Special Projects & Engineering Division

MATERIALS TECHNOLOGIES

Bridge Coating

Non-Destructive Evaluation

Recycling

Asphalt Concrete

Portland Cement Concrete

Highway Operations

RoSAN

SIMAP

U.S. Department of Transportation
Federal Highway Administration

Research and Development
Turner-Fairbank Highway Research Center
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S I M A P

Simulation, Imaging, and Mechanics of Asphalt Pavements

Asphalt concrete is a complex material that consists of aggregates, asphalt, and air voids. Aggregates are held together by asphalt and form a skeleton to support the weight of vehicles. The stiffer the asphalt, the tighter the aggregates are held together and the heavier the load a pavement is able to handle. Certain aggregate structures have stronger skeletons than others and thus can support heavier loads.

In an effort to build more durable pavements, State highway agencies use different mix-design procedures to find the strongest aggregate skeletons. Current mix procedures are empirical and are based on trial-and-error methods. They are time-consuming and may sometimes lead to costly pavement failures. The Asphalt Team at the Turner-Fairbank Highway Research Center (TFHRC) is currently working to develop the scientific basis underlying the mix-design process and to establish criteria to predict pavement performance. These efforts involve the simulation, imaging, and mechanics of asphalt pavement (SIMAP).

Through a multidisciplinary approach, the SIMAP program is pursuing the following objectives:

- To develop three-dimensional (3-D) imaging techniques to capture the internal structure of asphalt concrete specimens.
- To predict the response of asphalt concrete by applying mechanics to 3-D images.
- To analyze and quantify the aggregate structure to determine aggregate orientation, segregation, and aggregate-aggregate contacts.
- To develop computer models to simulate the internal structure of asphalt concrete and to predict its behavior based on volumetric and mechanics principles.
- To develop a systematic process that incorporates the technology acquired in this project into a useful tool for asphalt-mix design.

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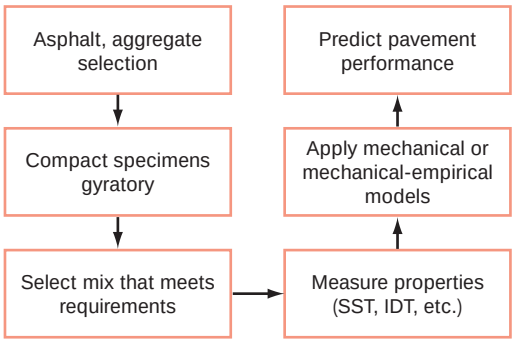
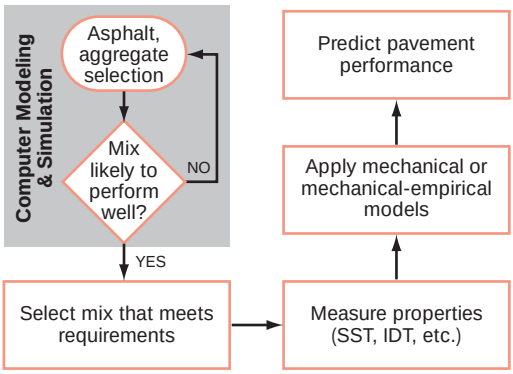
Where We Are

Superpave Method



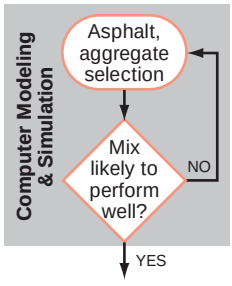
What If?

Proposed Method



How to Accomplish?

3-D Imaging and Simulation



Research Topics

- Aggregate structure-performance relationships?
- Optimum aggregate structure?
- Load bearing abilities?
- Effect of asphalt/mastic?

Approach	Methods
Aggregate structure	3-D imaging (x-ray tomography)
Optimum aggregate structure	Computer simulation and optimization of aggregate packing
Load bearing abilities	Granular mechanics
Effect of asphalt/mastic	Contact mechanics

Why?

The methods that are currently being used for the description of aggregate structures are based on consensus properties. In fact, most of the information available on gradation, angularity, texture, and volumetric properties of asphalt pavement are solely based on previous field experiences. By developing techniques to image and to quantify the structure of aggregates in asphalt concrete, and by applying mechanics that account for the aggregate structure, it will be possible to quantitatively relate the raw material properties to the performance of pavements in a scientific way. This will develop the foundations to building more durable pavements.

