)
*(1) Consultant; (2) Abatech Inc.*

The Strategic Highway Research Program (SHRP) introduced new techniques for measuring and characterizing the engineering properties of asphalt binders and these techniques have largely replaced the empirical pre-SHRP techniques. Pre-SHRP indicators of performance, such as relationships between penetration and ductility and indicators of temperature susceptibility such as PI, PVN and VTS provided pre-SHRP asphalt technologists with considerable insight into binder "quality". These have largely been forgotten in today's technology, primarily because the SHRP and pre-SHRP indicators are not related fundamentally. This dis-connect between the old and new is indeed unfortunate, as much of the pre-SHRP knowledge regarding asphalt binder quality has not been translated to the post-SHRP technology. Approximate relationships, such as those between the pre-SHRP measures PI, PVN and VTS and the mastercurve parameters R and $\omega_c$ are presented in this paper. The performance of selected pre-SHRP field trials are then re-evaluated using estimated parameters based on SHRP-based rheological measures. Bridging this disconnect provides another level of validation for material characterizations and specifications that are now being developed.

## UTILIZATION OF BIO-OIL FRACTIONS AS AN ASPHALT ADDITIVE

R. Christopher Williams, Justinus Satrio, Margorie Rover, Robert C. Brown, Ryan Shropshire and Shang Tang
*Iowa State University*

Lignin derived from wood products and agricultural sources has been shown to provide beneficial enhancement to asphalt binders. However, little research has been done to investigate the performance of lignin derived from bio-oil. Bio-oil is derived from the process of fast pyrolysis of biomass. By a simple hydrolysis extraction technique, a lignin high phenolic fraction content material can be separated from bio-oil. The lignin fraction is water insoluble and mixes well into asphalt. Lignin derived from agricultural processes is a very appealing performance additive for asphalt. This is due to the low cost of lignin compared to conventional asphalt modifiers. Using bio-oil as an asphalt modifier would not only be more economical for asphalt producers, but would also increase the value of common agricultural co-products while producing transportation fuels and sequestering carbon for use as an agricultural fertilizer.

Research at Iowa State University is currently underway to investigate the performance of utilizing bio-oil as an asphalt additive. A high lignin content fraction of bio-oil derived from the fast pyrolysis of two different biomasses are each combined with four different asphalt binders to determine the bio-oil's effect on the physical and rheological properties of the binders. The biomasses used to produce the bio-oil are corn stover and oakwood. Rolling thin film ovens and pressure aging vessels will be used to simulate short and long-term aging. The research shows substantial performance grade enhancement when blended with a polymer modified asphalt binder and limited effects when combined with non polymer asphalt binders.

## INDUCED OXIDATION OF SBS-MODIFIED ASPHALT CEMENTS

Ionela Glover, William Daly and Ioan Negulescu (1); Louay Mohammad (1,2); Christopher Abadie (2); and Raphael Cueto (1)
*(1) Louisiana State University*; *(2) Louisiana Transportation Research Center*

SBS Polymer Modified Asphalt Cement samples of different compositions were subjected to TFOT and PAV aging (both in dry and wet atmosphere). The chemical impact of aging of PMAC components has been modeled using a cobalt naphthenate/cumene hydroperoxide redox system in order to obtain a better understanding of the role of radicals during oxidative processes. It has been found that the polymer served as a sacrificial partner and protected the asphalt components from oxidation. The extent of oxidation has been quantified from changes in the molecular mass of asphalt cement components as determined by GPC analysis. The high molecular weight components (~600 Kdaltons) derived from SBS rapidly converted to medium molecular weight fractions (~20 Kdaltons), which are mixtures of polystyrene fragments and asphaltenes in the presence of a redox system. The GPC data of the radical induced oxidized samples matched well with field aged asphalts when the distribution of the medium molecular weight and low molecular weight fractions were compared.

## RECENT DEVELOPMENTS IN SULFUR-EXTENDED ASPHALT TECHNOLOGY

Imants Deme, Mark Bouldin and Norman Pugh
*Shell Sulfur Solutions*

Recently, a significantly enhanced, pelletized sulfur-based asphalt mix modifier has been developed. The plasticized, low odor sulfur pastilles may be added to a paving mix at the asphalt hot-mix plant, melt quickly on contact with the mix and disperse readily. The mix can be produced and compacted at temperatures well below conventional asphalt, comparable to warm mix asphalts. Numerous projects in North America, Asia and the Middle East using this 2nd generation sulfur modifier will be discussed.

