SOUTHERN PLAINS TRANSPORTATION CENTER

SPTC Brief

Highlighting Developments at Southern Plains Transportation Center
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NUMERICAL MODELING OF ASPHALT CRACK RESISTANCE

OVERVIEW: Over the past few decades, most of the state departments of transportation (DOTs), especially in the southern region, have used stiffer hot mix asphalt (HMA) to mitigate rutting. The shift toward stiffer mixes has resulted in asphalt pavements that are more prone to reflective and fatigue cracking. Cracking in HMA usually results in much faster deterioration rates of the pavement. The Overlay Tester (OT) has been implemented by the Texas DOT (TxDOT) to predict HMA resistance to cracking. However, most of the research related to OT test has focused on its variability and correlations with the field performance. Numerical simulations of the test are limited to studying the levels of stress and strain developed within the tested specimens. A numerical approach that is capable of studying the interrelated effects of aggregate strength, gradation, shape, and asphalt grade on the asphalt mix crack resistance is needed.

CURRENT RESEARCH: In this study, a numerical model of the Overlay Tester (OT) and Semi-Bending Circular (SCB) test were developed that combined discrete element modeling (DEM) with imaging techniques to study asphalt mix crack resistance. In DEM, which synthesizes macro continuum material behavior from the interactions of micro discrete elements, the input properties usually are not known and can only found by calibration. The development of the OT-DEM model was achieved in four steps. Step 1 focused on developing material-genesis for asphaltic materials; the one phase asphalt material-genesis (homogenous) was based on representing the material with dense-packing of non-uniform circular (2D) or spherical (3D) discrete elements that are bonded at the contact points. Step 2 focused on expanding the model from homogenous to heterogeneous. X-ray images were stacked to form the three dimensional representation of the asphalt mixes internal structure (3D aggregate representation). The third step was the addition of the loading plates. Three methods were considered: loading plates as rigid walls in DEM, loading plates using DEM particles, and applying the boundary conditions to the bottom of the OT sample. All three methods produced similar results; however, the third method was selected due to its computational time. In the last step - resolution (diameter of the discrete element particles) was studied, and it was concluded that the discrete elements radius range of 1 to 2 mm is sufficient to capture the internal stresses.

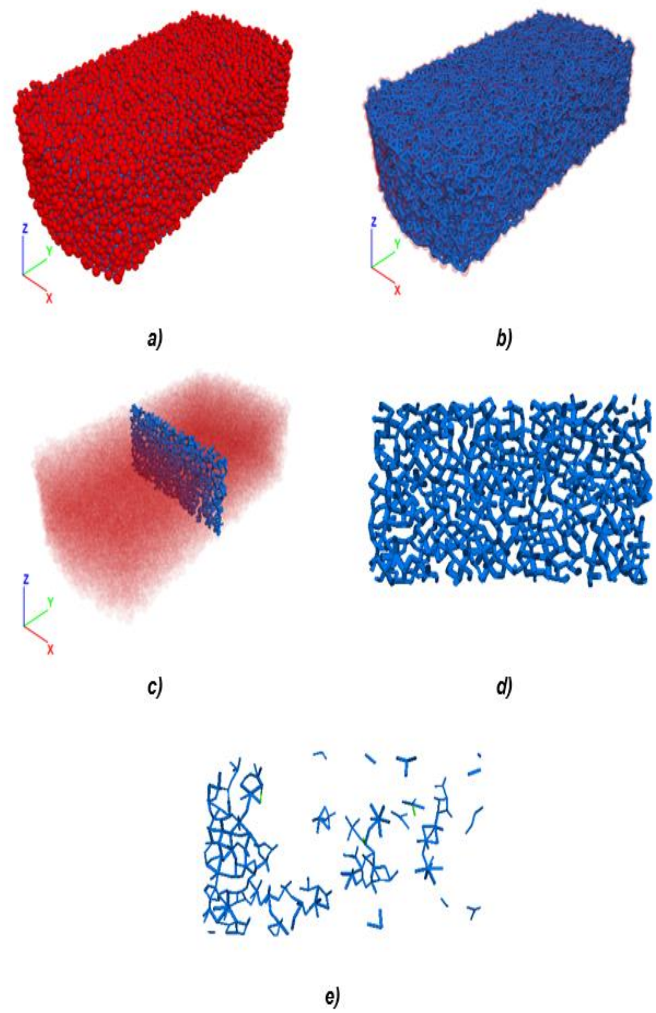

Figure 1: Overlay Tester Development: a) OT Sample, b) OT Sample Bonds, c) OT Sample Center Bonds, d) Center Bonds Isolated, e) Center Bonds after One Loading Cycle

