Bituminous Materials

- 05-0063 Hot-Mix Asphalt Moisture Damage as a Function of Air Void Size Distribution, Pore Pressure, and Bond Energy
- 05-0113 Development of Laboratory-Based Unified Permanent Deformation Model for Hot-Mix Asphalt Mixture
- 05-0130 Laboratory Evaluation of Semicircular Bending Tensile Strength Test for Hot-Mix Asphalt Mixtures
- 05-0174 Application of Dissipated Energy Concept in Fatigue Endurance Limit Testing
- 05-0199 Comparative Study of Stone-Matrix Asphalt Mixes with Different Stabilizers
- 05-0226 Numerical Modeling of Asphalt Mixture Site Permeability
- 05-0254 Two Approaches to Predict Fatigue Life of Hot-Mix Asphalt Concrete Mixtures
- 05-0330 Raveling of Asphalitic Mixes Due to Water Damage: Computational Identification of Controlling Parameters
- 05-0470 Development of Computational Model to Predict Damage-Induced Behavior of Asphalt Mixtures Under Cyclic Loading
- 05-0480 Thin Asphalt Film Behavior as Determined by Specially Designed Sliding Plate Rheometer
- 05-0555 Study of Fatigue Properties of Asphalt Mixtures with Fiberglass-Polyester Mat Reinforcements
- 05-0635 Aging Effect on Functional Characteristics of Bituminous Mixtures
- 05-0655 Rheological Changes in Crumb Rubber-Modified Asphalts with Long-Term Aging
- 05-0691 Creep and Recovery in Asphalt Modified by Radial Styrene-Butadiene-Styrene
- 05-0869 Characterizing Significant Increase in Hot-Mix Asphalt Moisture Retention Using Ground-Penetrating Radar: Case Study on Indiana US-41
- 05-0971 Low-Temperature Property Evaluation and Fragility of Asphalt Binders Using Non-Arrhenius Viscosity Temperature Dependency
- 05-1137 Effect of Filler on Aging Potential of Asphalt Mixtures
- 05-1201 Advanced Testing and Characterization of Interlayer Shear Resistance
- 05-1241 Relating Adhesion and Cohesion of Asphalts to Effect of Moisture on Laboratory Performance of Asphalt Mixtures
- 05-1346 Effect of Coarse Aggregate Morphology on Resilient Modulus of Hot-Mix Asphalt
- 05-1361 Initial Functional Performance of Stone Matrix Asphalt Placed on Virginia Roads in 2003
- 05-1510 Development of Florida Department of Transportation’s Percent Within Limits Hot-Mix Asphalt Specification
- 05-1633 Fast Nondestructive Field Test Method for Determination of Stiffness of Subsurface Layer in Thin Surface Hot-Mix Asphalt Pavement
- 05-1692 Comparison of Moisture Damage in Hot-Mix Asphalt Using Ultrasonic Acceleraated Moisture Conditioning and Tensile Strength Test Results
- 05-1830 Factors Affecting Specific Gravities of Aggregates
- 05-1841 Interpretation of Transverse Profiles to Determine Source of Rutting Within Asphalt Pavement System
- 05-1916 Numerical Simulation of Laboratory Tests on Asphalt: Comparison of Direct Tensile and Indirect Tensile Tests
- 05-2149 Mechanistic and Volumetric Properties of Asphalt Mixtures with Recycled Asphalt Pavement
- 05-2262 Simulation of Mode I and Mixed-Mode Crack Propagationin Asphalt Concrete Using Bilinear Cohesive Zone Model
- 05-2291 Performance-Based Algorithm for Selection of Superpave High-Temperature Performance Grade for Asphalt Binders
- 05-2294 Experimental Investigation of Anisotropy in Asphalt Concrete
- 05-2332 High-Temperature Rheological Properties of Asphalt Binders
- 05-2366 Mathematical Relationships for Various Methods of Measurement of Bulk Specific Gravity of Hot-Mix Asphalt
- 05-2394 Investigation of Fracture Resistance of Hot-Mix Asphalt Concrete Using Disk-Shaped Compact Tension Test
- 05-2406 Effects of Rejuvenating Agents on Recycled Aged Rubber-Modified Binders
- 05-2425 Measuring and Predicting Thermally Induced Stresses in Modified Asphalt Mixtures
- 05-2465 Inverse Gas Liquid Chromatography Study of Asphalt Composition and Oxidative Aging
- 05-2511 Laboratory Investigation of Mixing Hot-Mix Asphalt with Recycled Asphalt Pavement
- 05-2535 Comparison of Rutting Potential Resulting from Different Levels of Coarse and fine aggregate Angularity
- 05-2636 Verification and Improvement of the Rate of Asphalt Aging Simulated by AASHTO PP1-98 Protocol
05-2736 Characterization of Mix Fatigue Damage Process Using Three-Stage Weibull Equation and Tree-Based Model

05-2791 Development of Microfabric Discrete Element Modeling Techniques to Predict Complex Modulus of Asphalt-Aggregate Hollow Cylinders Subjected to Internal Pressure
Design and Construction Group Practical Papers

TRB’s Design and Construction Group committees have identified the following papers as containing information for possible immediate application by practitioners in their daily operations.

**Bituminous Materials**

05-0286 Test for Presence of Asphalt Antistripping Additive
05-0346 Use of Accelerated Loading Equipment for Determination of Long-Term Moisture Susceptibility of Hot-Mix Asphalt
05-0348 Guidelines for Prime Coat Usage on Low-Volume Roads
05-0389 Practical Procedure for Developing Dynamic Modulus Master Curves for Pavement Structural Design
05-0483 Asphalt Mix Design Method for Permeability
05-0508 Field Evaluation of Porous Friction Course for Noise Control
05-0537 Establishment of Precision of Rapid-Angle Measurement Device for Superpave Gyratory Compactors
05-1109 Influence of Truck Volume Distribution on Flexible Pavement Performance
05-1175 Performance Evaluation of Hot-Mix Asphalt Using Rotary Loaded-Wheel Testing
05-1285 Predicting Field Permeability from Testing Hot-Mix Asphalt Specimens Produced by Superpave Gyratory Compactor
05-1291 Evaluation of Gradation Effect on Dynamic Modulus
05-1309 Evaluation of Predicted Dynamic Modulus for Florida Mixtures
05-1422 Forensic Analysis of Slippage Cracking
05-1518 Investigation of CoreLok Device for Maximum, Aggregate, and Bulk Specific Gravity Tests
05-1655 Evaluation of Two Compaction Levels for Designing Stone-Matrix Asphalt Mixture
05-1766 Comparison of Thin-Lift Hot-Mix Asphalt Surface Course Mixes in New Jersey
05-1980 Comparison of Superpave and Marshall Mix Performance in Alabama
05-1981 Evaluation of Circular Texture Meter for Measuring Surface Texture of Pavements
05-2069 Design of a Specific Bituminous Surfacing for the Highest Orthotropic Steel Deck Bridge in the World: The Millau Viaduct
05-2089 Construction Quality, Temperature, and Rutting Effect on Top-Down Cracking Initiation
05-2112 Evaluation of Witczak Dynamic Modulus Prediction Model
05-2315 Critical Evaluation of Use of Superpave Volumetric Mixture Design Procedure for Modified Binders
05-2472 Control of Superpave Gyratory Compactor’s Internal Angle of Gyration: Utah Department of Transportation Experience
05-2566 Road to Quiet Neighborhoods in Arizona
05-2714 Laboratory Characterization and Empirical Prediction of Dynamic Modulus of Superpave Mixtures
05-2725 Refinement of Hot-Mix Asphalt Ignition Method for High-Loss Aggregates
Title: “HMA Moisture Damage as a Function of Air Void Size Distribution, Pore Pressure and Bond Energy”

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ABSTRACT

The relationship between hot mix asphalt (HMA) moisture damage, air void structure, pore pressure, and cohesive and adhesive bond energies was investigated in this study using mixes with two different aggregate types and varying gradations. Moisture damage was evaluated using parameters derived based on the principles of fracture mechanics. Air void distribution was analyzed using a probabilistic approach with the assistance of X-ray computed tomography and image analysis techniques. Statistical parameters of the air void distribution were related to permeability, which controls the ability of the water to infiltrate into and drain out of the mix. The air void distribution was found to significantly influence moisture damage. A “pessimum” air void size was found at which the moisture damage was maximum. The cohesive and adhesive bond energies of the mix were calculated based on experimental measurements of aggregate and asphalt surface energies. These measurements were used to explain the difference in moisture damage between the two mixes that were used in this study.

KEY WORDS: Moisture, Damage, Void Distribution, Microstructure, Pore Pressure
Development of Laboratory Based
Unified Permanent Deformation Model
for HMA Mixture

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ABSTRACT

Conventionally, the resistance of hot mixed asphalt (HMA) mixtures to permanent deformation is measured by repeated load triaxial (RLT) or repeated shear at constant height (RSCH) testing. The data from these tests have been treated as independent data sets in the prediction of rutting potential in HMA layers. This paper presents a unified permanent deformation model using response measurements made from both tests. The new model quantifies the accumulated permanent shear strain as a function of number of load cycles and factor of safety (FOS). The factor of safety is defined in the q-p space and is evaluated based on the applied stress ratio (q/p), deviatoric stress (q), and triaxial compression strength properties (cohesion and angle of internal friction). A good correlation was found between the cumulative permanent shear strain and the FOS level irrespective of the stress conditions and the type of test used.

Keywords: Permanent Shear Strain, Drucker-Prager, Failure Envelope, Factor of safety, Unified model, Triaxial Strength Test, Repeated Load Triaxial, Repeated Shear Constant Height.
LABORATORY EVALUATION OF SEMI-CIRCULAR BENDING TENSILE STRENGTH TEST FOR HMA MIXTURES

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ABSTRACT

This paper presents the results of a laboratory study in which the Semi-Circular Bending (SCB) test was evaluated for its suitability to characterize the tensile strength of hot-mix asphalt (HMA) mixtures. Analytical and numerical simulations were employed to interpret the experimental results. Indirect tensile test (IDT), a standard test method of AASHTO and ASTM, was used to compare with SCB test. The results from this study indicated that SCB was capable to provide consistent results with reasonable variability. In addition, SCB exhibited several advantages over IDT in characterizing HMA mixtures, such as testing mixtures at elevated temperatures.

INTRODUCTION

Semi-circular bending (SCB) test for HMA mixtures has drawn more and more attention in US since it was introduced to the asphalt community in US by the Europeans and South African researchers [1–4]. The semi-circular test was originally used to characterize the fracture resistance in rock mechanics [5–9]. It has been used to characterize the tensile strength properties by van de Ven and Smit [1] and fatigue resistance properties by Kran et al. [2] in HMA mixtures. Mull et al have been using SCB test on notched specimens to evaluate the fracture resistance of asphalt mixtures through the J-integral [10].

Figure 1 illustrates a typical setup for SCB test. It consists of two supporting rollers at the straight (bottom) edge and a loading roller at the mid-point of the semi-circular arch. A loading strip with an arc conforming to the specimen similar to the indirect tensile strength test setup and two flat supporting strips were reported by some previous researchers [1 – 3]. Van de Ven and Smit recommended rollers as loading and supporting in order to reduce frictions [1]. The spacing between the two supports has been reported to be 0.8 times of the diameter in references [1 – 4]. Monotonic or cyclic load is applied through the loading strip during an SCB test. The advantages of SCB test are obvious. The test setup is very simple: virtually any laboratory loading frame can be modified to conduct basic SCB test. In addition, the specimens can be easily prepared.
Application of Dissipated Energy Concept in Fatigue Endurance Limit Testing

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ABSTRACT

A fatigue endurance limit has been postulated to exist in HMA pavement performance. It cannot be observed and studied using traditional phenomenological approaches as seen by the totally different fatigue behavior at low strain/damage levels close to the fatigue endurance limit. The Ratio of Dissipated Energy Change (RDEC) succeeds in defining and investigating the existence of a fatigue endurance limit with a unique relationship between Plateau Value (PV) and fatigue life (Nf), regardless of strain/damage levels, mixture types, loading modes, and other testing conditions.

Determining a fatigue endurance limit requires extraordinary long time to conduct a test. This paper applied the PV to the study of a fatigue endurance limit to validate a shortened laboratory testing procedure. Statistical analysis shows that the shortened test can predict the PV with sufficient accuracy. By applying the validated relationship between PV and Nf, the extremely long fatigue life under low strain/damage condition can be predicted without conducting millions of loading cycles.

Key Words: Dissipated Energy, Fatigue, Endurance Limit, Ratio of Dissipated Energy Change (RDEC), Plateau Value (PV), Statistical Analysis
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ABSTRACT
Fibers are conventionally used as stabilizers in the construction of Stone Matrix Asphalt (SMA) pavements. These fibers are not manufactured in India and are imported from Germany. Naturally occurring jute fibers were coated with low viscosity binder and were used in the present study as an alternative to the patented fibers. Use of crumb rubber modified binder (CRMB) is also investigated as stabilizer in SMA mixes. The performance of these mix were evaluated by conducting draindown, moisture susceptibility test, rutting test, durability test, fatigue life and skid resistance tests. The results of mix prepared with indigenously available fibers are comparable to the patented fibers. Mix prepared with modified binder alone provides encouraging results. However, skid resistance of beams after creep tests, measured by British Pendulum was less in mix with CRMB than that in fiber mix. The reason for low value of skid resistance in rubber modified mix could be quick abrasion of rubber particles during creep tests on beams.
Numerical Modeling of Asphalt Mixture Site Permeability

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ABSTRACT

The permeability of an asphalt mixture pavement is an important mechanical parameter. For the case of hot mix asphalt (HMA), it is often desirable to limit the permeability to a minimum value in an effort to reduce the damage to the pavement resulting from moisture damage and oxidation of the binder. Conversely, for a porous asphalt mixture a minimum value for permeability may be specified to allow for surface water drainage. The measurement of permeability may be undertaken either in a laboratory or on site, using either a falling head or constant head arrangement. One of the main inaccuracies in undertaking site permeability testing is the assumption that the water flows directly downwards from one layer to the next. In reality the direction of water flow is determined by the gradient of the potential field which in turn is dependent on the pressure head applied, saturation of the layer, radius of the permeameter and permeability of the layer. This paper quantifies the inaccuracy involved in assuming direct vertical flow by utilizing numerical techniques to model the flow and determine correction factors. It also presents a procedure enabling permeability to be determined from a site permeability test for a layer of infinite depth, suitable for the sub-grade or a thick asphalt mixture layer. The hydrostatic potential plots and resulting flow paths which can be expected from typical scenarios are investigated. The aim of the paper is to improve the understanding of the basic flow mechanism involved in site permeability testing and the correlation between laboratory and site results.
Two Approaches to Predict Fatigue Life of Hot Mix Asphalt Concrete Mixtures

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Two Approaches to Predict Fatigue Life of Hot Mix Asphalt Concrete Mixtures

ABSTRACT

Over the past decade the Texas Department of Transportation (TxDOT) focused research efforts on improving HMAC mixture design to preclude rutting in the early life of the pavement. These stiff mixtures may be susceptible to long-term fatigue cracking in the pavement structure or if the binder stiffens excessively due to oxidative aging. To address this concern, TxDOT initiated a research study with the primary goal of evaluating and recommending a HMAC mixture fatigue design and analysis system to ensure adequate overall mixture performance in a particular pavement structure under specific environmental and traffic loading conditions. A secondary goal of the research was to compare the fatigue resistance of commonly used TxDOT HMAC mixtures to include the investigation of the effects of binder aging on fatigue performance.

