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Effect of hydrated lime on fracture performance of asphalt mixture

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HIGHLIGHTS

- A modified conditioning procedure was used to better simulate field conditions.
- The hydrated lime helped stiffen the mixture without increasing its brittleness.
- The hydrated lime helped reduce rate of damage accumulation in the mixture.
- Introduction of hydrated lime resulted in better fracture performance.
- The lime-treated mixture was found more cost-effective than the untreated one.

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ABSTRACT

A recently developed conditioning procedure was employed to better simulate effects of field conditions on asphalt mixtures. The energy ratio (ER) approach, capable of integrating various factors affecting cracking performance, including key mixture properties and pavement structure, was used to evaluate the effect of hydrated lime (HL) on fracture performance of conditioned and unconditioned asphalt mixtures. The results showed that HL was beneficial in resisting detrimental effects on damage and fracture-related properties caused by the conditioning. Also, HL resulted in better fracture performance for the same design asphalt concrete layer thickness, or in less cost to achieve the same performance.

1. Introduction

1.1. Background

Hydrated lime (HL) is widely used as an additive in asphalt layers because of its beneficial effects in terms of resistance to moisture damage which is a major contributor to premature distress. Numerous laboratory conditioning methods have been developed to evaluate mixture resistance to moisture damage. However, many of the methods used to induce moisture damage in asphalt mixtures may not capture major factors associated with mechanisms of moisture damage in field pavement sections. Also, parameters to evaluate moisture damage are commonly based on a single mixture property, which may fail to provide consistent results regarding the effect of conditioning on mixture performance. A brief summary of findings from the literature is provided below.

Among the various test methods developed to induce and evaluate moisture damage of asphalt mixtures, AASHTO T283 procedure is most widely used, which includes vacuum saturation and free-thaw processes [1–3]. The ratio of indirect tensile strength after and before conditioning (TSR) is calculated to determine moisture susceptibility of the mixtures. However, the procedure does not necessarily simulate field conditions [4], which involve heat oxidation, water damage and other environmental damage. Recently, a test known as the saturation aging tensile stiffness (SATS) was developed which combines heat oxidation and moisture to simulate in the laboratory the loss of stiffness of asphalt pavement in the field [5,6]. During the conditioning process, samples are placed in a high temperature and pressure environment in the presence of moisture for a period of 65 h. The method was able to distinguish between good and poor performing mixtures with respect to moisture damage. However, due to the aggressive nature of the method, it generally resulted in more severe damage in mixtures than the T283 procedure. In addition, tests have been developed to simulate field conditions through repeated application of pore pressure on compacted asphalt mixtures, although the effect of oxidative aging was not considered. The moisture induced stress tester (MIST) is one of the recent developments that simulate cyclic pore pressure under wheel load [7,8]. However, the system relies on the TSR for moisture damage evaluation, which is based on one single mixture property. Although turbidity of water inside

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the conditioning chamber was monitored, the changes in turbidity and TSR were not found to be closely related. The other system that utilizes cyclic pore pressure conditioning (CPPC) was recently developed at the University of Florida (UF), which simulates the moisture damage mechanism in the field by exerting repeated pressure on the internal void structure of laboratory-compacted asphalt mixtures [9]. Furthermore, the energy ratio (ER) parameter was adopted for relative comparison of moisture susceptibility, which takes into account several mixture properties that have been shown to control fracture performance of asphalt mixture [10]. It appeared that all these recent developments aimed to replace traditional methods such as the T283 procedure still suffer from one or more deficiencies. Nevertheless, recent developments have laid the foundation for a more suitable and consistent approach of moisture conditioning and evaluation.

In this study, a modified UF moisture conditioning procedure was presented which applies the SuperPave long-term oven aging (LTOA) conditioning to the compacted specimens before subjecting them to the CPPC to more appropriately simulate field conditions [11]. Three types of asphalt mixtures (untreated granite, lime-treated granite, and untreated limestone mixtures) were conditioned using the modified procedure. SuperPave indirect tensile (IDT) tests were performed to determine damage and fracture related properties of all mixtures for both conditioned and unconditioned states. The ER approach, capable of integrating varying effects of conditioning on several key mixture properties into the change in cracking performance, was used to evaluate the effect of HL on fracture performance of asphalt mixture subjected to the improved conditioning procedure: LTOA plus CPPC.

1.2. Objectives

The primary objective of this study was to evaluate the effect of hydrated lime on fracture performance of asphalt mixture subjected to a modified conditioning procedure that was developed to more suitably simulate field conditions, including heat oxidation, presence of water, and cyclic traffic loading. Detailed objectives are summarized as follows:

- Present and demonstrate the effectiveness of the modified conditioning procedure (i.e. LTOA plus CPPC).
- Evaluate the effect of HL on properties of mixture subjected to the modified conditioning procedure.
- Evaluate and quantify the effect of HL on fracture performance of asphalt mixture.

