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Rheological Behaviour of Ethylene-Vinyl-Acetate (EVA) Modified Road Bitumen

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ABSTRACT

In this present study, the effects of Ethylene-Vinyl-Acetate (EVA) on the conventional characteristics and rheological properties of pure bitumen were investigated. The modified bitumen (PMB) has been prepared in laboratory by mixing bitumen with copolymer EVA. Three different contents of polymer have been tested to evaluate the modification. The basic properties of the PMBs have been determined by using conventional test methods. The results indicated that polymer modification improved the conventional properties of the base bitumen such as; penetrability, softening point and temperature susceptibility. Some observations by UV florescence microscopy have been performed to show the differences in the morphology of the PMBs as a function of polymer content. The rheological behaviour was evaluated with a widely used test that is the complex modulus test in order to reach a model. The results of the investigation indicate that the rheological models can reproduce the effect of polymer modifications with an increase of initial modulus and a decrease of the relaxation time and phase angle with polymer content. Two rheological models such as Huet modified model and Prony series model were used to to characterize the rheological behaviour.

Key words: Bitumen, ethylene-vinyl-acetate, rheological properties, Huet modified model, prony series, relaxation time

INTRODUCTION

Road pavement structures are subjected in service, to highly complex stresses. Traffic and climate have a significant influence on the behaviour of pavement materials. Therefore, it is necessary to deepen the studies on pavement materials, particularly bitumen (Kumar and Garg, 2011).

Modification of binders with polymers improves the performance of the bituminous binders and reduce the frequency of road maintenance operations.

The use of polymer to modify the performance of conventional bituminous binders dates back to the early 1970s (Ajour, 1981; PIARC., 1999), these binders subsequently having decreased temperature susceptibility, increased cohesion and modified rheological characteristic.

Currently, the most commonly used polymer for bitumen modification is the Styrene Butadiene Styrene (SBS) followed by other polymers such as Styrene Butadiene Rubber (SBR), Ethylene-Vinyl-Acetate (EVA) and polyethylene (Airey, 2004).

However, like all thermoplastic materials, bitumen suffers from a major drawback: It is very sensitive to temperature (Airey, 2004; Isacsson and Lu, 1999). In addition, the significant increase of traffic density and higher axle loads requires adaptation of bitumen in the direction of improved durability (PIARC., 1999).

The EVA based polymers are classified as plastomer that modify bitumen by obtaining a rigid and three-dimensional structure to resist deformation. Their characteristics lie between those of low-density polyethylene, semi-rigid, translucent product and those of a transparent and rubbery material similar to plasticized polyvinyl chloride (PVC) and certain types of rubbers (Panda and Mazumdar, 1999). This type of polymers have revealed as good modifiers which improve some mechanical characteristics (Tayfur *et al*., 2007; Gonzalez *et al*., 2004).

Although considerable research has been undertaken in this area, EVA PMBs have still to be comprehensively characterized due to the complex nature and interaction of the bitumen and polymer system (PIARC., 1999; Airey, 2004; Isacsson and Lu, 1995, 1999; Kamiya *et al*., 2001).

Some of tests like softening point, penetrability and viscosity give satisfactory indication of the fragility and susceptibility of the bitumen but not sufficient to identify its viscoelastic behaviour (Widyatmoko and Elliott, 2008).

To improve the performance of the pavement by an incorporation of polymers in the binder, the understanding of the improvement by using some experimental investigations is needed and the quantification of the effect of polymer content can be evaluated with some rheological models.

FUNDAMENTAL ASPECTS OF THE RHEOLOGICAL PROPERTIES

The bitumen is identified as a viscoelastic material. The rheological response of the bitumen is intermediate between an ideal elastic solid symbolized by a spring and a Newtonian viscous liquid symbolized by damper viscosity. The elasticity reflects its ability to store and release energy after deformation while the viscosity is its ability to dissipate energy.