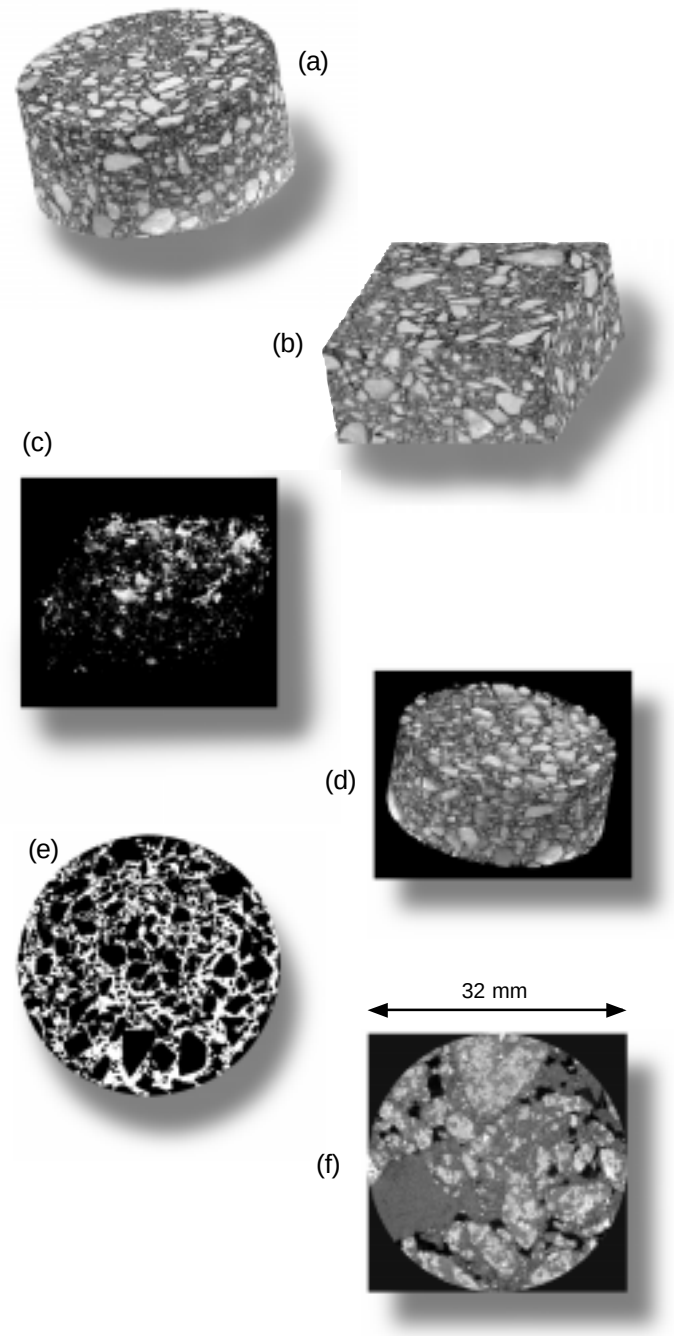
How?

Our basic approach to studying asphalt is to develop parameters that describe the aggregate structure and relate to pavement performance. This approach will enable us to develop a deeper understanding of the structure, develop and optimize the parameters, and optimize pavement performance.

X-ray tomography (CAT scanning) is being used to visualize aggregate structures in 3-D. We are currently developing the capabilities of 3-D image analysis to utilize this cutting-edge technology to its fullest potential. Through two-dimensional (2-D) image analysis, we have successfully quantified aggregate orientation and aggregate segregation and have gained useful information about the internal aggregate structure. We are also using computer simulations to find the relationships that exist between gradations and the internal structure of aggregates and to determine which gradations should be used to obtain a predesigned aggregate structure.

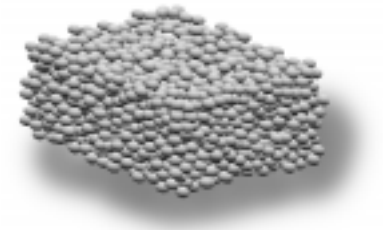
The SIMAP program treats asphalt pavement as cemented granular material and uses granular mechanics as a means to describe the stress-strain behavior of pavements. Photoelastic imaging and mechanics modeling are being used to obtain qualitative and quantitative descriptions of aggregate structures. Unlike previous efforts, these techniques will incorporate the effect of asphalt/mastic on pavement performance.

Asphalt Concrete Imaging and Analysis



A 3-D image of a 150-mm diameter core of asphalt concrete (from the WesTrack project) was obtained by x-ray tomography (a). This image can be treated as a virtual specimen that can be cut (as in (b)), analyzed to study voids (c), aggregate structure (d), and other features. Efforts are underway to quantify these features and to study the mechanical behavior of this virtual specimen. Simultaneously, 2-D image analysis is also being applied to study aggregate alignment, aggregate segregation, voids content and distribution, and to perform gradation analysis (e). X-Ray micro-tomography is also being utilized to study asphalt concrete in a finer scale such as in (f), in which the uneven distribution of asphalt in a typical pavement is shown.

Aggregate Packing Simulation



- Study influence of gradation, shape, etc., on aggregate structure.
- Optimize percent voids, aggregate aggregate contacts, etc.

Granular Mechanics

- Treats asphalt concrete as a collection of aggregates cemented with mastic.
- Considers each aggregate as a discrete element.
- The system's response is equal to the sum of the responses of individual elements.

