RHEOLOGICAL PROPERTIES OF EVA POLYMER MODIFIED BITUMEN

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Abstract

This paper presents a laboratory study of modified bitumen containing ethylene vinyl acetate (EVA) copolymer. A 35/50 penetration grade base (unmodified) bitumen has been mixed with EVA polymer at different proportions (3%, 5% and 7%). Therefore, this study was conducted to investigate the effects of the modifier on the rheological properties. The rheological characteristics of the EVA-modified bitumen have been analyzed using dynamic shear rheometer (DSR).

The dynamic shear rheometer test reported that added content of EVA has great effect on the rheological properties of the binder such as increased elastic responses (increased complex shear modulus and decreased phase angle) at low to high temperatures. EVA improves rutting resistance and fatigue behaviour at high temperatures and low temperatures respectively.

Keys words: *Polymer modified bitumen; EVA; Rheological property.*

1. Introduction

Bituminous roads are the major part of network in Algeria. The high intensity of traffic in terms of vehicles and the over loading of trucks have been responsible for early development of distress symptoms like undulations, rutting and cracking of pavement. The durability of asphalt pavement is greatly influenced by the environmental changes during the year, between hot and cold temperatures and between day and night. High temperatures can soften the bitumen and consequently reduce the stiffness of asphalt pavement, making the mix more susceptible to rutting [1]. A conventional bitumen 35/50 penetration grade is commonly used in Algeria. Unfortunately, high temperature rutting and low temperature cracking of asphalt pavement or coating layer due to severe temperature susceptibility limits its further application [2]. The factors, which are of serious concern, are the varying temperature conditions prevalent in south of Algeria and the inadequate quality control during the construction of the road. In this case, the rheological properties and durability of conventional bitumen are not sufficient to resist pavement distresses. This has resulted in the need to enhance the properties of existing asphalt material [3]. The objective of this research is to present a laboratory evaluation of base bitumen and EVA modified bitumen (EVAMB) in terms of morphologies and rheological properties. The EVAMBs were produced by laboratory mixing using tree polymer contents. The rheological properties of the EVAMBs were determined by means of an oscillatory type of testing of dynamic mechanical analysis (DMA) generally conducted within the region of linear viscoelastic response. The viscoelastic properties considered in this paper are complex shear modulus, storage shear modulus, loss shear modulus and phase angle.

2. Experimental program

2.1. Materials

The base bitumen used was a 35/50 penetration grade provided by the Algerian Oil Refining Company "NAFTAL. The results of penetration grade trials and softening temperature tests, according to ASTM D5 and D36, respectively, as well as chemical composition in terms of Sara's fractions are presented in table 1.

Table 1. Conventional physical properties and SARA composition of the base bitumen.

Physical properties	Penetration (25°C; 1/10 m)	41
	Softening point (°C)	52
	Penetration index (PI)	-1.16
SARA composition	Saturates (%)[a]	8.7
	Aromatics (%)[a]	36.4
	Resins (%)[a]	44.6
	Asphaltenes (%)[a]	10.3
	Colloidal index[b]	0.234

[a]Iatroscan thin film chromatography SARA analysis.
[b]Colloidal index (I_c) = (asphaltenes + saturates) / (resins + aromatics).

The thermoplastic polymer used as modifier is Ethylene Vinyl Acetate (EVA). The main characteristics of EVA polymer as given by the manufacturers are reported in table 2.

Table 2. Main physical and chemical characteristics of EVA Polymer used as modifier for the base bitumen.

Properties	EVA Polymer
Physical aspect	Granular
Molecular structure type	Linear
Vinyl acétate (wt.%)	18 %
Density (ASTM D792)	0.939 g-cc
Viscosity	1.25 Pa.s

2.2. Preparation of EVA modified bitumens

Four EVAMBs were produced by mixing EVA polymer at different polymer content levels (3, 5, and 7 % by weight of bitumen) with base bitumen. The EVAMBs were prepared using a high shear mixer at 180°C with shearing speed of 600 rpm. First, the base bitumen is heated to fluid condition (about 175°C), and is poured into a 2000 ml spherical flask. The EVA is then added slowly to the base bitumen. The mixing was continued at the temperature for two hours. The mixer speed was maintained through the mixing process. After completion, the modified binders was removed from the flask and divided into small containers. The blend was cooled to room temperature, sealed with aluminum foil, and stored for further testing.