The behaviour of the bitumen can be studied dynamically by subjecting it to strain or stress varying sinusoidally with time. These measurements are made in the field of small deformations so that the material response is linear viscoelastic. The complex modulus can be defined as the ratio between the amplitude of the sinusoidal stress and the amplitude of the resulting sinusoidal deformation.

The description of the linear viscoelastic behaviour of the bitumen is obtained by the dependence between the complex modulus with the frequency and the temperature.

From the results of complex modulus, different representations of rheological behaviour are commonly used (Olard, 2003). Some values from the complex modulus can learn about the properties of bitumen uses.

The rheological properties provide information about the structure of bitumen and modified bitumen that allow us to make any predictions about the behaviour of asphalt.

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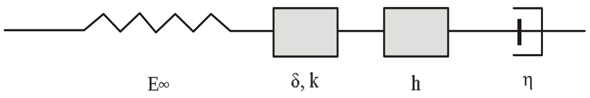

Fig. 1: Representation of the Huet-modified model

METHODOLOGY

Huet modified model: For a given material and from the complex modulus measurements $G^*(i\omega)$, the following rheological functions for creep noted F(t) and for relaxation noted R(t) allow determining the material response for a fixed loading. Hence, many models have been proposed to describe the dependence of the viscoelastic response of bitumen with frequency and temperature. Most of them are based on the master curves obtained with the method of slip factors of Williams, Landel and Ferry (WLF) (Airey, 2002), implying that the principle of time-temperature equivalence is applicable. The rheology of bitumen is therefore governed by the relaxation time spectrum (Such, 1982).

To interpret the experimental results that describe the rheological behaviour of bitumen, Huet-modified model is chose to adjust them (Wu *et al*., 2012).

Such (1982) suggested to modify the Huet model by adding, in series, a linear damper $\eta = E_\infty \beta \tau(\theta)$. After adjusting the value in the Black curves, linear damper allows to give the fluidity of bitumen at high temperature (Marciano *et al*., 1997). Figure 1 shows the Huet modified model.

Expression of the corresponding complex modulus is given by equation:

$$E^*(\omega) = \frac{E_\infty}{1 + \delta (i\omega\tau)^{-k} + (i\omega\tau)^{-h} + (i\omega\beta\tau)^{-1}} \tag{1}$$

For this model, the creep function F (t) is also known:

$$F(t,\theta) = \frac{1}{E_\infty}\left[1 + \delta \frac{\left(\frac{t}{\tau(\theta)}\right)^k}{\Gamma(k+1)} + \frac{\left(\frac{t}{\tau(\theta)}\right)^h}{\Gamma(h+1)} + \frac{t}{\beta\tau(\theta)}\right]$$

With this model, it is possible to describe the behaviour of bitumen in the frequency and the time domain while taking account thermal susceptibility.

The parameter calibration has been performed by using the visco-analysis software developed.

The identification of the model parameters is performed from the master curves for a temperature of 15°C.

After calculation with the modified Huet model, one obtains the shape of the master curves. For this, a wedging of the master curve is make modeled on the master curve obtained experimentally with nonlinear optimization algorithm by the gradient method. The optimization criterion used is a least squares sum:

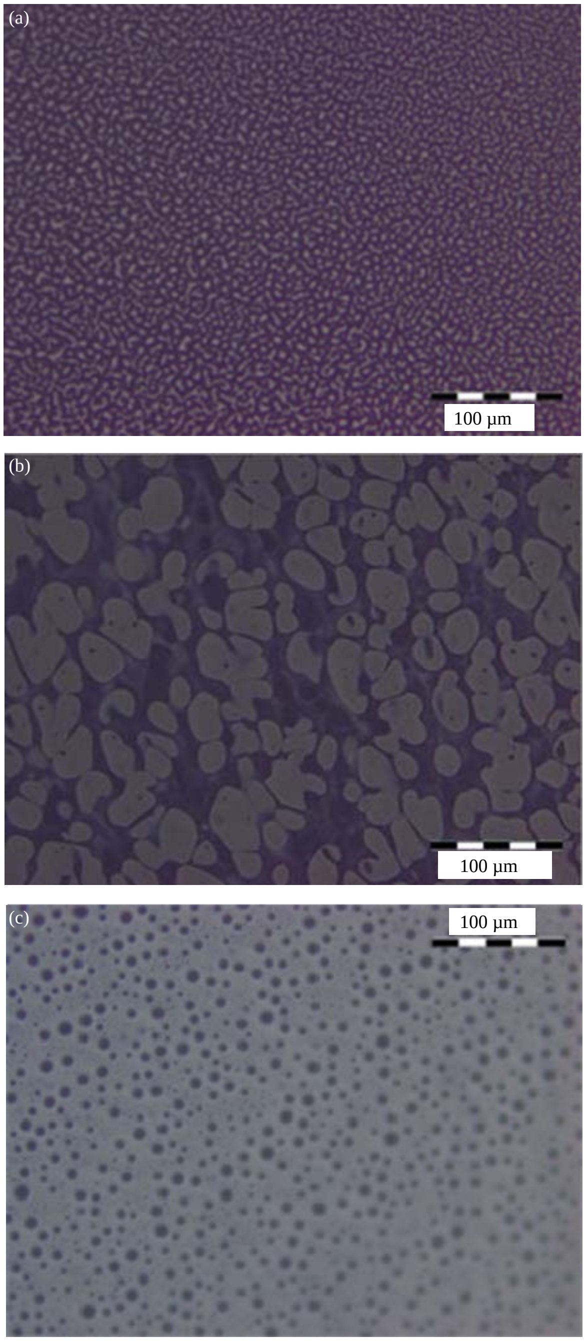

Fig. 2(a-c): Fluorescent images of (a) 3%, (b) 5% and (d) 7% of EVA modified bitumen

$$R = \sum_{i=1}^{n}\left[\left(\delta_{\exp}(\omega_i) - \delta_{\text{model}}(\omega_i)\right)^2 + \left((\log_{10}\left|E_{\exp}(\omega_i)\right| - \log_{10} E_{\text{model}}(\omega_i)|\right)^2\right]$$

where, ω_i represent the reduced frequency, for not to favor a frequency range denser of experimental points, reduced frequency spectrum is interpolated and distributed logarithmically.

Parameters are modified Huet found for a temperature. Then, only the τ parameter is adjusted on the master curves constructed for the remaining temperatures. The parameters E_∞, δ, k, h, β not vary.

With temperature only the parameter τ varies according to the following relationship:

$$\tau(\theta) = e^{A_0+A_1\theta+A_2\theta^2}$$

Preparation of EVA copolymer modified bitumen: The modified binders were prepared at 180°C and a speed of 600 rpm using a high shear mixer. While preparing EVA modified binders, 600 g of the bitumen was melted and poured into a 2000 mL spherical flask. Upon reaching 175°C, the powdered EVA polymer was added to the bitumen. The EVA concentrations in the base bitumen were chosen as 3, 5 and 7% by weight. After reaching 180°C, the mixing process was continued at the specified temperature during 2 h. The mixer speed was maintained through the mixing process. After completion, the EVA-PMBs 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.

Observation on the UV fluorescence microscope: The evaluation of the dispersion state of the polymers in the bituminous binder was performed by UV fluorescence microscopy.

The optical microscopy is the technique most commonly used to appreciate the dispersion state of the polymer phases in the bitumen. It is based on the principle that the polymer swollen with some components of the bitumen which they are added fluorescence when they are illuminated by the ultra-violet light.

Reflection (Sengoz and Isikyakar, 2008) allows the effective visualization of these microstructures. The polymer phase appears light while the bitumen phase appears black. It is necessary that the surface be perfectly plane (Trakarnpruk and Chanathup, 2005), the process is describe as:

Sample with 3% EVA content is shown in Fig. 2a. In this case, the bitumen constitutes the continuous phase of the system wherein the polymer phase is dispersed.