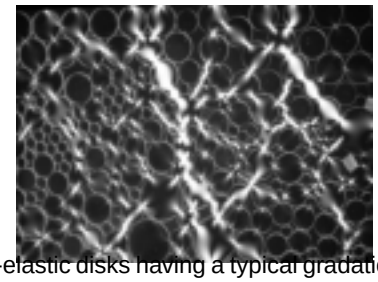
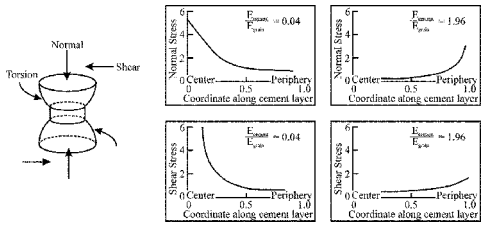


Photo-elastic disks having a typical gradation were viewed through polarized light. The bright lines show the stress paths within the system. While under 50 percent particles transmitted load, only 15 percent carried substantial load.

Contact Mechanics



- Stress transfer through an aggregate-aggregate contact depends on the relative stiffness of mastic and aggregate.
- Optimize mastic properties for performance.

Benefits

So far, it has been possible to measure aggregate segregation and orientation and to compare different compaction methods. Not only are we being able to characterize an asphalt core thoroughly, but we have also started correlating pavement performance to internal aggregate structures.

The SIMAP program now has the tools necessary to verify some concepts used in asphalt technology such as asphalt film thickness and voids in mineral aggregates. We have also started using 3-D imaging in forensic work to determine causes for pavement failure. In the future, we will work towards the optimization of mixture components and the development of a mixture-design process.

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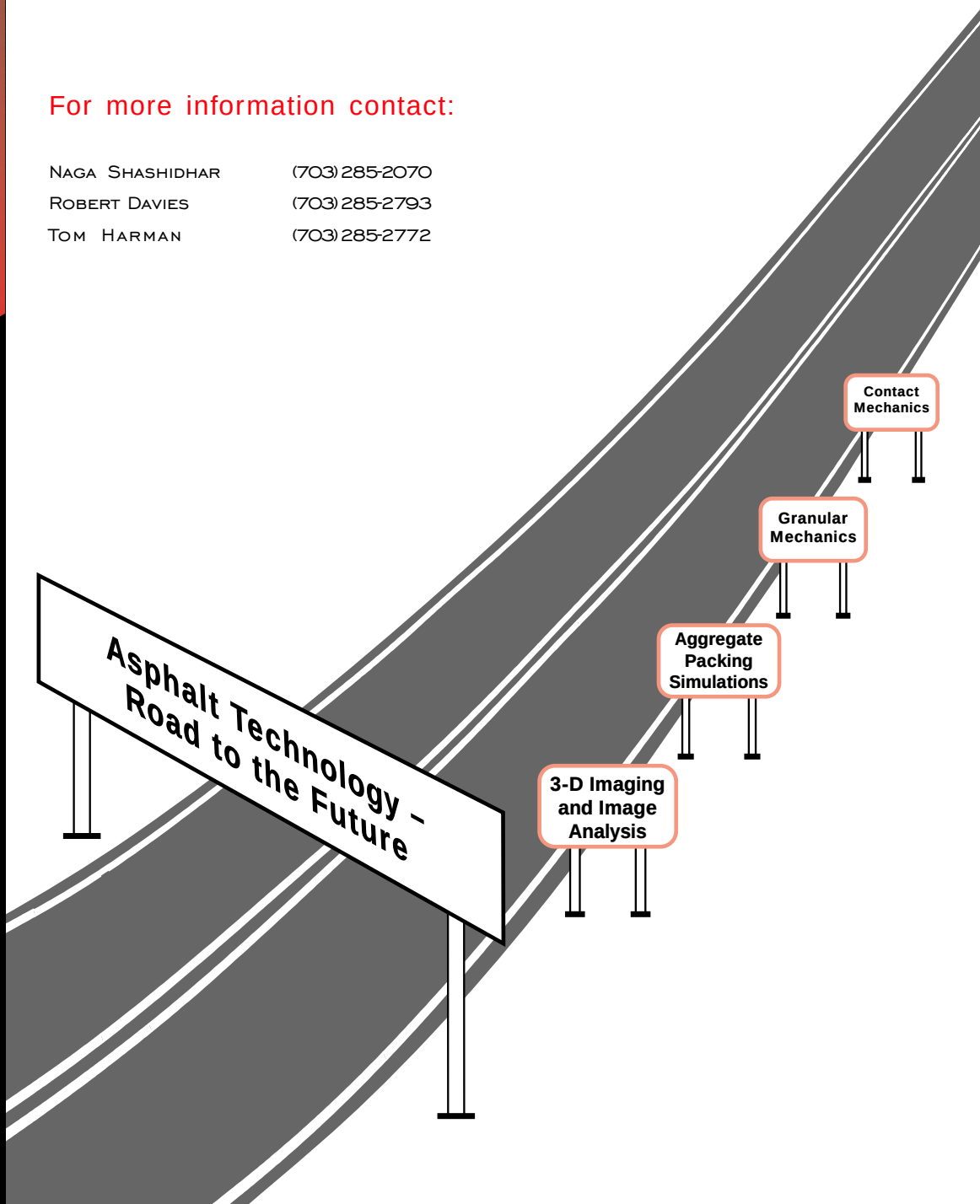

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