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Storage Stabilityand Compatibility of Dura Asphalt Modified by SBS

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ABSTRACT

The purpose of this study was to characterize the physical behaviour of Dura asphalt modified by styrene-butadiene-styrene (SBS)co-polymer. The polymer modified asphalt (PMA) was produced by mixing a 40/60 penetration grade Dura (base) asphalt withdifferent ratios of the copolymers. The resultsthus exhibited that the modification of the authentic asphalt by SBS had great impact on the physical properties of the asphalt. Furthermore, the high temperature performance of the original asphalt was enhancedsuch that the morphology observed by microscope examinationrevealed the compatibility between SBS and asphalt. Additionally,the storage stability of the binder was significantly improved in comparison with Dura asphalt.

Keywords: Asphalt, SBS, compatibility, Storage stability.

أستقرارية الخزن والتوافقية لأسفلت الدوره المحور بواسطة SBS

الملخص

أن الغرض من هذه الدراسة هو تحديد السلوك الفيزيائي للأسفلت المحور بإستخدام بوليمر SBS بمزج إسفلت ذي أختراقية 40/60 حيث ان كمية ال SBS له تأ ـثير كبير على الخصائص الريولوجية للإسفلت والتحسن في أدائه العالي تجاه الحرارة الى حد كبير، كما تم دراسة توافق الأسفلت مع SBS وذلك بدراسته من خلال المايكروسكوب وأستقرارية الخزنإذ لُوحظ تحسن كبير في أستقرارية الخزن للاسفلت مقارنة مع الاسفلت (الأصلي) قبل المعالجة.

الكلمات الدالة: أسفلت، SBS، توافقية، استقرارية الخزن.

INTRODUCTION

Asphalt is a highly complex hydrocarbon compound with high molecular weight,and high degree of hardness, and plasticity at prevailing temperatures (Salih, 2008).

The modification of asphalt had been shown to improve the performance ofthe pavement. Pavements constructed with modified binders have some merits,such as resistance rutting and thermal cracking, as well as decreasing fatigue damage, stripping and temperature susceptibility. Modified binders have been used with success at locations of high stress, such as at intersections of busy streets, airports and vehicle weigh stations (Kareem, 2016). Styrene-Butadiene-Styrene (SBS) is one of the elastomeric polymer that was widely used to improve properties of asphalt binder.SBS polymer exhibits a two-phase morphology consisting of glassy polystyrene (PS) end blocks connected together by the rubber polybutadiene (PB) segments. The hard PS end blocks provide SBS its high tensile strength and flow resistance at high temperature. The rubbery PB mid blocks provide elasticity, fatigue resistance, and flexibility at low temperatures. When SBS is mixed with hot asphalt, the PS end blocks begin to soften while PB mid blocks start absorbing the maltene component present in asphalt and begin to swell. Cooling of this blend leads to the formationof

strong, elastic and three-dimensional network of polymers within asphalt (Swamy *et al*., 2017). Many researchers have shown their interest in studying the properties of the modified binders and evaluating their advantage over the conventional asphalt. The major studies carried out by different researchers using Styrene Butadiene Styrene (SBS), Airey (2003) found of the effect of SBS polymer modification on the conventionalpolymer content. Although the decrease in penetration is relatively in uniform with increasing polymer content but there isa significant larger increase in softening point at high polymer content of 5% and 7%. In addition to the increase in stiffness, the increased penetration indices of PMB indicate a significant reduction in temperature susceptibility with polymer modification particularly at higher polymer content (Airey, 2003; Zhang *et al*., 2010) studied the effect of ageing on rheological properties of storage-stable SBS/sulfur-modified asphalts. Asphalt compounds can be separated by chromatographic techniques into four generic groups (SARAs): saturates, aromatics, resins (which make up the maltene fraction) and asphaltenes. The complexity, aromaticity, heteroatom content, and molecular weight increase in the order [S<A <R <As] , as shown in Fig. (1) (Navarro and Partal, 2009). There are obvious differences in physicochemical properties among SARA fractions, which havesignificant effects on properties of asphalt binder (Firoozifar and Foroutan, 2014). The term “compatibility” was introduced to describe the “level ofinteractions” between the asphalt and polymer. This term has an intuitive significance but remainsan evanescent property that is rather difficult to be directly measured. Several methods weretherefore developed over the years to indirectly estimate compatibility in asphalt/polymer blends.From this perspective, the investigation of the blend morphology is probably the most direct methodand optical microscopy is the most popular method because it allows the rapid and economicalobservation of the sample. A picture obtained using optical microscopy allows for a meaningfulrepresentation of compatibility and can be successfully used to predict the macroscopic stability ofthe blend. (Polacco *et al*., 2015).