In this paper, a mechanistic empirical (ME) fatigue analysis approach and a calibrated mechanistic approach with surface energy (CMSE) measurements are comparatively evaluated based on one common TxDOT HMAC mixture. Results on the effects of aging on fatigue performance for both of the aforementioned fatigue analysis procedures are also reported. Although preliminary results were comparable, the continuum micromechanics based CMSE approach exhibited greater flexibility and potential to account for most of the fundamental HMAC material properties that affect HMAC pavement fatigue performance. These properties include fracture, binder aging effects, healing, visco-elasticity, anisotropy, crack initiation and crack propagation. The variability of the CMSE results was relatively low as compared to the ME approach. For the materials and test conditions considered, binder aging reduced the HMAC mixture resistance to fracture and its ability to heal, and this factor must therefore be taken into account during mixture design and analysis.

Based on the laboratory test results, statistical analysis, and relative comparison of each analysis procedure, the CMSE fatigue test protocol was preferred over the ME approach for predicting HMAC mixture fatigue life.

Keywords: Asphalt, fatigue, aging, fracture, microcracking, healing, environment, temperature, mechanistic empirical, calibrated mechanistic, surface energy, anisotropy, dissipated pseudo strain energy
Raveling of Asphaltic Mixes Due to Water Damage: Computational Identification of Controlling Parameters

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ABSTRACT

Open graded asphalt mixes are often used for wearing surfaces of roads that are exposed to large amounts of rainfall throughout the year. The high permeability of the mix guarantees a fast drainage of the water away from the surface, thus increasing the road safety. However, the large amounts of water that flow through the asphalt have a negative effect on the material characteristics of the mastic and cause debonding of the aggregates from the mastic, called raveling. In order to understand and quantify the physical processes and the mechanics leading to raveling, an extensive, experimental and analytical, investigation is being undertaken at Delft University of Technology in the Netherlands. One of the goals of the investigation is the development of the Finite Element tool RoAM (Raveling of Asphalt Mixes), capable of simulating the gradual development of damage throughout asphalt mixes due to water infiltration. Desorption, diffusion and dispersion are included as fundamental processes. This paper shows the results of a computational analysis to identify the impact of the different water damage phenomena, and presents the results of a sensitivity study of the relevant parameters. From the computational analyses it is concluded that simulation of water damage in asphaltic mixes is possible if the desorption characteristics as well as the diffusion and the dispersion coefficients can be determined.
DEVELOPMENT OF A COMPUTATIONAL MODEL TO PREDICT DAMAGE-INDUCED BEHAVIOR OF ASPHALT MIXTURES UNDER CYCLIC LOADING

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Word Counts

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ABSTRACT
Fatigue cracking and failure of inelastic heterogeneous asphalt mixtures is modeled computationally by using the finite element method. The model incorporates elastic behavior of the aggregate particles, viscoelastic behavior of the asphalt matrix, and time dependent fracture both within the asphalt matrix and along boundaries between matrix and aggregate particles. Rate-dependent progressive cracking up to failure is implemented by incorporating a nonlinear viscoelastic cohesive zone model. The resulting composite model is used to simulate the response of several different asphalt mixtures, which are composed of different mixture constituents resulting in differing damage evolution characteristics. The effects of surface energy properties on fracture and failure are also implemented into the finite element model. Computational simulations demonstrate that variations in fundamental material properties and surface energy related damage characteristics significantly influence the fatigue behavior of the asphalt mixtures. The approach proposed herein can be employed to predict complex fatigue behavior of asphaltic pavement by considering only fundamental material properties and fracture/damage characteristics of mixtures and without recourse to expensive laboratory fatigue tests.

Key Words: Asphalt Mixtures, Fatigue, Fracture, Modeling, Finite Element Method
Thin Asphalt Film Behavior as Determined by Specially Designed Sliding Plate Rheometer

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ABSTRACT
A specially designed sliding plate viscometer fixture was built to investigate the physical properties of thin asphalt films between aggregate plates. Viscosities were measured using the specially designed fixture in an Instron instrument. The properties of thin asphalt films are not predictable from thick (1.0 mm) films on steel plates, which are used in the current Superpave® specification. Rheological properties of thin films (20 micron thick) of neat SHRP asphalt AAD-1, PAV-aged AAD-1 (20 hours at 100°C), and decanedicarboxylic acid-modified AAD-1 were determined at 25°C using the specially designed fixture. Atomic force microscopy (AFM) was applied to investigate the surface roughness profiles of different substrates including glass and aggregate plates. It was found that the roughness of the glass plate was only 20nm disparity in height, approximately one one-thousandth of the film thickness being studied. The AFM profiles of the polished aggregate plates were used in the study showed that they had a surface roughness of approximately two microns, i.e., approximately ten percent of the film thickness. The results showed that thin film physical properties are dependent upon asphalt composition, aggregate type, oxidation, and asphalt modification. Separately, preliminary results from a water soaking experiment show that the specially designed fixture may be a useful tool for the characterization of moisture damage.

INTRODUCTION
Attention has been so largely focused on the bulk properties of asphalts that the polarizing effect of mineral surfaces on the properties of these materials in the immediate vicinity of the mineral surface has been overlooked. The asphalt in this interphase region can be oriented and highly structured. Evidence for abnormally high viscosity in the immediate vicinity of a solid surface is extensive. Unfortunately, many of the experiments used to evaluate the interfacial region involve the relative motion of two solid surfaces in close proximity with each other, and hence, are open to criticism on the basis of possible asperities of the surfaces. In 1933, Talmud found that a monomolecular layer on a solid surface had a profound effect on the compressive strength of a paraffin in a layer 40,000A thick (1). A mass of sand particles coated with the paraffin had a compressive strength of 12 kilograms per square centimeter. However, if a monolayer of amyl alcohol was first adsorbed on the sand, the mixture showed a compressive strength of 28 kilograms per square centimeter. A similar effect on silica gel was observed by adsorbing paratoluidine on the surface of the silica.

Marades and de Waele (2) reported that thin films of liquid at surfaces had special properties due to orientation of the molecules from surface adhesion forces which imparted a form of rigidity to the liquid to a depth beyond the monomolecular layer held to the surface by the London-Van der Waal’s forces. The depth of penetration of surface adhesion forces into a liquid is not known. Marades and de Waele invoked the concept of diachysis, by which it is supposed that the molecules of the liquid behave like a chain of iron filings attached to the pole of a magnet, and so transmit the surface forces to a considerable depth.

Fundamentally, it is important to ascertain how the physical properties of such submicroscopic structures differ from those of the bulk materials, and in particular the size dependence of this variation. Results of the direct measurement of interaction forces, such as the van der waals forces between surfaces and liquids, are well described by continuum theories only at large distances; however, they fail drastically when two surfaces are closer than a few molecular diameters of the intervening liquid molecules. This effect is due to the ordering induced into discrete liquid molecular layers brought about by the approach of the second surface, which leads to a non-uniform variation of the liquid density in such thin films, and to an oscillatory force law.

It is proposed that for films whose thickness exceed 1 millimeter, both their static and dynamic behavior can usually be described in terms of their bulk properties; but as films become thinner, their behavior becomes progressively more solid-like and can no longer be described, even quantitatively, in terms of bulk properties. In 1957, Mack used an empirical approach to study asphalt-aggregate interfaces at film thicknesses between 20 and 70 microns (3). He concluded that the surface molecules orient themselves in the direction of their polarization, and that this causes a similar alignment of the molecules.
Study on the Fatigue Properties of Asphalt Mixtures with Fiberglass/polyester Mat Reinforcements

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Study on the Fatigue Properties of Asphalt Mixtures with Fiberglass/Polyester Mat Reinforcements

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ABSTRACT

Asphalt pavements are widely used due to their advantages such as low cost and comfortable ride, etc. However, early damage to asphalt pavements, especially cracking, is becoming a more and more serious problem as load and vehicle counts have increased. Fatigue cracks in asphalt pavement are one of the most significant factors in early pavement damage. Hence, improving the fatigue performance of asphalt pavements has become a research topic receiving increased attention. This paper presents a laboratory study of the fatigue properties of asphalt mixtures with and without a fiberglass/polyester mat reinforcement. In this paper, a commonly used dense-graded asphalt mixture was tested in beam fatigue using a UTM (Universal Testing Machine) system. The fatigue life equation expressed by strain is analyzed and developed in this paper. At the same time, the fatigue testing data are analyzed by an energy dispersion method, and a fatigue testing equation relating cumulative dissipated energy and cycles is established. Using fatigue testing research, this paper demonstrates that an energy dispersion method is good for evaluating and predicting the fatigue properties of both asphalt mixtures and asphalt mixtures containing fiberglass/polyester reinforcing mats. The mixtures containing the fiberglass/polyester mats demonstrate excellent fatigue performance in this evaluation.

KEY WORDS: Fiberglass/polyester mat; Asphalt mixture; Energy Dissipation; Fatigue properties
Ageing Effect on Mechanical Characteristics of Bituminous Mixtures

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ABSTRACT
Traditionally, asphalt concrete requirements are based on recipe specifications for bituminous mixtures which do not consider changes in the mechanical properties of materials over time. It is known that a considerable hardening of bitumen occurs with age which must be considered in the evaluation of bituminous materials. In asphalt concrete evaluation work, such as pavement design or end-product contracts, the age of asphalt materials may have a considerable impact on the outcome. This investigation was undertaken to aid the development of a performance specification based on the structural functional properties of asphalt concrete. Asphalt concrete properties of cores from various road sections were evaluated with respect to changes in stiffness and creep properties over several years with an emphasis on the hardening during the early life of the pavement. Relationships between mechanical properties of bituminous mixtures and age have been established. The results make it possible to take into account the effect of ageing during pavement evaluation and when characterizing mixes with respect to ageing properties. It was shown that stiffness modulus and creep deformation of bituminous layers can change significantly during the early life of the pavement and this change should be considered in performance specifications and pavement analysis.
Rheological Changes in Crumb Rubber-Modified Asphalts with Long-Term Aging

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ABSTRACT
SHRP asphalts AAD-1 and ABD were mixed with crumb rubber and their rheological properties were studied as a function of long-term oxidative aging. Master curves were constructed by shifting the aging time-frequency data to assist in the interpretation. The results show that the stiffness effect of crumb rubber to asphalt AAD-1 is higher than to asphalt ABD. Addition of crumb rubber to both asphalts AAD-1 and ABD reduced viscosity buildup with aging. In addition, rubber modification dramatically increased the elasticity of both asphalts. It is possible that rubber modification will improve rutting resistance because of the increased viscosity and elasticity at high temperatures and improve thermal cracking and fatigue resistance by either decreasing viscosity or lowering viscosity buildup with aging at low temperatures.

INTRODUCTION
Despite a relatively large amount of work done in the past to investigate the aging behavior of conventional asphalts and/or asphalt-aggregate hot mixes, little information exists about the long-term oxidative aging behavior of crumb rubber modified asphalt binders. Furthermore, little work has been carried out on the effects of shear frequency on the microstructure breakdown curve of rubberized asphalts during rheological measurements. This is presumably due to the difficulty of obtaining a wide enough frequency and strain range together in one apparatus.

In recent years, polymer modification has been done to improve asphalt performance at pavement service temperatures. Field studies have shown that crumb rubber modification of asphalts can improve the binder properties, and improvements have been observed in field studies of crumb rubber modified pavements (1-8). The use of crumb rubber modifiers with asphalt binders seems to enhance the fatigue resistance, as illustrated in a number of studies (9-17). The improved performance of asphalt rubber pavements compared with conventional asphalt pavements has resulted from improved rheological properties of the asphalt-rubber binder.

Naturally occurring carboxylic acids in asphalt have been observed to degrade (digest) finely ground crumb rubber (18, 19). When the acids were removed, the asphalt no longer digested the rubber. When the same naturally occurring (or some synthetic) acids were added to an acid-free asphalt, the crumb rubber became digestible. There is no obvious mechanism or evidence that the carboxylic acids alone will cause degradation of crumb rubber. Hence, it is logical that the acidic function assists the active species in the digestive process. While the mechanism(s) of degradation of crumb rubber are still unknown, the beneficial effects of crumb rubber in virgin asphalt are well known. However, a fundamental question to be answered is: Are the beneficial effects of crumb rubber modification maintained during the aging process?

It is hypothesized that the acids in asphalt binders will digest the crumb rubber. It is believed that a physico-chemical interaction occurs between the asphalt and the crumb rubber alters the effective size and physical properties of the particle, thus influencing pavement performance properties. Long-term aging is a consequence of progressive oxidation of the in-place mixture in the field. Although, in general, aging results in stiffening (hardening) of the mixture, which may be beneficial from the viewpoint of load distribution and permanent deformation, it can also result in embrittlement and loss of durability.

The objective of this paper is to study the effect of short-term and long-term aging on the CRM modified acid-containing asphalt binders via rheological measurements using dynamic shear rheometer. Meeting this objective could provide a better understanding of the effects of crumb rubber particles on the physical, chemical, and rheological properties of asphalt binders so that their performance in the field can be more accurately predicted.

EXPERIMENTAL
Two Strategic Highway Research Program (SHRP) asphalts, AAD-1 and ABD, were selected for this study. Asphalt AAD-1 has high sulfur (>6%) and high asphaltene content (20.5%), whereas the sulfur content of ABD is low (<2%) and it also has low asphaltene content. Asphalt ABD is higher in nitrogen (1.2%) and oxygen (1.2%) than AAD-1. Asphalt AAD-1 is a less compatible (gel-type) asphalt and ABD
ABSTRACT

Creep and recovery were studied in base asphalt (200/300 Pen grade) modified with different amounts of radial styrene-butadiene-styrene (SBS) copolymer. The attempt of this article is the comparison of estimated zero-shear viscosity (ZSV) from both parts of creep and recovery curve with directly measured ZSV (ARES viscosity) for binders modified with various amounts of SBS. Various time durations of creep and recovery were examined (other than the prescribed method for the repeated creep and recovery binder test of 1 second loading and 9 second unloading). The impact of waiting time between tests on creep compliance and zero shear viscosity was investigated; and, the influence of stresses (ranging from 25 Pa up to 5 kPa), which is also outside the prescribed stress levels in repeated creep and recovery binder test (30 to 300 Pa), was also studied. Both the steady state and viscous compliances of the materials were calculated and compared with the binders’ viscosities measured in an ARES rheometer. The viscous compliance that was needed for the evaluation of the creep stiffness parameter (suggested by researchers to replace the existing parameter for rutting evaluation) was investigated as well.

Estimated ZSV and steady-state compliance ($J_1$) were stress dependent above stress level of 25 Pa. This is an unexpected result, as $J_1$ should be stress independent. This may point to the non-linear region in measurements above 25 Pa, but most probably to the fact, that the steady-state was not reached, especially for short cycles of creep and recovery.

