Engineering Properties of Asphalt Mixtures And the Relationship to Their Performance

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Foreword

This publication, *Engineering Properties of Asphalt Mixtures and the Relationship to their Performance,* contains papers presented at the symposium of the same name, held in Phoenix, AZ on 6 December 1994. The symposium was sponsored by ASTM Committee D-4 on Road and Paving Materials. Gerald A. Huber of Heritage Research Group in Indianapolis, IN and Dale S. Decker of National Asphalt Pavement Association of Lanham, MD presided as chairmen is the editors and of the resulting publication.

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Overview

The Asphalt Program of the Strategic Highway Research Program (SHRP) represents a landmark in asphalt technology and marks a shift in the underpinnings of asphalt binder specification and asphalt mixture design. It is the beginning of performance based specifications for asphalt materials.

Historically, asphalt mixture design has been based upon empirical properties that, when controlled, provide mix designs with a high probability of good performance. Air voids and voids in the mineral aggregate have been recognized as important mix parameters since the 1920s. The Hubbard Field method of mix design developed in the era following World War 1 used the volumetric properties of air voids, Voice in the Mineral Aggregates (VMA) and a mechanical property test, the Hubbard Field Stability Test, as the basis for design.

The Marshall and Hveem methods of mix design that are the predominant mix design methods used today each use the same approach. Both mix design methods are based on volumetric properties and an empirical mechanical property. In both methods engineering properties are not controlled directly but are controlled indirectly through the empirical properties.

Since the development of Marshall and Hveem mix designs in the 1930s and 1940s, the research community has spent considerable effort to measure fundamental engineering properties and relate these properties to performance on the roadway. Early efforts tried to measure fundamental shear properties using various shear tests and triaxial tests adopted from the geotechnical field. Asphalt mixtures were evaluated as a partially saturated or nearly saturated three-phase system analogous to partially saturated soils. The main differences between soil and asphalt are that asphalt is more viscous than water and aggregate has a larger grain size than soils.

Also, efforts were made to measure the modulus of the asphalt mixture using different methods. Stiffness measurements were made from beams, axially loaded tall cylinders, and diametrically loaded short cylinders. Each method yielded an engineering property, but each result was different, dependent upon specimen configuration and load application.

As methods to measure laboratory properties continued to advance, efforts to relate the fundamental engineering properties to roadway performance showed less progress. Mechanical behavior of the asphalt mixtures is complex and the ability to model behavior using the measured engineering properties was questionable. Uncontrolled variables in the field could not be handled with existing models. Simplifying assumptions were required to obtain predicted performance. The prediction results were severely degraded rendering the approach less than useful.

Direct measurement of engineering properties and use of engineering properties in mix design has not become common practice for several reasons. Measuring engineering properties on hot mix asphalt is difficult. More importantly, understanding that engineering properties control performance of the completed pavement has not been obvious.

Engineering properties are difficult to quantify. They change depending upon test temperature and rate of loading. Modulus values, such as resilient modulus or creep modulus, change dramatically with temperature and confining pressure, both that vary within the pavement.

Hot mix asphalt is a composite material exhibiting visco-elastic behavior of the asphalt binder and elastic behavior of the aggregate skeleton. Early attempts to measure failure properties of the aggregate skeleton used triaxial testing. The triaxial test accounted for changes in aggregate skeleton strength from changes in confining stress but did not account for visco-elastic behavior of the asphalt binder in the skeleton.

Dynamic modulus as measured by ASTM Test Method for Dynamic Modulus of Asphalt Mixtures (D 3497) was developed to measure visco-elastic behavior of the mixture. The test, which requires servo-hydraulic equipment, can measure stiffness at different loading rates. This stiffness is a combined effect of elastic behavior of the aggregate skeleton and visco-elastic behavior of the asphalt binder. Historically, no clear method has existed to combine engineering properties measured by the triaxial test or the dynamic modulus test and relate them to permanent deformation performance.

Fatigue tests were developed to measure the resistance of asphalt pavements to repeated loading. The test required special equipment and fabrication of beam specimens. Beam fatigue behavior has been most commonly used in structural thickness design. In mixture design fatigue prediction has not been commonly used.

In summary, determining which properties most control behavior of the mixture and that can best be correlated to observed performance has been elusive.