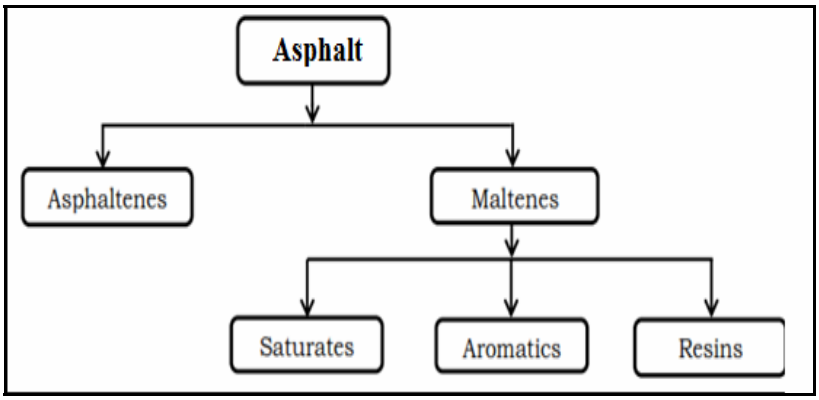

Fig. 1: (SARA) Parts separated from asphaltMaterials

EXPERIMENTAL

The materials used in this study are:

1. Asphalt:

One type of asphalt binder wasused in this study.It is (40-50) penetration grade from DuraRefinery. The physical properties of asphalt before added SBS that are used aretabulated in (Table 1).

Table 1:Physical properties of asphalt before add SBS

General physical properties	The value in modified
Specific Gravity @ 15.6°C	1.04
Flash point °C	326
Ductility @ 25 °C (cm)	100+
% wt. Solubility. in CH_2CL_3	99.9
Penetration. @25°C (100gm,5sec. 0.1 mm)	40
Original of penetration After loss on heat %	92
Softening point °C	51.5
H_2O % Vol	NIL

2- Additives:

Styrene-Butadiene-Styrene polymer (SBS) D1192in the form of porous pellet was obtained from Kratonpolymers (USA). As shown in Fig. (2).

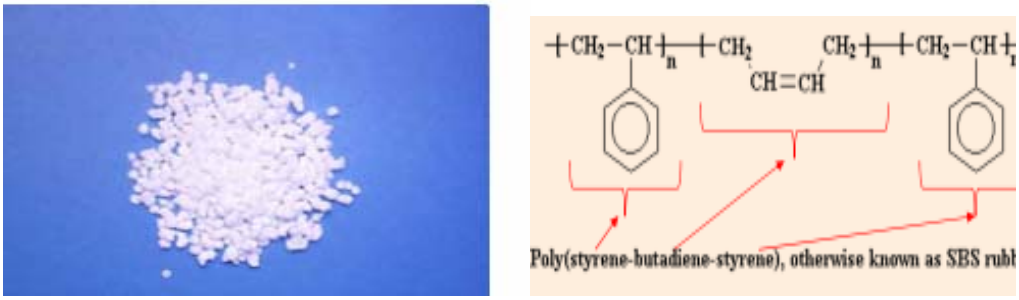

Fig. 2: A; Image of material SBS , B; Chemical formula SBS

Preparation of Sample

To prepare the blends of the modified binders, (100gm) of asphalt binder was placed in the 1litr metal container and heated to fluid state. The mixing of modifiers is carried out using a mechanical stirrer. Asphalt binder was heated to a temperature of160°C and the appropriate quantity of SBS copolymer was added separately inmetal container at given Fig. (3). The SBS modified binder, mixture was maintained attemperature between (160-165°C) (Al-Layla, 2006) and contents were gradually stirred for about 5 hours.

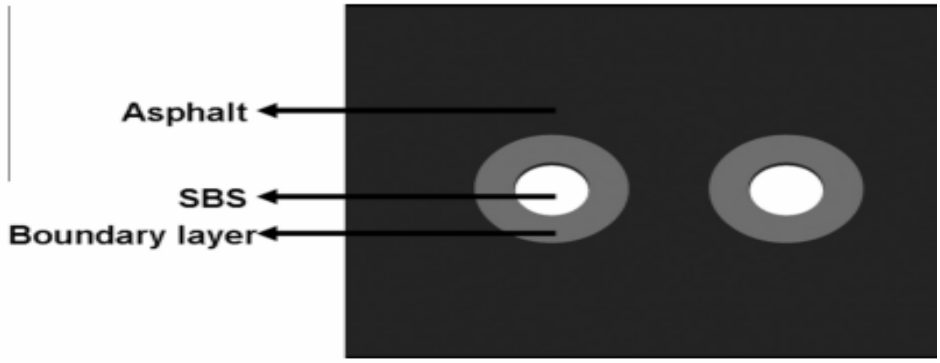

Fig. 3: Modification mechanism of SBS modified asphalt

Separation of asphalt into four fractions: (SARA)

This was accomplished according (ASTM D4124, 2009). The principle of the separation method is based on the different SARA fractionation of asphalt into four Fractions using different solvents in a chromatography column using alumina.

