Construction and Building Materials 95 (2015) 497–505

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Homogeneity of filler distribution within asphalt mix – A microscopic study

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HIGHLIGHTS

- Three fillers (limestone dust, granite dust and rhyolite dust) are chosen based on their surface charge.
- These fillers are separately used to make asphalt mix.
- Limestone is used as aggregates for all the asphalt mix samples.
- Analyses of SEM images suggest that the fillers are homogeneously distributed within asphalt mix.
- This homogeneity of distribution is independent of possible surface charge of filler particles.

ARTICLE INFO

Article history:
Received 4 January 2015
Received in revised form 23 May 2015
Accepted 12 July 2015
Available online 25 July 2015

Keywords:
Asphalt mix
Filler
Surface charge
Scanning electron microscope
Homogeneity
t-Distribution

ABSTRACT

In the present work distribution of filler particles within asphalt mix is studied using scanning electron microscope (SEM). Three different fillers namely, limestone dust, granite dust and rhyolite dust are used for making separate asphalt mix samples. Images are captured at two locations within the asphalt binder film, (i) close to the aggregate surface and (ii) away from the aggregate surface, typically at the middle of the binder film. Images are analyzed for (i) each location and (ii) each of the type of fillers. Image analysis results suggest that the fillers are homogenously distributed within the asphalt binder film and the distribution is not affected by the nature of possible surface charge of the filler particles.

1. Introduction

Filler particles are the finer fractions in asphalt mix which are dispersed in the asphalt binder without particle to particle contact [1]. The functions of the filler are to (i) increase the stiffness of asphalt binder, (ii) increase the bond strength between asphalt binder and aggregates, (iii) reduce permanent deformation in asphalt mix, and so on [2–4]. Although some guidelines prescribe specific gradations for filler [5–8], typically particles below 75 μ are considered as filler material [2,9–13]. The same definition is adopted in the present study.

A number of researchers have studied the influence of filler (in terms of its physical and chemical characteristics, quantity, particle size distribution, shape, surface texture, mixing sequence, etc.) on the property of asphalt mix [4,9,14–17] or, asphalt mastic [15,18–20]. Experimental and numerical studies on asphalt mastic typically assume filler and other finer particles are homogenously distributed within the asphalt binder [21–26].

With the availability of advanced microscopic imaging techniques, it is now possible to verify the nature of distribution of fillers within the asphalt mix. This forms the motivation of the present study. In this study, scanning electron microscope (SEM) is used as the imaging tool. The present study seeks answer to the following questions.

(a) How are the fillers distributed within the binder film of the asphalt mix? Are the filler particles homogenously distributed or the particles forms clusters (near or away from the coarser particles)?
(b) Does the distribution get affected when acidic or basic type of aggregates and fillers are used in various combinations?

These are discussed in the following.

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http://dx.doi.org/10.1016/j.conbuildmat.2015.07.043

Table 1
Composition of asphalt mix used in the present study.

Total composition of asphalt mix	Sieve size (mm)	Percent passing upper limit	Percent passing lower limit	Mid-point (%)	Amount per 1000 g of total mix (gm)
Coarse and fine aggregates	19	100	100	100	
	13.2	100	90	95	47.25
	9.5	88	70	79	151.20
	4.75	71	53	62	160.65
	2.36	58	42	50	113.40
	1.18	48	34	41	85.05
	0.600	38	26	32	85.05
	0.300	28	18	23	85.05
	0.150	20	12	16	66.15
	0.075	10	4	7	85.05
Filler	Pan				66.15
Asphalt binder					55.00
Total					1000.00

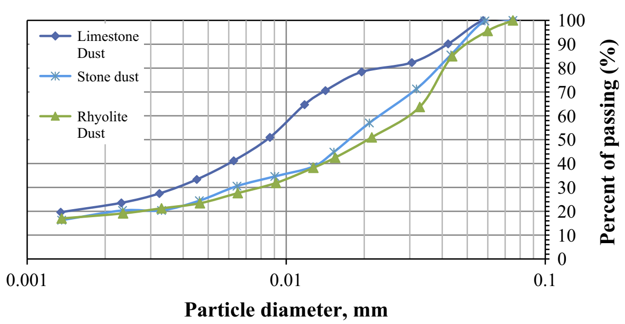


Fig. 1. Particle size distributions of the fillers used in the present study.

