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Full Length Research Paper

Chemically Modified Rubberized Asphalt Binder Effects on Open Graded Asphalt Concrete Properties

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Abstract

The properties of open graded asphalt concrete (OGAC) can be enhanced by using chemically modified rubberized asphalt binder. The chemical modification for crumb rubber (CR) enhanced its distribution through asphalt, which led to better mechanical and physical properties of OGAC than asphalt and blank rubberized asphalt binders. The cost of rubberized asphalt, blank and/or chemically modified, was decreased comparing to conventional asphalt binder.

Key words: *Rubberized asphalt, chemically modified, open- graded, modified binder, crumb rubber.*

Introduction

Open graded asphalt concrete (OGAC) is a surface course with an aggregate gradation that provides an open void structure.Air void content typically ranges between 15 to 25% resulting in a highly permeable mixture.The principal benefit derived from OGAC is a significant reduction in splash and spray and a reduction in tire noise and an increase in the frictional characteristics relative to dense graded mixtures.The use of modifiers such as asphalt rubber may be used to address different environmental and climatic conditions, and allow for thicker films to improve durability [2]. Crumb rubber (CR) using with asphalt as asphalt modifier to improve the asphalt mixture performance has been succeeded; however the compatibility between CR and asphalt is usually poor at elevated temperature. Once agitation stops, the dispersed tire rubber particles separates quickly from the asphalt and the polymer rich phase migrates to the upper part of the storage tank, while an asphalt rich phase segregates into the lower parts which results in an inhomogeneous material [5]. US Federal Highway Administration (FHWA) has developed chemically modified crumb rubber asphalt (CMCRA) in an attempt to alleviate the problem of separation. The proprietary process developed at the FHWA has produced a chemically modified crumb rubber 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 [4]. CMCRA can generate storage stable rubberized asphalt and it can also allow the system to produce warm crack sealant [3].

Materials

Asphalt

Table (1) shows the used asphalt properties.

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

Modified Chemical

Silicone oil (from Sigma-Aldrich for Chemicals) was used as CR modified chemical which 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.

Aggregate

The coarse aggregate was crushed lime stone in two sizes, the fine aggregate was crushed sand stone and the mineral filler was natural lime stone dust. Table (3) shows the properties of used aggregate and Table (4) shows mixed aggregate gradation.

Table (3) Aggregate characteristics

Aggregate type	Coarse aggregate		Fine aggregate	Mineral filler
	1st size	2nd size		
Sieve size	Passing (%)	Passing (%)	Passing (%)	Passing (%)
1 "	100			
3/4 "	89			
1/2 "	29	100		
3/8 "	3	99	100	
No.4	0	21	98	
No.8		8.7	84	
No.16		6	74	
No.30		4.8	65	100
No.50		4.1	43	97
No.100		3.4	17	70
No.200		2.7	11	35
Abrasion resistance loss (%)				
After100 revolutions	4	4		
After500 revolutions	23	24		
Specific gravity				
Total	2.605	2.583	2.454	2.236
Saturated	2.652	2.646		
Apparent	2.734	2.756		
Absorption (%)	1.8	2.4		
Aggregate mix (%)	70		28	2

Table (4) Mixed Aggregate gradation

Sieve	Passing (%)
1/2 "	100
3/8 "	85
# 4	30
# 8	12.5
# 30	9.5
# 50	7
# 100	4.5
# 200	2

Experimental Techniques

Modifying Chemical was added to CR by 1.5 percent per hundred weight of CR (phr), then CR blank or chemically modified, was added to asphalt with 10 percent per hundred weight of asphalt (pha).The rubberized asphalt binders were mixed at elevated temperature of 170±10°C using direct flame for 90 minutes. The binder at 150°C added to aggregate at 150°C to form the OGAC mixture.

Surface morphology

The surface morphology for solid blank and chemically modified rubberized asphalt binders were examined using scanning electron microscopy (SEM).

Mechanical measurements

Two mechanical measurements were done which were stability value and rutting depth measurements for OGAC with asphalt, blank and chemically modified rubberized asphalt binders.

The stability value measurementwas done based on AASHTO T 245 -97 with 4.0, 4.5, 5.0, 5.5 and 6.0 percent per hundred weight of aggregate (phg).

The rutting depth measurement was performed according to AASHTO T 324-04 and modification recommend at ECP104/2008(104/4) with binder content of 5 phg according to Asphalt Institute, 1978 "Mix design method for open- graded asphalt friction courses" [1].