INTRODUCTION

Zero-shear-viscosity received lots of attention by researchers in the past years as a predictor of the rutting potential of bituminous binders, especially modified ones (Binard et al. [1]). Precise measurement techniques for ZSV were described in Visscher et al. [2] and Desmazes et al. [3]. ZSV from oscillation and repeated creep tests was compared in Visscher et al. [4].

A number of researchers have questioned the validity of the Superpave binder specification parameter $\frac{G^*}{\sin \delta}$. Hu and coworkers [5] proposed the use of dynamic creep measurement for the study of high-temperature performance in binders. Studies by Stuart et al. [6] and Bouldin et al. [7] indicated that the frequency (10 rad/s) did not properly capture the properties of the viscoelastic material.
CHARACTERIZING A SIGNIFICANT INCREASE IN HMA MOISTURE RETENTION USING GROUND PENETRATING RADAR: A CASE STUDY ON INDIANA US – 41

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January 9 – 13, 2005
ABSTRACT

Moisture retention is a source of distress for asphalt pavements. This distress can lead to rutting, cracking, raveling, and potholes. Pavement distress is an important factor in pavement rehabilitation planning; consequently, information on the locations of sections of water retaining asphalt pavements is valuable. A section of US-41 exhibited signs of premature rutting not caused by shear failure. Ground penetrating radar was chosen as a non-destructive method to characterize water retention in the pavement. An empirical relationship between high dielectric constants and pavement stripping was observed.

INTRODUCTION

Moisture retention is a source of distress for asphalt pavements. This distress can lead to rutting, cracking, raveling, and potholes. Pavement distress is an important factor in pavement rehabilitation planning; consequently, information on the locations of sections of water retaining asphalt pavements is valuable. The Indiana Department of Transportation (INDOT) manages a highway network system consisting of approximately 11,000 miles of Interstates, US Roads, and State Routes. A section of one of the US highways, US-41, was showing signs of premature distress including rutting in the left wheel path. An analysis of the pavement was conducted including an evaluation of performance of the pavement surface, and a nondestructive characterization of moisture retention.

The performance of the pavement surface was evaluated using data from international roughness index (IRI), friction analysis, pavement profile (Rut), and pavement quality index (PQI).

Ground penetrating radar (GPR) was selected as a tool for non destructive evaluation for characterization of water retention. GPR has been successfully utilized for both thickness evaluation (1) and forensic analysis (2) for a number of years; consequently, the physical properties governing GPR are well known. The physical relationship between dielectric constant and moisture content has been well established for soils (3,4), and reservoir rocks(5,6). The dielectric constant value of a pavement is one of the physical properties governing the behavior of GPR; therefore, dielectric constant values are well documented for both asphalt and concrete pavements. (7). Published dielectric constant values include both saturated and dry samples (8).

Mixture models and other empirical relationships have been developed describing the effect of moisture content on the dielectric constant of pavements and base materials. An empirical relationship using least squares regression was developed where the dielectric constant of an asphalt pavement is estimated by five parameter linear equation in which moisture content, percent water by volume is one of the parameters. (9). Dielectric mixture models were evaluated and compared with GPR dielectric values for structural concretes (10), and for base materials (11). Changes in pavement moisture content are detectable with GPR due to changes in the dielectric constant. The objective of this study was to utilize GPR for characterization of pavement water retention.

PRINCIPLES OF ASSESSING MOISTURE CONTENT USING GPR
Low Temperature Property Evaluation and Fragility of Asphalt Binders Using Non-Arrhenius Viscosity Temperature Dependency

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3933 + 5 FIGURES (250*5 = 1250) + 7 TABLES (250*7 = 1750) = 6933
Abstract: The rotational viscosities of different asphalt binders were determined at temperatures between 80°C to 185°C. Viscosity-temperature dependence of asphalt binders was described using the Vogel-Tammann-Fulcher (VTF) and the William-Landel-Ferry equations. The Vogel temperature ($T_v$) and the glass transition temperature ($T_g$) of different asphalt binders were determined by fitting experimental values of viscosity at different temperatures using the two equations. For asphalt binders, the difference between $T_v$ and $T_g$ is around 40K. Effects of asphaltene, aging, modification and polymer content on these temperatures were evaluated. As the asphaltene content increases, both temperature increases. Different polymers have shown different effects on these temperatures. The values of the Vogel and glass transition temperature were correlated with the Critical Cracking temperature ($T_{cr}$) determined using bending beam rheometer and direct tension tests. The results suggest that the correlations between $T_v$, $T_g$ and $T_{cr}$ may be used to determine $T_{cr}$ using the rotational viscosity results tested at high temperature.
EFFECT OF FILLER ON THE AGING POTENTIAL OF ASPHALT MIXTURES

Abstract
In this work the effect filler has on the aging of bitumen is analyzed, but incorporating the filler in volume and not in weight. The UCL method is used as the process of accelerated aging and new direct tensile test is used to determine the toughness of the aged mixture and, thus, to assess the effect the filler has.

All the tests performed for this paper have shown the protective effect of the fillers used. The new direct tensile test developed by the Road Research Laboratory of the Technical University of Catalonia, allows to observe how an increase of filler produces the increase of the breaking load and the decrease of the maximum deformation, observing that the hydrated lime tends to stiffen the mixture less and make it less brittle than calcium carbonate.

In order to minimize the effect of aging on bitumen, the filler content proposed must be 20 or 30% less than the content recommended in conditions when there is no aging, so that when the mixture ages the mastic is able to build up the maximum energy possible.

1. INTRODUCTION

The processes that the binder undergoes when aging, which cause its progressive hardening, may damage its aggregate-bitumen adhesive qualities and, thus, the cohesion of the mixture.
ADVANCED TESTING AND CHARACTERIZATION OF INTERLAYER SHEAR RESISTANCE

by

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ABSTRACT

The performance of multi-layered pavement systems strongly depends on interlayer bonding. Thus, to guarantee good bonding, during pavement construction or overlay, tack coats (also indicated as bond coats) are usually applied at the various interfaces. The effectiveness of the tack coat can be assessed by making use of several devices which are arranged by different laboratories to evaluate interlayer shear resistance. The paper shows how interlayer shear resistance may be evaluated through ASTRA device. The ASTRA results, expressed in terms of maximum interlayer shear stress (τ_{peak}), highlight the effects of various influence parameters such as type of interface treatment, curing time, procedure of specimen preparation, temperature, applied normal load. Moreover, the paper compares the τ_{peak} results obtained by two different shear test devices: the ASTRA tester designed and developed in the Università Politecnica delle Marche (Italy) and the LPDS tester created by EMPA (Swiss Federal Laboratories for Materials Testing and Research). Both test methods provide different but comparable results showing the same ranking of shear resistance for different interface treatments.
TITLE:
Relating Adhesion and Cohesion of Asphalts to Effect of Moisture on Asphalt Mixtures’ Laboratory Performance

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Relating Adhesion and Cohesion of Asphalts to Effect of Moisture on Asphalt Mixtures’ Laboratory Performance
By Kunnawee Kanitpong and Hussain U. Bahia

ABSTRACT
Anti-stripping additives and polymer modifications are two commonly modifiers used to improve the fundamental properties of asphalt binders as related to the performance of asphalt mixtures. Adhesion and cohesion are also two important related properties of asphalt binder that can affect the asphalt mixture performance before and after water conditioning. This study is to quantify the effect of anti-stripping additives and polymers on the cohesion and adhesion of binders and to relate the effects to the performance of mixtures measured in laboratory before and after water conditioning. The performance of asphalt mixtures measured includes the Indirect Tensile Strength Test, the Uni-axial Compression Permanent Deformation Test, and the Hamburg Wheel Tracking Test. Asphalt mixtures were produced with different modified binders and with two aggregate types. The binders were modified using anti-stripping additive, polymers, chemically treated and oxidization methods. Granite and Limestone were selected as two types of aggregate sources. The results indicate that the performance of asphalt mixtures is highly dependent on modification techniques and water conditioning. The overall performances of polymer-modified mixtures are more desirable than those of unmodified mixtures and of mixtures modified with anti-stripping additives. Polymers are found to improve the rutting performance, the adhesion and the cohesion of asphalt binder. On the other hand, the anti-stripping additive can improve only the adhesion without changing the other properties. The results of this study also illustrate that the adhesion and cohesion of asphalt binder are good indicators to predict the performance of asphalt mixtures in the laboratory when conditioned with water.

Key Words: anti-stripping additives, polymer, modifier, adhesion, cohesion, moisture damage
Effect of Coarse Aggregate Morphology on the Resilient Modulus of Hot Mix Asphalt

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ABSTRACT

Resilient modulus $M_r$ measured in the indirect tensile mode as per ASTM D 4123 reflects effectively the elastic properties of asphalt mixtures under repeated load. The coarse aggregate morphology quantified by angularity and surface texture properties affects resilient modulus of asphalt mixes, however, the relationship is not yet well understood due to the lack of quantitative measurement of coarse aggregate morphology. This paper presents findings of a laboratory study aimed at investigating the effects of the major component material properties on the resilient modulus of asphalt mixes with the coarse aggregate morphology considered as the principal factor. With modulus tests performed at a temperature of 25°C, using coarse aggregates with more irregular morphologies improved substantially the resilient modulus of asphalt mixtures. An imaging based angularity index was found to be more closely related to the resilient modulus than an imaging based surface texture index as indicated by a higher value of correlation coefficient. The stiffness of the asphalt binder also had a strong influence on modulus. When the resilient modulus data were grouped based on the binder stiffnesses, the agreement between the coarse aggregate morphology and the resilient modulus was significantly improved within each group, and the resilient modulus consistently increased with the increments of both the angularity and surface texture indices for all the groups. While the changes in aggregate gradation did not significantly affect the relationship between the coarse aggregate morphology and the resilient modulus, decreasing the nominal maximum aggregate size from 19 mm to 9.5 mm indicated an increasing positive influence of aggregate morphology on the resilient modulus of asphalt mixes.

Keywords: Resilient Modulus, Asphalt Mixes, Coarse Aggregate Morphology, Asphalt Stiffness, Gradation, Nominal Maximum Aggregate Size
INITIAL FUNCTIONAL PERFORMANCE OF STONE MATRIX ASPHALT PLACED ON VIRGINIA ROADS IN 2003

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ABSTRACT

In 2003, Virginia launched an effort to achieve longer lasting asphalt concrete surfaces on interstate and high-volume primary routes. Instead of the Virginia Department of Transportation’s (VDOT) conventional surface mixes (i.e., Superpave-designed SM 9.5 and SM 12.5), selected projects in seven of VDOT’s nine districts used stone matrix asphalt (SMA). The expanded use of SMA included the successful installation of pavements using multiple gradations (SMA 9.5, 12.5, and 19.0) and binders (PG 70-22 and PG 76-22). In this effort, many contractors (and VDOT personnel) used a very complicated hot-mix asphalt technology for the first time, and nearly without exception, they used it successfully.

This paper documents the initial functional performance (i.e., roughness, friction, and texture) of SMA pavements placed during VDOT’s 2003 paving season. An overall review suggests that the pavements are meeting VDOT’s expectations. Ride quality is generally good, and there is good reason to believe it will improve as contractors gain more experience. Isolated friction problems were corrected quickly under traffic, and recent specification revisions should address a tendency to include too much liquid asphalt in some mixes. The wearing away of the asphalt film under traffic also helps to improve or eliminate glare. Finally, in spite of a minor loss of texture under traffic, the excellent overall texture of SMA should provide for very safe, low-noise surfaces.
Development of the Florida Department of Transportation’s Percent Within Limits Hot-Mix Asphalt Specification

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ABSTRACT
The Florida Department of Transportation, herein referred to as the Department, adopted a percent within limits approach in July 2002 for the acceptance and payment of all hot-mix asphalt. Contractor’s test data, after being verified by the Department, is used to calculate payment. Acceptance and payment for dense-graded Superpave mixtures is based on the following five asphalt material properties: 1) roadway density, 2) percent air voids, 3) asphalt binder content, 4) percent passing the No. 8 sieve, and 5) percent passing the No. 200 sieve. Acceptance and payment for open-graded friction course mixtures is based on the following four asphalt material properties: 1) asphalt binder content, 2) percent passing the 3/8 inch sieve, 3) percent passing the No. 4 sieve, and 4) percent passing the No. 8 sieve. Contractor’s test data from recently completed construction projects was used to develop representative standard deviations of the asphalt material properties used for payment and acceptance. These standard deviations were then used to develop tolerance values used in the percent within limits system. A system has been developed to handle acceptance and payment of small quantity LOTs (two or less sublots) within the same specification. In lieu of the Department sampling and testing numerous independent samples and performing F and t-tests to validate the Contractor’s results, an alternative verification and resolution system has been developed.

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ABSTRACT

Hydrated lime is often used as a mineral filler or antistripping additive in Hot Mix Asphalt (HMA). In fact, many agencies across North America require the use of hydrated lime in all HMA mixtures being placed on high-volume roadways. In spite of this wide use of lime, its effects on the HMA mixture dynamic modulus (E*) stiffness have rarely been evaluated. The new mechanistic-empirical (M-E) pavement design guide entitled “Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures” developed under National Cooperative Highway Research Program (NCHRP) Project 1-37A uses E* as the primary material property of asphalt mixtures for the HMA characterization.

A comprehensive study was completed at Arizona State University to assess the effect of lime addition on the E* stiffness of HMA mixtures. The study demonstrated that the standard test and design methodologies of the new M-E pavement design guide could be used effectively for lime-modified HMA mixes. Using these methodologies, hydrated lime was found to increase the E* of HMA mixtures by 17% to 65% across the range of mixtures, lime contents and temperature; with an overall average of 25% increase being found from 17 mixture-lime percentage combinations across 6 different HMA mixes. This paper also outlines a provisional protocol for evaluating the E* master curve for lime modified HMA mixtures using any of the three hierarchical levels found in the new NCHRP 1-37A Pavement Design Guide.
Distress Assessment of Conventional HMA and Asphalt Rubber Overlays on PCC Pavements using the Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures

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ABSTRACT

The purpose of this study was to assess the way distresses (cracking, rutting and ride smoothness) are predicted using the new 2002 Pavement Design Guide developed in the NCHRP project 1-37A project entitled “Mechanistic-Empirical Design of New and rehabilitated Pavement Structures” for two pavement sections: a conventional HMA reconstruction and an asphalt-rubber overlay on a PCC pavement. The Design Guide does not include rehabilitation design for asphalt rubber overlays. However, many large scale asphalt rubber overlays on Interstates highways in Arizona have been built and performed well, and provided an opportunity to determine to what degree the Design Guide can predict their performance.

The input data for both types of pavements were derived from two different projects on the same Interstate 40 highway. For the conventional HMA, data from a section of I-40 referred to as the Riordan I-40 Project was used. For the asphalt-rubber pavement section, data was assembled from the adjoining project referred to as Flagstaff I-40 Walnut Canyon Project.

For both projects, actual data measurements that summarize the pavement performance were compared to calculated values obtained using the Design Guide. Three pavement performance parameters were evaluated based on the available data: rutting, cracking and International Roughness Index ride smoothness (IRI).