2.3. Dynamic Shear Rheometer Test (DSR)

Dynamic mechanical analysis (DMA) was performed on the base bitumen and EVA modified bitumens, to determine their rheological properties using dynamic shear rheometer (DSR). The DSR provides an indication of the rutting resistance of bitumen immediately following construction.

The principal rheological parameters obtained from DSR were complex shear modulus (G*) and phase angle (δ). G* is defined as the ratio of maximum shear stress to maximum strain and provides a measure of the total resistance to deformation when the bitumen is subjected to shear loading [4]. The phase angle is the phase shift between the applied shear stress and shear strain response during a test and is a measure of the viscoelastic balance of the material behavior. The DSR tests reported in this paper were performed under controlled-strain loading conditions using frequency sweeps between 0.01 and 10 Hz at temperatures between 20°C and 80ºC. The tests were undertaken with parallel plates testing geometry. Diameter of plates was 25 mm with 1 mm gap.For specification purposes, the frequency is 10 radians per second, which has been related to a traffic speed of 100 km⁄h.

3. Results and discussion

3.1. Rheological properties of the EVA polymer modified bitumens

The rheological parameters should be obtained within the linear viscoelastic range, which is similar to the road traffic loading conditions [5]. It was considered quite interesting to compare the rheological behaviour with base bitumen and EVA modified bitumens. The complex shear modulus (G*) and phase angle (δ) as function of temperature were determined at 10 rad/s over a temperature range from 20°C to 100°C.

3.1.1. Isochronal plot

In DSR test, curves of the complex modulus G* and phase angle δ versus temperature at constant frequencies constitute the isochronal plots. The isochronal plot of complex modulus (G*) versus temperature at 10 rad/s frequency of base and EVA modified binders is shown in Fig. 1. It is well known that one of the effects of addition of small amount of polymer to a bitumen is to increase the viscosity, beyond the viscosity enhancement due exclusively to the oxidation of the bitumen during mixing process. As seen from Fig.1, the complex shear modulus G* of the base bitumen and EVA modified bitumen decreased sharply with increasing temperature. It also can be seen that with increasing modifier contents, the G* value of the modified bitumen increases significantly. However, the G* of EVA polymer modified bitumens are higher than of base bitumen over the entire temperature range. These high values indicate that the additive of EVA polymer make binders stiffer, consequently, increase their resistance to deformation. For low polymer contents (3 wt%), there are only minor increase in *G**. For the high polymer contents, there is a high and more uniform increase in G* over the entire temperature range especially for 5% and 7% EVA modified bitumen, which is an evidence of dominant polymer network.

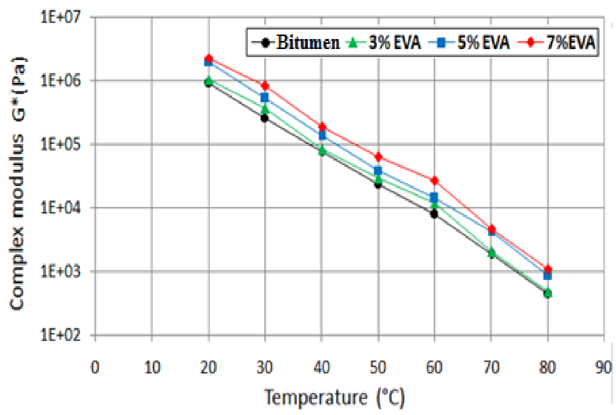

Fig. 1. Complex modulus versus temperature at 10 rad s^{-1} for base and EVA modified binders.

Phase angles isochrones at 10 rad/s for the base and EVA modified binders are shown in Fig.2. This figure clearly shows that increase in EVA polymer concentration leads to a decrease in phase angle (δ). After modification with a sufficient content of EVA polymer (3%), the binders change fundamentally in their rheological behaviour. Compared with base bitumen, δ values of all modified bitumen decreased at all temperatures. The decreasing extend of δ becomes greater when the content of modifier increases. The phase angle isochrones clearly illustrate the improved elastic response (reduced phase angles) of the modified bitumen. The phase angles data of EVA polymer modified bitumens have lower values than of base bitumen. The decrease in phase angle values obtained by polymer modification is an indicator of increasing in binder elastic properties and of reduction in binder permanent deformation occurred as a result of applied stress.