The bitumen phase depleted of oils and resins is correlatively enriched in asphaltenes, thermal susceptibility is less strong improving as well the properties at high temperature services.

At low temperatures, the modulus of the disperse phase is much lower than that the matrix in which moves favorably the threshold of fragility. In this case, the choice of the bitumen is determinant.

Sample with 5% EVA content is shown in Fig. 2b. It can be seen that microstructures which are obtained in both phases are continuous and overlapping. Such systems are generally difficult to control and pose stability problems. The micromorphology and the properties of the bitumen often depend on the recent thermal history.

Sample with 7% EVA content is shown in Fig. 2c. It is observed that the microstructure of a modified binder polymer matrix (this is a phase inversion). In this case, there is no need to modified but a plasticized by oil of bitumen. The polymer material is dispersed in a bitumen phase and is enriched with the small heavier fractions of the initial binder. This case (the dispersed phase becomes the continuous phase) may be treated in the same manner as the preceding case which will make them prohibitively expensive for conventional road application.

These considerations about the microstructure of polymer modified bitumen are extremely important where there is a close relationship between the microstructure of a modified binder and its physical properties (Soenen *et al*., 2008). Thus at constant polymer content, the polymer-modified bitumen, prepared from the same grade but different origins, may have microstructures and properties are (especially low temperature deformation) significantly different (Lesueur, 2009).

Experimental results of physical properties of the pure bitumen: Pure bitumen commonly used for pavement design was tested. The main properties of the materials are given in Table 1. The base bitumen used was a 50/70 penetration grade. The physical properties and chemical characteristics of the base bitumen are given in Table 1.

The value of the penetration is between 50 1/10 mm and 70 1/10 mm NF EN 1426 and then the softening point between 46 and 54°C NF EN 1427, they fully correspond with the recommended specifications for the 70/50 penetration grade for the pure bitumen.

The values of the temperature of softening point test for the basis binder are relatively low. This will certainly increase the risk of rutting in hot weather, knowing that in Algeria the temperature of 50°C is easily reached on pavement (Laradi and Haddadi, 1999).

The base binder had 23% of resin which is consistent with the literature which fixed the interval of the resins between 13-25% (Di Benedetto *et al*., 2001).

More I_C ratio is great less the asphaltenes were peptised in maltenique phase (Chen *et al*., 2003). Therefore, the bitumen is identified as a gel structure and the colloidal stability represented by I_C is poor.

Experimental results of physical properties of the modified bitumen: The effect of polymer modification for the different EVA modified bitumen can be seen in Table 2, as a decrease in penetration between 35 and 39 1/10 mm and an increase in softening point with increasing modification.

The increase of the softening temperature is quite favourable against permanent deformations (Lesueur, 2009). Indeed, the polymer mixture with bitumen often leads to an increase in the consistency of the modified bitumen which means a high resistance to deformation of the pavement. This is probably due to the diffusion of maltenes in the polymer phase causing swelling and also interactions between the polymer and polar asphaltene molecules (Ramond *et al*., 2000).

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

Parameters	Values
Physical properties	
Penetration (25°C; 1/10 mm)	54.000
Softening point (°C)	49.000
Penetration index (PI)	-1.284
SARA composition	
Saturates (%)	15.400
Aromatics (%)	46.900
Resins (%)	22.900
Asphaltenes (%)	14.800
Colloidal index	0.432

Table 2: Changes in conventional bitumen properties following EVA modification

Bitumen	Penetration (25°C, 1/10 mm)	Softening point (°C)	Penetration index (PI)
Pure bitumen	54	49.0	-1.284
PMB-EVA 3%	35	59.2	0.000
PMB-EVA 5%	38	67.0	1.646
PMB-EVA 7%	39	70.6	2.301

The Penetration Indices (PIs) indicate an improvement in temperature susceptibility with polymer modification.

In summary, these results clearly shows that the modification of polymers induces a rubbery elastic behaviour which gives the bitumen better resistance to low temperature cracking and permanent deformation (Lesueur, 2009).