The rutting in conventional HMA was one of the distresses that the Design Guide predicted more accurately. When a comparison of unconfined and confined dynamic modulus input values was performed for the asphalt rubber mixtures, it was found that the rutting values for the confined conditions matched more closely with the Design Guide predicted values.
Use of a Fast Non Destructive Field Test Method for Determination of Stiffness of Subsurface Layer in Thin Surface Hot Mix Asphalt (HMA) Pavement

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Use of a Fast Non Destructive Field Test Method for Determination of Stiffness of Subsurface Layer in Thin Surface Hot Mix Asphalt (HMA) Pavement

by

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ABSTRACT

Determination of moduli of subsurface stabilized layers in pavements with unknown and variable layers, and thin asphalt layers, is a challenging problem. Reliable estimation of moduli cannot be obtained from backcalculation of falling weight deflectometer data. Also, for many stabilized layers, full depth intact cores cannot be obtained from the field, and hence laboratory determination of modulus is not possible. Analysis of seismic property of pavement is a well known method for estimation of surface modulus of the pavement. In this paper, a simple methodology has been proposed on how seismic data acquired on the pavement surface can be effectively used to estimate the moduli of the surface layer as well as the subsequent subsurface layers of a flexible pavement. A research study was conducted on three HMA pavements with foamed asphalt stabilized base in Maine. These three pavements were tested with both portable seismic and falling weight deflectometer equipment. Cores were taken from the same location and tested in the laboratory for resilient modulus. The moduli values obtained from different tests were compared, the effect of temperature on moduli of foamed asphalt was evaluated, and deflection computed from layered elastic analysis using predicted foamed asphalt layer moduli were compared to observed deflections. It is concluded that the portable seismic equipment can be used to determine accurate moduli of subsurface stabilized layers. The practical advantages of using such an equipment warrant further studies for refinement of the method.
COMPARISON OF MOISTURE DAMAGE IN HOT MIX ASPHALT USING
ULTRASONIC ACCELERATED MOISTURE CONDITIONING AND TENSILE
STRENGTH TEST RESULTS

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ABSTRACT
Ultrasonic accelerated moisture conditioning (UAMC) has been demonstrated to be a quantitative analysis to evaluate the moisture sensitivity of a hot mix asphalt mixture. Data from the UAMC test procedure was evaluated for repeatability and statistically compared to tensile strength test results after one and multiple cycles of freeze-thaw conditioning.

UAMC is accomplished by containing a loose sample of hot mix asphalt on a sieve in a 60°C waterbath while subjecting the sample to ultrasonic energy. As the asphalt recedes from the surface of the aggregate, small particles of the mix are released and drop through the sieve. The percent of material lost from the sample is recorded for five hours and plotted with respect to conditioning time. The slope of a linear regression function that is fit to the data represents the rate at which the small particles are released as the asphalt recedes along the surface of the aggregate. The value of the slope has been demonstrated to be a quantifiable representation of the moisture sensitivity for a HMA mixture, and the greater the value the more susceptible the mixture is to moisture damage.

Seven mixes were subjected to UAMC. Replicate samples were used to define the UAMC slope of the linear regression function and evaluate the repeatability of the UAMC one-day test procedure. Repeatability was confirmed in six of the seven mixes, and the average UAMC slope for all mixes had a significant relationship to tensile strength test results after one and multiple cycles of freeze-thaw conditioning.

KEY WORDS:
1) Stripping
2) Conditioning
3) Ultrasonic
4) Asphalt
5) Moisture

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FACTORS AFFECTING SPECIFIC GRAVITIES OF AGGREGATES

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ABSTRACT

The combined bulk specific gravity of aggregates is a basic input in the Superpave asphalt mixture volumetric design. In order to identify and quantify the factors affecting the aggregate specific gravity values, tests methods similar to AASHTO T84 and T85 were conducted on aggregate samples collected from four different quarries in Kansas. All test results were statistically analyzed to find the significance of the factors, size and fine loss of the aggregates during replicate testing, used in the experimental program. The results show that the bed from which the aggregates are produced has a significant effect on the specific gravities. However, different aggregate products obtained from the same bed may have dissimilar specific gravities. The analysis also shows that the production process significantly affects the specific gravities when the aggregates are softer, such as, soft limestone in Kansas. The aggregates with low resistance to degradation in the Los Angeles Abrasion tests are more likely to produce results with high variability when tested for specific gravity. Fine loss during replicate testing does not affect the results for harder aggregates.
Interpretation of Transverse Profiles to Determine the Source of Rutting Within Asphalt Pavement System

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Abstract. The transverse profilograph has been recognized as one of the most accurate devices to measure rut depth. However, interpretation of surface transverse profile measurements poses a major challenge in determining the contribution of the different layers to rutting. A literature review has shown that the estimation of the actual rutting mechanism can be made from a surface transverse profile in determining the relative contribution of the layers to rutting. Unfortunately, no verification or data were available on much of the research. In addition, some of the techniques presented cannot be used if the rut depth is not well pronounced. Other techniques may be costly and time consuming. In this research, an approach was developed that integrates Falling Weight Deflectometer (FWD) and core data along with 3.6 meter transverse profile measurements to assess the contributions of different pavement layers on rutting, and identifies the presence (or absence) of instability within the asphalt surface layer. This approach can be used regardless of the magnitude of the rut depth. Based on the analysis conducted, absolute rut depth should not be used to interpret the performance of the asphalt mixture. In addition, continued instability may not result in an increase in rut depth because the rutted basin broadens as traffic wander compacts or moves the dilated portion of the mixture. The approach developed appears to provide a reasonable way to distinguish between different sources of rutting. The conclusions from the approach agreed well with observations from the trench cuts taken from four different sections.
Title: NUMERICAL SIMULATION OF LABORATORY TESTS ON ASPHALT - COMPARISON OF THE DIRECT TENSILE AND THE INDIRECT TENSILE TESTS

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ABSTRACT

This paper addresses the numerical simulation of laboratory tests on asphalt comprising the comparison of the direct tensile test and the indirect tensile test exemplarily. A computation model based on the finite element method is used for the realisation of the numerical simulation. The non-linear stress-strain relations are considered by introducing a rheological model in the study. This model provides the data recording of elastic, visco-elastic and visco-plastic deformation characteristics in dependence on temperature and stress. The loading specific effects (e.g. loading frequency at cyclic loading) and the manufacturing specific effects (e.g. void content) in regard to the deformation behaviour of the asphalt mixes are not discussed in this paper. In addition to the deformation characteristics above mentioned the rheological model contains the fatigue and crack behaviour of asphalt mixes, too. For this purpose a specific strain component (tertiary strain) is introduced. Tertiary strain occurs for material damage due to microcrack formation. The beginning of microcrack formation as well as the progression of tertiary strain are described formally in this paper. The rheological model is based on material parameters and calibrated by direct tensile tests.

An adequate numerical method providing the effective application of the computation model at cyclic loading (in particular at high numbers of load cycles) is presented. Possible applications and limits of the method are discussed. An indirect tensile test is simulated numerically on the basis of the computation model and compared to the results of an appropriate laboratory test.
Mechanistic and Volumetric Properties of Asphalt Mixtures with RAP

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ABSTRACT
This research examines how the addition of RAP changes the volumetric and mechanistic properties of asphalt mixtures. A Superpave 19 mm mixture containing 0% RAP was used as the control for evaluating properties of mixes containing 15%, 25%, and 40% RAP. Two types of RAP were evaluated: a processed RAP and an unprocessed RAP (grindings). Testing included dynamic modulus in tension and compression, creep compliance in compression, and creep flow in compression. Using the time-temperature superposition principle, dynamic modulus and creep compliance master curves were constructed to describe the behavior of each mix over a range of temperatures. The VMA and VFA of the RAP mixtures increased at the 25% and 40% levels, and there was also an influence of pre-heating time on the volumetric properties. The dynamic modulus of the processed RAP mixtures increased from the control to 15% RAP level, but the 25% and 40% RAP mixtures had dynamic modulus curves similar to the control mixture in both tension and compression. The creep compliance curves showed similar trends. A combination of gradation, asphalt content, and volumetric properties is likely the cause of these trends.

INTRODUCTION
The use of recycled asphalt pavement (RAP) material is increasing as local, state and federal transportation agencies make more efficient use of their resources. RAP material is generated when old, damaged pavement materials are milled and crushed for addition as a component to new mixtures placed in the pavement structure. Historically, old pavement material was removed and disposed of in landfills. As landfilling these materials has become less practical and more expensive and the availability of quality virgin materials declines, the addition of RAP to pavement mixtures has become more and more prevalent. Recycling of pavement material can be done as an in-place process or a central plant process. The in-place process combines the reclamation, mixing, laydown, and compaction procedures into a single paving train in the field. In-place recycled materials are typically used for base or binder courses and are typically overlaid with a surface course. The central plant process involves stockpiling RAP at the asphalt plant, which is then mixed with virgin materials at the plant and trucked to the construction site for laydown and compaction. Currently, the state of New Hampshire allows up to 30% RAP from a known source or 15% RAP from an unknown source to be used in a mixture. These values were selected based on general guidelines developed at the national level for the use of RAP in HMA (1,2,3), however, the actual effect of the RAP on the mixture properties and field performance of these mixtures is unknown.

The addition of RAP to an asphalt mixture changes the mechanistic properties (i.e., strength, durability) of the mixture and affects its performance (i.e., resistance to cracking and deformation) in the field. The mechanistic properties change as a result of the aged binder introduced to the mixture as part of the RAP. The binder in the RAP will have a different chemical composition and different properties than the virgin binder added during the mixing process. These two binders will mix to some extent, changing the properties of the mixture containing RAP from one that contains only virgin material. A study by Huang, et al (4) showed that the addition of RAP increased mixture stiffness, measured by the indirect tension and semi-circular bending tests. As the pavement industry moves towards more mechanistic based pavement design and analysis methods such as the American Association of State Highway and
SIMULATION OF MODE I AND MIXED-MODE CRACK PROPAGATION
IN ASPHALT CONCRETE USING A BILINEAR COHESIVE ZONE MODEL

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ABSTRACT

This paper presents the adaptation of a cohesive zone model (CZM) to simulate crack initiation and propagation in asphalt concrete. The cohesive zone modeling approach involves the use of intrinsic constitutive laws, where elasticity and softening behavior are taken into account. Furthermore, both finite material strength and fracture energy are incorporated in the CZM, which eliminates the need to resolve singular fields associated with linear elastic fracture mechanics (LEFM). The approach taken herein involves the adaptation of a bilinear cohesive zone model into the finite element program ABAQUS. The bilinear constitutive model is applied as an interface element, which governs the response of element separation, e.g., crack nucleation, initiation, and propagation. The undesirable structural compliance that is introduced by some CZMs can be reduced by using the bi-linear model, by controlling the pre-peak slope of the cohesive law. Using the newly implemented bi-linear CZM, crack propagation in a disk-shaped compact tension (DC(T)) test is simulated. This paper demonstrates that using the CZM approach, fracture test results can be accurately modeled even with very simple descriptions of bulk and interface constitutive properties. Next, the bi-linear CZM is used to simulate mixed-mode crack initiation and propagation in a single-edge notched beam (SE(B)) test. The cohesive elements are inserted over an area to allow the crack to freely propagate without the need for a pre-defined crack path. The crack trajectory of the present numerical results matches remarkably well with that of experimental results. The development of a viscoelastic constitutive model for the CZM is now under development.

Keywords: Bilinear, cohesive zone model, CZM, asphalt, asphalt concrete, fracture, cohesive parameters, DC(T), mixed-mode, SE(B), compact tension

INTRODUCTION

Background

Under climatic and traffic loading, several forms of cracking can develop in asphalt pavements; all of which diminish pavement life, increase roughness, and elevate maintenance costs. Majidzadeh (1) first attempted to measure the fracture properties asphalt concrete. Since then, several researchers (2,3,4,5,6) have explored fracture mechanisms in asphalt concrete with varying degrees of success. However, most studies of fracture in asphalt concrete have been limited to either experimental investigations and/or the study of stationary cracks. In this work a powerful numerical scheme called the cohesive zone model (CZM) is introduced to investigate the fracture behavior of asphalt concrete and to simulate crack nucleation, initiation, and propagation of mode I (opening) and mixed-mode cracks (opening and shear sliding). Even under the assumptions of linear elasticity in the surrounding material, the cohesive model will be shown to match well to experimental tests conducted at low temperatures with minor calibration.

Cohesive zone models have been used in the simulation of fracture for both homogeneous and nonhomogeneous materials. Barenblatt (7,8) proposed a cohesive
Performance Based Algorithm for the Selection of SUPERPAVE High-Temperature Performance Grade (PG) for Asphalt Binders

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Abstract

SUPERPAVE asphalt binders are selected using the Performance Grade (PG) methodology introduced by SHRP. The PG grading system has two components; low-temperature and high-temperature. The work presented in this paper provides an improved methodology to select the high temperature PG grade for asphalt binders. An enhanced high-temperature transfer function for pavement temperatures was developed through a comprehensive application of the Integrated Climatic Model (ICM). This model was developed using hourly climatic data, providing a more accurate representation of the high-temperature conditions in the pavement. Using the hourly high-temperature calculations, a performance based procedure utilizing current empirical models for HMA stiffness and rut predictions was developed. This procedure is a damage based comparison of rut development and the impact of the use of different PG graded binders to compare the accumulation of damage. This procedure accounts for extended hot periods in certain climates, which could not be considered in the original selection procedure. Models were developed to extend the PG damage concept from the limited number of stations with hourly temperature data to the entire database using daily temperature data. A Degree-Days concept was developed to relate the number of days the pavement temperature is over 10 C to the PG damage calculation.
EXPERIMENTAL INVESTIGATION OF ANISOTROPY IN ASPHALT CONCRETE

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ABSTRACT
Accurate multiaxial characterization of asphalt concrete requires a thorough understanding of its anisotropic behavior. To this end a study has been conducted to examine the anisotropic properties of asphalt concrete in the linear viscoelastic range, with growing damage, and during volumetric deformation. Tests were conducted on specimens cored in the vertical and horizontal directions from gyratory compacted specimens. Anisotropy was found to have no effect on the linear viscoelastic properties of the material. This finding is supported by subsequent results from monotonic constant crosshead rate uniaxial tension and uniaxial compression tests. It was also found that anisotropy contributes greatly to the behavior of asphalt concrete in compression, but shows very little, if any, effect on tensile properties. In addition, the strong dependence of anisotropy on temperature and strain rate is presented. Finally, promising results from a simplified method of extracting the anisotropic behavior of asphalt concrete using the hydrostatic test are also introduced.
High Temperature Rheological Properties of Asphalt Binders

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ABSTRACT
In recent years research efforts have shown that the current rutting parameter used in the Performance Grading (PG) asphalt binder specifications, $|G^*| / \sin \delta$, does not reasonably predict the rutting potential of asphalt mixtures especially when modified binders are used. A number of researchers have investigated the use of other parameters, such as the zero shear rate viscosity and the permanent strain accumulated under repeated creep and recovery, however, there is no consensus with respect to which parameter is better to use. This paper investigates the use of zero shear rate viscosity and of repeated creep permanent strain as potential specification parameters and discusses the importance of temperature susceptibility and of strain tolerance in relation to the rut resistance of asphalt binders.