Spectralstudy

In order to identify the general formula, to separate compounds and determine the effective groups, IR spectroscopy was used.

Testing Methodology

To study the effect of polymer modification on asphalt cement properties, the following conventional tests were conducted on the prepared blends of the modified and original asphalt.

1. Conventional Measurements

Softening pointtest (ASTM D 36, 2009), Penetration test (ASTM D 5, 2006) and ductility test (ASTM D 113, 2007).

In addition, the temperature susceptibility of the modified bitumen samples has been calculated in terms of penetration index (PI) using the results obtained from penetration and softening point tests. Temperature susceptibility is defined as the change in the consistency parameter as a function of temperature. A classical approach related to PI calculation has been given in the Shell Bitumen Handbook as shown with the following equation:

$$PI = \frac{1952 - 500 * \log(Pen_{25}) - 20 * SP}{50 * \log(Pen_{25}) - SP - 120}$$

where Pen 25 is the penetration at 25^{o}C and SP is the softening point temperature of PMB. (Sengoz *et al*., 2009).

2. Elastic recovery test

The elastic recovery of the asphalt cement is evaluated by measuring the recovery ofthe binder thread formed by the elongation of binder specimen when it is cut down by scissors at standard conditions. The elastic recovery test is carried out as (ASTM D6084, 1997)

3. Storage stability test

The storage stability of modified asphalts was measured as follows. The samplewas transferred into an aluminum tube (32 mm in diameter and 160 mm in height). The tube was sealed and stored vertically in an oven at 163^{o}C for 48 hr, then taken out, cooled to room temperature, and cut horizontally into three equal sections. The samples taken from the top and bottom sections were used to evaluate thestorage stability of the SBR modified asphalts bymeasuring their softening points. Ifthe difference of the softening points between the top and the bottom sections was less than 2.5^{o}C, the sample was considered to have good high-temperature storage stability. If the softening points differed by more than 2.5^{o}C, the SBS-modified asphalt was considered to be unstable. (Zhang and Hu, 2013).

4. Morphology of Asphalt

The morphology was measuredusing amicroscope of the type (Optika B-353Pol) with 100 magnification, describing the microstructure interacting between asphalt and polymer,morphology of the polymer modified asphalt (PMA) by determining the state of dispersion of the polymer within the base asphalt as well as to characterize the nature of the continuous and discontinuous phases.

PMA samples for the morphology analysis were prepared using the following preparation method. After the modified sample was prepared, a glass rod was used dip into the sample immediately and one drop of it was put in the center of a glass slide. Then, this drop was covered by a piece of cover glass. In order to obtain smooth surface of the sample for nice observation, the covered sample was heated up to 135^{o} C at a certain heating rate in an oven, and a translucent film was formed on the glass slide after about 10 min. After this, the film covered with a cover glass was cooled down to the room temperature (Sengoz *et al*., 2009).

RESULTS ANALYSIS AND DISCUTION

Fraction Asphalt

Asphalt can be divided into four parts, as shown in the Fig. (4) which shows that the asphalteneratio represents 19% of the overall asphalt composition. The separated maltenes by a chromatography column, shared that asphalt was found to be rich with aromatic compounds compared to saturated compounds, as described in (Table 2).

Table 2: The contents and appearances of SARA fractions in asphalt

SARA fraction	Content (wt%)	Appearance
Saturates	19.53%	Colourless or Yellow Oil
Aromatics	26.80%	Yellow or red sticky liquid
Resins	29.47%	Brown viscous semi-solid
Asphaltenes	19%	Black fragile powder solid

