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PERFORMANCE ENHANCEMENT OF ASPHALT PAVEMENT

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Abstract

Age hardening of paving grade asphalt is a major factor affecting the durability of bitumen pavement. In this research, 60/70 penetration grade asphalt is modified using Styrene Butadiene Rubber(SBR) in percentages by weight of asphalt ranging from 2 to 6% and 1% by weight of asphalt of an antioxidant namely 4.4. thio bis (6- tertiary butyl – m – cresol (TBMTBP). The antioxidant is used to delay the age hardening . Hot mixes asphalt using the virgin and modified asphalt samples are prepared and evaluated using Marshall test method . Fourier Transform Infra Red (FTIR) is used to analyze all samples of asphaltic materials. The results reveled that, the polymer increased the performance of hot mix and the antioxidant delayed the formation of carbonyl group which is formed as a result of asphalt aging. So, this type of modification is considered as an attractive solution for increasing the performance and the service lifetime of asphalt mix .

Keywords
Asphalt – aging – antioxidant - SBR

1. Introduction

Asphalt is a major factor affecting the durability of road construction. With age, asphalt gets stiffer and brittle. The major cause of hardening commonly cited includes oxidation, volatilization, polymerization, thixotropy, synersis, and separation (1). Oxidation and volatilization are considered as the most important factors affecting the aging and durability of the asphaltic binder. The use of an antioxidant as a performance enhancer in the asphalt binder could delay aging , thus increasing the life of the asphalt pavement . Different modifiers have been used to increase the durability of asphalt among which` the polymers. However, the polymers are used to give the asphaltic material superior properties such as fluidity resistant, thermal susceptibility and draining (2). Several antioxidants have been used in past to control the oxidative hardening like silicone fluid, hydrated lime, lead and other chemical compounds (3-12). Recently, some additives are used including vitamin E , Irganox 1010 , and DLTDP /furfural (13), lignin (14) ,chemical species such as lead diamyl dithiocarbamate (LDADC), zinc dialkyl dithiophate (ZDDP) , zinc dibutyl dithiocarbamate (ZDBC),naphthenic oil (16-18) , and by products from red wine industry (19). Nowadays, another method to delay the aging phenomenon is to use a compound containing antioxidants and UV absorbers (20). However, the occurrence of carbonyl groups and the increase in asphalt molecular weight are the aging results in oxidant of base asphalt. Generally, modified asphalts are resistant to the formation of carbonyl and can keep the asphalt molecular weight nearly uncharged (17).

2. Materials used

1- Local (virgin) asphalt of penetration grade 60/70 produced by EL- Nasr Petroleum Company in Suez city, Egypt.
2- SBR obtained from Become Reseller India Co, Ghoghal India having the chemical formula as shown in figure (1).

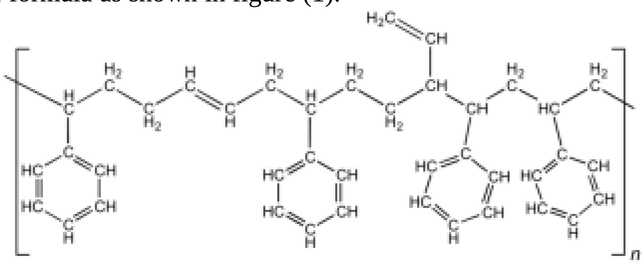


Figure (1): Chemical formula of SBR

3- Anti oxidant: namely 4.4-thio bis (thio bis (6-tert – butyl –m-cresol)(TBMTBP) with a chemical formula as shown in figure (2) . The material produced by Zibo Linzi Darong Fine Chemicals Co.,

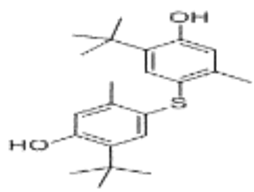


Figure (2) : Chemical formula of TBMTBP

4- solid materials :

- Dolomite aggregate of sizes 2 and 1 obtained from Ataka query (Suez governate).
- Natural sand obtained from Abassa query (Cairo governate).
- filler (limestone type) .