INTRODUCTION
In the past years Minnesota Department of Transportation has embarked in the development of a comprehensive database that could be used for storing and disseminating various types of information for asphalt pavement construction projects around the state. One essential part of this database is the development of an inventory of the properties of certified performance grade (PG) asphalt binders used in Minnesota. The main purpose is to provide a much broader representation of the rheological properties of asphalt binders in addition to the traditional PG data that can significantly improve the selection process of the binders used for different construction jobs. This paper presents the analysis performed on the initial nine asphalt binders included in the data base with respect to their rut resistance properties. Although rutting does not represent a major distress in Minnesota, the use of PG -34 and PG -40 binders that have low temperature susceptibility has raised questions with respect to the influence of this low temperature requirement on the rutting potential of these binders.

OBJECTIVES
The objectives of this paper are to investigate the use of zero shear rate viscosity and repeated creep and recovery permanent strain as potential specification parameters and to discuss the importance of temperature susceptibility and of strain tolerance in relation to the rut resistance of asphalt binders.

MATERIALS
Nine different asphalt binders were provided to the University of Minnesota from various refineries around the area. The asphalt binders and their grades are listed in Table 1. The first four are PG 64 binders and the remaining five are PG 58 binders. The low temperature grades varied from -28 to -40. Two of the binders did not have any modifiers added, BI6 and BI7. The remaining seven binders were modified with different percentages of various additives.

EXPERIMENTAL PROCEDURE
All nine asphalt binders used in this study went through identical handling, aging and testing procedures. All of the dynamic shear rheometer (DSR) testing was performed on an AR 2000 rheometer equipped with an environmental test chamber from TA Instruments.

Frequency sweep tests were performed on asphalt binders in all three conditions: unaged, RTFOT, and PAV. The unaged binders were tested for grade verification only. The RTFOT
Mathematical Relationships for Various Methods of Measurement of Bulk Specific Gravity of Hot-Mix Asphalt

(abstract = 237 words, text = 3564 words, 9 tables & figures = 2250 words)

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ABSTRACT
Bulk specific gravity (Gmb) is a property that is used in virtually all aspects of design and production of asphalt pavements. Thus, it is imperative that the best possible method be used to determine this property.

The SSD method has been used as the standard Gmb test method for many years. This method is believed to be accurate for fine-graded specimens, but it may not provide correct results for samples possessing a large number of sizeable surface voids. The recent increase in use of coarse-graded mixes has prompted the investigation of other tests to serve as viable alternatives to the SSD method.

Because different test methods provide different Gmb values, changing to a new test method could seriously impact current asphalt design and production specifications. Until such changes are made, the ability to calculate an SSD measurement from the results of another method could allow the user to take advantage of the benefits of other test methods while alleviating the need to adjust current specifications.

In this study, five test methods (SSD, height-diameter, CoreLok, CoreReader, and Kuss methods) were examined to determine factors affecting their results, and to determine potential relationships among methods. Test method, nominal maximum aggregate size (NMAS), and absorption values were determined to be significant factors affecting various Gmb measurement methods. Significant mathematical models were developed to translate Gmb values from the height-diameter and CoreLok methods to values as measured by the SSD method.
Investigation of the Fracture Resistance of Hot-Mix Asphalt Concrete Using a Disk-Shaped Compact Tension Test

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ABSTRACT

In recent years, the transportation materials research community has focused a great deal of attention towards the development of testing and analysis methods to shed light on the mechanisms of fracture development in asphalt pavements. Recently, it has been shown that crack initiation and propagation in asphalt materials can be realistically modeled with cutting-edge computational fracture mechanics tools. However, much more progress is needed towards the development of practical laboratory fracture tests to support these new modeling approaches. The goals of this paper are two-fold: (1) to present a new disk-shaped compact tension [DC(T)] test as a practical method for the determination of low-temperature fracture properties of cylindrically-shaped asphalt concrete test specimens and; (2) to illustrate how the DC(T) test can be used to obtain fracture properties of asphalt concrete specimens obtained from field cores, following dynamic modulus and creep compliance tests performed on the same specimens.

Testing of four mixtures with varied composition demonstrated that the DC(T) could detect the transition from quasi-brittle to brittle fracture by testing at several low temperatures selected to span across the glass transition temperatures of the binders used. The tendency towards brittle fracture with increasing loading rate was also detected.

Finally, the DC(T) test was used in a forensic study to investigate premature reflective cracking of an isolated portion of pavement in Rochester, NY. One benefit of the DC(T) test revealed during testing of field samples was the ability to obtain mixture fracture properties as part of an efficient suite of tests performed on cylindrical specimens.

INTRODUCTION

Asphalt pavement lifespan, rideability, and the need for costly maintenance treatments are significantly affected by the type, extent, and rate of fracture that occurs in the surface layers of these facilities. Various forms of fracture are commonly observed, including thermal cracking (through-thickness, and transverse to the direction of traffic), longitudinal surface or “top-down” cracking, and reflective cracking of asphalt overlays placed on existing jointed or cracked pavement (1). In recent years, a great deal of effort has been directed towards the development of testing and analysis methods that can be used to study the mechanisms of crack initiation and propagation in asphalt pavements (2-5). Recently, it has been shown that crack initiation and propagation in asphalt materials can be realistically modeled with cutting-edge computational fracture mechanics tools (6, 7). This approach incorporates a cohesive zone interface fracture model within a finite element modeling framework to describe the initiation and propagation of fracture (separation) of the material. An advantage of an integrated testing and modeling program is the ability to extract information from the laboratory results that cannot be determined from measurements alone. For instance, this approach can be used to gain insight towards the isolation of crack formation energy from other sources of energy consumption in fracture tests. Furthermore, once a cohesive zone constitutive model is calibrated to laboratory test results, the extension of the model to field studies can be accomplished with reduced model calibration. This will lead not only to better prediction of field deterioration, but will also provide more realistic insight towards deterioration mechanisms.

To take full advantage of these new modeling approaches, advances in laboratory fracture tests for hot-mix asphalt (HMA) concrete are needed. In the cohesive zone fracture model,
Effects of Rejuvenating Agents on Recycled Aged Rubber Modified Binders

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Effects of Rejuvenating Agents on Recycled Aged Rubber Modified Binders

ABSTRACT

In some states, recycling of aged rubber modified binders is increasing because more and more of these pavements are over 10 or 15 years old. The properties of the blends of aged rubber modified binders and rejuvenating agents are still not very clear due to the presence of crumb rubber modifier (CRM) in the aged binders. In this study, two rubber modified binders used in the South Carolina and one control PG76-22, are artificially aged and then used as recycled materials by adding different rejuvenating agents, i.e., a rejuvenator and a softer binder. The properties of the blends of aged modified binders and the rejuvenating agents at various contents were evaluated by Dynamic Shear Rheometer (DSR), Bending Beam Rheometer (BBR), and as well as viscosity tests. The testing included three different aging states of the blends: original, RTFO residual and RTFO+PAV residual. Results from this study show that 1) the two aged modified binders could be recycled up to a targeted PG grade; 2) the rejuvenating agents used in this study are effective when used with the aged modified binders; 3) the presence of crumb rubber in modified binders enhances their aging resistance. It was also concluded that the aged modified binders are relatively easier to reach a targeted PG grade by using the rejuvenating agents compared to the control PG76-22.

Keywords: Rubberized asphalt, recycling, DSR, BBR, rejuvenating agents
TITLE:
Measuring and Predicting Thermally-Induced Stresses in Modified Asphalt Mixtures

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ABSTRACT

Low-temperature cracking remains to be a major cause of pavement failure in cold climates. It is known that the main cause of it is the accumulation of thermal strains and stresses in asphalt concrete pavements due to temperature decrease, which could exceed the tensile strength or strain tolerance of the mixture causing cracking occurs. During the past several decades, mechanical, empirical, or semi-mechanical models, which predicted the behavior of the asphalt mixtures at low temperatures, were proposed in conjunction with many methods of measuring the relevant properties of asphalt mixtures.

In all these models, it is known that the thermo-volumetric properties of asphalt mixtures are needed. Recently the authors of this paper introduced a method of measuring these properties and using them in a prediction model to estimate thermal stresses. This study was conducted to build a Thermal Restrained Stress Testing device to verify the need for thermal volumetric properties by measuring directly the thermal stress build-up in the laboratory. The results collected include testing of various mixtures produced with different aggregate sources, aggregate gradations, and different modified binders. A total of 11 mixtures produced with 3 different modified binders were tested and the results analyzed to show the effect of each control variable on cracking behavior and to compare predicted stresses using the thermo-volumetric properties with measured stresses. The results show the importance of modification in relation to aggregate properties.

Key Words: Modified asphalt mixtures, low-temperature cracking, thermally induced stress, thermo-volumetric properties, thermal stress prediction model, indirect tension tests, thermal stress test device, failure stress (strength), cracking temperature.
An Inverse GLC Study of Asphalt Composition and Oxidative Aging

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An Inverse GLC Study of Asphalt Composition and Oxidative Aging
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ABSTRACT:

The chemical composition of an asphalt binder significantly affects oxidative aging, interactions with aggregate and binder modifiers. In turn, it may cause premature asphalt pavement failures through fatigue cracking, moisture damage, or other failure mechanisms. Analytical chemical procedures, such as ion exchange chromatography, are time-consuming and cost-prohibitive procedures to be used as a routine test. The inverse gas liquid chromatography (IGLC) is a relatively faster and simpler technique that provides the chemical composition and polarity characteristics of asphalt samples. In the IGLC technique, asphalt is used as the liquid substrate on an inert support in a GLC column and is characterized by measuring the retention behavior of selected test compounds possessing different functional groups. The interaction behaviors among seven test compounds and nineteen unaged and GLC column-aged asphalt samples were determined and compared with functional group concentrations presented in the asphalts and the nonaqueous potentiometric titration study. It was found that the retention behaviors of the test compounds are strongly related with the types and concentrations of functional groups present in the asphalt. For unaged asphalts, the retention behavior of strongly basic test compounds is highly correlated with concentration of acidic functional groups in asphalts while the retention behavior of phenol with oxidatively aged asphalts is highly correlated with the sulfoxide concentration, one of the major products of asphalt oxidation.

Key words: inverse GLC, asphalt chemistry, composition, oxidation
LABORATORY INVESTIGATION OF MIXING HMA WITH RAP

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ABSTRACT

This paper presents a laboratory study in which the blending process of RAP with virgin mixture was analyzed through controlled experiments. One type of screened RAP was blended with virgin (new) coarse aggregate at different percentages. A blended mixture containing twenty percent of screened RAP was subjected to staged extraction and recovery. The result from this experiment indicated only a small portion of aged asphalt in RAP actually participated in the re-mixing process while other portions formed a stiff coating around RAP aggregates and RAP functionally acted as “composite black rock”. The resulting composite layered structure was desirable to improve the performance of HMA mixture.

INTRODUCTION

Reclaimed asphalt pavement (RAP) has been used in hot-mix asphalt mixtures for paving purposes since 1930s. Unlike the recycled aggregates or crushed Portland cement concrete, the possibility of utilizing the old asphalt binder in the newly blended mixtures, and therefore, reducing the required (new) asphalt content, makes the use of RAP in HMA mixtures more economically attractive [1].

Numerous research works have been reported in the literature regarding the methods of utilizing RAP and the performance of HMA mixtures containing RAP [2-5]. However, one critical question still remains unanswered: how much old asphalt is actually blended with new (virgin) asphalt during the mixing process? Common belief is that the RAP does not act in the new mixture merely as a “black rock.” The aged asphalt does blend with the new (virgin) asphalt during the mixing of new mixtures. Kandhal and Foo suggested that up to 15%, RAP could be used without changing PG binder grade. Between 15 and 25% RAP, the virgin binder grade should be decreased by one increment.
COMPARISON OF RUTTING POTENTIAL RESULTING FROM DIFFERENT LEVELS OF COARSE AND FINE AGGREGATE ANGULARITY

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ABSTRACT

This study evaluated the rutting performance of several different combinations of two fractured face counts on the coarse aggregate. For this work, two different mix designs were used with three different levels of two face crushed counts. This study also evaluated the rutting performance of two different percentages of fine aggregate angularity. For this work, only one mix design was used, but with two different combinations of two-face crushed values for the coarse aggregate and two different combination of FAA for the fine aggregate. A single binder, PG 64-28 was used for the testing.

Rut testing was conducted using the Asphalt Pavement Analyzer. It was determined that the amount of rutting was similar for all three combinations of coarse aggregate two face crushed count for a traffic level of greater than 30 million ESALs. The mix containing 100 percent one face and 90 percent two face crushed gravel performed as well, in terms of resistance to rutting, as the mix containing 100 percent one and two face crushed limestone.

Testing was also conducted on four 12.5 mm Superpave mixtures which had different values of fine aggregate angularity. Two of the mixes were designed for a traffic level of greater than 30 million ESALs and two of the mixes were design for a traffic level of 3 to 30 million ESALs. It was determined that the amount of rutting in the two mixes with a fine aggregate angularity of 43 was similar to the amount of rutting in the two mixes with a fine aggregate angularity of 45. The mixtures containing all natural sand performed as well, in terms of resistance to rutting, as the mixes containing a 50/50 blend of natural and manufactured sand.
Verification and Improvement of the Rate of Asphalt Aging Simulated by AASHTO PP1-98 Protocol

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ABSTRACT

It is well documented that environmental effects play a significant role in characterizing the material properties, which in turn affects the pavement performance. Studies under the Strategic Highway Research Program (SHRP) were carried out to study the age hardening characteristics of asphalt binders and mixes. As a result, laboratory procedures to simulate the field-hardening of asphalt binders and mixes, American Association of State Highway and Transportation Officials (AASHTO) Provisional Protocols, PP1-98 and PP2-99 were developed. The approaches followed in these procedures are of great value for the ongoing research on pavement aging; however, due to limited resources and time constraints under the SHRP program, these provisional procedures have certain limitations associated with them. A research study, National Cooperative Highway Research Program (NCHRP) 9-23, was initiated to overcome these limitations and enhance the predictive capabilities of these protocols. The current research paper is a part of the NCHRP 9-23, which deals with the PP1-98 Protocol.

Binders and field cores were obtained from Long Term Pavement Performance (LTPP) and other sites across the United States. Original, laboratory-aged, and field-aged binders were characterized using Dynamic Shear Rheometer (DSR) testing. The existing protocol was verified; based on the findings, the protocol was improved to include the effect of field aging conditions and mix properties. The developed model was calibrated and validated using field data. Parametric analysis was performed on the final model to ascertain the practicality of the output. Based on the findings, a recommended provisional protocol was developed. The recommendations only apply for conventional, non-modified binders.

INTRODUCTION

In the last 50 to 60 years, a significant amount of research has been focused on the use and behavior of asphalt cements within pavement applications. It is well documented that environment plays a significant role in characterizing the paving material properties as a function of time, which in turn affects the pavement performance (1). Work done under SHRP A-005 clearly showed the environmental (temperature) effect on the age hardening characteristics of asphalt binders (2). The study concluded that higher Mean Annual Air Temperatures (MAAT) result in relatively higher rate of aging compared to the cooler climates (3). The study also showed the effect of other parameters such as volumetric properties, location of asphalt layer in the pavement system, asphalt source and asphalt manufacturing methods on asphalt mix aging. Higher air-voids results in higher oxidation and hence more stiffening of the asphalt mix. Asphalt layers that are located deeper in the pavement system do not come in direct contact with air; as a result, the oxidation of the binder in these layers is reduced. Therefore, the stiffening of the asphalt mix is inversely proportional to the depth at which it is located in the pavement system (4).

