**Executive Summary of Technical Presentations made at the Annual Meeting of the Association of Asphalt Paving Technologists held in Savannah, Georgia, March 2006.**

The Association of Asphalt Paving Technologists (AAPT) is the leading learned society in its field world-wide and the annual meeting, this year held at the Hyatt Regency in Savannah, Georgia, is a major forum for the presentation of research and development work. The very detailed papers, subjected to extensive peer review, are published annually in the Association's journal, 'Asphalt Paving Technology.' Since the Journal is not published until 10-12 months following the annual meeting, the AAPT Board of Directors decided to distribute an executive summary of the technical sessions within 3 to 4 months of the annual meeting.

As usual, the presentations covered a wide range of experimental and theoretical studies on asphalt cement and HMA. The summary below has been arranged within the main general topics which were discussed.

## 1. Mechanical properties of HMA

**Terhi Pellinen** from **Purdue University** presented the background to a performance-based specification for HMA in Indiana based on the measurement of key mechanical properties, rather than relying on indirect parameters such as void content. Measurement of complex shear modulus (G*) at 40$^{o}$C and 10Hz, with indirect tensile strength ($S_t$) at 35 $^{o}$C and 0.06mm/min were recommended. Complex modulus could be either measured with the Superpave Shear Tester or a repeated load compression test (Simple Performance Test). The Indirect Tensile Test was used for $S_t$. Both tests required 150mm diameter test specimens preferably in the form of cores from the newly paved highway. The paper presents the comprehensive background studies and includes recommended specified values for the two parameters designed to provide a good balance between resistance to fatigue cracking and to rutting in service.

**Christopher Robinette** described a project conducted at **Michigan Tech** based on use of the **Superpave Simple Performance Test (SPT)** to determine the HMA stiffness and resistance to rutting. Values of complex modulus (E*) and Flow Number ($F_N$) obtained on 100 mm diameter specimens cored from a compacted 150 mm specimen were compared with those that were compacted to 100 mm. The mixture contained 15% RAP and was sampled from a paving project. Results indicated that test history did not change the average measured E* and $F_N$ values, but increased variability.

**Strain Levels Used in Dynamic Modulus Testing of HMA** were studied in a project reported by **Nan Tram** from the **University of Arkansas.** The SPT test procedure described in AASHTO TP62 specifies a range of allowable recoverable axial strains between 50 and 150 microstrain. Two identical sets of HMA test specimens were prepared using 12.5mm maximum sized aggregate. One set was tested at 50-100 microstrain and the other at 100-150 microstain. The results showed that testing at the lower strain level gave consistent results for the linear viscoelastic responses at various temperatures and frequencies. However, because of an accumulation of viscous strain at higher temperatures, significantly different results were obtained at the two strain levels, changing E* by up to 55%. The impact of this effect on

predicted pavement performance was estimated using the provisional version of the new mechanistic-empirical design guide.

**Andrew Collop** from the **Nottingham Centre for Pavement Engineering** in the UK described research into the permanent deformation characteristics of two HMA's in which the increase in volume (dilation) was a significant parameter, quantified in various compression tests on cylindrical specimens. A wide range of test conditions was used and both loading and recovery strains were measured. Phenomenological models were shown to provide good predictions of performance.

**Dallas Little** from **Texas A&M University** reported on a technique for the **fast, simple prediction of fatigue cracking in HMA** using the asphalt-filler-fine aggregate part of the mixture. The results, interpreted within an analytical method, can predict the fatigue cracking of the whole mixture. Testing of the material without the coarse aggregate improves repeatability. The Authors state that their approach has the potential for use in standard specifications.

The problems presented by the **testing of HMA field cores to determine material properties for use in predictive models** of pavement behaviour were discussed by **Michael Waggoner** from the **University of Illinois**. He described a suite of suitable tests for dealing with cores from thin layers in the context of a study of reflection cracking. The tests were divided into those required to define the overall continuum response of the mixture, such as complex modulus, and those needed to evaluate the separation properties, such as tensile strength. The tests included indirect tension and compact tension tests on thin discs.