3. Experimental

3.1. Preparation and evaluation of SBR modified binders .

Blends of asphalt , 1% of BMTBP as an antioxidant and SBR modifiers are prepared. The modifier content are 2,4&6%(w/w) of asphalt. The blending conditions are conducted at 163º C ,with stirring rate ,500 rpm for 2 hours (after complete addition of polymer into asphalt) . The prepared samples are tested for penetration (ASTM D5) , Softening point (ASTM D36), Specific gravity(ASTM D70), kinematic viscosity(ASTM D2170) and FTIR . (ASTM E 1252) of model 960 Mooog, AIT Mattson Infinity Series(USA).The factor penetration index (P.I) has been calculated as a measure of temperature susceptibility using the following equation(21).

P.I = 1952-500 *log(pen 25)-20*soft.pt/ 50-log(pen25)-soft pt-120

3.2. Preparation and determination of suitability of asphalt aggregate mixes for use as a wearing course by using Marshall test method .

In this step, asphalt mixes using the virgin and modified binders are prepared and tested using Marshall test method (ASTM – D6927). The mixes are designated according to the Egyptian standard limits of wearing course (4C) . According to the selected job mix formula , the percentages by weight of the solid materials in the blend were as follows : -

Coarse and fine aggregates , sand and fillers as 28,22,46 and 4 , respectively. The mix tested for maximum load and flow . Density and air voids percentages are determined on the prepared specimens . The criterion selected was for a 75 blows Marshall compaction ,using for levels of asphalt content (4.5.6 and 7 based on weight of solid materials) .

4 . Results and discussion

4.1. Characteristics of virgin and polymer modified asphalt

4.1. Physical properties of virgin asphalt and polymer modified asphalt Table (1) illustrates that, the addition of SBR as polymer to virgin asphalt increased its viscosity and softening point while the penetration value decreased and this lead to increase in the rigidity and hardness of the original sample. Also, penetration index (PI) increased with the increase in polymer content. So, the modification of asphalt increase its temperature susceptibility as well as its resistance to cracks at low temperature and to rutting(permanent deformation) at high temperature.

4.2.Infrared spectroscopy analysis

FTIR analysis results (figures (1) to (4)) illustrated that;

For virgin asphalt (figure(1)) the following bands are observed:

(1) Band at 2867 cm^{-1} shows Aliphatic groups (---CH3)

(2) Band at 1456.97 cm^{-1} show benzene derivatives

(3) band at 1370 cm^{-1} shows Aliphatic groups ---C-(CH3)3

For modified asphalt (figures 2,3&4) new groups are appeared as:

(1) Band at 3007.77 cm^{-1} show vinyl diene(R2 C=CH2) and this groups found in SBR .

(2) band at 721 cm^{-1} shows (Aryl ---S—R) is attributed to sulfide compounds found in antioxidant compound .

(3) Band at 1165 cm^{-1} shows (Aryl—s—Aryl) and this group found in Antioxidant compound.

- With the increase in the percent of SBR compound lead to increase in the intensity of (OH, ---CH=CH2 , Aryl—s---R) groups .

4.2: Mechanism of Antioxidant

Under sever aging condition like increasing temperature, decreasing asphalt film thickness and increasing oxygen and pressure, the initiation reaction of autoxoxidation of asphalt molecules are involved including formation of free radicals as shown

$$RH \xrightarrow{\text{activation}} R^{o} + (H^{o})$$

Where RH is asphalt molecules.

