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Sensitivity Analysis of the IDEAL CT Test Using the Distinct Element Method

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Introduction

Cracking is a primary mode of failure for asphalt concrete (AC), resulting in extensive road damage and deterioration which significantly leads to an increase in road hazards and fatalities. Therefore, understanding and studying the fracture behavior of AC provides an effective pathway to learn how to best enhance their cracking resistance, effectively improving roadway safety and longevity. To this end, the indirect tensile cracking laboratory test (IDEAL-CT) was developed and used to assess AC cracking behavior. The IDEAL-CT, which has recently been accredited by ASTM (2016), is one of the innovative ways to assess cracking performance. It uniquely quantifies and differentiates mixes through a unique index that represents their respective cracking resistance, thus providing crucial insight for roadway improvement strategies. Several parameters impact the results of IDEAL-CT. This study focuses on the variation of air voids, loading rate, aggregate shape, bonding type, and gradation mix. Exploring these parameters requires a broad spectrum of tests, with this study alone necessitating more than 450 test scenarios. Executing such a vast number of physical tests would undoubtedly consume substantial resources and time. In order to solve this issue, the sensitivity analysis and parameters variation was conducted through the Particle Flow Code in two-dimension software (PFC2D), which employs the discrete element method (DEM) mitigating the need for actual laboratory tests. This innovative solution circumvented traditional lab testing, saving valuable time and resources while maintaining accurate and insightful results.

Study Methods

The test was conducted through the PFC2D software, first by modelling aggregate shape as per their real texture, then adding the air voids and filling the remaining area of the cylinder by asphalt. Bonding types were initiated describing the tensile and shear resistance of every mix type. The simulation begins with a wall body moving downward, creating fractures in the cylinder mix, until the cylinder breaks. The load displacement curve provided by the software is assessed to calculate the CT-index of every different mix.

Findings

- IDEAL-CT test is sensitive to air void content; it has a negative impact on the IDEAL-CT output.
- Even though an increase in loading rate yielded a poorer performance in cracking resistance and in decreased peak load before breaking, T-test showed that this increase is random and that loading rate doesn't have much impact on the cracking resistance.
- CMHB gradation mixes have better performance than superpave mixes, hence mixes with a greater percentage of aggregates have better cracking resistance.
- Hard limestone can support greater peak loads prior to breaking and have slightly greater cracking resistance than granite based on the contact bond properties introduced.
- Angularity of aggregates has a great deal of impact on cracking resistance. The lower the mix's angularity is, the better the cracking resistance will be and the greater load a mix will support before failure.
- Sorting the variables by the most impactful to the least impactful will be: aggregate shape and angularity, mix gradation, and then the material.
- Mix gradation and material type change are introduced in the software through the values of the particles' bonding strength.
- The IDEAL-CT test can be considered a repeatable cracking test based on its low coefficient of variation for every mix studied.
- Air void distribution in the sample dictates the trajectory of failure.
- Cracks mostly initiate underneath the loading bar and develop through air voids up until fractures connect and break the specimen.

Policy Recommendations

For further sensitivity analysis studies, base the research on the distinct element model to model any laboratory test based on cracking, complete a calibration study to reach accurate results, and then use the model to conduct any sensitivity analysis needed.

> The PFC2D software based on the distinct element method can account for the sensitivity analysis of the IDEAL CT in respect to gradation, air void content, aggregate angularity, and material properties.

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