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Laboratory evaluation of stabilizing methods for porous asphalt mixtures

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HIGHLIGHTS

- Stabilizing additives should be incorporated into porous asphalt mixtures.
- Cellulose fibers and crumb rubber were the most effective means of reducing draindown.
- Cellulose fibers and crumb rubber improve the long-term draindown resistance.
- Crumb rubber improved the abrasion resistance of the porous asphalt mixture.

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ABSTRACT

The objective of this study was to compare the performance of different stabilizing additives (cellulose fibers, styrene–butadiene–styrene [SBS], and crumb rubber modifier [CRM]) in a porous asphalt mixture. The mix evaluation was based on draindown, permeability, abrasion resistance, moisture susceptibility, and rutting. The results emphasized the importance of stabilizing additives in porous asphalt mixtures. Further, the results indicated that the addition of fibers or CRM were the most effective at minimizing draindown; CRM or the combination of fibers and SBS were the most effective at increasing the abrasion resistance; and the fibers had no effect on the mix strength.

1. Introduction

Porous asphalt is an asphalt mixture with little or no fine aggregate. The reduced amount of fines creates interconnected, stable air pockets in the asphalt mix that allow water to flow through the mix. Porous asphalt is used across the world for two main pavement applications: Wearing courses on high-speed roadways and for porous pavements for stormwater management. As a wearing course, a thin layer of porous asphalt ranging from 19 to 50 mm thick is placed over a conventional impermeable pavement surface [1]. This porous overlay, referred to as an open graded friction course (OGFC) or porous friction course (PFC) has been shown to improve roadway safety by allowing water to drain into the porous layer and then flow laterally within the porous layer until it exits the pavement through a daylighted edge [2–6]. When used for stormwater management purposes, a thicker porous asphalt layer (50–100 mm thick) is placed over an open graded aggregate base course that acts as a reservoir for stormwater before it infiltrates into the underlying soil [7]. In these applications, the quantity of stormwater runoff to be accommodated by conventional stormwater management infrastructure is significantly reduced due to infiltration and the porous pavement structure acts as a filter during the process [8,9].

With all of the positive attributes of porous asphalt mixtures for specific applications, there are two common problems that have caused inconsistency in porous asphalt performance, specifically in OGFC applications: Raveling and binder draindown [1,5,10].

Raveling is a pavement distress resulting from the loss of individual aggregate particles at the surface of a pavement due to a loss of adhesion between the binder and the aggregate or due to poor cohesion within the binder mastic coating the aggregate. In porous asphalt, this problem is thought to be caused by the open void structure typical of such a mix which increases the exposure of the binder film to air and the elements compared to traditional

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dense graded mixes. This increased exposure can lead to premature oxidation of the binder, thus making it brittle and leading to raveling [11]. In addition to aging, other factors can lead to raveling of OGFC mixtures including: Stripping, low binder content, dust coated aggregates, aggregate gradation, compaction temperature and effort, traffic frequency, studded tires, and others.

Draindown can be seen as excess asphalt binder that drains out of a porous asphalt mixture at temperatures typically used for production and construction and it is attributed to the lack of fines to promote permeability and the increased asphalt binder content to increase durability [12]. In addition to production temperatures, draindown can also occur over time at high service temperatures (hot summer days) if the mix design does not include materials to prevent draindown. In this case, the high pavement temperature causes the binder to soften and gradually flow downward through the void structure due to gravity until it reaches a cooler portion of the pavement (approximately 12.5 mm below the surface) where it then stops flowing. This long-term draindown can reduce the permeability of the porous asphalt [13].

If the binder content of a porous asphalt mixture is arbitrarily increased to improve durability without some other adjustment to the mix design, a portion of the added binder will be lost due to draindown. To design porous asphalt mixtures with higher binder contents, additives are typically incorporated to stabilize the mix and prevent draindown. The stabilizing additives employed most commonly in porous asphalt mixtures are polymers which stiffen the asphalt binder and fibers which absorb the additional binder creating a thicker mastic around the aggregate particles that is less susceptible to draindown [1,5].

