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Characterization of oxidative aging in asphalt concrete using a noncollinear ultrasonic wave mixing approach

Reis, Henrique, h-reis@illinois.edu; McGovern, Megan; Buttlar, William,
University of Illinois at Urbana-Champaign, United States

ABSTRACT

Although possessing remarkable toughness in its original state, asphalt concrete (AC) becomes brittle and prone to damage with time in the form of costly pavement cracking. The time required to reach an unacceptable level of embrittlement depends upon a number of factors and varies widely from pavement to pavement, even within a given region and mixture type. Given the annual costs associated with pavement repair of damage caused by mechanical and thermal loads, considerable interest exists in testing methods to estimate damage in AC pavements. Current methods to evaluate the existing conditions of AC pavement surfaces for sustainability-based pavement asset management are based upon the binder's rheological properties, are time consuming, costly, and by themselves, may cause additional damage. Oxidative aging is a key contributor in the deterioration of AC pavements. Exposure to environmental conditions causes gradual oxidative aging of the AC, where the highest aged material is located at the surface, whereas the material at the bottom of the pavement is significantly less aged. Over time, increasing aging at the surface leads to a pavement with graded material properties through its thickness where the material near the surface has warmer embrittlement temperatures and higher stiffness when compared with the bottom of the layer. Increasing aging also results in significant loss of adhesion between the binder, aggregates, and fines, which contributes to an increase in the microflaw population in the mastic and at the interfaces between the mastic and the aggregates. As the pavement is subjected to thermal and mechanical loads, microcracks develop and coalesce to form larger cracks. Repeated loading and exposure to environmental conditions eventually leads to significant deterioration of AC pavements. Although surveys are conducted to monitor the condition of pavements and to determine when preventative or corrective maintenance is necessary, accurate assessment of the amount of pavement deterioration has remained a challenge. A study to assess oxidative aging of AC using noncollinear wave mixing of two dilatational waves will be presented. Criteria are used to assure that the detected scattered wave originated via wave interaction in the AC and not from nonlinearities in the testing equipment. These criteria include frequency and propagating direction of the resultant scattered wave, and the time-of-flight separation between the two primary waves and the resulting scattered wave. It was observed that AC exhibits nonlinear behavior. It was also observed that the nonlinear response decreases with increased aging until ~24 hours of aging after which the nonlinear response exponentially increases. This observation is consistent with earlier studies including acoustic emission response to thermal loading, and with changes in dynamic modulus and fracture energy with increasing aging.