Summary Report ICAR-502-1S

INTERNATIONAL ICAR CENTER FOR AGGREGATES RESEARCH

STRUCTURAL CHARACTERISTICS OF UNBOUND AGGREGATE BASES FOR MECHANISTIC DESIGN

The next *AASHTO Guide for the Design of Pavement Structures* will make extensive use of mechanistic-empirical design principles, and may result in pavement designs with different layer thicknesses than are currently common. ICAR Research developed new testing protocols and materials characterization models that properly characterize unbound granular materials. Now, for the first time a structural model accurately characterizes unbound aggregate bases for evaluation during design against other types of layers in flexible and rigid pavements.

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Approximately three billion tons of crushed stone, sand, and gravel are produced annually in the United States. A large quantity of this material goes into the construction of pavements. In flexible pavements, the unbound granular layers may serve as major structural components of the pavement system. Methods that more realistically characterize unbound aggregate bases (UABs) will significantly improve our ability to predict the performance of such material layers reliably. Previous pavement design procedures have taken a very conservative view of the relative strength properties of unbound granular materials.

ICAR has developed a protocol that defines the UAB as having significantly different resilient properties in the horizontal direction than it has in the vertical direction. It also defines the UAB's resilient response to load as dependent on the level of confinement and stress induced by a moving wheel. This is technically termed as "stress-sensitive" and "cross-anisotropic." ICAR has also developed a computer code in the form of a finite element model of the pavement which can accommodate this stress-sensitive, cross-anisotropic characterization. The predicted response of UAB when characterized in the conventional manner (linear elastic or stress-sensitive, isotropic, elastic) is very different than when it is characterized using the ICAR Method. The major difference is that when the conventional characterization is used, substantial tensile stresses are erroneously predicted within the UAB. Since an unbound material cannot handle tension, this incorrect analysis generally causes the UAB to be penalized structurally. When the more correct stress-sensitive, cross-anisotropic model is used, these tensile stresses do not occur, and the UAB can be assigned a more accurate and, sometimes, more favorable structural response.

ICAR has also characterized the permanent deformation characteristics of the UAB based on a three-parameter model. When the ICAR Resilient Model and permanent deformation model are used together, a complete structural characterization of the UAB is achieved. This

characterization protocol was validated through field testing at the Texas A&M Riverside Research Campus and by evaluating full-scale data from a test pit constructed at Georgia Tech. ICAR has been able to relate the resilient and permanent deformation properties of the UAB to grading properties of the UAB and moisture retention (suction potential) properties of the aggregate fines.

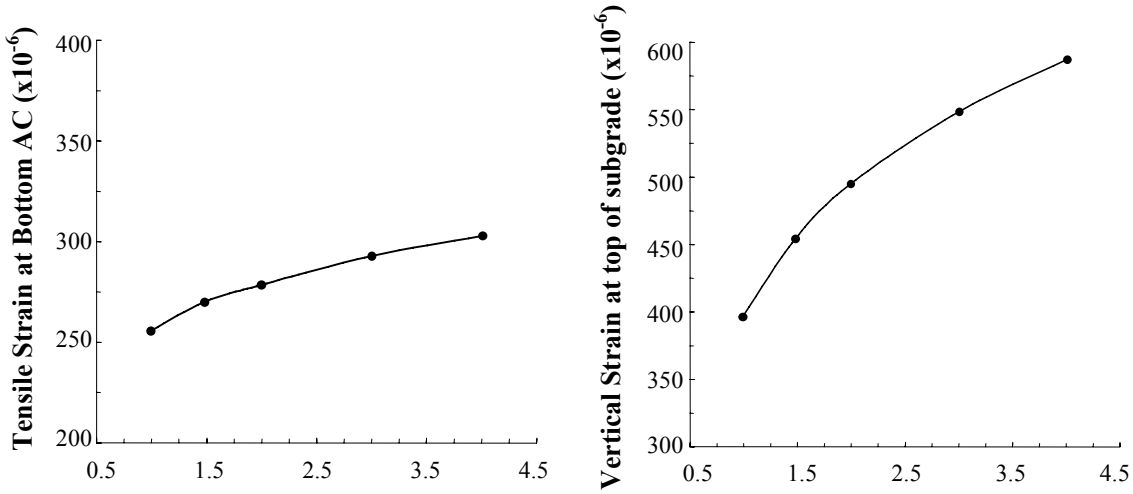
The figures below illustrate the importance of accounting for directional properties (anisotropy) in a pavement base course. Parameters such as tensile strain in the asphalt layer and vertical strain on the subgrade, resulting from wheel loadings, are considered critical pavement performance indicators. As shown in the figures, the degree of anisotropy present in the base course significantly affects these performance indicators and, hence, influences pavement life. The new model accurately accounts for this phenomenon.

This successful research has been a team effort between Dr. Dallas Little of ICAR and Dr. Erol Tutumluer at the University of Illinois, with invaluable assistance from Dr. Richard Barksdale, Professor *emeritus* of Georgia Tech. ICAR has completed comprehensive reports that document the following in a straight-forward, user-friendly manner: (1) testing protocol, (2) use of the finite element computer model for pavement design/analysis, and (3) use of grading and fine aggregate properties to predict the structural quality of UABs.

The information in this summary is detailed in ICAR Reports 502-1, Structural Characteristics of Unbound Aggregate Bases to Meet AASHTO 2002 Design Requirements Interim Report, *by Alex Adu-Osei, Dallas N. Little, and Robert L. Lytton; ICAR 502-2,* Field Validation of the Cross-Anisotropic Behavior of Unbound Aggregate Bases, *by Erol Tutumluer, Alex Adu-Osei, Dallas N. Little, and Robert L. Lytton; and ICAR 502-3,* Characterization of Unbound Granular Layers in Flexible Pavements, *by Alex Adu-Osei.*

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

Effects of Anisotropy on Critical Pavement Responses:



Degree of Anisotropy of Base Layer, E_v/E_h