Methodology of characterization of the bitumen viscoelastic properties: Bitumen viscoelastic properties are determined from the mechanical response in the frequency domain. The rheological measurements are performed in strain controlled mode. In order to ensure the measurements remain in linear viscoelastic domain, strain level is chosen to be inferior to 50×10^{-6} µm. The rheological experimental tests are carried out by means of a visco-analyzer METRAVIB. Figure 3a-b shows the device of METRAVIB.

Two loading modes are used:

- Annular shearing mode for high temperatures (20, 60°C) with an annular shear specimens hollow cylinder (inner diameter = 8 mm, outer diameter = 10 mm, height = 20 mm)
- Tension-compression mode for low temperatures (-20, 20°C), were conducted on cylindrical specimens (diameter = 10 mm, height = 22 mm)

The measurements are carried out from 1-100 Hz. The complex shear modulus G* given by the annular shearing experiment is converted into the Young modulus E* (tension-compression) by assuming the Poisson' ratio equal to 0.5.

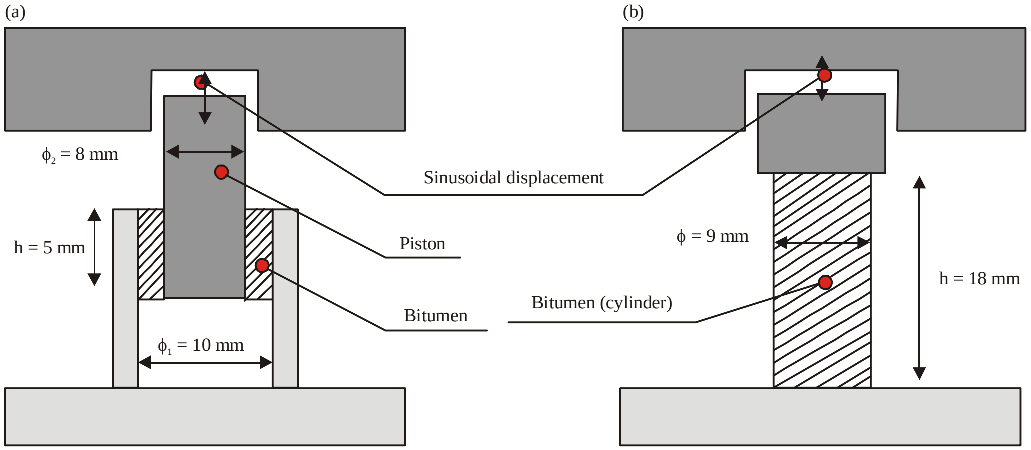

Fig. 3(a-b): Schematic view (a) Annual sharing and (b) Tension-compression test of the experimental set-up for complex modulus measurement

The settling time applied between each temperature step is 15 min. With these two modes, the mechanical test was performed with imposed displacement.

Based on the experimental results and assuming that the material follows the Time-Temperature Superposition Principle (TTSP), the master curve of complex modulus and the phase angle can be obtained.

RESULTS AND DISCUSSION

Isochrones of the complex modulus: The isochronal plots of complex modulus |G*(T)| versus temperature at 1 Hz is represented for both pure bitumen considered as reference and copolymer modified bitumen.

Figure 4 shows the values of complex modulus as a function of the temperature of the modified bitumen at different concentrations for a frequency 1 Hz.

For temperature range ≤20°C, the EVA polymer has no effect on the rheology of the bitumen regardless of content.

For 20°C, the results show that the complex modulus G* increases after adding the polymer which results in that the consistency (indicated by the value of the complex modulus G*) of bitumen and modified bitumen are different.

The improvement in terms of deformation resistance (G^*_{PMB}/G^*_{B5070}) is represented in Fig. 5. After adding 3% of EVA polymer, there is a significant increase of the modulus ratio (G^*_{PMB}/G^*_{B5070}).