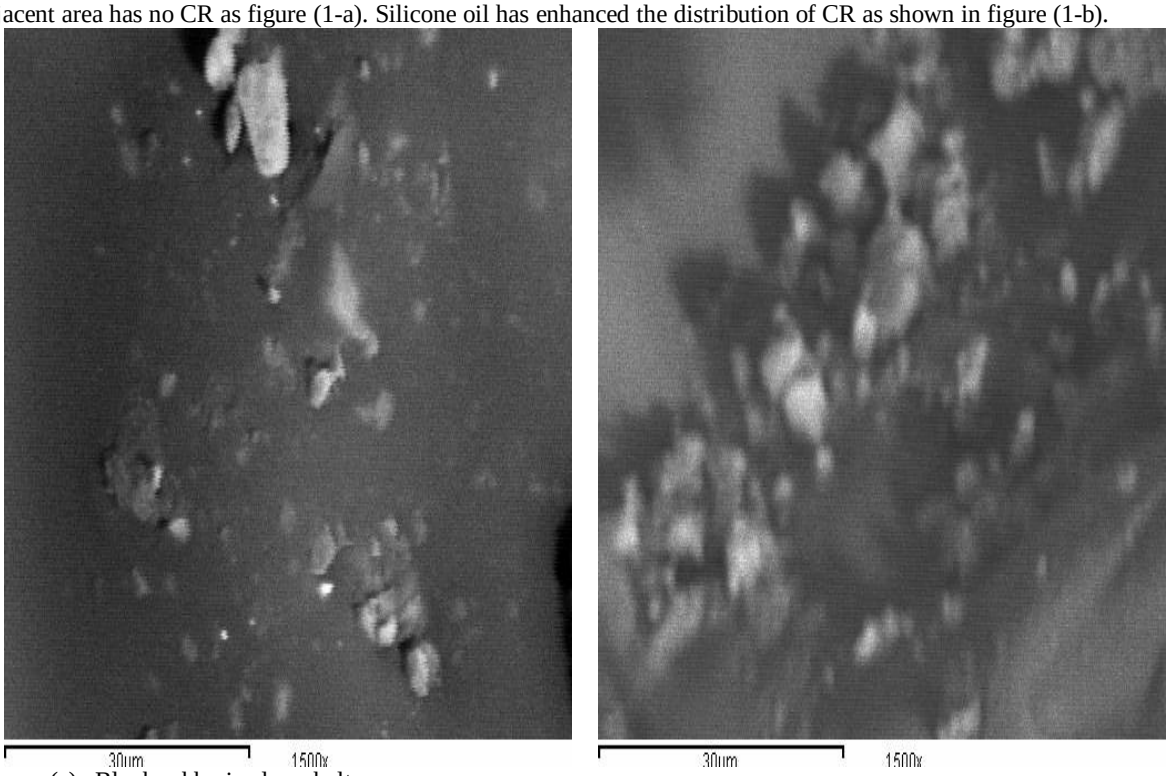
Physical coefficient measurements

Two physical coefficients were determined which were sound absorption and water permeability coefficients for mixtures with binders' content of 5 phg according to ASTM E1050-10 and ASTM PS129-01 respectively.

Results and Discussion

Surface morphology

Figure (1) shows SEM examination for samples. Blank rubberized asphalt has an accumulation of CR in the center of the photo and adjacent area has no CR as figure (1-a). Silicone oil has enhanced the distribution of CR as shown in figure (1-b).



(a) Blank rubberized asphalt

(b) Rubberized asphalt with silicone oil modification

Figure (1): Rubberized asphalt SEM with 1500x magnification

Mechanical measurements

Figure (2) shows that modified rubberized asphalt binder gave the highest stability values, while blank rubberized one gave higher stability value than conventional asphalt.

Figure (3) shows that modified rubberized asphalt binder enhanced rutting resistance compared with blank rubberized asphalt and conventional asphalt. The modified rubberized asphalt binder gave the lowest rutting depth, and blank rubberized one gave lower rutting depth value than conventional asphalt.

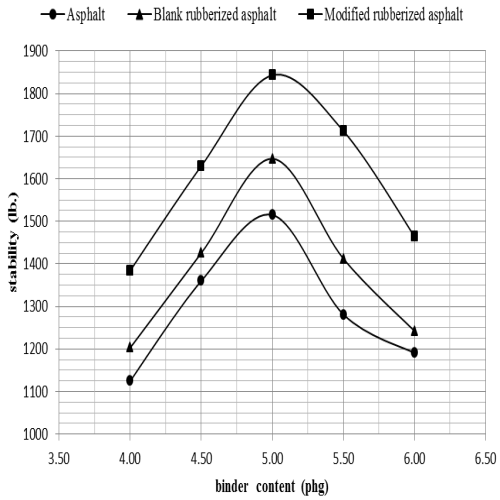


Figure (2): Stability value results

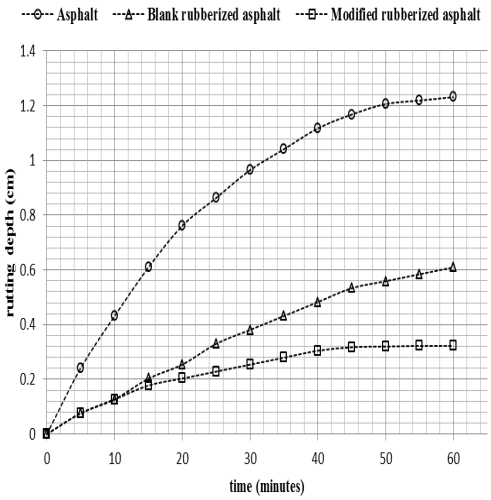


Figure (3): Rutting depth results

Physical coefficient measurements

Figure (4) shows sound absorption coefficient measurement. As shown, the open aggregate gradation has a great effect on sound absorption coefficient and the binder types have no considerable effect as the values as they almost matched.