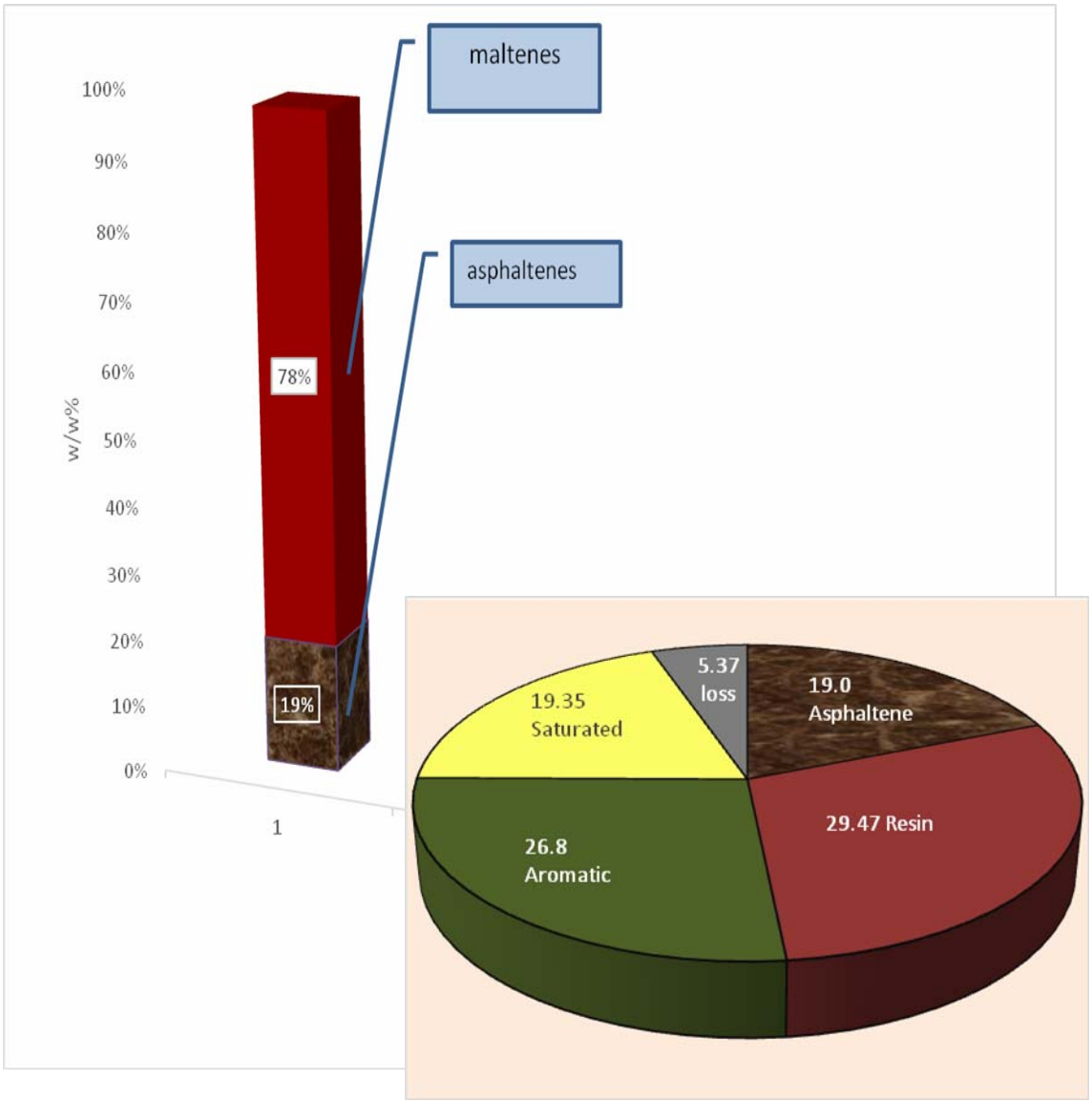

Fig. 4: Fractions of asphalt

Spectral study

It has been done by obtainingthe spectral packages in the (Table 3), (Abdul-Jaleel *et al.*, 2016).

Table 3: Spectral packages for fraction asphalt

Group	Asphaltene	saturated	Aromatic	Resins
$O\text{-}H_{st.}$	******	******	3448	3394
$C\text{-}H_{st.}$	2923-2854	2924-2854	2920-2851	2924-2854
$C{=}O_{st}$	1692	******	*****	1703
$C{=}C_{ro.}$	1610-1550	1655-1562	1564	1603
$C\text{-}H_{be.}$	1459	1460	1459	1460
$C\text{-}H_{be}$	1377	1377	1375	1375
$C\text{-}O_{st}$*	1185	******	******	1161
$=C\text{-}H_{oop}$	1061	*****	1016	1032
	968	*****	*****	*****
$C\text{-}X_{st}$	688	*****	*****	739

*Carboxylic acids, esters, ether/ **alcohols, phenols // oop=out of plane, st= stretching, ro=Rock, be = bend

It has been observed that there are wide peaks at (3448,3394 cm^{-1}) related to stretching OH, in alcohols and phenols, peak at (2923-2851 cm^{-1}) to four bands related to stretching C-H, and there peak within range in (1610-1550 cm^{-1}), related to absorption rocking (C=C) in aromatic ring. and there a sharp medium peak in (1459 cm^{-1}) and within range (1377 cm^{-1}) due to bending of C-H it special $-CH_2$, $-CH_3$ for saturated part, and found peak in (1185 cm^{-1}), (1161cm^{-1}) related to stretching C-O for groups phenols and alcohols. It is worth mentioning thatbands are found in (1016 cm^{-1}). It is related to band out of plane Figs. (5- 8), that shows the spectral study of asphalt parts.