Strategic Highway Research Program

In the mid 1980s the American Association of State Highway and Transportation Organizations (AASHTO) initiated discussion regarding a highly focused research with potential for high pay back. One area identified was asphalt binders and asphalt mixtures. Under the SHRP $50 million was earmarked for asphalt research.

The objective of SHRP was to develop a specification for asphalt binders and asphalt mixtures founded on performance based properties. Performance based properties are defined as fundamental engineering properties which are directly linked to roadway performance. Previous research was the basis for determining which properties should be measured, which tests could be used to measure the properties and how the properties could be used in a performance prediction model.

In the spring of 1993, the SHRP was completed. Products of the research program include performance based properties and performance based models which were embedded into the new Superpave method of mixture design. Superpave implementation has begun starting first with Level 1 mixture design that is based on volumetric properties. Mix design Levels 2 and 3 require greater capital expense and higher levels of training. Implementation of Superpave Level 2 and Level 3 mix design will lag several years behind Level 1.

Symposium Purpose

This symposium was intended as a forum for presentation of research to measure fundamental engineering properties and relate the engineering properties to pavement performance. Since SHRP had ended 18 months before the symposium, it was expected that SHRP researchers would present results of their work and that other researchers perusing independent lines of research would present results of their activities. As a result, leaders of this Special Technical Publication (STP) are presented with a synopsis of a portion of the SHRP research considering performance based properties that can be compared to other fundamental engineering properties.

This STP is organized into two main topic areas. The first five papers deal specifically with SHRP research results. The remaining eight papers discuss other fundamental engineering properties and methods used by the researchers to relate the properties to performance.

The first three papers in the publication, "Investigation of the Relationship Between Field Performance and Laboratory Aging Properties of Asphalt Mixtures," "Validation of SHRP A-003A Flexural Beam Fatigue Test," and "Performance Based Properties of Asphalt Concrete Mixes," all originate from the SHRP Contract A-003A. These papers deal with development of test methods used in the Superpave method of mix design. The papers also discuss material properties that the authors believe could be used to predict pavement performance in fatigue and permanent deformation. The performance prediction approach as presented offers an alternative to the performance prediction approach contained within the Superpave method of mix design.

The next two papers, "Development of the SHRP Superpave Mixture Specification Test Method to Control Thermal Cracking Performance of Pavements" and "The Use of Time-Temperature Superposition to Fundamentally Characterize Asphaltic Concrete Mixture at Low Temperatures," discuss performance based properties to predict low-temperature cracking, tests used to measure the properties and models that are used to predict low temperature cracking. The two papers form a concise documentation of development of the low-temperature cracking portion of Superpave.

The following two papers, "Behavior Analysis of Asphalt Mixtures Using Triaxial Test Determined Properties" and "Engineering Properties of Asphalt Mixtures and Their Relationship to Performance," discuss engineering properties with a longer history in performance prediction literature.

The next paper, "Evaluation of Aging Characteristics of Modified Asphalt Mixtures," investigates aging behavior of modified asphalt systems as compared to unmodified asphalt systems and the relationship of aging to pavement performance.

The next two papers, "Analysis of a Well Performing Desert Pavement" and "Evaluation of Aging Characteristics of Asphalt Concrete Using Wave Propagation Techniques," approach the problem of prediction pavement performance by investigating existing pavements, then measuring properties that can be used to explain the observed performance.

The paper "Temperature Dependent Tensile Strength of Asphalt Mixtures in Relation to Field Cracking Data" investigates the tie between tensile strength of asphalt mixtures and the resistance to low temperature cracking.

The last two papers, "Potential of Dynamic Creep to Predict Rutting" and "Comprehensive Characterization of Performance Related Properties of Asphalt Concrete Mixtures Through Dynamic Testing," investigate laboratory properties that can be used to predict pavement performance in permanent deformation and fatigue cracking.

Summary

In the future the asphalt paving industry will face increased demand for improved performance and reduced risk of premature failure. One approach to reduce risk is the ability to measure performance-based properties as part of mix design process and predict in-service performance. Efforts to develop strong links between measured engineering properties and observed performance have been ongoing for the last several decades. SHRP technology has provided an advancement that remains to be implemented.

This STP contains information about both SHRP and non-SHRP approaches. It will provide the reader with part of the background behind the Superpave method of mix design including development of test methods for fatigue cracking and permanent deformation as well as an alternative method of using the SHRP tests to predict future distress. Development of Superpave tests for low-temperature cracking is discussed, as is the performance models for predicting low-temperature cracking.

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