The active free radical will further react with oxygen to intermediate hydroperoxide as shown in the propagation steps

$$R^{o} + O_2 \rightarrow RO_2^{\ o}$$

$$RO_2^{\ o} + RH \rightarrow ROOH + R^{o}$$

$$RO_2^{\ o} + C{=}C \rightarrow ROOC{-}C^{o}$$

The antioxidative process of TBMTBP added to PMA would delay the field aging in two ways:

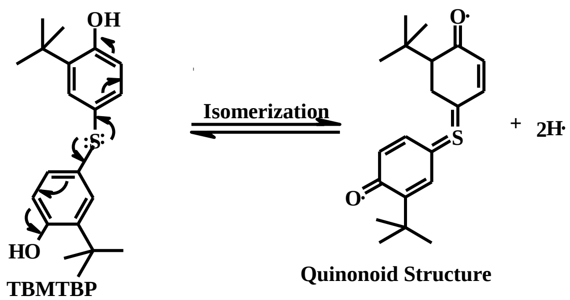
i. By inhibition of peroxide propagation, since sulfur-containing TBMTBP react with hydroperoxides by a molecular process at low temperatures but perhaps by an ionic process at higher temperatures. The antioxidants are themselves oxidized to acids, which promote a concurrent catalytic decomposition as shown in the following.

$$ROOH + R'SR'' \rightarrow ROH + R'S(O)R''$$

$$ROOH + R'S(O)R'' \rightarrow ROH + R'S(O)_2R''$$

Where ROOH is the hydroperoxides, R'S R" is TBMTBP

ii. By radical scavenging, since TBMTBP isomerizations gives free radicals as shown below that prevent further kinetic chains propagation of free radical.



$$ROO^{o} + AH \rightarrow ROOH + A^{o}$$

$$R^{o} + AH \rightarrow RH + A^{o}$$

Where AH is TBMTBP and ROO' is peroxide molecules.

4.3. Characteristics of HMA prepared

Data in tables (2) to (5) illustrated that:

- All mixes prepared comply with the Egyptian standard specifications for wearing course.

- Modified asphalt containing 6%Of SBR produced HMA as it had very high stability values to an extent as it is not workable. This may attributed to hardness of asphalt sample produced.

- With the increase of polymer content, the values of flow and air voids decreased . This is attributed to increase in the hardness of modifies asphalt samples prepared.

- Comparing to control mix ,it was noticed addition of 4% SBR produce is the best hot mix as it had highest stability value and accordingly best resistance to cracking and permanent deformation..

Table (1): Characteristics of virgin and modified asphalt samples

Virgin asphalt	Polymer modified asphalt (polymer content, %wt)		
	2	4	6
63	58	54	43
51	58	62	65
385	1850	2070	2130
-0.26	0.689	1.187	1.542

Table (2): Characteristics of solid materials

Test	ASTM Method	Size 2	Size 1	sand
A-Loss Anglos abrasion test (loss % wt)	C131			
-after 100 revolution		5.000	5.800	
-after 500 revolution		21.800	2400	
B-Specific Gravity				
-Bulk SP Gravity	C127	2.568	2.521	2.573
-Bulk SP Gravity(SSD)*		2.607	2.567	2.595
-Apparent SP Gravity		2.673	2.644	2.632
C-Absorption ratio (%wt)	C127	1.800	2.800	
D-Soundness		1.340	2.330	
E-Per crushed		98.700	97.900	
F-Per natural		1.300	2.100	
G-Per flakiness		2.050	2.450	
S- Per elongated		4.030	2.660	

***** Saturated surface dry

Table (3): Sieve analysis of solid materials

Sieve size inches (mm)	Size (2)	Size(1)	Sand	Filler
1 (25.4)	100	100	100	100
3/4 (19)	88.70	100	100	100
3/8 (9.5)	8.10	81.50	100	100
NO.4 (4.75)	2.00	19.60	100	100
NO.8 (2.38)		2.10	96.30	100
NO.30 (0.59)			58.10	100
NO.50 (0.297)			18.90	100
NO.100 (0.149)			14.50	95.00
NO.200 (0.075)			2.10	80.00