**A revised version of the Witczak complex modulus predictive model for HMA** was presented by **Javed Bari** from **Arizona DOT.** This well-established model was revised to use shear modulus (G*) in place of viscosity to characterise the binder and the master E* database was increased from 205 to 346 mixtures increasing the total number of data points used to determine the model parameters from 2750 to 7400. A model was presented to predict G* from viscosity data. Model sensitivity to volumetric and gradation parameters was presented. The presentation lead to a vigorous discussion which included a question about how the accuracy of prediction might change when measured values of G* for the binder become available.

## 2. Asphalt binders

An investigation into the absorption of asphalt binders into tire rubber conducted at **Liverpool University in the UK** was presented by **Hussain Khalid.** Both automobile and truck tire rubbers were investigated in two different binders. Higher asphaltene binders showed lower absorption into the rubber and truck tire rubber had higher absorption than that from automobiles. As temperature increased, the diffusion coefficients of the rubber increased. The study indicated that the activation energy for automobile tire rubber is greater than that from trucks.

**Hilde Soenen** from **Nynas in Sweden** described work to evaluate permanent deformation performance indicators for modified and unmodified binders and to select those indicators that relate best to permanent deformation in laboratory asphalt

mixture tests. Rheological characteristics, including the SHRP rutting parameter, zero shear viscosity and the recently proposed repeated creep test were used. The permanent deformation of the mixtures was determined using the French (wheel tracking) rut tester and a cyclic load triaxial compression test. Strict control of testing parameters was absolutely necessary in order to determine repeatable and reproducible binder performance indicators. For unmodified binders, all the performance indicators related binder properties to mixture properties but, for polymer modified binders, the behaviour was more complex and only carefully selected parameters determined from binders that had been exposed to appropriate thermal preconditioning could be used.

A study conducted for the Kentucky Transportation Cabinet on **evaluation of asphalt binders to determine the efficacy of using the AASHTO MP-1a specification** as an alternate means of specifying the low temperature grade was described by **Mike Anderson** of the **Asphalt Institute.** In this specification, the critical cracking temperature (CCT) is determined and compared to the required climatic grade. Four asphalt binder grades (PG 58-22, PG 64-22, PG 70-22, and PG 76-22) were provided for this study by five different producers and tests were conducted by the suppliers and the KTC laboratory. In about 25% of the cases for each laboratory, the data indicated that the low temperature grade will change when using the CCT instead of the M320 grading. About 10% of all comparisons indicated a warmer grade than expected and the same proportion indicated a colder grade. The data also indicated that the average CCT varied significantly amongst the '-22' binders.

**Dave Anderson** from **Penn State University** described **a new quality acceptance plan for PG graded asphalt binders,** which also embraces a payment protocol. The proposed scheme is intended to be reasonable to all the parties involved by balancing their individual risks. Acceptance of the asphalt binder is dependent upon the test results from the supplier and user so the potential effects of variability and bias must be carefully considered in the acceptance and payment protocol. A statistically-based acceptance and payment plan was developed, which considers laboratory specific testing variability and bias and is a different approach from the traditional percent within limit (PWL) method, which requires a large number of samples and testing.

## 3. Aggregate Structure in HMA

The Bailey method of aggregate grading design was described at the 2001 AAPT meeting and has been applied in a comprehensive study at **Louisiana State University** described by **Louay Mohammad.** Three different aggregate types were used, all with 12.5mm maximum sizes. The Bailey method is based on the packing characteristics of the aggregate, which allow different particle shapes to be accommodated within a rational approach representing an advance on the traditional use of a power law grading curve. Comparison of key HMA characteristics was made between those designed using the Bailey method and others using a normal power law approach. Results were presented from compaction and aging studies and from the measurement of mechanical properties in a range of tests that included wheel tracking, indirect tensile test and the semi-circular fracture test. Good performance was recorded for all the Bailey designed mixtures with improved resistance to rutting and lower permeabilities relative to the standard approach. There was a

recommendation to reduce the number of gyrations used in the standard compaction test for design.

**The effect of aggregate characteristics on the permanent deformation resistance of HMA** was described by **Samer Dessouky** from the **University of Illinois.** The objective of this research was to develop a constitutive model that incorporates features of microstructure and relates the model parameters to aggregate physical characteristics. Aggregate properties were determined using the Aggregate Imaging System (AIMS) and three different aggregates (gravel, granite and limestone) were evaluated. An elasto-viscoplastic model was developed to account for microstructure properties and which demonstrated that permanent deformation response is sensitive to aggregate characteristics. It can be used to select combinations and ranges of aggregate characteristics to provide desirable permanent deformation performance in an asphalt mixture.

