International Journal of Environmental Sciences Vol.2 No.4. 2013. Pp. 158-162

Full Length Research Paper

Chemically Modified Crumb Rubber Effects on Rubberized Asphalt Properties

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Abstract

The rubberized asphalt binder properties are affected by crumb rubber (CR) distribution through matrix. The distribution could be enhanced by chemically modification for CR. Silicone oil, maleic anhydride and dispersing agent were used as chemicals to modify CR by10 per hundred weight of asphalt (pha) with different doses and physical, mechanical and morphology properties of rubberized asphalt binder were examined. The chemicals led to increase penetration and softening point values till a certain chemical dose then decreased, and the tensile strength and elongation at break values was also affected by dose of chemical. Scanning electron microscopy (SEM) illustrated that silicone oil and dispersing agent caused better distribution of CR, while maleic anhydride affected CR to be cross linked with asphalt matrix. The best dose of silicone oil and dispersing agent was 1.5 per hundred weight of rubber (phr), while maleic anhydride was 1.0 to 1.5 phr.

Key words: *Chemically modified, crumb rubber, modified binder, rubberized asphalt, binder compatibility.*

Introduction

Crumb rubber (CR) has been suggested as an asphalt modifier for pavement applications. Caltrans asphalt rubber usage guide has mentioned that development of asphalt rubber materials for use as joint sealers, patches, and membranes began in the late 1930s. Charles H. McDonald worked extensively with asphalt and rubber materials and was instrumental in development of the wet process of producing asphalt rubber [9]. Although the use of CR as an asphalt modifier to improve the asphalt mixture performance has been succeeded, the poor compatibility between CR and asphalt is usually poor at elevated temperature and this is a main concern [4]. This is in part due to the crumb rubber remaining in particle form after mixing, not reacting chemically or dissolving in the asphalt binder. Recently, the US Federal Highway Administration (FHWA) has developed chemically modified crumb rubber asphalt (CMCRA) with superior separation characteristics during hot storage compared to standard crumb rubber asphalt. This is accomplished by treating the crumb rubber with certain chemicals in order to generate free radicals on the surface. This allows the CR to better interact with the asphalt [1]. A patent has mentioned that the distribution of modifier material 'crumb rubber' through the asphalt to form a homogenous mixture could be achieved by adding a dispersion agent such as furfural or vegetable oil to a modifier material then mix the modifier material with asphalt [2]. Two types of blending process are used to add CR in asphaltic mixtures. The wet process which has the advantage that the binder properties are better controlled and the dry process which is less popular due to the increased costs for specially graded aggregate to incorporate the reclaimed tire crumb, construction difficulties and most importantly poor reproducibility and premature failures in terms of cracking and raveling of the asphalt road surfacing [3].Also dry process rubberized asphalt exhibits poor short-term performance under moderate to heavy traffic loadings [8].In the wet process, the interaction between asphalt and CR depends on CR preparation type [9]. The ambient preparation process gives better properties like viscosity, susceptible to rutting at high temperatures and resistance to cracking on low temperature [6].The wet process requires thorough mixing of the CR in hot asphalt cement (190ºC to 224ºC) and holding the resulting blend at elevated temperatures (190ºC to 218ºC) for a designated minimum period of time (typically 45 minutes) to permit an interaction between the CR and asphalt [9]. As the temperature increases, from 160 to 200ºC, the rate of swelling increases, but the effect is on the extent of swelling decreases as the rubber network becomes stiffer to achieve equivalent change in entropy [7]. A published laboratory study discussed time reaction and the best results was 90 minutes of reaction time at reaction temperature of 180°C in which the crumb rubber is completely incorporated in the asphalt [5].

Materials

Asphalt

The asphalt type used has properties shown in Table (1).

Table (1) Asphalt properties

Property	Value
Penetration	65.47 dmm
Softening point	50.6°C
Flash point	+270°C
Kinematic viscosity	387 St
Specific gravity	1.017

Crumb rubber

The crumb rubber is prepared by grinding at ambient temperature to size distribution shown in Table (2). The specific gravity of CR was 1.130.

Table (2) CR size distribution

Sieve	Passing (%)
# 30	100
# 40	83.5
# 50	66.5
# 100	13.5
# 200	2.5

Chemicals

The three chemicals used were silicone oil, maleic anhydride (from Sigma-Aldrich for Chemicals) and dispersing agent (from BYK for Additives and instruments). The silicone oil has a viscous form, colorless appearance, melting point of -55°C, boiling point greater than 140°C, flash point - closed cup - of 316°C and 0.971 g/mL at 25°C relative density. The maleic anhydride has a solid form and white color. The dispersing agent has density of 1.056 g/ml at 20°C and flash point greater than 150°C.