Table (4): Design Gradation of prepared HMA

Sieve size inches (mm)	Design mix	Egyptian specification limits (4C)
1 (25.4)	100	100
3/4 (19)	98.3	80-100
½ (12.7)	80.1	
3/8 (9.5)	69.9	60-80
NO.4 (4.75)	53.5	48-65
NO.8 (2.38)	37.1	35-50
NO.30 (0.59)	28.3	19-30
NO.50 (0.297)	18.9	13-23
NO.100 (0.149)	8.7	7-15
NO.200 (0.075)	6.7	2-8

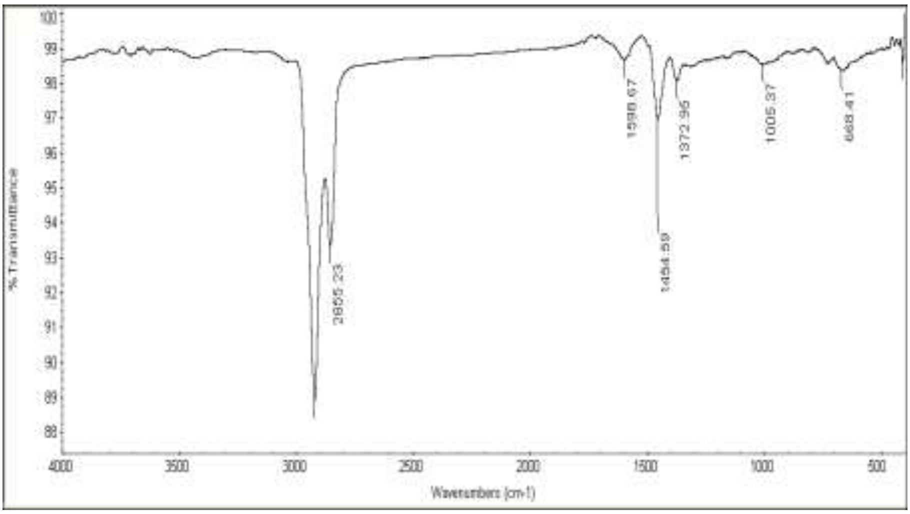


Figure (1): FTIR spectra of virgin AC

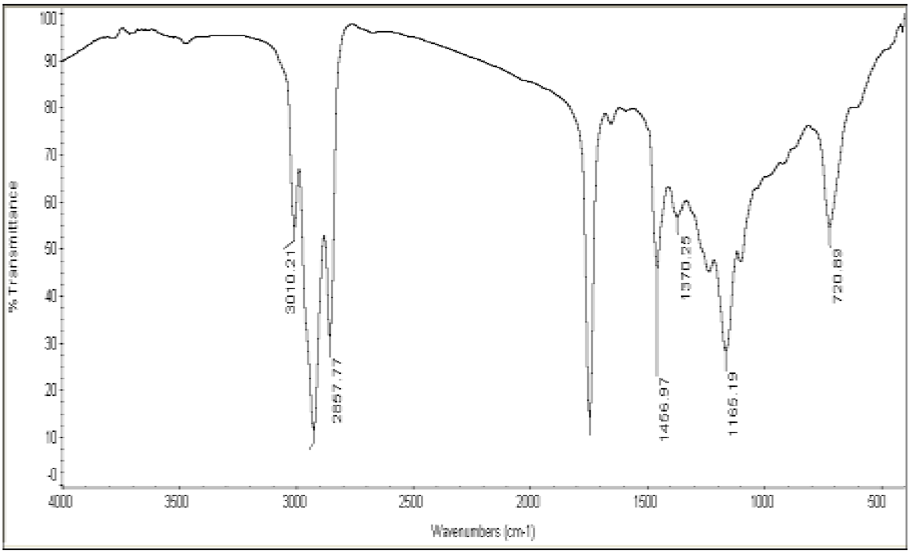


Figure (2): FTIR spectra of AC +2% SBR+1%TBMTBP

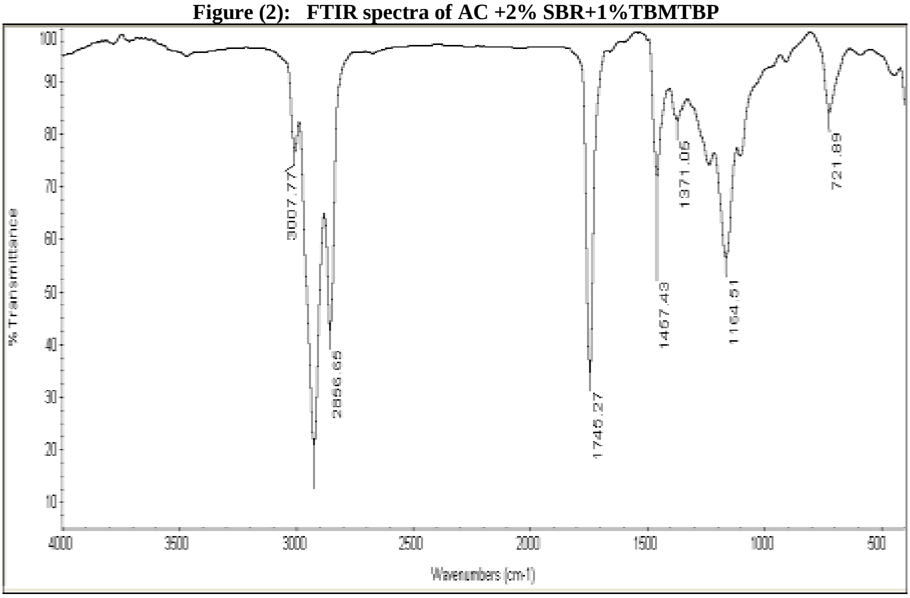


Figure (3): FTIR spectra of AC +4% SBR+1% TBMTBP