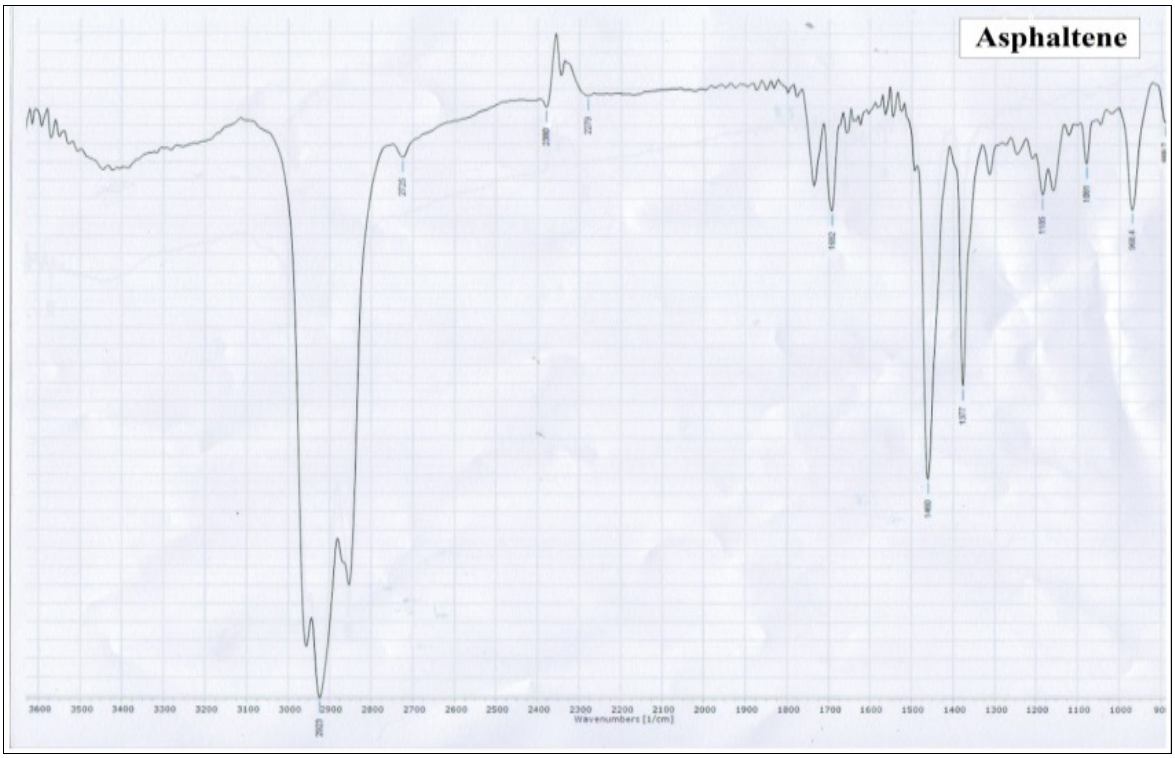

Fig. 5: IR spectrum for asphaltene

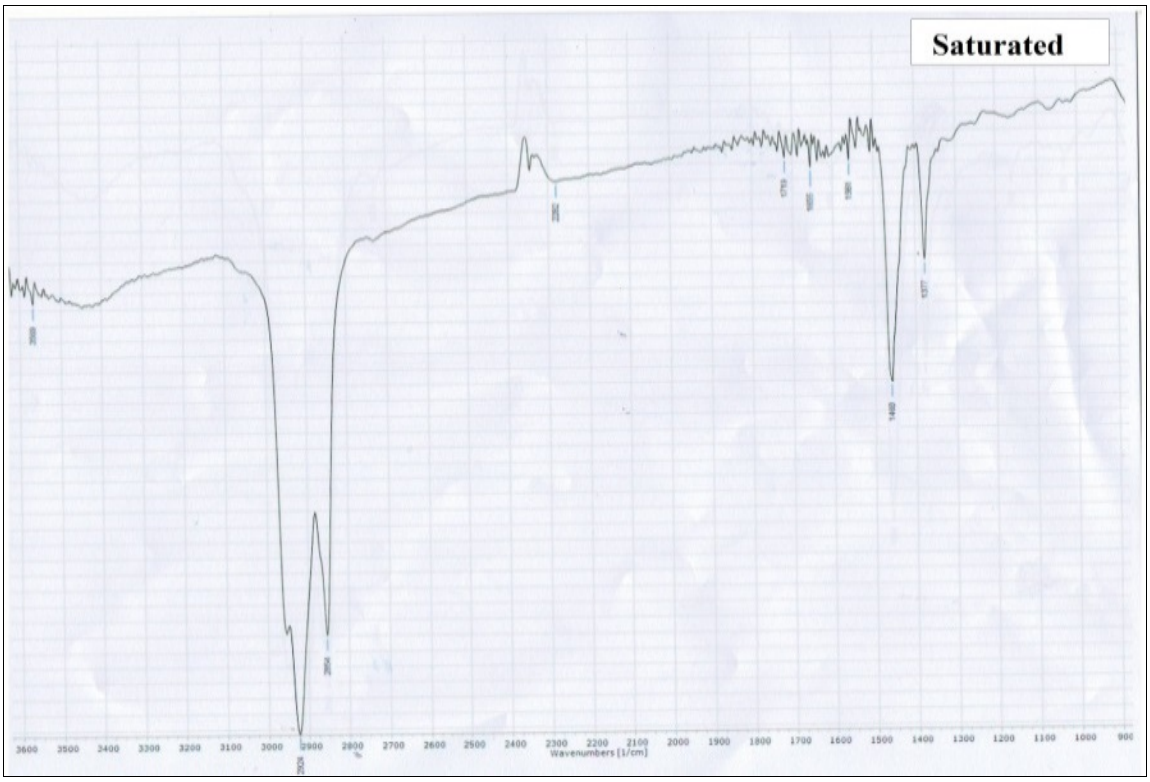

Fig. 6: IR spectrum for saturated

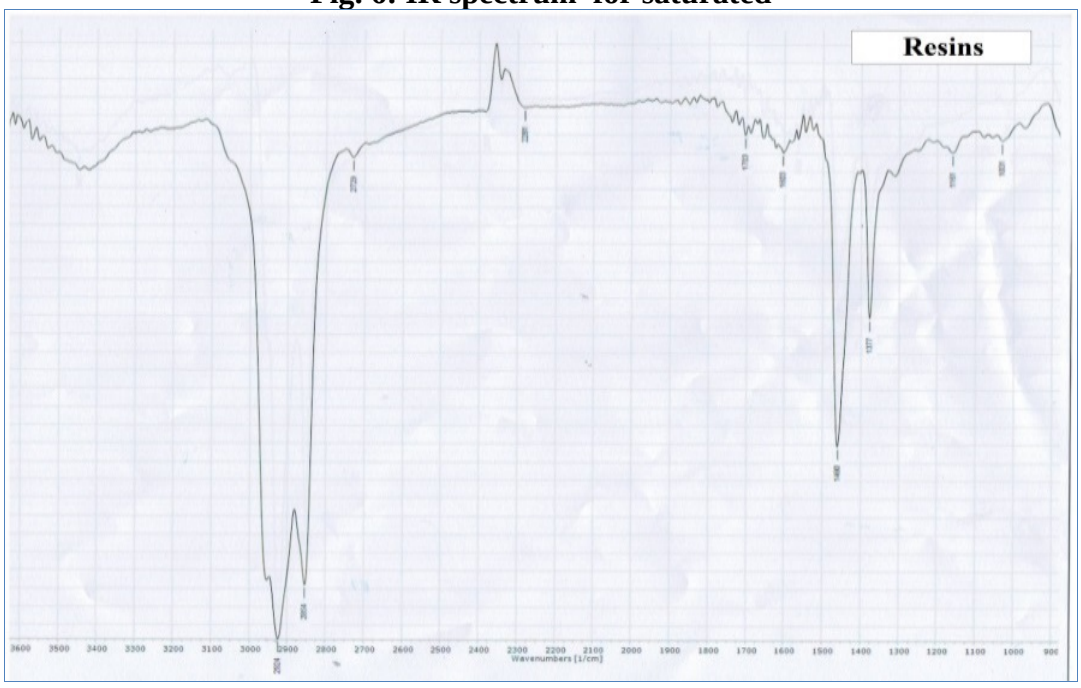

Fig. 7: IR spectrum for resin

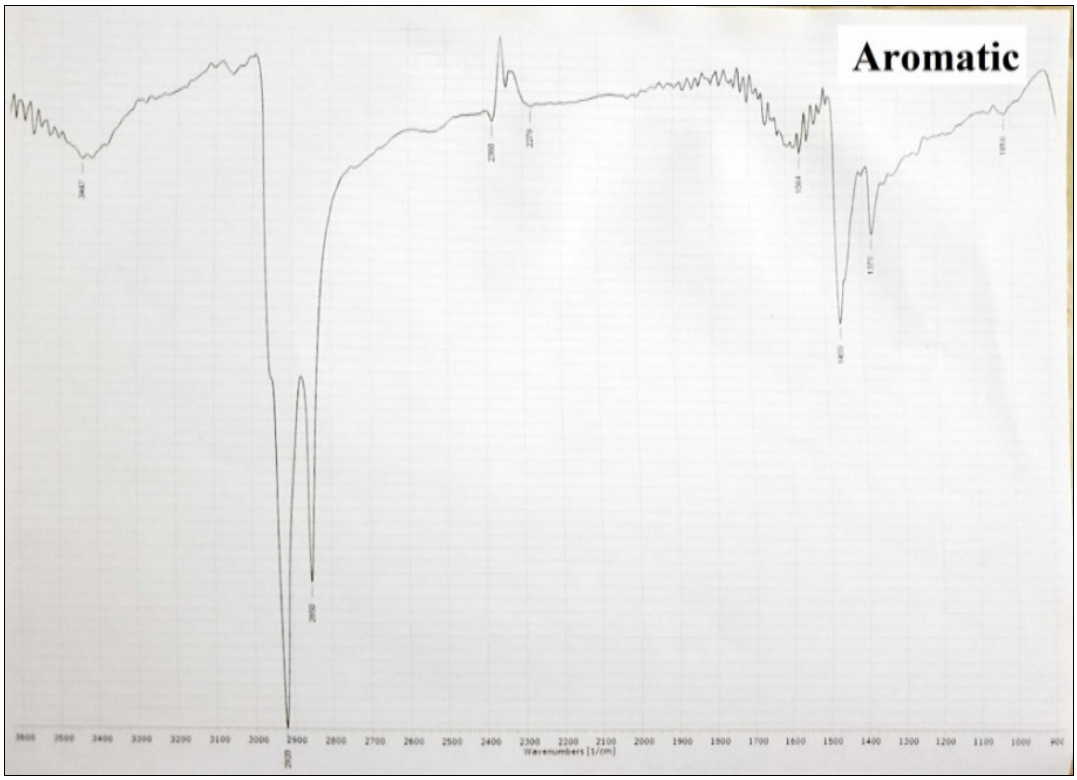

Fig. 8: IR spectrum for aromatic part

Physical measurements

After the addition ofSBS to asphalt and physical measurements, the results obtained are given in Fig. (9).

As noted in the values listed in the (Table 4), the differences in the softening point between the top and bottom sections of the samples (2% , 3%) were not more than 2.5 °C. It can bededuced that fresh prepared asphalt binder can be used inpavement at once and can be stored at room temperaturefor long. (Fu and Xie, 2007)

The effect of SBS Polymer modification on the properties of the original asphalt could be seen in Fig. (9) as decrease in penetration values and an increase in softening points with increasing polymer contents. The increase in softening point temperature is favorable since asphalt with higher softening point may be less susceptible to permanent deformation (rutting).

Polymer modification reduces temperature susceptibility of the asphalt; lower values of PI indicate temperature susceptibility. Asphalt mixtures containing asphalt with higher PI are more resistant to low temperature cracking as well as permanent deformation. (Lux,1997).

Table 4: Storage stability of polymer modified asphalt

%SBS	Softening Point (°C)	Storage stability		
		S.P (°C) at Bottom	S.P (°C) at Top	ΔT
0%	51.5	___	___	___
1%	56	56	59	3
2%	60	50	51	1
3%	60	53	51	2
5%	74	53	63	10