The materials and mixes selected covered wide range of aggregate gradations, strength, and shape properties, the mixes included were: Superpave-C, CMHB-C, and PFC, while the aggregates were: a hard limestone, soft limestone, and granite. Split tensile testing results for the nine combinations of mixes and aggregates were available in addition to the modulus, compressive strength, and split tensile for the aggregates. Based on the results of the study the following conclusions can be drawn:

- DEM is a viable numerical technique to study crack and fracture within asphalt mixes, it is capable of capturing the viscoelastic behavior and damage can be tracked based on the breakage of the bonds between the model elements. Additionally, DEM models of splitting tensile test and compressive strength can be successfully used to match laboratory testing results.
- DEM-OT can be successfully simulated with three types of loading conditions: rigid walls, DEM particles loading plates, and applying the boundary conditions to the bottom of the OT sample.
- X-ray images provide a great mean to develop heterogeneous DEM-OT, however, the process of converting the images to a 3D model is cumbersome, and time consuming. Automating such a method would result in less accurate representation of the aggregate shape and size and is not recommended.
- DEM model resolution could affect the accuracy of results, thus, it is very important to conduct a sensitivity analysis to obtain acceptable basic results.
- DEM-OT test is best analyzed by tracking the number of broken bonds rather than attempting to track the active bonds in the center of the sample. Additionally, the numerical simulations are more reliable and meaningful when heterogeneous sample is considered rather than homogeneous one.
- OT-DEM simulation with rigid wall loading plates provided more realistic results and is recommended for future studies.
- SCB-DEM can be successfully simulated and virtual samples can be generated to match typical asphalt mix gradations.

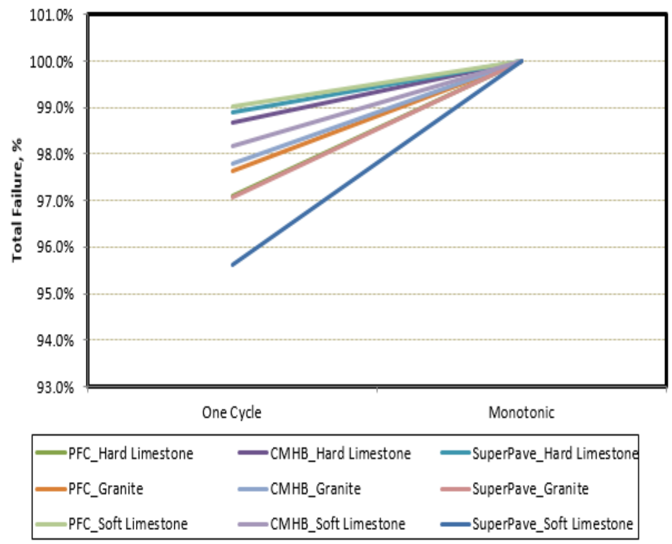

Figure 2 Percent Failure after One Cycle- Homogenous DEM

IMPACT: This research provides a numerical approach that is capable of studying the interrelated effects of aggregate strength, gradation, shape, and asphalt grade on the asphalt mix crack resistance is needed. Such approach will allow for a reduction in experimental testing and serve as a screening method prior to starting a full scale experimental testing program. It is anticipated that this approach will be beneficial to the state DOTs in general, and more specifically to the southern plains region.

About the Researchers

Dr. Enad Mahmoud is the Principal Investigator. Drs. Imad Abdallah and Soheil Nazarian are Co-Principal Investigators on the project. Students David Renteria and Roberto Yanez also contributed. The team represent the University of Texas at El Paso.

The *Southern Plains Transportation Center* is a consortium of eight universities in U.S. Department of Transportation Region VI: the University of Oklahoma, Oklahoma State University, Langston University, University of Arkansas, University of New Mexico, Louisiana Tech University, University of Texas at El Paso and Texas Tech University.

The SPTC provides a unique opportunity through multi-institutional initiatives to develop comprehensive, cost-effective, and implementable solutions to critical infrastructure issues facing the transportation systems of the region and the nation, and to prepare transportation professionals for leadership roles through *Research, Leadership, Collaboration, Education, Outreach, Tech Transfer* and *Workforce Development* activities.