The importance of the **coarse aggregate structure in offering resistance to rutting in HMA** was explored in a presentation by **Rey Roque** from the **University of Florida**. He described a conceptual, theoretical approach to evaluating this structure from the grading curve in the context of a contiguous network with a porosity less than 50% being formed to resist deformation. A Dominant Aggregate Size Range (DASR) was defined for the network and its porosity was proposed as a parameter to assess the suitability of a particular aggregate grading.

**4. HMA durability**

**The effects of moisture on the long-term aging of Polymer Modified Asphalt Cements** was reported by **Ioan Negulescu** of **Louisiana State University.** Pressure Ageing Vessel (PAV) tests in the absence and in the presence of water were conducted on a PG 76-22 binder. An HMA with a similar binder was sampled from a road after up to seven years service. The extent of oxidation and changes in the molecular mass of the asphalt cement components were estimated from other testing and dynamic viscoelastic properties were determined using a high torque instrument. A characteristic point of interest was the temperature at which $\tan\delta$ became unitary at a frequency of 10rad/s. Oxidative aging in the presence of water promoted an increase in the carbonyl content of aged samples but the high humidity aging reduced the extent of asphalt hardening. A correlation between laboratory and field results was obtained.

**Use of the SPT for moisture damage predictions in HMA** was presented by **Mansour Solaimanian** from **Penn State University.** A summary of NCHRP project 9-34 which involved using the SPT with the Environmental Conditioning System (ECS) to predict moisture damage was presented. Mixtures of known pavement performance made with a variety of aggregates were tested with the SPT-ECS and with the indirect tensile strength (TSR) and the Hamburg Wheel Tracking Device (HWT). Test results from the SPT-ECS indicated that complex modulus (E*) was more discriminating than the permanent deformation parameters, Flow Time ($F_T$ ) or Flow Number ($F_N$). Samples were conditioned with water from the ECS at 60$^o$C. Comparison of the modulus ratio of E*, before and after conditioning, predicted

moisture damage better than the TSR or HWT tests. Since the modulus ratio is a function of testing frequency, a minimum value of 0.75 at 10 Hz was suggested.

**A new method for characterizing the fatigue of asphalt mixtures** and to investigate the effects of oxidative aging of asphalt binders was presented by **Lubinda Walubita** from **Texas A&M University.** The method is known as the Calibrated Mechanistic Approach with Surface Energy (CMSE) and it uses data generated from various aggregate, binder, and HMA mixture tests to determine key parameters from which the mixture fatigue resistance can be predicted. Two Texas asphalt mixtures with different aging conditions, pavement structures, and climate conditions were used. The findings indicated that the mixtures could be expected to perform differently in the field depending on the actual pavement structure and climate. In general, aging of the asphalt binder reduces the projected fatigue life and ability to heal exponentially. The authors believe that the CMSE approach is a rational, promising methodology that provides reasonable results with low statistical variability.

The **new concepts of fracture energy and surface energy** were used in a project presented by **Eyad Masad** from **Texas A&M University** that was concerned with **moisture damage in HMA**. An understanding of the mechanisms of adhesive bond between aggregate and binder (from surface energy measurements) and the fracture of visco-elastic materials was shown to assist in assessing moisture damage.

**5. Theoretical predictions and observations of pavement performance**

**Rongzong Wu** from the **University of California at Berkeley** presented a **mechanistic model for reflective cracking in AC overlays.** The model was developed using non-local continuum damage mechanics and finite element analysis and was calibrated in the laboratory using flexural beam fatigue testing conducted on two mixtures with different binders under varying temperature and strain conditions. The calibrated model results matched reasonably with observations from a full-scale Heavy Vehicle Simulator test. The authors believe that the new model provides a promising tool for simulating reflective cracking in asphalt overlays.