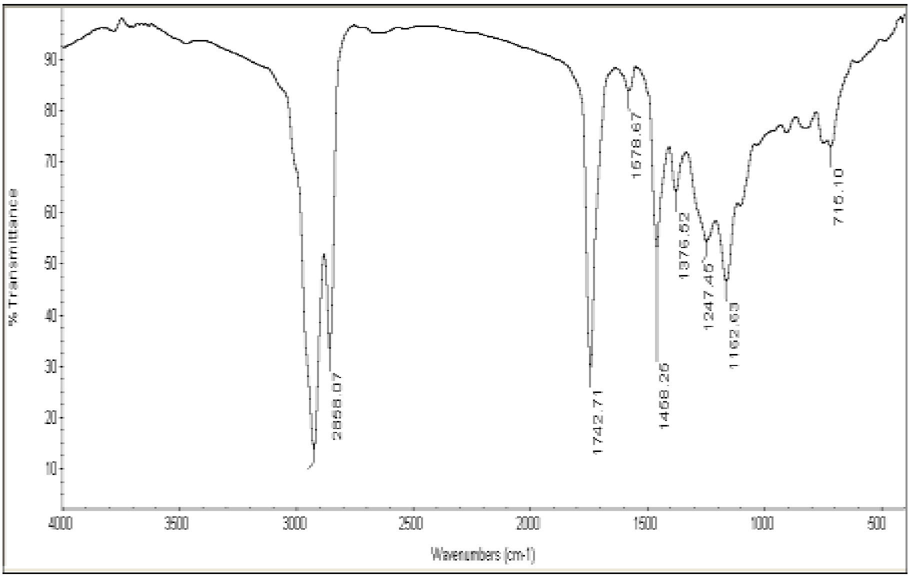


Figure (4): FTIR spectra of AC +6% SBR+1% TBMTBP

Table (5): Characteristic of HMA prepared

Characteristics	Control Mix	PMA samples / Polymer content			ESS(*)
		2	4	6	
-Optimum Asphalt content	5.500	5.600	5.500	5.400	
-Stability of mixture asphalt (Ibs)	2550	2900	3600	3150	Min 1800
-unite weight (t / m3)	2.330	2.359	2.355	2.353	
-flow of the mixture (0.01)inch	15.600	14.900	14.300	14.000	8-18
Air voids in mix (%)	4.000	4.200	4.000	3.600	3-5
Air voids in solid Aggregate(%)	15.500	15.900	16.200	16.300	Min 13.5

