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Investigation of rutting, fracture and thermal cracking behavior of asphalt mastic containing basalt and hydrated lime fillers

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HIGHLIGHTS

- Rutting performance and aging potential of asphalt mastic is greatly influenced by addition of hydrated lime filler.
- Combinations of basalt and hydrated lime fillers have significant influence on fracture properties of asphalt mastic.
- Hydrated lime with the combination of basalt filler exhibited good resistance to low temperature cracking of asphalt mastic.

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ABSTRACT

The present study was undertaken to evaluate rutting, fracture and thermal cracking resistance behavior of asphalt mastic containing inert and active fillers. A control neat binder (AC-30) along with basalt (B) as an inert filler and hydrated lime (HL) as active filler were selected in this study. The asphalt mastics were prepared for different percentages of HL (5, 10, 15 and 20%) filler, in such a way that Filler to Binder (F/B) ratio becomes 0.8. A total of five combinations of asphalt mastic were prepared such as: AC-30 + 80% B + 0% HL, AC-30 + 75% B + 5%HL, AC-30 + 70% B + 10%HL, AC-30 + 65% B + 15%HL, and AC-30 + 60% B + 20% HL. The rutting, fracture and thermal cracking resistance of asphalt mastics was evaluated using Superpave rutting factor parameter, Double Edge Notched Tension (DENT) and Bending Beam Rheometer (BBR), respectively. Influence of HL on the performance of neat asphalt mastic was observed to be predominant in high-temperature range as obtained from the $G^*/\sin\delta$ value. The aging resistivity of asphalt mastic increased with the inclusion of HL, indicating a better rutting performance of asphalt mastic. The intermediate-temperature performance of asphalt mastic with HL was found to be higher compared to neat asphalt mastic from Critical Tip Opening Displacement (CTOD) results, implying better resistance to fracture. The addition of HL increased the low-temperature performance of asphalt mastic obtained from S(t) and m(t) values with S(t) and E(t) master curve, indicating enhanced resistance to thermal cracking. The combined effect of B and HL filler on the $G^*/\sin\delta$, CTOD, S(t), m(t) and E(t) parameters are presented in this study. In addition, ranking of asphalt mastics based on various parameters (i.e. CTOD and m(t)) is discussed in this paper.

1. Introduction

Asphalt mix consists of asphalt, aggregate, and mineral filler. The mixture of asphalt and mineral filler is usually called asphalt mastic. Mineral fillers are expected to contribute to the stability of asphalt mix by reducing voids and increasing stiffness [1,2]. Surface area, texture, type and elemental composition of mineral filler are major influencing factors affecting the performance of asphalt mastic [1,3]. Usually, inert and active fillers are used for the preparation of asphalt mastic. Stone dust, limestone, granite etc. are considered as inert filler, whereas, hydrated lime (HL), cement, fly ash, and diatomite etc. fall in the category of active filler. Active fillers like HL, diatomite are being used to improve antistripping and antiaging properties of asphalt mixes [4–6]. Numerous researchers showed that asphalt mix with active fillers showed enhanced rutting, fatigue and moisture damage resistance properties [4,7,8]. The filler to binder (F/B) ratio in the asphalt mix significantly affects the internal bonding between aggregates [9,10]. Tan Yi-qiu et al. [10] reported that asphalt mastic having F/B ratio within the range of 0.9–1.4 can have better mechanical performance.

Though inert fillers contribute to better rutting performance by increasing the stiffness of asphalt mix, they can make a mix

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Table 1
Basic physical properties of AC-30.

Test properties	Results	Standards
Penetration, 0.1 mm @ 25 °C	46	ASTM D5
Softening Point (°C)	48	ASTM D36
Ductility at 25 °C, mm	>100	ASTM D113
Absolute Viscosity @ 60 °C, Poise	Min. 2400	ASTM D2170

Table 2
Basic characteristics of fillers.

Fillers	SSA (m^2/g)	SG	HC
B	9.2	2.78	0.78
HL	11.3	2.2	0.81

*SSA (Specific surface area), SG (Specific gravity), HC (Hydrophilic coefficient).

susceptible to ductile failure and thermal cracking. Ductile failure/fracture of asphalt binder can happen at intermediate temperature. Recently developed Double Edge Notched Tension (DENT) is reported to be a reliable test to evaluate the ductile failure behavior of asphalt [11]. Thus, this test can also help in understanding cracking potential of asphalt mastic associated with yielding, ductility, and plasticity behavior by measuring specific work of failure and Critical Tip Opening Displacement (CTOD) values. A good correlation was reported between the CTOD value and fracture resistance of asphalt binder [12].

