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UTILIZATION OF REACTIVE RUBBER NANOPARTICLES AND WASTE POLYMERS IN IMPROVING ASPHALT PERFORMANCE

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Summary: *This research aims to examine the use of reactive rubber nanoparticles (RRNP) as well as waste polypropylene as asphalt modifiers to get rid of the undesirable aforementioned characteristics as a method for waste solid disposal. To achieve this goal, RRNP were prepared in the lab via emulsification of natural rubber with a suitable emulsifying agent. The nanoparticles as well as waste polypropylene were mixed separately with asphalt of penetration grade 60/70 in percentages ranging from 3 to 10% (w/w). The prepared RRNP were then tested for their particles size using DLS while, the prepared coatings were applied to carbon steel panel and tested for bending. Furthermore, the mechanical characteristics of the modified asphalt were determined using dynamic mechanical Analyzer (DMA). The experimental observations showed that blends of asphalt cement and RRNP and waste polypropylene produce effective materials for industrial coating applications as compared with virgin asphalt cement.*

1 INTRODUCTION

Nowadays, polymer modified asphalt have been used with success at different applications especially at paving locations of high stress[1]. Styrene butadiene rubber (SBR), Ethylene vinyl acetate (EVA), and natural rubbers are examples of polymers have been widely used as binder modifiers [2,3,4]. Researchers [5,6,7,8] described the benefits of SBR modified bitumen in improving the properties of asphalt pavement and seal coats. It has been indicated that there are some challenges in using rubber such as low compatibility (low storage stability) due to its high molecular weight [9,10,11] and chemical decomposition via oxygen absorption due to the presence of free double bonds in rubber. Furthermore, other practical problems in using natural rubber were reported due to its need for high temperatures for long time period to achieve good dispersion in the bitumen [12]. The improvement of asphalt properties had been studied [13] by using fumigated rubber to reduce molecule by dissolving rubber into fluxing oil until it became Liquid Natural Rubber (LNR), by various kinds of natural rubber latex [14] ,by powdered natural rubber, or powdered reclaimed rubber [15]. A critical challenge to these asphaltic modifications is the potential for poor dispersion of the polymeric materials into the bitumen matrix. It is critical to overcome such critical drawback if rubber to be used in modifying asphalt.

Scrap tire rubber is used to improve the quality of the asphalt since the complex cross-linked rubber in scrap tires prevents the decomposition of rubber [16]. The compatibility and consequently storage stability of rubber modified asphalt will be improved by nano-size modification and surface activation of tire rubber with functional groups [2]. Moreover, scrap tire rubber contains anti-oxidants [17] that will give a great resistance to aging of rubber modified asphalt [18]. On the other hand, the addition of virgin polymers to asphalt was contemplated quite some time ago, waste and recycled polymers added to asphalt have shown the ability to improve the bitumen performance as compared with virgin polymers. The challenge is the finding the methodology of good dispersion and mixing. Different types of waste polymers are known for bitumen modifications with an additional goal is helping to decrease the solid waste disposal in land and obtaining a clean environment[19,20,21,22].

2. EXPERIMENTAL METHODS

2.1. Materials

- Asphalt Cement: local virgin asphalt cement of penetration grade (AC 60/70) produced by Alexandria Petroleum Company (APC) in Alexandria, Egypt.
- Chemicals: Polyisoprene (NR; Narobien), Divinylbenzene as crosslinker was dried and vacuum distilled over calcium hydride. palmitic acid, benzoyl peroxide (BPO), potassium hydroxide KOH, Hydrochloric acid, Toluene and Methanol.
- Waste polypropylene: it was obtained as by product of the polypropylene production line of Egyptian Petrochemicals Holding Company- Port said- Egypt.