Table 2
Physical properties of asphalt binder.

Properties	Value	Guidelines
Penetration	90	IS 1203-04 [32]
Softening point	51 °C	IS 1205-04 [33]
Flash point	270 °C	IS 1209-04 [34]
Ductility	76 cm	IS 1208-04 [35]
Absolute viscosity at 60 °C	2987.8 Poise	ASTM D2171 [36]

2. Experimental studies

In this study, mid-point gradation of Bituminous Concrete (BC) (grade 2) conforming to Indian specification [6] is chosen as asphalt mix (refer Table 1). Asphalt binder content is kept fixed as 5.5% with respect to the total weight of the mix and the filler content is kept fixed as 7% with respect to the total weight of the mix for all the samples prepared. The weights of individual components (per 1000 g of total mix) are shown in Table 1.

3. Materials used

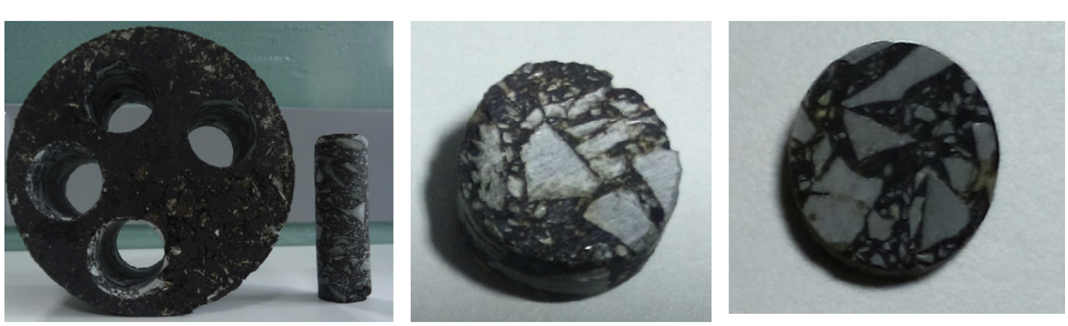
Aggregates, fillers and asphalt binder used in this study are collected locally. Three different types of fillers namely limestone dust, granite dust and rhyolite dust are used to prepare individual asphalt mix samples. Limestone is used for the remaining part of the aggregates for all the asphalt mix samples. Particle size distribution of the fillers obtained by hydrometer analysis is shown in Fig. 1.

The chemical compositions of the fillers are studied in X-ray fluorescence (XRF) spectrometer. From this test, silica content (SiO_2) of limestone dust, granite dust and rhyolite dust fillers are obtained as 28.49%, 62.02% and 78.57% respectively. Considering that a substance can be categorized (based on the silica content) as ultrabasic (SiO_2 content < 45%), basic (45% < SiO_2 content < 52%), intermediate (52% < SiO_2 content < 63%) and acidic (SiO_2 content > 63%) [27], limestone dust, granite dust and rhyolite dust fillers are identified as ultrabasic, intermediate and acidic respectively. Given that the surface charge is generally positive for basic substance and negative for acidic substance [28,29], it is envisaged that the current choice of fillers will be able to capture the effect of surface charge on filler distribution (within the binder film), if any. The specific gravity values of limestone dust, granite dust and rhyolite dust are obtained [30] as 2.76, 2.59 and 2.43 respectively. Physical properties of the asphalt binder [31] are given in Table 2.

4. Preparation of the asphalt mix samples for SEM study

Asphalt mix samples are prepared using Marshall molds [37,38] for each type of fillers. Further, the following process is adopted for preparing samples suitable for SEM study.

(a) *Cutting:* 25 mm diameter cores are cut from the Marshall samples (refer Fig. 2(a)). These cylindrical core samples are further cut into small pieces (thickness of 5 mm ± 1 mm) by using diamond saw cutter (refer Fig. 2(b)).



(a) (b) (c)

Fig. 2. Steps involved in sample preparation for SEM study (a) core cutting from Marshall samples, (b) saw cutting, (c) grinding and polishing.