Test techniques

Modifying chemicals were added to CR had gradation shown in Table (2) with doses 0.5, 1.0, 1.5, 2.0, 2.5 phr, then CR with chemical dose was added to asphalt by 10 pha and mixed at elevated temperature of 170±10°C using direct flame for 90 minutes to get the rubberized asphalt blend.

Physical tests

Two physical tests were done on the prepared rubberized asphalt blend. The first was penetration test to give index of asphalt consistency according to AASHTO T 49-03 and the second was softening point test to give the temperature susceptibility according to AASHTO T 53-96.

1.1. Mechanical testing

The tensile and elongation measurements were used according to ASTM D412 to predict the behavior of solid dumbbell shaped rubberized asphalt binder under axial tension measuring the tensile force and the elongation percent of a specimen before breaking when two ends are pulled at specified speed.

1.2. Surface morphology

The surface morphology of samples examined using scanning electron microscopy (SEM) for blank rubberized asphalt binder, chemically modified by silicon oil with dose of 1.0 phr, maleic anhydride with dose of 0.5 phr and dispersing agent with dose of 2.0 phr.

Results and Discussion

Physical tests

(a) Penetration test

Figure (1) shows that the penetration values increased gradually till chemical dose of 1.5 phr and then decreased. Silicone oil has the highest penetration values compared with the same dose to other two chemicals, while dispersing agent gave penetration values higher than maleic anhydride.

(b) Softening point test

Figure (2) shows that the penetration values increased gradually till chemical dose of 1.5 phr and then decreased. Maleic anhydride gave slightly higher softening point value than silicone oil and dispersing agent gave the lowest softening point value with same weight dose of chemical.

Mechanical testing

(a) Tensile test

Figure (3) shows that tensile strength for dispersing agent samples increased till dose of 1.5 phr and then deceased. Also tensile strength for maleic anhydride increased, but till dose of 1.0 phr and then deceased, while tensile strength for silicone oil increased gradually with the increase of its dose.

(b) Elongation test

Figure (4) shows that the elongation at break for silicone oil and maleic anhydride samples decrease gradually with the increase of its doses, but sharper for maleic anhydride. The elongation at break for dispersing agent decreased gradually with the increase of its weight dose till dose of 1.5 phr. then increased.

Surface morphology

Figure (5) shows scanning electron microscopy (SEM) examination for samples. Blank rubberized asphalt has an accumulation of CR in the center of the photo and adjacent area has no CR. Silicone oil has enhanced the distribution of CR as shown in figure (5-b). Maleic anhydride in figure (5-c) made CR cross linked with asphalt. Figure (5-d) shows CR better distribution than blank one.