Several studies have been conducted on stabilizing additives for mixtures that are susceptible to draindown, such as porous asphalt and stone matrix asphalt (SMA). However, the majority have investigated only one category of stabilizers, either polymer modifiers or fibers, but not both [14,15]. Brown et al. evaluated two different types of polymers and two types of fibers in the same study and determined that the fibers and polymers were effective in reducing high temperature draindown of SMA mixtures, but the cellulose and rock wool fibers were significantly more effective stabilizers than the styrene–butadiene–styrene (SBS) and polyolefin polymer modifiers used in the study [16]. Similar results were found in a study by Stuart and Malmquist [17]. In addition to traditional polymers, crumb rubber derived from scrap tires has been used as a binder modifier resulting in stiffer binders having increased viscosity at high temperatures [18]. The stiffening effect of crumb rubber on asphalt binders can help to minimize or prevent draindown while increasing the durability of the mix [19,20].

1.1. Research objective

The primary objective of this study was to investigate the influence of different stabilizing additives on porous asphalt mixtures. This was accomplished by comparing porous asphalt (or OGFC) mixtures made with three different types of stabilizing additives (SBS polymer, crumb rubber, and cellulose fibers). The study focused on both the stabilizing effect of the additives as well as the influence on the performance properties of the mixtures.

2. Experimental materials and methods

To satisfy the objectives of this research, six different mixtures were prepared and evaluated using one aggregate source and gradation and three different stabilizing additives (SBS, crumb rubber, and cellulose fibers). Each mixture was evaluated to determine the influence of the stabilizing additive (or combination) on draindown before measuring the performance properties of each mix.

Table 1
Aggregate properties.

Property	Value
Bulk Specific Gravity	2.60
Bulk Specific Gravity (SSD)	2.62
Apparent Specific Gravity	2.65
Absorption	0.8%
LA Abrasion Loss (C Grading)	29%

Table 2
Aggregate gradation evaluated in this study.

Sieve size (mm)	% Passing
19.0	100
12.5	94.0
9.50	69.0
4.75	19.0
2.36	6.0
0.60	4.0
0.15	2.3
0.075	1.0

2.1. Materials

2.1.1. Aggregate

For this study, one crushed granite aggregate source was used for the comparative investigation as granite is a common aggregate type used for asphalt mixtures in the Southeastern US. The properties of the aggregate used in this study are summarized in Table 1. The aggregate was sampled from the quarry and transported to the lab where it was dried in an oven at 110 °C, then mechanically sieved into the individual size fractions needed to produce the mix gradation in Table 2.

2.1.2. Binder

In total, four different binders were used in this study: A neat binder, a modified binder made by adding 3% SBS to a PG 64-22 binder, a modified binder made by adding 5% crumb rubber to the neat binder (CRM5%), and a modified binder made by adding 12% crumb rubber to the neat binder (CRM12%). The neat binder had a performance grade of PG 64-22 and was obtained from an asphalt terminal. This neat binder was used by itself as one of the binder treatments in this study and it was also used as the base binder to produce the crumb rubber modified (CRM) binders. The SBS modified binder was obtained from the same terminal, however, it could not be confirmed if the source of the base binder used to produce the modified binder was the same as the PG 64-22 neat binder used in this study. This SBS modified binder is marketed as a PG 76-22 binder. The properties of all of the binders used in the study are summarized in Table 3.

2.1.3. Crumb rubber

The crumb rubber modifier (CRM) used to produce the CRM binders was manufactured by processing scrap passenger automobile tires using an ambient shredding operation at a tire processing facility. The crumb rubber was classified as a 30 Mesh crumb rubber (Class 30-1) in accordance with ASTM D5603 [21]. This designation means that the rubber has no more than 10% cumulative retained on the No. 30 (0.6 mm) sieve and is a Grade 1 rubber (processed from whole passenger car, truck, and/or bus tires from which the fiber and metal have been removed). The gradation of the rubber as determined in accordance with ASTM D5644 is included in Table 4 [22].

2.1.4. Cellulose fibers

Cellulose fibers were included in this study as they are commonly used as a stabilizing additive to minimize, or prevent draindown in porous asphalt mixtures. The fibers were derived from post-consumer paper and shredded to a maximum fiber length of 6 mm. When included in an asphalt mixture, the fibers were added at a rate of 0.3% by total mixture weight [23].

2.1.5. Hydrated lime

All of the mixtures evaluated in this study incorporated hydrated lime as an anti-stripping additive as required by many transportation agencies. The hydrated lime was added at a rate of 1% by weight of the aggregate [23]. After mixing with the dried aggregate, water was added (5% of the aggregate weight) to activate the hydrated lime.