



CENTER FOR AGGREGATES RESEARCH

EVALUATION OF AGGREGATE CHARACTERISTICS AFFECTING
HOT-MIX ASPHALT (HMA) RESPONSESummary
Report
ICAR-203-1S

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PROBLEM STATEMENT

Aggregate shape properties are known to influence asphalt pavement performance. Angularity and texture govern the frictional properties and dilation of the aggregate structure. Aggregate texture plays a major role in influencing the adhesive bond between the aggregate and the binder, while aggregate form influences the anisotropic response of asphalt mixes.

Empirical relationships typically have been used to relate aggregate shape characteristics to asphalt mix mechanical properties. This approach is commendable as it provides very useful information on the ability of test methods to capture the different characteristics of aggregate shape, and it highlights the different mechanical properties influenced by shape. However, these empirical relationships cannot be used in performance predictions as they do not allow for the evaluation of the interactions among these properties and their influence on performance. Only mechanistic models can offer the framework to account for the interactions of different aggregate shape characteristics with other mix constituents and to establish the link between these interactions and performance under realistic loading, environmental, and boundary conditions.

The general response of hot-mix asphalt (HMA) can be described by an elasto-visco-plastic model, while the relative contribution of each component depends on temperature and

rate of loading. Several studies have shown that the viscoplastic component (including the instantaneous plastic component) is the underlying mechanism of permanent deformation at relatively high temperatures, while the accumulated viscoelastic contribution to permanent deformation is relatively small. However, the viscoelastic response governs the mix response at intermediate temperatures associated with fatigue cracking. The viscoelastic portion of the model has been developed in a series of studies at Texas A&M University. This model is based on the elastic-viscoelastic correspondence principle and continuum damage mechanics. This study is concerned with the development of the viscoplastic portion of this model and the influence of aggregate shape properties on the model parameters. The model considers several factors that are known to influence HMA permanent deformation such as aggregate structure friction, aggregate structure dilation, confining pressure dependency, strain rate dependency, anisotropy, and microstructure damage following the mix hardening.

Researchers have adopted two main approaches in modeling permanent deformation: the continuum modeling approach and the micro-mechanistic modeling approach. Continuum models are powerful as they lend themselves to Finite Element (FE) implementation to predict performance under boundary conditions that simulate the field conditions. However, they generally do not account for the

effect of the microstructure on the macroscopic behavior of the material. In contrast, micro-mechanistic models directly account for the microstructure in modeling complex geometry as in HMA. This approach, however, has been limited by the accuracy to model the actual geometry of the microstructure in FE or discrete element models. In addition, micro-mechanistic models are computationally intensive and limited in their applicability to be used as performance prediction models.

There is a profound need to develop a microstructure-based continuum viscoplastic model for permanent deformation that can account for the effect of the microstructure in terms of the anisotropy of aggregate distribution and damage in terms of voids. By doing so, the model will have the advantages of a continuum model and will simultaneously account for the effect of the microstructure distribution.

OBJECTIVES

1) Evaluate the sensitivity of HMA performance to aggregate shape properties measured using conventional and image-analysis methods.

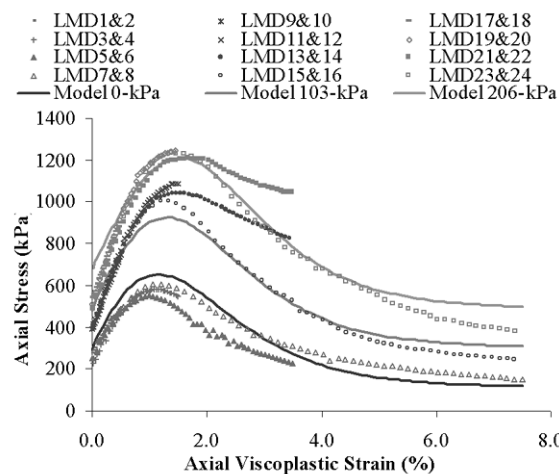
2) Develop a fundamental microstructure-based viscoplastic continuum model that links the microstructural properties in terms of aggregate anisotropy and damage to the permanent deformation of the material. The model needs to account for all the characteristics influencing permanent deformation including rate dependency, pressure dependency, dilation under shear loading, damage in terms of cracking, and anisotropy due to the microstructure distribution. Furthermore, the model parameters should reflect the effect of the different aggregate shape properties on the material response.

3) Conduct an experiment to capture and characterize the evolution of damage due to permanent deformation.

FINDINGS

This study developed methods to characterize aggregate shape properties and evaluated their influence on HMA mechanical properties. The Aggregate Imaging System (AIMS) was found to provide detailed and accurate measurements of form, angularity, and texture. Tests performed on aggregates before and after crushing demonstrated the sensitivity of AIMS analysis parameters to changes in shape characteristics. Very good correlation was found between the AIMS measurements and HMA properties measured in the laboratory. The permanent deformation results from repeated load uniaxial, controlled-stress testing were similar for mixtures prepared with limestone and granite aggregates in the dry condition, but better than the mixtures prepared with gravel aggregates.

A microstructure-based viscoplastic continuum model was developed in this study to link the microstructure properties influenced by aggregate shape to HMA behavior at high temperatures.



Model-Predicted vs. Measured Strains

Although the model was developed within the continuum mechanics framework, microstructure parameters were incorporated in the model in order to enrich it with virtues usually monopolized by discrete models. The microstructure properties accounted for in the model are the anisotropic aggregate distribution and damage in terms of crack initiation and growth.

The developed model links the microstructure distribution to the HMA response. The figure below left is illustrative of the model's capability to predict deformations. As such, the model can be used to examine the influence of changes in the mix design and material properties on the microstructure distribution and performance directly. This feature of the model offers the opportunity to optimize the mix design that will produce the maximum resistance to failure.

The model is developed within the framework of continuum mechanics, and it is readily available for numerical implementation in a Finite Element (FE) code. Implementation of the model in an FE code will enable the detailed simulation and study of the initiation and development of the distresses under various loading conditions. It will provide the necessary means of modeling the deformation process in order to predict rut depth in advance of construction.

The information in this summary is detailed in research report ICAR 203-1, Evaluation of Aggregate Characteristics Affecting HMA Concrete Performance, by Eyad A. Masad, Dallas N. Little, Laith Tashman, Shadi Saadeh, Taleb Al-Rousan, and Rajni Sukhwani.

The contents of this summary do not necessarily reflect the official views of AFTRE or ICAR.