The laboratory and field mix testing indicate that the stability, deformation resistance, stiffness and fatigue performance of these sulfur-enhanced mixes were particularly suitable for high stress applications, such as heavy-duty pavements, high traffic intersections, container terminals and airports as well as full-depth asphalt pavements. The mixes exhibit significantly less temperature sensitivity than conventional asphalt mixes. Performance tests indicate that this sulfur modifier system does not affect the low temperature cracking resistance.

From conservation and sustainable development standpoints, this product provides a viable outlet for sulfur while conserving hydrocarbon resources through reduction of asphalt content. It also provides energy saving associated with the lower processing temperatures. From an environmental perspective this technology creates an opportunity to capture CO2 credits while significantly lowering VOC emissions.

## EFFECT OF SBS DISPERSION AND OTHER ADDITIVES IN PMA BINDERS ON MSCR TEST RESULTS

Raj Dongré (1) and John D'Angelo (2)
*(1) Dongré Laboratory Services Inc.; (2) Federal Highway Administration*

The rheological properties of SBS modified asphalt binders (SBS-PMAs) depend on formulation variables. The most sensitive among them may be listed as polymer amount, cross-linking agent amount (%), and other additives (PPA). The dispersion of SBS in an asphalt binder depends on blending time and temperature. In this study an incompatible and a compatible base asphalt binder were selected and modified with various amounts of SBS. Elemental sulfur was used as a cross-linking agent in various proportions. Other additives such as PPA at 0.5% concentration and wax at various amounts were also used. High shear blends of SBS-PMAs were made in the laboratory by varying blending time until an optimum dispersion of polymer was obtained. The dispersion of the polymer was studied using a fluorescence microscope. Various amounts of RAP were also added to a different commercially available PMA. MSCR test was used to study creep and recovery behavior of these modified binders.

It was found that MSCR test results ($J_{nr}$ and % recovery) were able to characterize the extent of dispersion of SBS in these PMAs. This implies that a fundamental test method is now available to discriminate between the 'dump&stir' type PMAs and those that have been optimally dispersed. This presentation discusses the effect of SBS dispersion and other additives on the MSCR test results.

## SESSION 5

### MODELING THE RESPONSE OF POLYMER-MODIFIED ASPHALT BINDERS UNDER MONOTONIC SHEAR LOADING

Carl M. Johnson and Codrin Daranga
*University of Wisconsin-Madison*

There has been an increasing effort to develop a laboratory test method that can accurately characterize the fatigue resistance of binders. Cyclic testing is one proposition, but it is a time-consuming, impractical procedure. A new monotonic shear test is being developed by UW-Madison to characterize the damage accumulation properties of binders. The fundamental modeling of this behavior uses viscoelastic continuum damage concepts, similar to those used for mixtures. By first measuring the linear viscoelastic (undamaged) properties at small strain levels, the stress-strain behavior of the material under monotonic shear loading can be predicted. For many linear viscoelastic materials, the discrepancy between predicted and measured behavior is attributed to damage; however, some polymer-modified asphalts show higher than predicted stresses at high strain levels, indicating that the material is strengthening rather than becoming damaged. This could be due to the significant molecular size difference between the polymers typically used for binder modification and the binder itself. As the bitumen loses material integrity, the polymer could become increasingly responsible for the resistance to the applied load, thereby changing the material properties. A more comprehensive method for characterizing undamaged behavior would then be needed to accurately indicate how much damage is accumulated under loading.

### EFFECT OF TEMPERATURE ON THE MOISTURE SUSCEPTIBILITY OF HOT-MIX ASPHALT

Pedro Romero (1), Kevin VanFrank (2) and Jason Nielson (1)
*(1) University of Utah; (2) Utah Department of Transportation*

A study was conducted to determine the effect of temperature on the moisture susceptibility of asphalt mixtures. Two different sources of neat binders with a grade of 58-28 were modified with polymers and polyphosphoric acid (PPA) to a grade of 70-28. The two grades were then blended to obtain an intermediate grade of 64-28 according to Utah specifications. These six binders were then mixed, without lime, with an aggregate that is known to be susceptible to stripping. They were tested using the Hamburg Wheel Tracking Device at different temperatures to determine the 'critical stripping temperature' defined as the temperature above which there is enough energy to strip the binder from the aggregate. The results indicate that, for a specific binder-aggregate combination, the critical stripping temperature increases with binder performance grade. For most modified binders, this temperature was above 50°C, which is the standard test temperature for the HWTD. This indicates that the current protocols of testing at one temperature are not adequate for modified binders since these binders will be used at locations where the temperature often reaches above the critical stripping temperature. Preliminary data also indicate that the critical temperature might be influenced by the addition of PPA.