Similarly, low temperature thermal cracking in a flexible pavement occurs in cold regions. Due to rapid drop of temperature, thermal stresses develop in flexible pavement surface layer [13,14]. Bending Beam Rheometer (BBR) test is used to evaluate low temperature performance of asphalt binder and mastic based on stiffness and rate of relaxation properties [15]. Further, physicochemical interaction of binders and mineral fillers can influence the aging behavior of asphalt mastic. Aging commonly occurs due to oxidation and evaporation of volatile and light fractions of asphalt binder [16] and it can reduce elastic response of asphalt mastic, making it prone to cracking, especially at intermediate and low temperatures. Roman Lackner et al. [17] reported that low temperature creep stiffness of asphalt mastic was influenced because of random distribution of mineral filler particles within asphalt.

1.1. Research objectives

Few studies were reported to investigate combined effects of inert and active filler on the performance of asphalt mastic. The majority of the studies were concluded based on performance evaluation through Dynamic Shear Rheometer (DSR), and basic preliminary tests such as softening point, penetration, and viscosity. Hence, the present study was undertaken to evaluate intermediate temperature fracture failure and low temperature thermal cracking behavior of asphalt mastic with combinations of the inert and active fillers using DENT and BBR tests, respectively. Further, aging potential of fillers was evaluated by using Superpave rutting parameter with help of DSR test. Basalt (B) and hydrated lime (HL) were selected as an inert and active fillers, respectively. The proportion of HL was ranged from 0 to 20%. The F/B ratio was kept to 0.8. This ratio was selected as average value of standard range of 0.6–1.2 [18].

2. Materials and experimental program

2.1. Materials

A control asphalt binder (AC-30) was selected, which is commonly used for the construction of surface course of flexible pavements in India. The basic properties of AC-30 are given in Table 1. The B and HL were selected as inert and active fillers, respectively. Both fillers used for production of mastics in this research passed through the #200 sieve (75μ).

2.2. Characterization of fillers

The basic characterization of B and HL fillers was carried out using laser particle size and shape analyzer, BET-specific surface

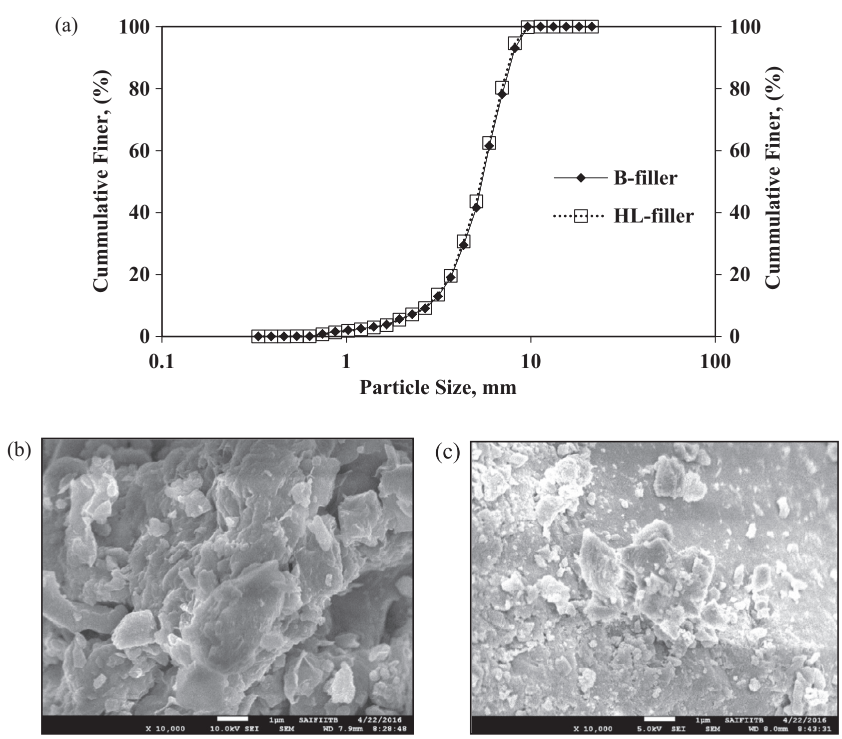

Fig. 1. (a) Particle size distribution curve of B and HL fillers; SEM imaging of (b) B filler and (c) HL filler, at a zoom level of 10,000 X.