1.3. Scope

This study was mainly focused on evaluating the effect of HL on fracture performance of asphalt mixture subjected to a modified laboratory conditioning procedure designed to more suitably simulate field conditions. The ER parameter, which was developed using the HMA fracture mechanics model and calibrated with field aged cores from Florida pavements, was adopted in the evaluation process.

2. Materials and methods

Materials used to produce laboratory specimens, and methods for sample preparation and testing are described in the following subsections.

2.1. Materials

Two aggregate types were selected: Georgia granite and Florida oolitic limestone. These aggregates have been widely used in the state of Florida and are approved by the Florida Department of Transportation (FDOT) for road construction and rehabilitation projects. Three types of asphalt mixtures were produced, including two granite mixtures (one was untreated and the other was treated with 1% hydrated lime) and one limestone mixture (untreated). The untreated granite and limestone mixtures were used to help demonstrate the effectiveness of the conditioning procedure employed, and the lime-treated granite mixture was incorporated to evaluate the effect of lime on mixture performance. The gradations of the granite and limestone mixtures (untreated) are shown in Fig. 1. Both mixtures were designed with 12.5 mm nominal maximum aggregate size gradations and a traffic level corresponding to 3–10 million Equivalent Single Axle Loads (ESALs) over 20 years. The lime-treated granite mixture was designed by modifying the untreated granite mixture without changing its original gradation. Specifically, 1% of the material passing no. 200 sieve by total weight of the aggregates (untreated mixture) was replaced by the same weight of the dry hydrated lime. The same binder (PG 67-22) was used for all mixtures. The binder contents of the untreated granite and limestone mixtures determined in the mix design were 4.8% and 6.6%, respectively. The effective binder contents of both mixtures were identical (4.5%). The binder content of the lime-treated granite mixture was maintained at 4.8% to assure that only lime would affect test results.

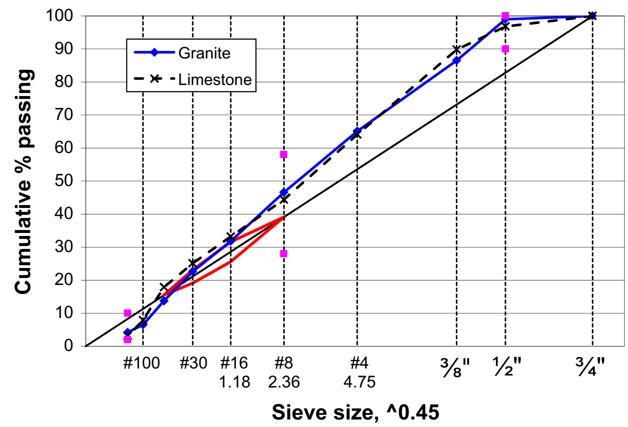

Fig. 1. Asphalt mixture gradations.

2.2. Sample preparation

Short-term oven aging (STOA) and long-term oven aging (LTOA) procedures were introduced by the strategic highway research program (SHRP) to simulate oxidative aging of field asphalt mixtures [12]. The STOA mimics the aging effect during the process of mixing and placement of asphalt mixtures corresponding to the condition immediately after construction, and the LTOA simulates the additional aging effect corresponding to the condition in the field after 5–10 years. All three types of mixtures were short-term oven aged and then compacted to 7% (±0.5%) air voids using the SuperPave gyratory compactor. For each type of mixture, one half of the compacted pills were further aged following the LTOA process. All pills (150 mm in diameter) were then sliced into specimens of desired thickness (around 38 mm). Gage points were attached to each face of the prepared specimens along the vertical (loading) and horizontal axes for deformation measurements during the SuperPave indirect tensile (IDT) tests described in Section 2.4.

2.3. Cyclic pore pressure conditioning

The cyclic pore pressure conditioning (CPPC) system developed at UF was composed of three primary subsystems: (i) a triaxial cell designed for containing 100-mm diameter specimens, (ii) a water pressurization and distribution subsystem, and (iii) a water temperature control subsystem [9]. Recently, the CPPC system was modified to induce moisture damage in specimens aged with both the STOA and LTOA procedures [11]. In the modified system, the triaxial cell was replaced with a new tabletop triaxial chamber to accommodate 150-mm diameter IDT specimens, which can be directly produced from SuperPave gyratory compacted pills or field cores. In addition, the external loading frame associated with the original triaxial cell was removed since only cyclic pore pressure was used for moisture conditioning. Fig. 2 shows the new tabletop triaxial chamber containing IDT specimens. As can be seen, spacers were introduced between all specimens to allow for water infiltration and to protect the gage points from being damaged during the conditioning process.

In this part of the study, the specimens were first subjected to a two-cycle saturation process. Each cycle included a 15-min vacuum saturation period at 12.3 psi (±1.0 psi (6.9 kPa)) followed by a 20-min submergence period at atmospheric pressure. No specific saturation levels were targeted since each mixture has a unique void structure that may enhance or reduce its saturation capacity. The specimens were then placed in the tabletop triaxial chamber and subjected to a combination of pore pressure cycles and temperature determined to be appropriate during our