### UPDATE ON TFHRC RESEARCH:
### THE EFFECT OF MOISTURE ON HMA MIXES MODIFIED WITH PHOSPHORIC ACID

Terry Arnold (1) and Susan Needham (2)
*(1) FHWA; (2) SES Group & Associates, LLC*

Adding a hydrophilic material like phosphoric acid to asphalt has the potential to change the water sensitivity of the mix, in terms of both water absorption and phosphoric acid leaching. It can also affect the stripping behavior of the mix. Research showed that asphalt type, aggregate type, PPA loading and air void level are important factors.

Phosphoric acid leaching was examined by soaking gyratory specimens in water and measuring the amount of phosphate extracted into the water over time. The rate of water absorption into PPA modified asphalt and 50% mastic was studied by measuring the weight gain of samples immersed in water. To show the effect of aggregate type, three different aggregates were used in the mastics. To evaluate how acid modification affects stripping, the Hamburg Device was used to measure the stripping of HMA samples containing four different anti-strip additives, amine, non-amine and lime. Turner-Fairbanks Highway Research Center has developed a simple, easy test to determine if PPA is present in asphalt. An overview of the test method and discussion on its proper use and applications will be included.

### POLYPHOSPHORIC ACID (PPA) MODIFIED ASPHALT BINDERS:
### FACTORS OF INFLUENCE ON RHEOLOGICAL PROPERTIES

Cristian Clopotel and Codrin Daranga
*University of Wisconsin-Madison*

Polyphosphoric acid (PPA) is a commonly used modifier for asphalt binders. Successful modification of an asphalt binder with PPA is intended to improve the high temperature stiffness of the material without negatively affecting the low temperature properties. The overall mechanism of reaction between asphalt and PPA it is not very well understood, although it seems to be generally accepted that the PPA reacts with the asphaltene fraction of the binders. This study investigates two different asphalt binders, one with high asphaltene content, and one with low asphaltene content. The selected binders are modified with PPA and the rheological properties of both the modified and unmodified binders are recorded using the Dynamic Shear Rheometer. The surface area of the samples, the storage time and temperature and the asphaltene content of the binders are all important factors examined in this study. By varying these parameters, we are able to discriminate between the behavior of the liquid binder during storage and the behavior of the asphaltic mixtures during processing and handling at high temperature.

## POLYPHOSPORIC ACID MODIFIED ASPHALT IN CONJUNCTION WITH LIME AS AN ANTISTRIPPING AGENT: PERFORMANCES OF ASPHALT MIXES USED IN MN ROAD PAVEMENT TEST TRACK—PRELIMINARY RESULTS

JV Martin (1), G. Reinke (2), T. Clyne (3) and D. Fee (4)
*(1) Innophos; (2) MTE; (3) Minnesota Department of Transportation; (4) ICL-Performance Products*

Polyphosphoric acid (PPA) has been used to improve the stiffness of asphalt binders for more than a decade either as a solo modifier or in conjunction with other additives such as polymers. Whereas a significant amount of information is now available on the asphalt binder and asphalt mix properties[ ], little information on pavement performances involving PPA in different technologies under a controlled environment has been reported. Among the critical questions remaining regarding PPA modified binder performances is their compatibility with other additives and in particular lime used as antistripping agent in an asphalt mix. This paper will present the preliminary results of asphalt mix performances used to pave four different sections built on the MN Road paving track facility in Albertville, MN, made of PPA, PPA-SBS, PPA-Elvaloy, SBS modified binders and lime as an antistripping agent.

# In 2008,

# WRI is celebrating 25 years of Achievement

***WRI acknowledges all our current employees and past employees***—including those of our predecessor organizations—whose contributions have made this milestone possible.

***WRI traces its beginnings to 1924***, when the U.S. Bureau of Mines established a petroleum field office to aid the development of Wyoming oil and oil shale reserves. The building was a tin shack behind the College of Engineering building on the University of Wyoming campus.

***The organization that was to become WRI*** operated as the Bureau of Mines until 1974, when the Laramie Energy Research Center was established under the U.S. Energy Research and Development Administration. In 1977, with the formation of the U.S. Department of Energy, the organization operated as the Laramie Energy Technology Center until it was de-federalized in 1983. Throughout these years, the organization was a leader in petroleum, oil shale, tar sand, and coal gasification research.

***WRI's internationally recognized asphalt research program*** began in the 1960s. Dr. J. Claine Petersen organized the first asphalt research conference in 1964, emphasizing the effects of the chemical and physical properties of asphalts on their performance in pavements over time. Significant developments were made in the separation and identification of compounds in heavy oils.