Work on age hardening properties was carried out under SHRP A-003A, to simulate the field aging in the laboratory. As a result, laboratory procedures were developed to simulate the field-hardening of asphalt binders and mixes. The two procedures developed were: AASHTO Designation: PP1-98, Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV) for the asphalt binders, and AASHTO Designation: PP2-99, Standard Practice for Mixture Conditioning of Hot Mix Asphalt (HMA) for the mixes (5). The approaches followed in these procedures are of great value for the ongoing research on pavement aging; however, due to the limited resources and time constraints under the SHRP program, these provisional procedures have certain limitations.

NCHRP 9-23: Environmental Effects in Pavement Mix and Structural Design Systems is a research study initiated to verify the work done under SHRP and to provide conclusions on the significance of the limitations associated with the existing protocols. Overcoming these limitations would involve the validation of these procedures with respect to their capability of predicting the age hardening characteristics of asphalt binders and mixes. To achieve this objective, laboratory tests were conducted on the binders and field cores obtained from LTPP and other sites across the United States at the Arizona State University Advanced Pavement Laboratory. The research study presented herein is a part of the NCHRP 9-23 research study and deals with the PP1-98 test procedure.

CURRENT CONDITIONS AND LIMITATIONS OF THE EXISTING PP1-98 PROTOCOL

The standard testing procedure under the existing PP1-98 protocol requires asphalt samples to be tested at the following conditions:

- Asphalt Binder Aged using T240 (RTFOT)
Characterization of Mix Fatigue Damage Process Using Three-Stage Weibull Equation and Tree-Based Model

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ABSTRACT

The primary purpose of this paper is to demonstrate the applicability of the Three-Stage Weibull Equation to describe the fatigue damage process using flexural controlled-deformation fatigue tests. A data set of 179 beam fatigue tests originally designed for exploring the fatigue performance of conventional Dense Graded Asphalt Concrete (DGAC) and Asphalt-Rubber Hot Mix Gap-Graded (ARHM-GG) mixes was utilized to inspect the Three-Stage Weibull parameters that were estimated using a Genetic Algorithm. The tree-based regression/category models were then utilized to uncover the data structure of the estimated parameters as a function of material properties, conditioning methods, temperatures, compaction methods, and strain levels. In general, the three-stage Weibull equation provides satisfactory fitting results for the three-stage fatigue damage process occurring in a beam test. It was found that the tree-based models of three-stage Weibull parameters associated with the crack initiation stage are statistically adequate and reliable compared with the models of parameters related to warm-up stage and crack propagation stage. It might suggest that these crack initiation parameters are better indexes to assess the fatigue performance.
Development of a Microfabric Discrete Element Modeling Techniques to Predict Complex Modulus of Asphalt-Aggregate Hollow Cylinders Subjected to Internal Pressure

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ABSTRACT
Benefiting from recent developments in image processing and discrete element modeling, a microfabric discrete element modeling (MDEM) approach has been developed over the past several years. The technique is an extension of a traditional discrete element modeling (DEM), where various material phases (e.g., aggregates, mastic) are modeled with bonded clusters of discrete elements. In this paper, the MDEM approach was developed and applied to simulate the hollow cylinder tensile test (HCT) for asphalt mixtures. The basic principle of the HCT is the application of internal pressure to the inner cavity of a hollow cylinder specimen, which produces circumferential strain. In the present study, an experimental program was conducted to measure the complex modulus of asphalt concrete mixtures at various loading rates and temperatures. The HCT test was then modeled using a two-dimensional, linear elastic MDEM simulation. Although future work will involve the development of viscoelastic material constitutive models, the current approach makes significant strides in coupling the measurement and prediction of modulus at several pre-selected temperatures and loading frequencies using the correspondence principle to bridge between the elastic simulation and viscoelastic response. The two-dimensional morphology of the asphalt concrete mixture was captured with a high-resolution scanner, manipulated using image processing techniques, and reconstructed into an assembly of discrete elements. Two phases were modeled; aggregate and mastic, where the mastic was assumed to be a combination of asphalt and aggregate finer than 2.36 mm. Despite the relative simplicity of the material constitutive models employed, the HCT simulation (asphalt-aggregate hollow cylinders subjected to internal pressure) results of the mixture complex moduli were in favorable comparison with experimental measurements across a range of test temperatures and loading frequencies. It appears that the model provides a reasonable physical portrayal of the force chains developed in the aggregate skeleton, which is known to be a critical aspect of asphalt concrete micromechanical modeling.
Keywords: micromechanical, micromechanics, asphalt mixture, discrete element, hollow cylinder tensile test, complex modulus prediction, asphalt-aggregate hollow cylinders, internal pressure

INTRODUCTION
Micromechanical modeling has benefits in the field of asphalt technology, for reducing or eliminating costly tests to characterize asphalt-aggregate mixtures for the design and control of flexible pavement structures and materials. A number of researchers used micromechanical models to study the mixture complicate behavior, which include Buttlar and You (1), Chang and Meegoda (2, 3), Rothenburg et al. (4), Kose et al. (5), Masad et al. (6), Dai and Sadd (7), Sadd et al (8, 9), You (10), and many others. With the recent developments in image processing and discrete element modeling (DEM), a microfabric discrete element modeling (MDEM) approach has been developed by Buttlar and You (1). The MDEM approach is simply an extension of the traditional DEM (11, 12), where various material phases (e.g., aggregates, mastic) are modeled with clusters of very small discrete elements. Particularly, discrete element modeling was first applied in the asphalt mixture microstructure using a number of discrete elements to represent the aggregate and mastic by Buttlar and You (1), where the mastic was assumed to be a combination of asphalt and aggregate finer than 2.36 mm. Buttlar and You (1) modeled complex aggregate shapes by modeling inclusions, such as aggregates, with a “mesh” of small discrete elements. The propagation of cracks around or through aggregates during a strength test has also been successfully simulated. You (10) and You and Buttlar (13) have employed the microfabric discrete element modeling (MDEM) technique to model and predict asphalt mixtures stiffness and strength. Herein the term “stiffness” in a general sense refers to any of a number of moduli that can be measured and/or predicted, such as complex modulus, relaxation modulus, or creep stiffness (inverse of creep compliance). The objective of this study is to develop the MDEM approach to simulate hollow cylinder tensile test (HCT) for asphalt mixtures.
TEST FOR PRESENCE OF ASPHALT ANTISTRIPPING ADDITIVE

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ABSTRACT

A small device available commercially has been developed that uses litmus paper and a spectrophotometer to analyze vapors from hot liquid asphalt binders and mixtures to determine the percentage of antistripping additive present. Approximately 60 five-point additive content–color index count regressions were performed on binders and mixtures to determine how well the device measured additive content. The regressions basically fit the quadratic format that is used by the manufacturer in the recommended calibration process. The regressions were best when the litmus color index count was calculated by subtracting the initial count of the blank strip from the final count after exposure for the mixtures.

Changes to the instrument software and testing temperature were necessary as the investigation progressed to accommodate different grades of binders. After the planned testing was completed, some retesting of the binders was performed using modified equipment and procedures. The changes appeared to improve the consistency of the results. Test results with mixtures were less accurate than for binders; however, if the vapor trap is modified as described, the accuracy for mixtures should be improved substantially. Since the test can be performed quickly, it would be possible to perform multiple tests on a sample. Multiple tests would increase the confidence of the test results.
Use of Accelerated Loading Equipment for Determination of Long Term Moisture Susceptibility of Hot Mix Asphalt

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Use of Accelerated Loading Equipment for Determination of Long Term Moisture Susceptibility of Hot Mix Asphalt

ABSTRACT

Stripping of HMA with moisture susceptible aggregates, under high temperature and aircraft loading has been a persistent problem in some areas of the Logan International Airport in Boston, Massachusetts. These problem mixes generally meet the retained tensile strength criteria, after freeze-thaw conditioning. This study was conducted to evaluate the use of accelerated loading equipment for identifying moisture susceptible mixes, and also to evaluate the effect of lime. Mixes with three different aggregates were prepared with PG 76-28 asphalt binder according to specifications. Specimens were conditioned by three different methods, 1) multiple cycles of freeze-thaw, 2) wet trafficking with the Model Mobile Load Simulator (MMLS3) and 3) cycles of stress with the Moisture Induced Stress Tester, (MIST). Thereafter the respective indirect tensile strengths were determined. The results showed that accelerated loading can provide useful information for evaluating resistance of HMA to moisture damage under traffic at high temperature. For mixes to have adequate resistance to moisture damage by volumetric expansion-contraction, acceptable tensile strength tests were needed after at least six freeze-thaw conditioning cycles. The evaluation of resistance to moisture damage under traffic at high temperature using moisture stress conditioning proved very promising. The methods should be investigated further. The use of hydrated lime, improved the resistance of HMA against moisture induced stress damage at high temperatures. On the basis of these conclusions, it is recommended that testing protocols, consisting of both freeze-thaw and accelerated loading/moisture induced stress testing at high temperature, be used for evaluating the most cost-effective anti-stripping agent (liquid or solid).
GUIDELINES FOR PRIME COAT USAGE ON LOW VOLUME ROADS

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GUIDELINES FOR PRIME COAT USAGE ON LOW VOLUME ROADS

ABSTRACT

Stephen A. Cross, Michael D. Voth and Pramed P. Shrestha

7500 equivalent words

Prime coat has a purpose in the pavement construction process, yet many times prime is misused or eliminated during the project. While most of the time no harm appears to occur to the roadway and thus may be viewed as acceptable, technical guidance is warranted to assure appropriate usage. The objective of this study was to produce a prime coat guide publication developed for Central Federal Lands Highway Division (CFLHD) project development and field personnel to provide decision-making guidance on how to use, when to keep, and when to eliminate prime coat.

The study consisted of a literature search, which focused on handbooks and technical reports, and a review of agency construction specifications. A phone survey of current practice of state DOTs from the region was undertaken to provide information on current practice. Finally, a review of the potential harmful and positive environmental effects of the prime coat process, including the various bituminous products used, was undertaken.

Based on the information collected, a guideline for project development and field personnel was developed. The guideline provides decision-making guidance on how to use, when to keep, and when to eliminate prime coats.
A Practical Procedure for Developing Dynamic Modulus Master Curves for Pavement Structural Design

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Abstract

A dynamic modulus master curve for asphalt concrete is a critical input for flexible pavement design in the Mechanistic-Empirical Pavement Design Guide developed in National Cooperative Highway Research Program (NCHRP) Project 1-37A. The recommended testing to develop the modulus master curve is presented in AASHTO Provisional Standard TP 62-03 “Standard Method of Test for Determining Dynamic Modulus of Hot-Mix Asphalt Concrete Mixtures.” This includes testing at least two replicate specimens at five temperatures between 14 and 130 °F (-10 and 54.4 °C) and six loading rates between 0.1 and 25 Hz. The master curve and shift factors are then developed from this database of 60 measured moduli using numerical optimization. This testing requires substantial effort, and there is much overlap in the measured data, which is not needed when numerical methods are used to perform the time-temperature shifting for the master curve. This paper presents an alternative to the testing sequence specified in AASHTO TP62-03. It requires testing at only three temperatures between 4 and 115 °F (4 and 46.6 °C) and four rates of loading between 0.01 and 10 Hz. An analysis of data collected using the two approaches shows that comparable master curves are obtained. This alternative testing sequence can be used in conjunction with the Simple Performance Test System developed in NCHRP Project 9-29 to develop master curves for structural design.
ASPHALT MIX DESIGN METHOD FOR PERMEABILITY

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Word count: 2,953 words + 3 tables + 8 figures = 5,703
ABSTRACT

Because of the observed porosity of new Superpave mixes, the Virginia Transportation Research Council conducted several investigations of permeability. As a result of these investigations and other related national studies, a mix design permeability test method was developed. The method involves testing a group of specimens prepared in the lab at a range of air-void contents and developing a permeability-void regression plot. From the regression, the permeability of pavement can be estimated.

The purpose of this project was to compare results between two labs using mixtures from 11 paving projects. There was general agreement between permeability-air voids regressions resulting from the testing for the two labs. In addition, testing of cores from six of the projects indicated that the lab method estimates pavement permeability rather well. Implementation of the test method by the Virginia Department of Transportation is discussed.
Field Evaluation of a Porous Friction Course for Noise Control

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ABSTRACT

In 2003, the Indiana Department of Transportation allowed a test section of Porous Friction Course (PFC) to be placed on I74 east of Indianapolis. This paper summarizes the design, construction and early performance of that surface compared to an adjacent SMA surface and a conventional Superpave HMA surface. All three mixes included steel slag aggregate and a PG76-22 binder. The PFC was designed at 18-22% air voids to provide a permeable surface. Noise measurements were made on all three surfaces using both the pass-by and close-proximity methods. The three surfaces were also evaluated in terms of surface texture using the Circular Texture Meter and friction using the Dynamic Friction Tester and towed friction trailer. Splash and spray were judged qualitatively. The early performance indicates that the PFC produced significantly lower noise levels, higher surface texture and friction, and reduced splash and spray compared to the other two surface types.
Establishment of the Precision of the Rapid Angle Measurement (RAM)
Device for Superpave Gyratory Compactors
(Word Count: 249-Abstract; 2907-text; 3500-Tables/Figures)

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Establishment of the Precision of the Rapid Angle Measurement (RAM) Device for Superpave Gyratory Compactors

Kevin D. Hall and Tamara Easley

ABSTRACT

Superpave hot-mix asphalt (HMA) specimens are compacted in the laboratory using the Superpave gyratory compactor (SGC) through the application of pressure and an applied angle of gyration. The original compaction specification for the SGC requires the angle of gyration to be 22±0.35 mrad (1.25±0.02 degrees), measured externally to the compaction mold. Questions concerning the ability of different compactors to produce HMA specimens of the same mix having the same density led to the development of the Dynamic Angle Validation (DAV) kit, which measures the angle of gyration internally (on the inside of the mold). The DAV procedure requires the use of HMA to measure the internal angle of gyration. Due to practical limitations of performing measurements using HMA and questions concerning the “proper” HMA mix to use in the measurements, a device – the Rapid Angle Measurement (RAM) – was introduced which effectively simulates the load placed on the SGC by a hot-mix asphalt specimen. An interlaboratory study was conducted in accordance with ASTM E691-99 to establish the precision of the internal angle measurement provided by the RAM. A total of eleven RAM units and five SGC models were included in the study. Based on the study data, estimates were developed of both repeatability (within lab) and reproducibility (between lab) for the RAM device for all five SGC models. It is recommended that all devices with the reported ability to measure internal angle of gyration be subjected to a similar interlaboratory study in order to compare devices on an equal basis.
INFLUENCE OF TRUCK VOLUME DISTRIBUTION ON FLEXIBLE PAVEMENT PERFORMANCE

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INFLUENCE OF TRUCK VOLUME DISTRIBUTION ON FLEXIBLE PAVEMENT PERFORMANCE

ABSTRACT

Accurate knowledge of truck volume and loading is essential to pavement design and performance. Underestimation of design traffic results in premature pavement failure and excessive rehabilitation costs, while overestimation results in an overly conservative pavement design that is not cost effective for owner agencies.