2.2. Experimental procedure

Synthesis of reactive rubber nanoparticles (RRNP)[23][24]

Reactive rubber nano particles (RRNP) was synthesized by emulsification of macro rubber molecules of type natural rubber (20 g) in 200 ml of toluene containing divinyl benzene in percents of 5-7% (w/w of asphalt) as monomer , palmetic acid in a percent of 5 (w/w of asphalt). Benzoyl peroxide was added as free radical initiator in a percent of 1% (w/w of asphalt).

The whole organic phase was slowly added to a vigorously stirred solution of KOH soluble in 100 mL of deionized H_2O until that the final emulsion has a pH slightly alkaline. The stirring was strongly continued for 30 min and then, the emulsion was homogenized by sonification for 30 min in an ultrasonic processor homogenizer operating at 300 bar under nitrogen. The flask was purged with N_2 for 30 min before rising the temperature to 90^oC. The processing time ranged from 2 to 6 hrs. The product was coagulated by HCl/methanol, re-dispersed in chloroform and precipitated with methanol to remove the surfactant before the material was dried for overnight.

Characterization of RRNP

The prepared RRNP was characterized using Dynamic light scattering (DLS) to determine the volume average diameters.

Modification of asphalt with RRNP[23] and waste polypropylene

The calculated amount of asphalt was heated up to 140 ± 5 ^{o}C in a container until it become pourable. The calculated amounts of RRNP and waste polypropylene were added separately and gradually to asphalt in percentages of 3%, 5%, 7% and 10% (w/w) using high shear mixer rotating at 2000 rpm for 2 hrs for complete homogeneity.

Evaluation of Polymer Modified Asphalt Samples Prepared

The prepared samples were applied on steel sheets and after complete curing they were tested for cracking resistance using Mandrel test (ASTM D522) and dynamic mechanical behavior as it is deformed under a sinusoidal strain deformation as a function of frequency and temperature using DMA . DMA tests was performed by Triton Technology-TTDMA which determines storage modulus, loss modulus and tan δ. Disk-formed specimens with 10 mm dia. and 3mm thickness were tested at room temperature and 1 Hz frequency.

3. Results and Discussion

3.1. DLS measurement

Figure 1 shows that by using emulsification method mentioned above; we obtained rubber nanoparticles with a size of about 140 with a narrow particle size distribution.

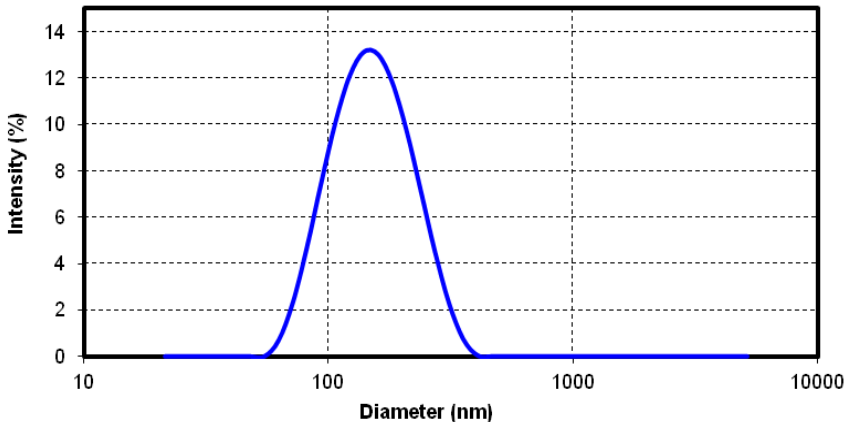


Figure 1: DLS of RRNP

3.2 Mandrel bending result

Based on ASTM D522 and from the corresponding elastic effect added to the Asphalt Cement (Ac) by either RRNP or PP, it is clear that these additives when mixed with Ac in 5% for RRNP and 3% for PP added, tested specimens become completely flexible and no crack appears. **Figures 2** shows the bending test result for both the virgin and modified asphalt samples; **Figure 2(a)** for 5 wt% RRNP and **Figure 2(b)** for 3 wt% PP.