***WRI's current asphalt research is conducted in partnership*** with the Federal Highway Administration, the Department of Transportation, and a consortium of research organizations and under contract to private clients.

***Energy research and technology development*** is conducted largely under cooperative agreement with the U.S. Department of Energy and with significant industrial co-sponsorship. Work is focused on fossil energy, biomass, and energy-related environmental technologies. Recent efforts are yielding new solutions in the areas of environmental mitigation, coal and biomass gasification, renewable fuels from biomass, and power generation from coal. Please explore our web site to learn more.

***Over the last 25 years, we've enjoyed working together and with you. We've been gratified by our accomplishments. Thank you for joining us in acknowledging our silver anniversary.***

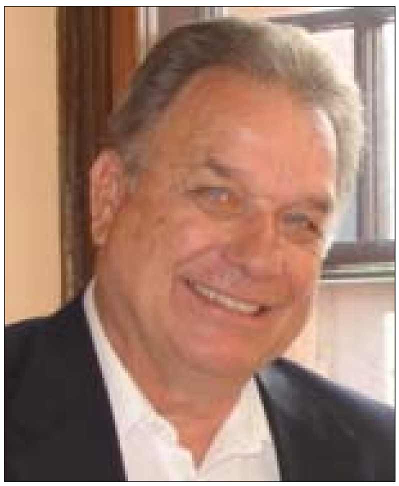
***Here's to the future!!!***

***WRI is honoring nine employees who began working at WRI in the year we were established. Of those who have reached their silver anniversary, four are members of the Transportation Technology team.***

**Fran Miknis 1967**

Fran was an offensive lineman and an Academic All-American while earning his degree in chemical physics at the University of Wyoming. In 1967, he was hired by the Bureau of Mines as a research chemist and has worked for WRI and its predecessors for more than 40 years.

In 1972, Fran began using solid-state nuclear magnetic resonance (NMR) techniques for the analysis and characterization of oil shales, coals, petroleum source rocks, and products from conversion of these materials. Now he is investigating the use of NMR to study the behavior of polyphosphoric acid in asphalt and to measure interfacial properties of asphalts.



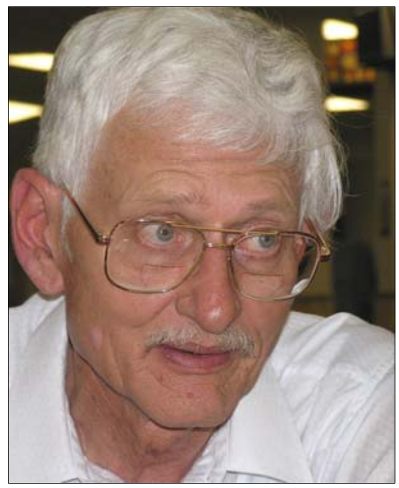
**Fred Turner 1975**

When Fred was hired by the Energy Research and Development Administration as a technician in 1975, he was the same age his younger son is now. Fred has worked in the Asphalt Program since 1993, when research began under the first Fundamental Properties of Asphalts and Modified Asphalts Program. Last year, Fred was appointed Principal Investigator for the Fundamental Properties of Asphalts and Modified Asphalts III Program.

Fred is also heading a new two-year Cooperative Agreement with the Department of Transportation's Research and Innovative Technology Administration. The program, known as "RITA," will develop a remote-sensing system that can be used in the field to predict asphalt aging.

**Raymond E. Robertson 1976**

Ray Robertson has worked in asphalt research since joining the Energy Research and Development Administration in 1976 and has taken asphalt research at WRI from the Strategic Highways Research Program of 1988 to a program that encompasses the FHWA-sponsored Fundamental Properties of Asphalt and Modified Asphalts III, the five-member Asphalt Research Consortium, and the RITA Cooperative Agreement, not to mention significant private contract work.



Ray is known to be fiscally responsible and honest, scrupulously following the letter of each contract. Perhaps that has something to do with being from the "Show-Me" state.

**Susan Sorini-Wong 1983**

As a lead scientist at WRI, Susan Sorini-Wong's responsbilities includes method and product development and validation, as well as environmental consulting. She has written and conducted validation studies for numerous ASTM standards, including ones that contribute to the market acceptance of instruments and devices developed at WRI.

For her work on the development of the Diesel Dog® soil test kit, which is used to detect fuel contamination in soils, and the X-Wand™ device for screening soil and water for halogenated volatile organic compounds, Susan received Regional Industrial Innovation Awards from the American Chemical Society in 2001 and 2007.

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