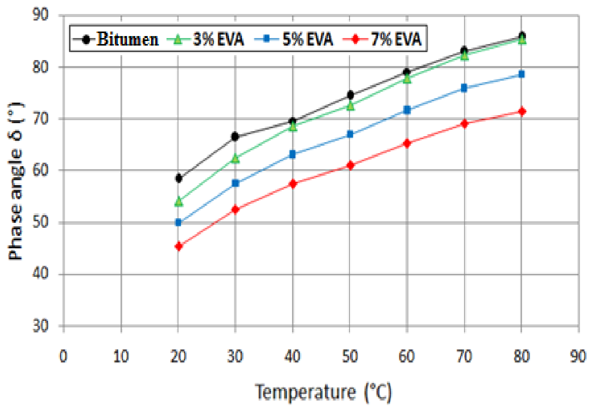

Fig. 2. Phase angle versus temperature at 10 rad s^{-1} for base and EVA modified binders.

3.1.2. SHRP rutting parameters

The Strategic Highway Research Program (SHRP) test [7], developed to replace old conventional tests with no sound theoretical background, represent an interesting effort to take advantage of the rheological measurements as a tool to analyze the ultimate properties of bitumen binders used in road pavements. According to a SHRP test, the temperature at which G*/sin δ ≥1 KPa marks the maximum temperature for a good viscoelastic performance of the binder once in the pavement. The rutting parameter G*/sin δ is defined as the stiffness indicator for evaluating the rutting resistance of both unmodified and polymer modified bitumen and as the permanent deformation of each layer of the pavement under repeated loads. The effect of temperature on the rutting parameter (G*/sin δ) is shown in Fig.3. It was observed that with increasing of polymer content, the G*/sin δ increased considerably and the TSHRP of the modified bitumens become higher, indicating that the improvement of high temperature property of the modified bitumens. Increases tend to be similar at low polymer content. The best results are obtained when the base bitumen is mixed with high EVA polymer contents. It shows that the rutting resistance performance of the EVA PMB is better than that of base bitumen.

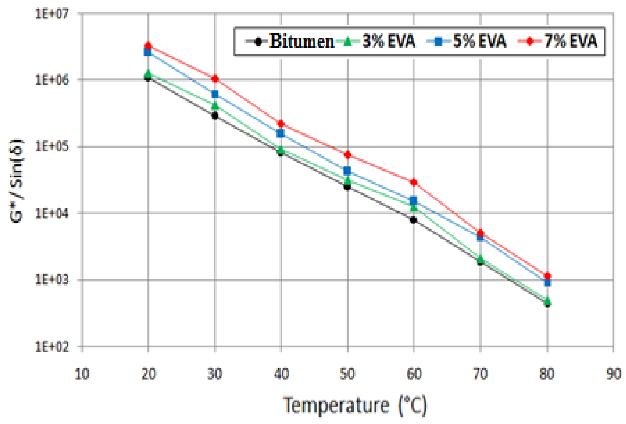

Fig. 3. G*/sin δ versus temperature at 10 rad s^{-1} for base and EVA modified binders.

3. Conclusion

The addition of EVA polymer to bitumen, in order to improve its performance for pavement applications has been studied. The rheological investigation of the EVA polymer modified bitumens, by means of empirical methods and dynamic shear rheometry, has shown that there is a considerably difference in behavior between the base bitumen and the EVA modified binders. Considering the results obtained by DSR test, it is seen EVA polymer modified bitumens binder exhibits increases complex modulus (G*), rutting parameters (G*/sin δ), and has more decreased phase angle values, consequently, using the EVA polymer is considerably improves the elastic properties and rutting resistance of bitumen. This study showed that the fundamental rheological characterization of binder properties is superior to the conventional empirical measures.

References

[1] Isacsson U and Lu X. *Characterization of Bitumens Modified with SEBS, EVA and EBA Polymers*. Journal of Materials Science 1999; 34: 3737-45.

[2] Shingo K, Shigeru T, Zhan X, Dong D, Norihiro I. *European polymer journal* 2001; 3 (33): 209-13.

[3] Airey GD. *Rheological evaluation of Ethylene Vinyl Acetate polymer modified bitumens*. Construct Built Mater 2002; 16: 473-87.

[4] Airey GD. *Rheological properties of Styrene Butadiene Styrene polymer modified road bitumen.* Fuel 2003; 82 (4)1709-19.

[5] *Superpave performance graded asphalt binder specification and testing. Superpave, Series N).1 (SP-1)*, Asphalt Institute, Lexington, KY, USA; 2003.