(*): Egyptian Specification limits

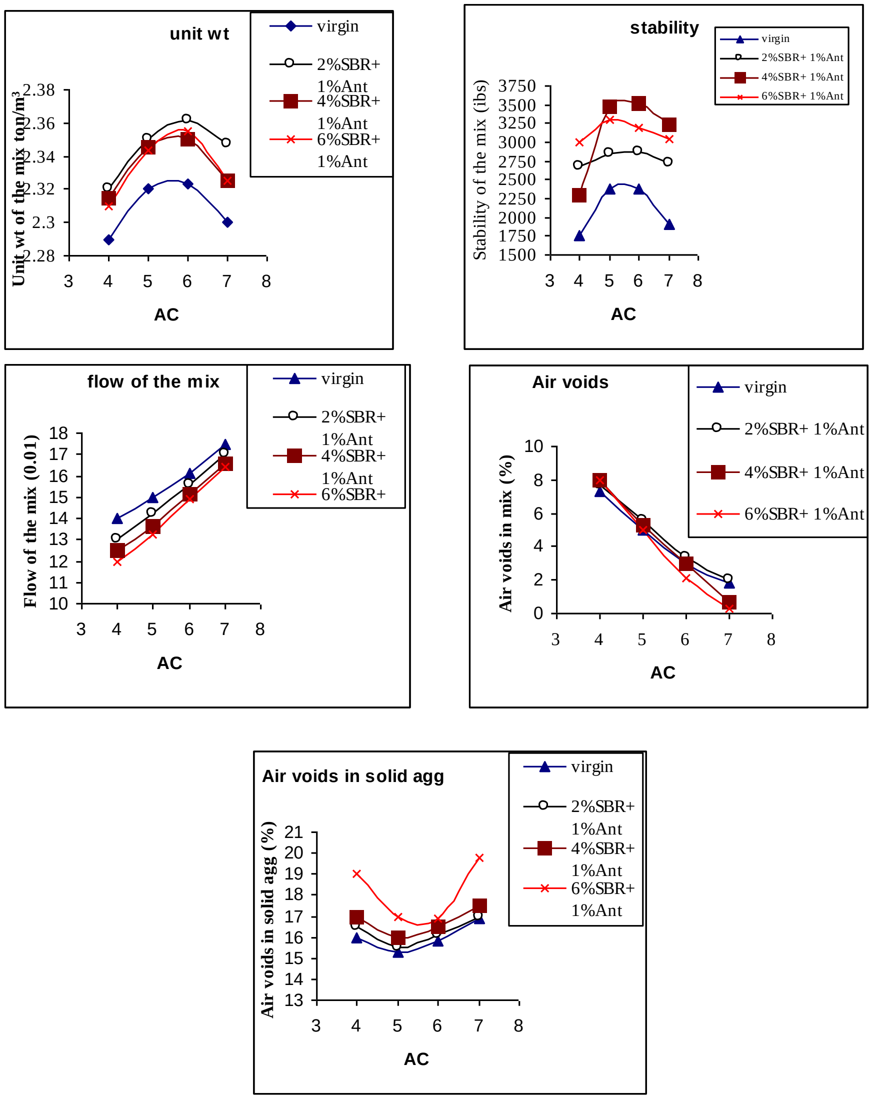


Fig (5): Marshall Curves of AC mixes

5. Conclusions

The SBR –modified Asphalt obtained by blending the SBR with traditional asphalt AC (60/70) produced a satisfactory technical solution to certain special problems in paving. Comparing to virgin mix , the use of SBR and the antioxidant grant stability and accordingly rutting resistance for the prepared mixes at the same content of asphalt. So,, it can be used in increasing the asphalt performance and producing an effective method for addressing pavement distresses

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