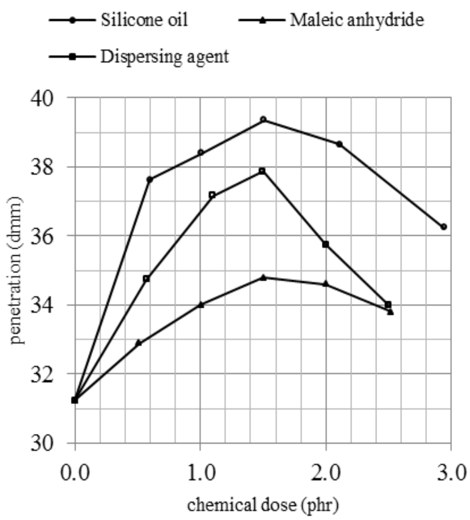


Figure (1): Rubberized asphalt binder penetration test results

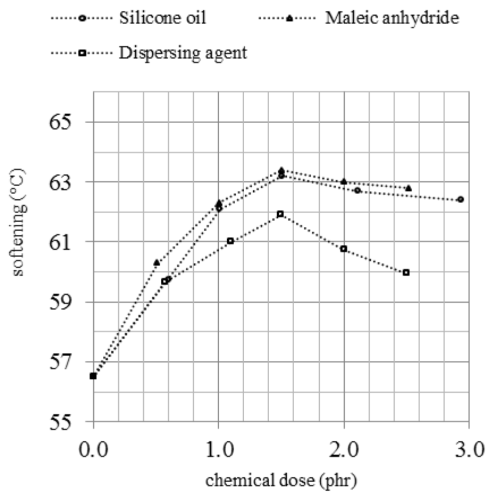


Figure (2): Rubberized asphalt binder softening point test results

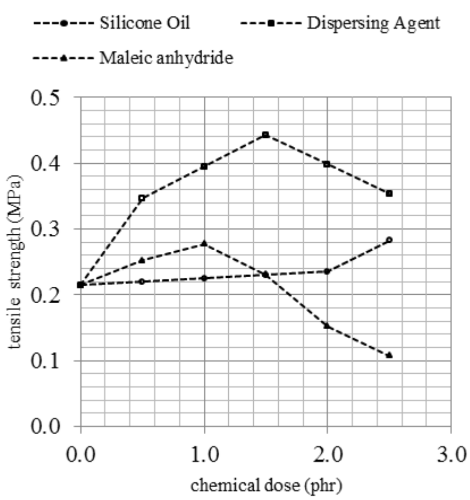


Figure (3): Rubberized asphalt binder tensile strength results

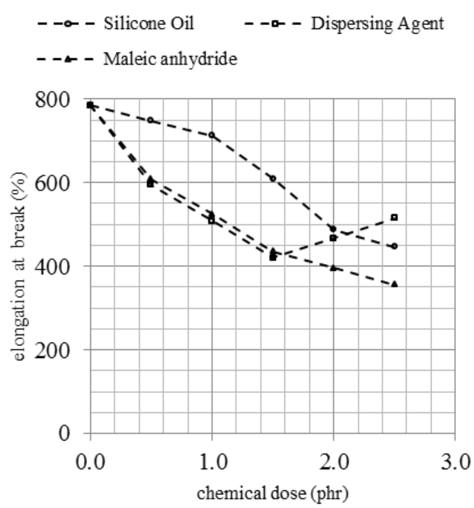
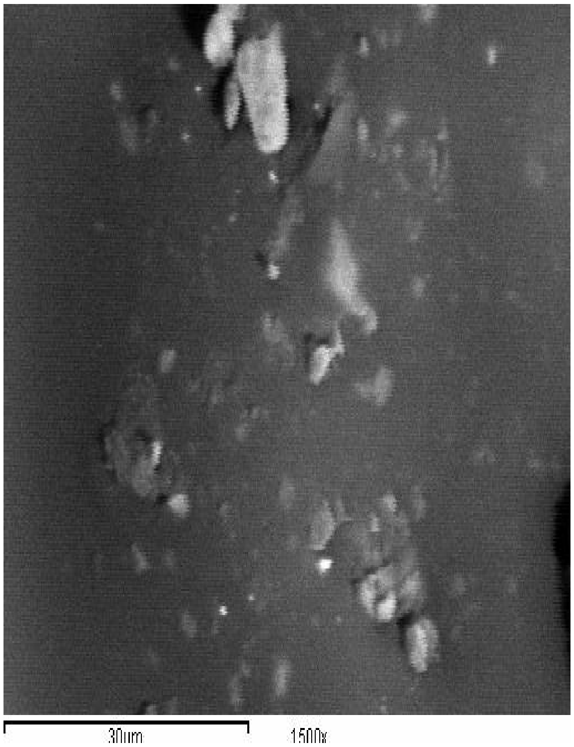
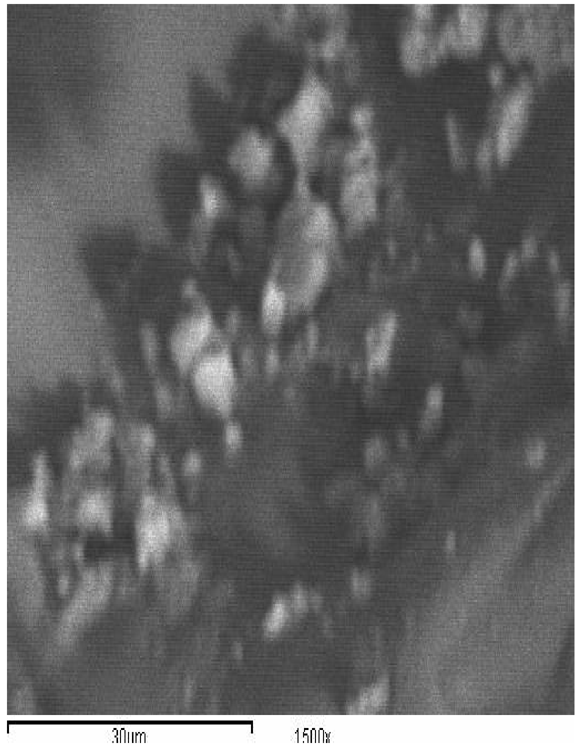