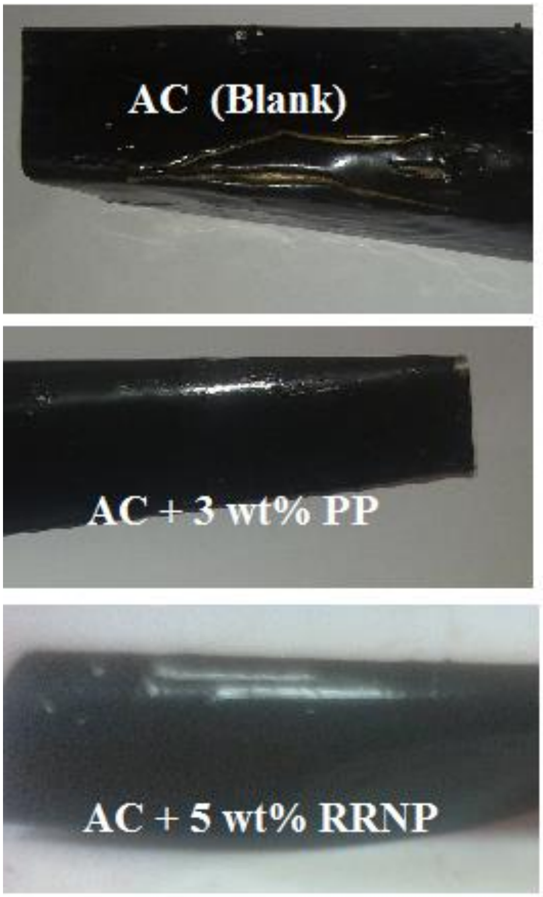


Figure 2: Bending result for virgin asphalt sample

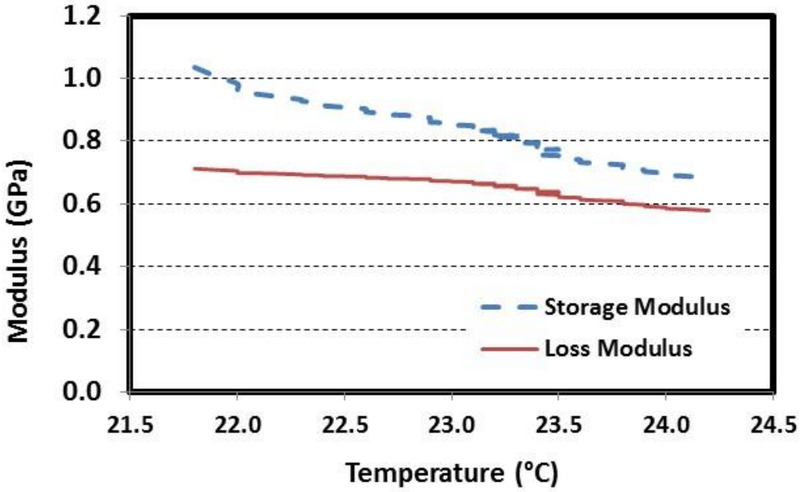
It is obvious from the figure that relatively small content of any of the selected additives greatly enhances the flexibility of the modified asphalt sample to the required value. In addition, all of these samples were tested for the impact, adhesion and abrasion resistance where all the results were the same as the blank sample. This is an important point that these additives have no negative effects on the other mechanical properties of the modified asphalt samples.