Figure (5) shows that rubberized asphalt, blank and chemically modified, have matched permeability coefficient values lower than conventional asphalt.

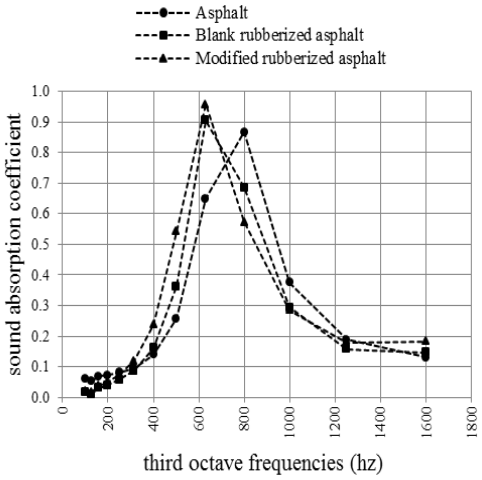


Figure (4): Sound absorption coefficient results

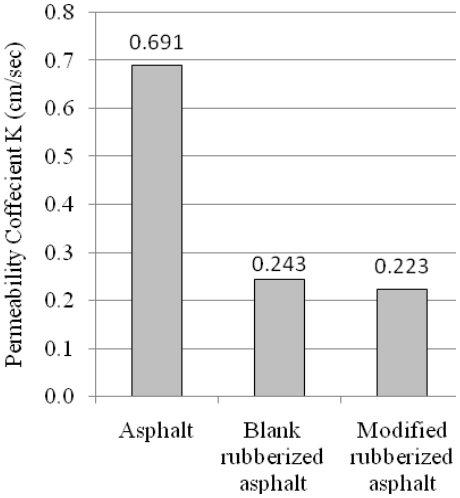


Figure (5): Water permeability coefficient results

Cost- properties comparison

Table (5) shows a brief cost comparison of the previous three binders used with the obtained properties results. The comparison shows that chemically modified rubberized asphalt has the best properties with slightly higher cost than blank rubberized asphalt binder for binder ton price.

(Noted that all prices according to Egypt local market in November 2012).

Table (5) Cost- properties comparison

Binder	Binder materials	Blend (Kg)	price (L.E)	Physical Properties (5phg)		Mechanical Properties (5phg)	
				sound absorption coefficient	permeability coefficient (cm/sec)	Stability (Lb.)	Rutting depth(cm)
Asphalt	Asphalt	1	4.086 /Kg	0.87	0.69	1515	1.232
	Total Blend	1	4.086 /blend				
	Ton Price	**1000**	**4086**				
Blank Rubberized asphalt	Asphalt	1	4.086 /Kg	0.90	0.24	1647	0.610
	CR	0.1	2.2 /Kg				
	Total Blend	1.1	4.306 /blend				
	Ton Price	**1000**	**3914.5**				
Chemically modified rubberized asphalt	Asphalt	1	4.086 /Kg	0.9585	0.22	1843.5	0.3226
	CR	0.1	2.2 /Kg				
	Silicon oil	0.0015	70 /Kg				
	Total Blend	1.1015	4.411 /blend				
	Ton Price	**1000**	**4004.5**				

Conclusion

The use of rubberized asphalt binder with blank and chemically modified has enhanced the properties of open graded asphalt concrete physical and mechanical properties. The following conclusions were deduced:

[1] The SEM examination showed that blank rubberized asphalt had poor CR distribution and a better distribution was achieved using silicone oil modification.

[2] The use of blank rubberized asphalt binder increased stability value for open graded aggregate mixture than asphalt binder. The use of silicone oil to modify surface of CR in rubberized asphalt blend binder with 1.5 phr gave the greatest stability value ever with the same binder content in mixture.

[3] The use of blank rubberized asphalt binder gave a better effect on rutting depth of open graded mixture and the rutting depth decreased after 60 minutes of wheel tracking. While modified rubberized asphalt binder mixture gave the best decreasing of rutting depth comparingwith mixture of asphalt binder and blank rubberized asphalt binder content the same CR and the same binder content.

[4] The using of open graded asphalt mixtures had a great effect on sound absorption coefficient and had high sound absorption coefficient value.

[5] The water permeability coefficient decreased by using rubberized asphalt binder in open graded mixture.

Acknowledgement

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