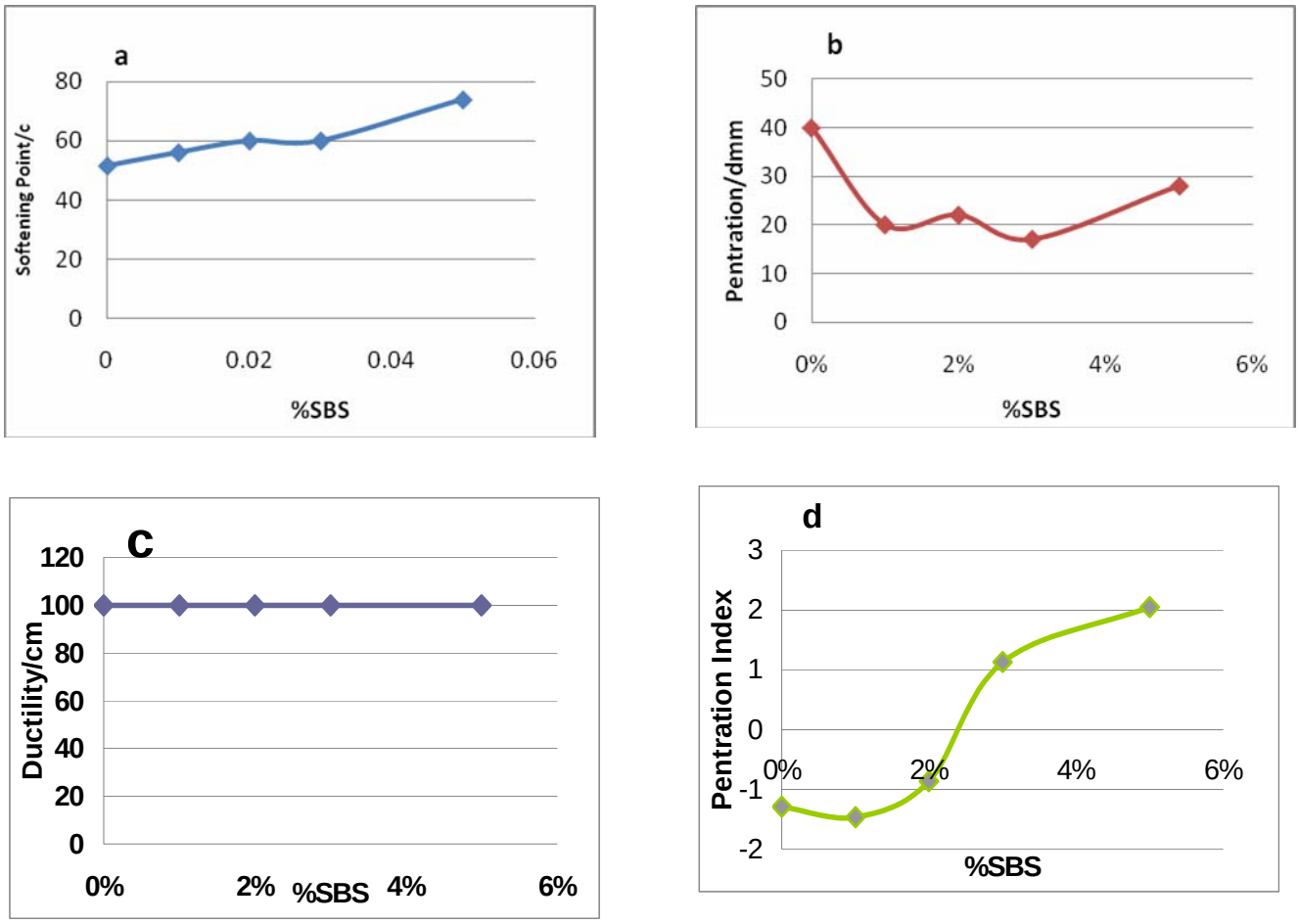

Fig. 9:physical properties after adding the polymer to the asphalt (a: softening point, b: penetration at 25 °C, c: ductility (cm), d: Penetration index)

Image Processing and Analysis

In this study, the image processing and analysis were used to quantify particle size distribution of SBS in the PMAs.

A distinction could be made between the PMAs whose continuousphase is an asphalt matrix with dispersed polymer particles andsamples whose continuous phase is a polymer matrix with dispersed asphalt globules. In the images, the swollen polymer phaseappears (light) while the asphalt phase appears dark. Where observed in the pictures below Fig. (12), the light phase in the picture represents the swollen polymer, and the dark phase is the asphalt. SBS is dispersed as small particles in the asphalt (Chen *et al*., 2002).

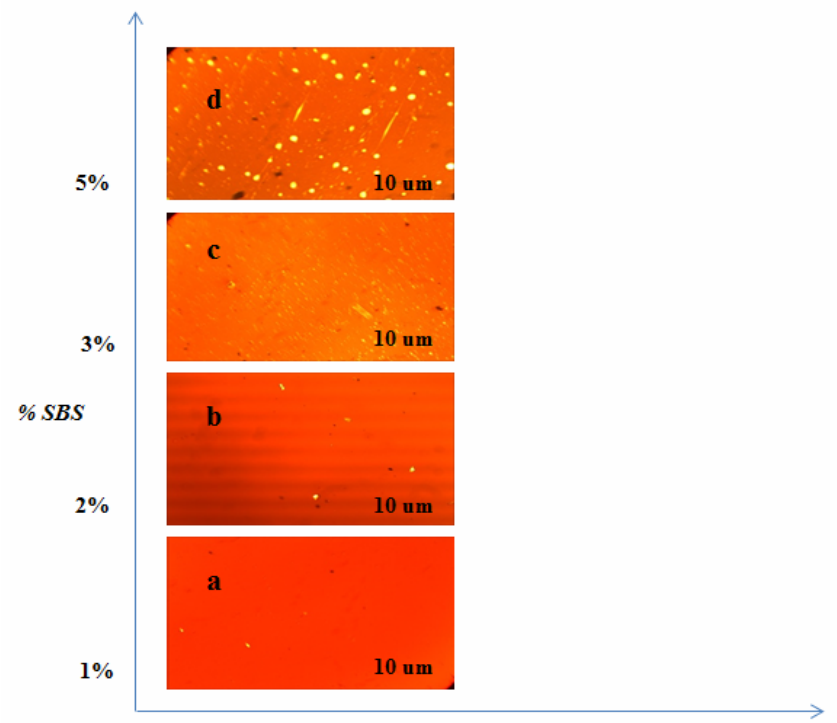

Fig. 12: Image of SBS PMA sample with 400 magnifications

CONCLUSION

The contents of saturates, aromatic, resins and asphaltenes are 19.5%, 26.8% 29.4% and 19% in asphalt binder, respectively. The contents of aromatics and resins are higher than those of saturates and asphaltenes.

The addition of SBS D1192 led to the creationofa3D network in the asphalt blends and enhanced rheological properties.

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