3.3 DMA Test Results

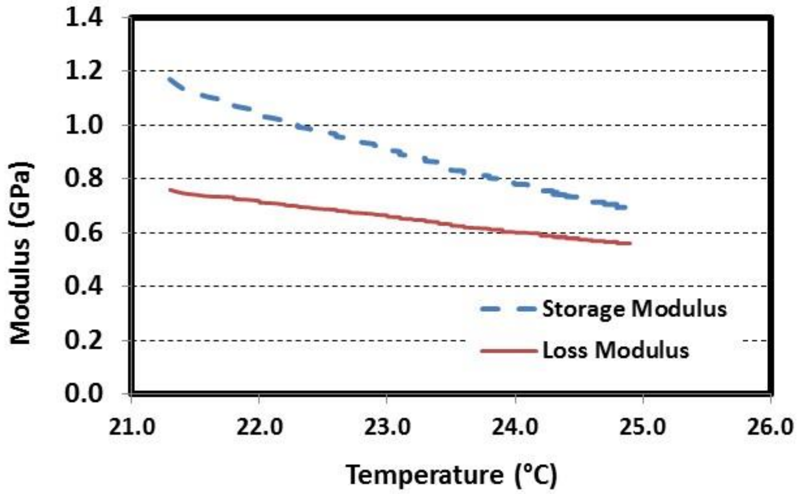
Figures 3(a,b,c) shows DMA results for blank AC, AC modified with 3 wt% PP and AC modified with 5 wt% RRNP; respectively and **Table 1** shows storage modulus of all samples at 22 ºC.

Percent addition	Elastic modulus (Pa)	
	RRNP	PP
(0%)	1.04x107	1.04x107
(3%)	1.5x106	1.13x107
(5%)	1.57x106	1.19x107
(7%)	2.13x105	1.17x107
(10%)	1.1x106	1.14x107

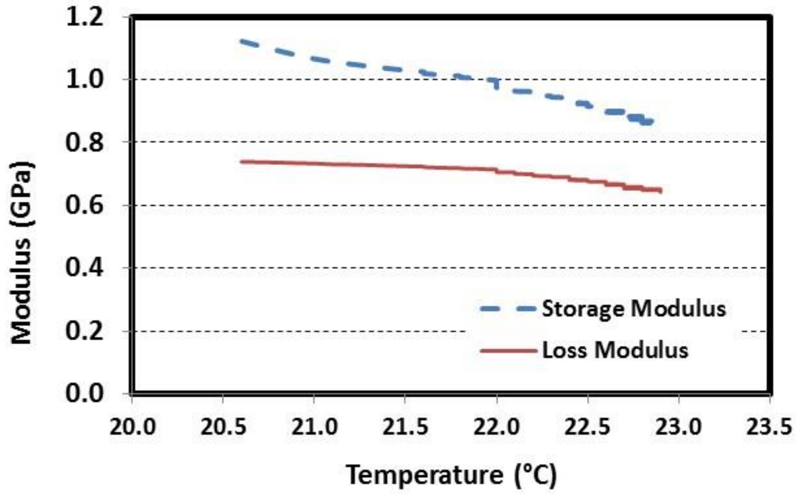
Table 1: Storage modulus of all asphalt samples



(a)



(b)



(c)

Figure 3: Change in storage and loss modulus for varying temperature at 1 Hz (a) Blank AC (b) AC + 3 wt.% PP (c) AC + 5 wt. % RRNP

The results show that the modified asphalt samples have high storage modulus than the blanl one when using either PP or RRNP as asphalt modifiers. On the other hand, the elastic modulus was reduced for samples modified using RRNP compared with the virgin asphalt. Furthermore, the elastic modulus for the samples incorporating RRNP were lower than that including PP. This may be attributed to thae fact that RRNP has lower glass transition temperature (- 40ºC) compared with PP (0 ºC).

4. CONCLUSIONS

The results show the possible combination of waste polypropylene and reactive rubber nanoparticles (RRNP) as asphalt modifiers to improve asphalt characteristics. This includes improving asphalt flexibility at low temperature for infrastructure applications. The use of waste polypropylene also helps reducing landfills of waste solid disposal. Waste polypropylene and RRNP prepared in lab were mixed with grade 60/70 asphalt with several concentrations ranging from 3 to 10% (w/w). The prepared coatings were applied to the surface of carbon steel sheets and were tested using DMA. The results show that the mix improved the cracking resistance of asphalt and improved its flexibility at low temperature.

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