**A viscoelastoplastic continuum damage model** was presented by **Shane Underwood** from **North Carolina State University.** The model was used to predict the performance of several asphalt mixtures tested by the FHWA's full-scale Accelerated Loading Facility (ALF). The four mixtures had different binders; unmodified, SBS-modified, ethylene terpolymer-modified, and terminal-blended crumb rubber-modified. Direct tension testing on cylindrical specimens (75 mm diameter, 150 mm height) was used to characterize linear viscoelastic behavior and constant strain rate monotonic tests at 5°C and 40°C were used to characterize visco-elastoplastic continuum damage behaviour. The principal finding was that the fatigue characterization of asphalt mixtures is complex and requires consideration of resistance to deformation, resistance to damage, and flow characteristics. The viscoelastoplastic continuum damage model provides a means to consider each of these.

**Bjorn Birgisson** from the **University of Florida** described the effects of viscoelastic stress redistribution on the cracking of asphalt mixtures. The mechanisms of bottom-

up and top-down cracking were discussed and the need for a relatively accurate, efficient modelling technique that could model cracking and the viscoelastic behavior of pavements was identified. It was concluded that the presence of significant tensile stresses at the top of the pavement layer results in the accumulation of dissipated creep strain energy (DCSE) with additional loading. Depending on both the DCSE limit of the asphalt mixture and the rate of DCSE accumulation at the top and bottom of the pavement layer, it is possible for the pavement to experience either mode of cracking.

**The effect of design and site factors on structural rutting of flexible pavements** was presented by **Syed Haider** of **Michigan State University** based on an investigation of the LTPP SPS-1 site. Because of incomplete data sets, the statistical analysis of LTPP data presents many difficulties. Rutting was found to occur mainly in the HMA layers of the site pavement, particularly where there were high asphalt contents compared to the mixture design or high air voids with low VFA. Fine grained subgrades in wet, non-freezing zones were most prone to exhibit rutting. Overall, pavement structural performance is improved by thicker pavement sections and in-pavement drainage.

**6. Construction issues**

A study of three warm mix processes for HMA was reported by **Brian Prowell** of **NCAT.** The systems were Aspha-min®, Sasobit® and Evotherm® and very good results were obtained for all of them, indicating that mixing and compaction temperatures can be reduced by as much as 50 $^{o}$C thus saving energy costs and environmental damage. In all cases, lower void contents resulted because of increased compactibility but, while this could lead to lower optimum binder contents, the authors recommend that the same value be used as for a normal HMA. The improved compaction lead to a slight increase in resilient modulus and no deterioration in rutting resistance relative to standard hot mix. Consequently, no increase in layer thickness is required in the pavement. No curing period is required and there was no change in short term aging characteristics. Since some additional residual moisture remains in the mixtures at the lower processing temperatures, there is concern about a possible increase in moisture damage in the long term. The paper describes laboratory and field tests and presents a summary of the chemistry involved in each system.

**Richard May** chaired the annual symposium session which addressed the topical issue of **Asphalt Concrete Quality Management using Percent Within Limits (PWL).**

**Chuck Hughes (Consultant)** discussed the various basic concepts of sampling product population and statistical estimates of quality measures and promoted the idea of balancing the risk between agency and contractor. **Mat Corrigan (FHWA)** provided the federal agency perspective and promotional efforts which encourage but do not require PWL. He discussed the necessity and benefits of using larger independent sample sizes. **Gale Page (Consultant)** described the efforts of a state agency in developing and refining a system, which was implemented in 2002 and reassessed in 2004. As a result, slight modifications were made to the tolerances on air voids and roadway density of fine-graded mixtures. **Carl Monismith (University of California at Berkeley)** presented an alternative approach to pay factors using

relative performance modeling for both fatigue and rutting to establish the impact on predicted service life. **James Schmidt (VP Engineering and Construction)** discussed the use of PWL specifications in warranty projects. He demonstrated both the success and limitations within the context of long term expectations as required by 15 and 20 year pavement performance warranties. **Adam Hand (Granite Construction)** illustrated the advantages and disadvantages of instituting QA specifications and offered some philosophical challenges in a contractor's perspective. This included the economic impacts of gearing up for increased testing responsibility in terms of rate of return on investment.

The session closed with a lively audience question and answer session that included a debate on independent sampling, verification testing and the costs of implementation.

**7. Next Meeting**

Next year's AAPT meeting takes place in San Antonio Texas from 11th to 14th March. Full details can be obtained from the web site at www.asphalttechnology.org. The site also provides general information about the association and how to contact the executive offices in Minnesota.

**Stephen F Brown**
**1st Vice President**
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