The recently developed National Cooperative Highway Research Program (NCHRP) 1-37A Design Guide (i.e., new design guide) specifically addresses truck volume distribution via the traffic input software module. Within the module, the user has an opportunity to specify average annual daily truck traffic (AADTT), monthly and hourly truck volume distribution, vehicle class distribution, and anticipated traffic growth over the design life.

Influence of these traffic factors on hot flexible pavement performance was determined with the new NCHRP design guide software for two highways in Mississippi. Results indicate AADTT, vehicle classification and traffic growth distribution most influence rutting, fatigue cracking, and longitudinal cracking distresses. Monthly and hourly truck distributions were not found to substantially influence performance.

Key Words: Monthly truck distribution, hourly truck distribution, pavement design, flexible pavement
PERFORMANCE EVALUATION OF HOT MIX ASPHALT (HMA) USING
ROTARY LOADED WHEEL TESTING

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Characteristics of Bituminous Paving Mixtures To Meet Structural Requirements

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PERFORMANCE EVALUATION OF HOT MIX ASPHALT (HMA) USING ROTARY LOADED WHEEL TESTING

ABSTRACT

Permanent deformation and moisture damage (i.e., rutting and stripping) are two predominant hot mix asphalt (HMA) distresses. Rutting can be caused by many factors, including stripping, all of which result in reduced HMA shear strength. Hot mix asphalt stripping evaluation is a source of significant industry discussion and debate.

Transportation agencies use a number of methods to evaluate stripping, with many methods customized by agencies depending upon local concerns and environmental conditions. Today, many agencies use some type of loaded wheel testing, with associated mix “pass/fail” criteria, as part of the mix design acceptance procedure. This process is often referred to as “proof” testing and provides a higher confidence that the HMA mix will perform satisfactory during service conditions.

A new device, the rotary wheel tester, has been recently developed to conduct rutting and stripping performance evaluation of HMA mixes. This device operates on a similar principle as the Hamburg wheel tester, with the main difference being the specimen is loaded along its diameter instead of from the top. The cost of the rotary wheel tester is less than half that of the Hamburg wheel tester.

Testing was conducted to determine if the rotary wheel tester could distinguish between good and poor performing mixes and to determine if PG 76-22 or PG 67-22 plus hydrated lime improves mix performance. Results indicate the rotary wheel tester is an easy to use testing device that appears to provide reasonable prediction of rutting and stripping performance of HMA mixes. It also appears that PG 76-22 asphalt binder improves mix performance to a greater extent than PG 67-22 plus hydrated lime.

Key Words: Rotary wheel testing, hot mix asphalt, permanent deformation, stripping
TITLE:
Predicting Field Permeability from Testing HMA Specimens Produced by the Superpave Gyratory Compactor

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Predicting Field Permeability from Testing HMA Specimens Produced by the Superpave Gyratory Compactor

By Kunnawee Kanitpong, Hussain Bahia, Jeffery Russell, and Robert Schmitt

ABSTRACT

This study was conducted to develop laboratory and field permeability testing procedures for design and quality control of Superpave mixtures in Wisconsin. A total of 16 mixes used on 9 field projects, including fine-graded and coarse-graded mixes, were evaluated. The in-place field permeability was measured by using the NCAT device; field cores were taken for measuring permeability in the laboratory by using the ASTM D5084 method; and laboratory compaction was used to prepare and test samples from loose mixtures recovered from the field. Two compaction procedures, called Method A and Method B were used in this study to produce Superpave Gyratory Compacted (SGC) specimens that have similar thickness, air voids, and aggregate orientation of the field cores. The result indicates that Method B, which is based on using Ndesign gyrations for different sample sizes, can be used to produce samples that give permeability values similar to values measured for field cores. The results of this study also indicate a good relationship between field permeability (using the NCAT device) and lab permeability measured on field cores of fine-graded mixes with amount of passing No. 8 sieve (P8) higher than 45%. However, the relationship between field permeability and lab permeability measured on field cores of coarse-graded mix (P8 lower than 40%) is very poor. It is therefore concluded that the NCAT permeability device could possibly be used in the field for fine-graded mix (with P8 higher than 45%) to measure a permeability index that is related to the true permeability of field cores as measured by the ASTM D5084. However, to measure the field permeability of coarse-graded mix (P8 lower than 40%), an approach to prevent water leakage along the sealant due to rough pavement surface should be established. For coarse graded mixtures, there appears to be no current alternative better than taking field cores and testing them in the laboratory. For estimating permeability during mixture design, a simple method for preparing and testing permeability of SGC specimens and interpolating based on expected field density is introduced. The results represent a good estimate of the expected in-place field permeability.

Key words: field, laboratory, permeability, gyratory, compaction, fine- and coarse- graded mixes
Evaluation of Gradation Effect on Dynamic Modulus

By Bjorn Birgisson and Reynaldo Roque

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Abstract. The importance of aggregate characteristics has been emphasized in the Superpave™ asphalt mixture design procedure. However, criteria for guidelines for the selection of suitable aggregate gradations have been neglected other than gradation limits for different nominal maximum size aggregate blends, including the restricted zone. With the move toward mechanistic-empirical pavement design, the dynamic modulus is used to account for mixture properties in the pavement design. It is of significant importance to mix designers to possess a framework for determining how to optimize a mixture for ensure an adequate dynamic modulus. This paper presents the results from a study of the effects of gradation characteristics on the dynamic modulus. Power law-based gradation factors are obtained for 13 different aggregate gradations (coarse- and fine-graded) composed of limestone and granite aggregates. These gradation factors were used to identify and evaluate relationships between the gradation factors and the dynamic modulus at higher temperature (40°C). Subsequently, a tentative framework was established for optimizing mixture gradations for dynamic modulus values. The findings illustrate that gradation factors based on power law parameters can be used to optimize mixture gradations for key mixture properties, such as the dynamic modulus. The results also demonstrate the critical nature of aggregate gradation in achieving desired mixture properties.
Evaluation of Predicted Dynamic Modulus for Florida Mixtures

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Abstract

The new 2002 AASHTO Guide for the Design of Pavement Structures is based on mechanistic principles and requires the dynamic modulus as input to compute stress, strain, and rutting and cracking damage in flexible pavements. The 2002 AASHTO Guide has 3 different levels of analysis, which depend on the importance of the pavement structure in question. Dynamic modulus testing is required for Level 1 pavement analysis, whereas the Level 2 and Level 3 pavement analysis requires no laboratory test data. Instead, a predictive dynamic modulus equation is used to generate input values. It is of significant importance to state agencies to understand how well the dynamic modulus for locally available materials compares to the predicted dynamic modulus. This paper presents the results of a study by the Florida Department of Transportation and the University of Florida that focused on the evaluation of the dynamic modulus predictive equation used in the new AASHTO 2002 Guide for mixtures typical to Florida. The resulting research program consisted of dynamic modulus testing of 28 mixtures common to Florida. The results showed that the predictive modulus equation used in the new AASHTO 2002 flexible pavement design guide appeared on the average to work well for Florida mixtures, when used with a multiplier to account for the uniqueness of local mixtures. The results of the study also identified optimal viscosity-temperature relationships that result in the closest correspondence between measured and predicted dynamic modulus values.
Forensic Analysis of Slippage Cracking

By

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ABSTRACT

Premature pavement failure is costly to agencies and disturbing to the traveling public. This paper discusses slippage cracking which occurred shortly after construction affecting about half of the overlay project length. This article offers a comparative analysis based on the review of quality control information, performance testing of the hot mix asphalt using the Superpave shear tester (SST), in situ evaluation of the unbound layers using the dynamic cone penetrometer (DCP) and computed surface deflections. A great emphasis was placed on the evaluation of the mix properties because of the perceived lack of mix cohesion when visually examining the damaged pavement. Performance testing of field cores indicated that the hot mix from the section with cracking performed similarly in terms of stiffness and slightly better in terms of accumulated permanent strain than the hot mix from the section without cracking demonstrating that the cause of the problem was not related to hot mix asphalt properties. Testing of laboratory samples prepared with various binders also confirmed the superior properties of the polymer-modified asphalt used on the project. The results of this study showed that the DCP curves were significantly different between the sections with and without slippage cracking. Estimated surface deflections were higher for the areas which had slippage cracking. An empirical relationship was used to estimate equivalent single axle loads (ESAL’s) to failure from surface deflection showing that it would take less traffic for the section that had slippage cracking to fail when compared to the section without cracking.

Key Words: Slippage cracking, Premature Failure, Tack coat, Hot Mix Asphalt, Shear Test, Shear Stiffness, Permanent Shear Strain, Dynamic Cone Penetrometer, Surface Deflection, KenPave, PG76-22
Investigation of the CoreLok for Maximum, Aggregate and Bulk Specific Gravity Tests

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ABSTRACT
The Florida Department of Transportation uses long established test procedures to determine the maximum specific gravity ($G_{mm}$) and bulk specific gravity ($G_{mb}$) of asphalt mixtures and bulk specific gravity ($G_{sb}$) of aggregates. The CoreLok, a vacuum-sealing device that can be used to determine these properties, was evaluated by the Department for these four test procedures. With respect to the $G_{mm}$ test procedure, for mixtures containing non-absorptive granites, the CoreLok determined equivalent results compared to the Department’s test procedure. However, for mixtures containing absorptive limestones, the CoreLok determined higher $G_{mm}$ values compared to the Department’s test procedure. The apparent reason for the discrepancy is because the CoreLok does not determine a saturated surface-dry condition of the sample. With respect to the aggregate specific gravity test procedures, the CoreLok provided equivalent test results to the Department’s test procedure for the non-absorptive fine aggregates only. For the absorptive fine aggregates and all of the coarse aggregates, the CoreLok determined significantly different $G_{sb}$ test results compared to the Department’s test procedures. The CoreLok may be suitable for determining $G_{mb}$ for coarse graded compacted specimens with high porosity and air voids. There are concerns with the accuracy of the CoreLok results due to the bridging effect of the plastic bag over the large surface voids and due to the CoreLok’s significant underestimation of the specific gravity of a solid aluminum cylinder.
Evaluation of Two Compaction Levels for Designing Stone Matrix Asphalt

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Evaluation of Two Compaction Levels for Designing Stone Matrix Asphalt

Hongbin Xie, Donald E. Watson, and E. Ray Brown

ABSTRACT

Current Stone Matrix Asphalt (SMA) design guidelines list two compaction options to design SMA, 50 blows Marshall or 100 Gyrations with the Superpave Gyratory Compactor (SGC). However, some states have found that 100 gyrations with SGC are excessive for their materials.

In this study, a lower compaction level of 65 gyrations was used to compare with the standard 100 gyrations to design SMA mixtures. Results showed that mixtures designed by 65 gyrations had an average of 0.7 percent higher optimum asphalt content and 1.5 percent higher VMA than those designed by 100 gyrations. All mixtures designed by 65 gyrations met the minimum asphalt content and VMA requirements for SMA, while only 8 of 15 mixtures designed by 100 gyrations met these two requirements. Compaction at 100 gyrations resulted in an additional 0.62 percent average aggregate breakdown at the critical sieve as compared to 65 gyrations. SMA mixtures designed by 65 gyrations and 100 gyrations had an average Asphalt Pavement Analyzer (APA) rut depth of 3.9 mm and 3.1 mm, respectively. Thirteen of fifteen mixtures designed by 65 gyrations performed well if 5.0 mm is set as maximum allowed rut depth.

Based on this study, 65 gyrations can be used to design a more durable SMA mixture, while still maintaining the good rutting resistance that SMA mixtures are noted for. The successful design by 65 gyrations for all five aggregates in this study indicates that a lower design compaction level may allow the use of more aggregate sources for SMA mixtures.

Keywords: Stone Matrix Asphalt (SMA), Mix Design, Compaction Level, Degradation, Asphalt Pavement Analyzer (APA).
Title: Comparison of Thin-Lift HMA Surface Course Mixes in New Jersey

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ABSTRACT

The use of thin-lift HMA surface course mixes has gained wide acceptance in the United States as a means of improving both ride quality and safety. These materials are generally classified as having an open-graded/gap-graded aggregate skeleton, nominal aggregate sizes of 12.5mm or less, higher than normal asphalt binder contents, and are placed in thickness’ less than one inch (25 mm). The use of the thin-lift materials has found to improve wet weather driving conditions, reduce traffic noise associated with the tire/pavement interface, and improve the ride quality measurements.

Thin-lift HMA surface course mixes typically found in New Jersey consist of open-graded friction courses (OGFC) and Novachip®, with a few roadway sections using micro-surfacing and stone-mastic asphalt (SMA). Each of these material types were evaluated to provide an assessment of their ride quality and safety. These thin-lift materials were compared to in-service dense-graded asphalt mixes (DGA) and Portland cement concrete (PCC). The PCC had surfaces that consisted on no treatment, transverse tined, and diamond grind. Noise measurements utilizing the Close Proximity method (CPX), wet skid resistance, and ride quality data consisting of RQI and IRI were used to establish “performance” comparisons between the different surface courses. The “performance” information, along with current costs associated with the materials and construction, can provide a means of establishing a cost-effectiveness for utilizing these surface treatments under specific situational conditions.

KEY WORDS

Thin-lift HMA, Ride Quality, Pavement Noise, Wet Skid Resistance
Evaluation of Round Robin Test Results from Caltrans Test Method for Measuring Resistance of Compacted Bituminous Mixture to Moisture Induced Damage

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ABSTRACT

This paper presents an evaluation of test results from two round robin tests conducted by the California Department of Transportation (Caltrans) in 2003 using the newly developed test for measuring resistance of compacted bituminous mixture to moisture induced damage (California Test 371) and the development of preliminary precision statements resulting from the round robin tests. The test is a modification of the AASHTO T-283-89 procedure using the recommendations of NCHRP Project 9-13. Twenty laboratories statewide participated in the tests. Thirteen of the laboratories participated twice. The material used in the round robin tests was dense-graded hot-mix asphalt. The loose mixtures were prepared by one laboratory and the same Rice value was provided to all laboratories. The evaluation includes examination of test data outliers, evaluation of means, precision, and test repeatability.

The evaluation indicates the following:

- The standard deviation of the tensile strength ratio (TSR) values from the two round robin tests falls within the ASTM D 4867 suggested between-laboratory precision criterion. However, the TSR range exceeds the ASTM D2s criterion.
- More than half of the participating laboratories met the ASTM D 4867 within-laboratory precision criteria.
- For evaluation of test repeatability, data from 11 participating laboratories indicate that nine laboratories achieved the same mean air void content and saturation for both round robin test series. Also, at least 4 of 11 laboratories achieved the same mean tensile strength for both round robin test series.