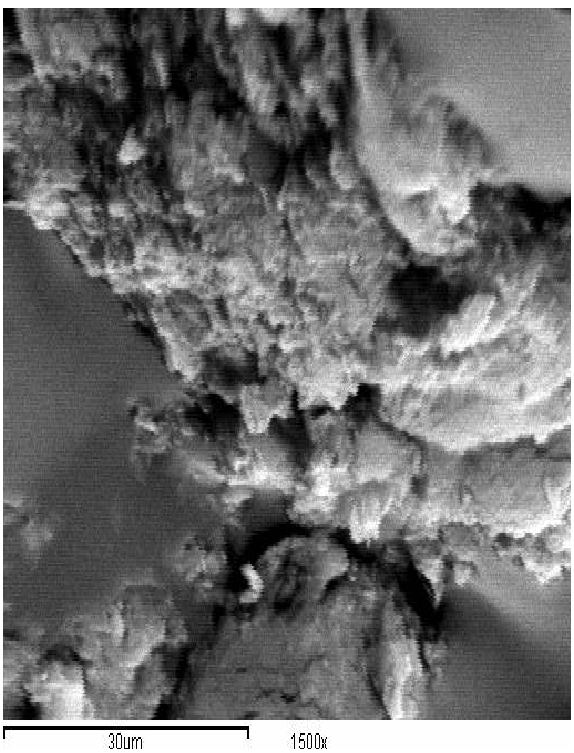
Figure (4): Rubberized asphalt binder elongation at break results



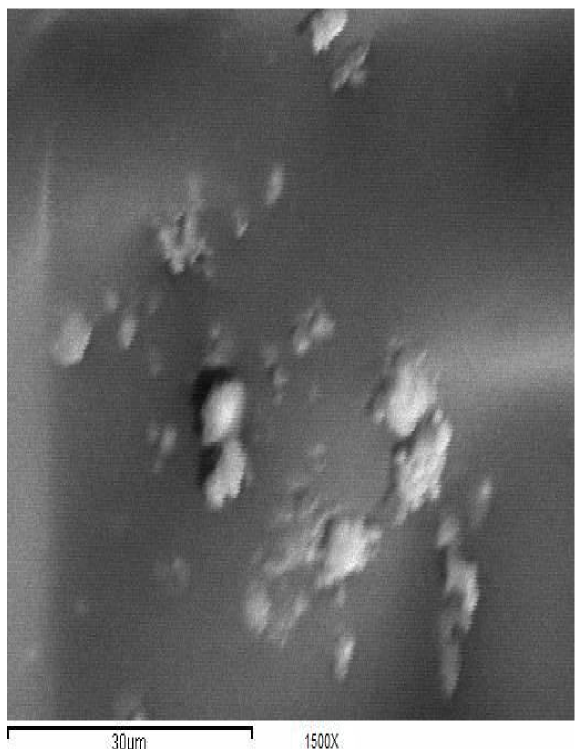
(a) Blank rubberized asphalt



(b) Rubberized asphalt with silicone oil modification



(c) Rubberized asphalt with maleic anhydride modification



(d) Rubberized asphalt with dispersing agent modification

Figure (5): Rubberized asphalt SEM with 1500x magnification

Conclusions

The use of chemicals (silicone oil, maleic anhydride and dispersing agent) with different doses ranged from 0.5 to 2.5 phr for modifying rubberized asphalt; improved the distribution of CR through asphalt matrix in rubberized asphalt blend, as well as, they affected physical and mechanical properties of rubberized asphalt blend. The following conclusions were deduced:

[1] The three chemicals increase the rubberized asphalt penetration value gradually till dose of 1.5 phr then decreased and the highest chemical records were for silicone oil.

[2] The softening point values of rubberized asphalt samples were affected by the three chemicals and the highest softening point value of the three chemicals was at dose of 1.5 phr.

[3] Dispersing agent chemical increased the tensile strength value of rubberized asphalt samples compared to the two chemicals and its higher value was with dose of 1.5 phr, while silicone oil increased tensile strength value gradually with the increase of its weight dose. Maleic anhydride chemical tensile strength values increased till chemical dose of 1.0 phr and then decreased.

[4] The elongation values were generally decreased with chemical dose increase, except for dispersing agent which decreased till 1.5 phr and then increased.

[5] The effect on rubberized asphalt binder was changed by dose of chemical. Silicone oil chemical gave generally the best behavior on rubberized asphalt binder with dose of 1.5 phr, dispersing agent had generally best results with dose of 1.5phr, and maleic anhydride had generally best results records with dose ranged from 1.0 to1.5phr.

[6] The SEM examination showed that blank rubberized asphalt had poor CR distribution and a better distribution was achieved using silicone oil and dispersing agent, while maleic anhydride a cross link between CR with asphalt.

Acknowledgement

The authors wish to acknowledge and thank general authority for roads, bridges and land transport (GARBLT) for its support.

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