Abstract:

Fatigue cracking is one of the major asphalt pavement distresses that have been studied extensively. Therefore, several test methods and theories have been developed to characterize asphalt mixtures resistance to fatigue cracking. Among these test methods, the cyclic fatigue test employs the simplified viscoelastic continuum damage model (S-VECD). The S-VECD model utilizes the viscoelastic continuum mechanics theories and damage evolution laws to fundamentally characterize asphalt mixtures' fatigue cracking performance. However, the implementation of the S-VECD framework remains restricted. The cyclic fatigue test is rigorous but time- and resource-intensive. Conventional specimen preparation is time- and resource-intensive, requiring precise cutting and the use of epoxy adhesives to mount specimens onto loading platens. These steps are critical for test success and typically require highly trained personnel, while also introducing delays due to epoxy curing. Moreover, the fatigue index derived from the test (S_{app}), has limited sensitivity to long-term aging. Long-term aged asphalt materials are more prone to cracking. Consequently, a fatigue cracking index intended to support performance-based decisions should be capable of reliably distinguishing among mixtures across different aging conditions. This research addresses the barriers limiting the widespread implementation of the S-VECD framework. A patented mechanical clamping system was developed to eliminate the need for cutting, and for epoxy adhesives which allows rapid, repeatable specimen mounting, thereby streamlining the workflow and reducing testing time. Additionally, an optimized protocol for both the dynamic modulus and cyclic fatigue tests was adopted. The optimized protocol included coring five specimens from a single Superpave gyratory compacted specimen (SGC), compared to the current practice of extracting four. Furthermore, the specimens tested in dynamic modulus were retested in cyclic fatigue test which improves workflows, save time, and materials without affecting the integrity of the test results. The S_{app} index is semi-empirical index based on the damage characteristic curve. The index penalizes the stiffer mixtures based on their linear viscoelastic modulus; however, this penalty does not counteract the changes in damage characteristic curve. Therefore, the S_{app} index was further normalized based on the modulus value to address its aging sensitivity resulting in the S_{flex} index. Further evaluation on the different long-term aging protocols (Method C and Method E) and their effect of the asphalt material fatigue cracking properties was evaluated using S_{flex} index. Building on the fundamental S-VECD framework, this work makes cyclic fatigue characterization more efficient and more sensitive to aging. In turn, agencies can make more reliable, performance-based design decisions, evaluate new and innovative materials with confidence, and build longer-lasting, more durable pavements.

Keywords: Simplified viscoelastic continuum damage (S-VECD), Uniaxial cyclic fatigue, Collet-Chuck, Apparent damage index (S_{app}), Long-term oven aging, Fatigue cracking.