Preliminary precision statements for inclusion in the newly developed test method were developed as below:

- Within-Laboratory Precision
  - Single-operator standard deviation (1s) of tensile strength (unconditioned or conditioned samples) is 74 kPa
  - D2s range is 210 kPa
- Between-Laboratory Precision
  - Multi-laboratory standard deviation of the TSR is 8%
  - D2s range is 23%

The recommended precision statements developed as a part of this study may be refined as more test data are generated.
COMPARISON OF SUPERPAVE AND MARSHALL MIX PERFORMANCE IN ALABAMA

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COMPARISON OF SUPERPAVE AND MARSHALL MIX PERFORMANCE IN ALABAMA

ABSTRACT

The Alabama Department of Transportation specifies the Superpave design system for the majority of its dense-graded HMA mixes. However, there is concern that the number of design gyrations ($N_{\text{Design}}$) may be too high for specified traffic levels. Mixes designed with too high of an $N_{\text{Design}}$ would be rut resistant, but may be difficult to compact in the field and may suffer from durability problems such as premature cracking and raveling.

The objective of this project is to evaluate the performance of Alabama’s mixes designed using Superpave criteria and compare them to the performance of Alabama’s Marshall designed mixes to determine if current $N_{\text{Design}}$ levels should be adjusted. Pavements were evaluated which used Superpave performance grade (PG) Binders and consensus aggregate properties with the same aggregates.

The following conclusions are based on an evaluation of 25 Marshall and Superpave projects placed about the same time and serving under approximately the same traffic conditions.

1. Both Marshall and Superpave mixtures are generally performing quite well with little rutting and cracking after a period of about four years.
2. Rutting and cracking resistance appears to be similar for both Marshall and Superpave mixtures.
3. The air void levels of in-place mixture had little relationship to laboratory compaction levels.
4. It appears that the field compaction and durability of Superpave mixtures can be improved by increasing the asphalt content without adversely affecting the rutting resistance. However, practitioners are cautioned to closely monitor rutting indicators during mixture design, production, and construction.

Keywords: Marshall, Superpave, rutting, cracking, gyratory
EVALUATION OF CIRCULAR TEXTURE METER
FOR MEASURING SURFACE TEXTURE OF PAVEMENTS

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ABSTRACT

The CT Meter is a laser based device for measuring the mean profile depth (MPD) of a pavement at a static location. Both MPD measurements from the CT Meter and mean texture depth (MTD) measurements from the sand patch test were obtained in five random locations in each of 45 sections of the 2000 National Center for Asphalt Technology (NCAT) Test Track. The NCAT Test Track provides a wide range of surface types including: coarse and fine dense graded Superpave mixes, Hveem mixes, Stone Mastic Asphalt (SMA) and Novachip. Testing indicated that CT Meter produced comparable results to the ASTM E965 Sand Patch Test. When open-graded mixtures were excluded, this study indicated that the offset was non-significant between CT Meter and Sand Patch test results.

Previously developed equations to predict macrotexture were found to be inadequate for the wide range of mix types and aggregate types found at the NCAT Test Track. An equation was developed to relate fineness modulus to macrotexture. This equation was validated with independent data collected by Virginia Transportation Research Council.

Testing conducted as part of a mini round robin indicated that two readings should be averaged to represent a single CT Meter measurement. The within-lab coefficient of variation for the CT Meter is estimated to be 2.3 percent. The between lab coefficient of variation for the CT Meter is estimated to be 4.2 percent. Both estimates are based on the average of two tests being reported as a single measurement. This indicates that the CT Meter is more variable than the sand patch test. However, less technician skill is required to operate the CT Meter.
Design of a specific bituminous surfacing for the highest orthotropic steel deck bridge in the world: the Millau Viaduct.

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Design of a specific bituminous surfacing for the highest orthotropic steel deck bridge in the world: the Millau Viaduct.

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ABSTRACT
This paper presents a rational approach for the performance-based design of bituminous wearing surfacings on orthogonally anisotropic steel bridges. Basically, the behavior of bituminous surfacings on steel orthotropic decks, under heavy truck traffic and environmental conditions, is highly complex. Both the geometry of the structure and the very high flexibility of metallic plates make the deformations and stresses very severe in steel bridge surfacings. In particular, the repeated loading make the fatigue strength be an important parameter for the design of such bituminous wearing courses. In addition, these specific surfacings must also have durability over the expected temperature range, in particular it must be resistant to thermal cracking at low temperatures and to rutting at high temperatures. The technical studies led in parallel to the construction of the Millau Viaduct (France) –the highest bridge in the world– have provided in particular the opportunity of new progress in the development of appropriate laboratory testing equipment and of an original polymer-modified surfacing. A comprehensive research program including both a large laboratory testing campaign and a finite element parametric study was performed in order to develop a handy tool for design of plate surfacings.

Keywords: orthotropic steel bridge deck, bituminous surfacing, five-point bending fatigue test, finite element analysis, Millau viaduct.
CONSTRUCTION QUALITY, TEMPERATURE AND RUTTING EFFECT ON TOP-DOWN CRACKING INITIATION

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Total: 6783 words

November 2004
ABSTRACT

Top-down cracking (TDC) is a flexible pavement distress caused by a number of factors, including high contact stresses from truck tires, mix design characteristics, (e.g., binder type and aggregate gradation) and poor construction quality, (e.g., segregation and compaction methods). This paper presents the findings of a study seeking to quantify the effect of these factors on TDC. It consists of a laboratory component involving an accelerated Wheel Tracking device and a modeling component involving a 3-D non-linear viscoelastic finite element model. The laboratory component of the study involved 17 asphalt bituminous slabs, constructed to simulate the variation in material properties observed in the field as part of an earlier forensic TDC study. The effect of air voids, bitumen content and type, aggregate gradation and segregation on TDC were studied under 3 temperature conditions. Air voids, segregation and binder content were found to have a significant effect on TDC for all the temperatures tested. Modeling the TDC involved laboratory testing to establish the viscoelastic and tensile strength properties of the asphalt mixtures tested. It was found that the rutted surface contributes significantly to TDC initiation.
Evaluation of the Witczak Dynamic Modulus Prediction Model

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ABSTRACT: The dynamic modulus $|E^*|$ is a fundamental property defining the response of hot mix asphalt (HMA) mixtures in flexible pavement systems and is one of the primary material inputs in the mechanistic-empirical design methodology developed in NCHRP Project 1-37A. An empirical predictive model for estimating $|E^*|$ for HMA has been developed based on work by Witczak and co-workers over many years (Andrei et al., 1999). This model relates $|E^*|$ to loading rate, temperature-dependent binder viscosity, and mixture volumetric and gradation parameters. The accuracy and robustness of the Witczak $|E^*|$ model is evaluated through a set of sensitivity and validation studies. Although the results from the validation study of 26 mixtures suggest that the model may overestimate $|E^*|$, particularly at higher temperatures, the overall findings confirm that the Witczak model can provide sufficiently accurate and robust estimates of $|E^*|$ for use in mechanistic-empirical pavement performance prediction and design. Because of the strong dominance of temperature influences over other mixture parameters, however, the model may not be able to make fine distinctions between predicted performance for different mixtures under the same environmental and other conditions. Laboratory testing of $|E^*|$ may still be required for this purpose.

Word Count: 6150 (text) + 500 (2 tables) + 5250 (21 figures) = 11900

INTRODUCTION

The dynamic modulus $|E^*|$ is one of the fundamental properties defining the response of hot mix asphalt (HMA) mixtures in flexible pavement systems. It is one of the primary material property inputs in the mechanistic-empirical design methodology developed in NCHRP Project 1-37A (the so-called “200X Design Guide”) and is a leading candidate for a Simple Performance Test as identified in NCHRP Project 9-19.

The NCHRP 1-37A mechanistic-empirical design methodology incorporates a hierarchical approach for specifying all pavement design inputs. The hierarchical approach is based on the philosophy that the level of engineering effort exerted in determining design inputs should be consistent with the relative importance, size, and cost of the design project. Three levels are provided for the design inputs in the NCHRP 1-37A procedure. Level 1 inputs provide the highest level of accuracy and the lowest level of uncertainty and would typically be used for designing heavily trafficked pavements or wherever there are serious safety or economic consequences of early failure. Level 2 inputs provide an intermediate level of accuracy and could be used when resources or testing equipment are not available for Level 1 characterization. Level 3 inputs provide the lowest level of accuracy and are intended for designs in which there are minimal consequences of early failure (e.g., low volume roads).

Level 1 input of HMA stiffness in the NCHRP 1-37A procedure requires direct measurement of $|E^*|$ via laboratory dynamic modulus testing. Level 2 does not require $|E^*|$ testing but rather applies an empirical model for estimating $|E^*|$ combined with laboratory measured binder stiffness or viscosity. Level 3 is based on the same empirical model for estimating $|E^*|$ but with default binder properties determined by
TITLE:
CRITICAL EVALUATION OF USING THE SUPERPAVE VOLUMETRIC MIXTURE DESIGN PROCEDURE FOR MODIFIED BINDERS

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ABSTRACT

This study was conducted to examine the possible interference of modified binders with the standard procedure for volumetric mixture design used in the Superpave system. Sensitivity of volumetric properties and moisture damage performance was evaluated using four binders modified with two different technologies (Polymer and no-additive modifications). The study included three tasks to evaluate effects of compaction temperatures (in the range of 72 °C to 148 °C), effects of vertical pressure (in the range of 200 kPa to 600kPa), and moisture damage according to the AASHTO T283 procedure. The Zero Shear Viscosity concepts were used to estimate mixing and compaction temperatures, compaction energy index was used to study changes in compaction effort, and cohesion and adhesion of binders were measured.

The results indicate that temperature effects, within a reasonable range, are somewhat marginal and that unless temperatures are reduced to below 80 °C, the effects on volumetric properties are rather small. It was also found that using a target viscosity of 1.5 Pa·s for mixing and 3.0 Pa·s for compaction can provide very reasonable compaction temperatures, particularly if Zero Shear Viscosity is used. These criteria for temperatures worked well for the grades and type of modification used in the study.

The vertical stress used in the gyratory compactor showed very significant effects on volumetric properties. Changing pressure from 600 kPa to 300 kPa resulted in 3.0 to 4.0 % increase in air voids, which is more significant than changing viscosity by more than 10 times. It is therefore postulated that the focus on keeping temperature high during compaction in the lab and in the field could be un-founded. With increasing pressure during compaction in the lab or weight of roller in the field, significant changes in density could be achieved.

Moisture damage does not appear to be affected significantly by the variation in binder viscosity profiles for the binders and aggregates used in this study. Because of the limited sample size, more work is needed in this area to study effect of mixing and compaction temperatures on moisture damage.
Control of the Superpave Gyratory Compactor’s Internal Angle of Gyration: Utah Department of Transportation Experience

Paper 05-2472

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Abstract

The State of Utah Department of Transportation (UDOT) started a program to use the Dynamic Angle Validator (DAV) to measure the internal angle of all Superpave gyratory compactors (SGC) used in construction of hot-mix asphalt in the State. The results show that differences in internal angle exist unless the compactors are calibrated regularly and technicians are trained in laboratory procedures. Once the program was in place, the internal angle of 37 out of 48 SGCs tested was within the specified limits of 1.16 ± 0.03°. However, eight SGC’s, all of one model, had angles between 0.860 and 1.212 degrees with an average angle of 1.026 degrees even after calibration. Preliminary results indicate that pucks compacted with these specific brand of SGC have lower density and require some type of correction factor.

The results also show that as long as the SGC internal angle is within the specified values, the pucks compacted with these devices will have consistent density values regardless of whether they are compacted by State labs or consultants.

It was concluded that the current internal angle limit of 1.16 ± 0.03° is adequate for the type of mixes used in the State of Utah. It was recommended that regular calibration be done on the SGC’s and that the internal angle be measured at least once a year. This will help reduce conflict between State Labs and consultants.

Keywords

Superpave Gyratory Compactor, Dynamic Angle Validator, Hot-mix asphalt, gyration angle.
Title: The Road To Quiet Neighborhoods In Arizona

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Transportation Research Board
85th Annual Meeting
Washington, DC
The Road to Quiet Neighborhoods In Arizona

Larry Scofield¹, Paul Donavan²

Abstract
The Arizona Quiet Pavement Pilot Program (QP3) is a $34 million project implemented to reduce highway related traffic noise. This pilot program represents the first time that pavement surface type has been allowed as a noise mitigation strategy on federally funded projects. The program will overlay most of the Phoenix metropolitan area PCCP with one inch of ARFC. As a condition of using pavement type as a mitigation strategy, ADOT developed a ten-year, $2 million research program to evaluate the efficacy of using ARFC. Historically, pavement surface type was not considered a permanent solution due to the change in acoustic properties with time. This research program will evaluate the change in pavement acoustic properties through three means, (1) conventional roadside testing (eg far field measurements), (2) the use of near field measurements, both Close Proximity (CPX) and Sound Intensity (SI), and (3) far field measurements taken within the surrounding neighborhoods. This paper provides an overview of the program development, presents the research conducted to support the decision to overlay the urban freeway, and the status of current research. Particular emphasis is placed on the development and use of near field measurement systems consisting of CPX and SI

Preliminary results from the research to date indicate that the near field measurement systems are providing meaningful assessments of pavement acoustic performance and the SI and CPX methods compare favorably. The overlays placed reduce the near field measurement levels between 7 to 9 dBA. Average reductions of 5 dBA occurred in the neighborhoods and 7 to 9dBA at the 50 ft roadside location.
Title: Laboratory Characterization and Empirical Prediction of Dynamic Modulus of Superpave Mixtures

Authors: Louay N. Mohammad; Zhong Wu; Leslie Ann Myers; Sam Cooper; Chris Abadie

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Refinement of the Hot Mix Asphalt Ignition Method for High Loss Aggregates

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Refinement of the Hot Mix Asphalt Ignition Method for High Loss Aggregates

Graham C. Hurley and Brian D. Prowell

ABSTRACT

This study evaluated four methodologies for determining the asphalt content of mixtures containing high loss aggregates in the ignition furnace. The methodologies tested were the standard method using the Thermolyne furnace (control), the Troxler NTO Infrared furnace, the Ontario Method and a Tempyrox glass cleaning oven.

Six aggregate sources with high ignition furnace aggregate corrections were obtained from around the country: four dolomites, basalt and a serpentine/chlorite. Calibration factors were determined for each method at optimum asphalt content. Additional samples were then tested at optimum plus 0.5 percent asphalt content and the measured asphalt content calculated using the correction factor determined for that method/aggregate source.

The Tempyrox Pyro-Clean furnace, commonly used for cleaning laboratory glassware, produced the lowest aggregate correction factors. The standard method and the Ontario method, both using the Thermolyne ignition furnace produced the smallest bias or error in measured asphalt content. The standard deviation of the corrected asphalt contents for these high loss sources was higher than the within-lab standard deviation reported for AASHTO T308. The only exception was the Alabama source using the standard method. The Ontario Method and Tempyrox Oven generally reduced the variability of asphalt content measurements for high loss aggregates.

None of the methods evaluated statistically reduced aggregate breakdown on the NMAS and 4.75 mm sieves. The Ontario method significantly reduced, but did not eliminate aggregate breakdown on the 0.075 mm sieve.

The Ontario method is the best method for immediate implementation for determining the asphalt content by the ignition method for high loss aggregates.