For temperatures greater than 30°C, the results indicate that there are significant differences in the modification of bitumen with higher polymer contents.

Isochrones of the phase angle: The isochrones of angle phase at 1 Hz for the different binders are shown in Fig. 6.

The phase angle isochrones illustrate improved elastic response (that correspond to a reduced phase angle) of the modified bitumen.

The lower values of phase angle of the polymer modified bitumen indicate lower viscous component. The decreases of the phase angle with polymer content indicate also an improvement of the elastic properties of the binder.

The improvement at lower temperatures is observed with 7% EVA polymer content but it's much less significant than that obtained at high temperatures services.

Exploitation diagram cole cole: The cole-cole graph is shown in Fig. 7.

This representation is to plot the real part G' of the complex modulus in the abscissa and the imaginary part G" in the axis.

The Cole-Cole figure provides the same rheological information than those obtained from the master curves of the complex modulus. It is noted that whatever the bitumen tested (pure or modified) the general shape of the curve is the same. The main differences are in the value the slopes that have these curves near the origin and in their declining portion.

The curves describe an arc from the origin and closing on the value of the modulus G_∞ achieved at very low temperatures and high frequencies.

There is a decrease of the elasticity depending on the degree of modification especially for high values of stiffness.

Black curves: The modification by EVA copolymer can be represented in Black space which greatly facilitates the exploitation of these rheological measurements.

The Black curves graph is shown in Fig. 8.

Figure 8 shows the results in black space (the phase angle as a function of complex modulus) of the different binders with the pure bitumen 50/70 bitumen and the bitumen modified by the polymer EVA with different contents.

Frequency sweeps and temperature lead to obtain a unique curve for each tested binder regarding the time-temperature equivalence principle (Glaoui *et al*., 2011).

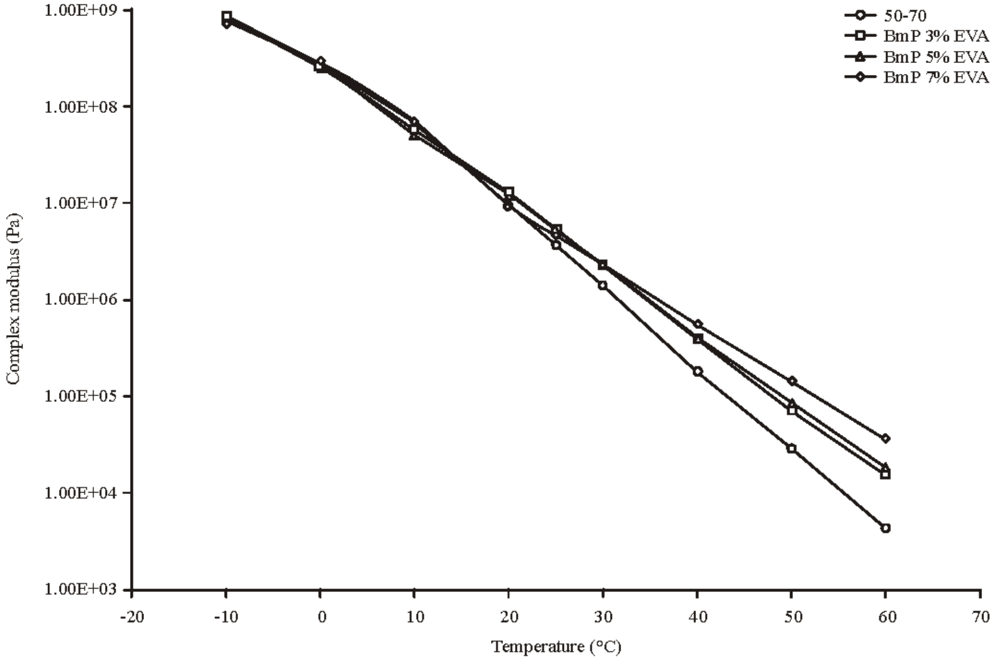

Fig. 4: Isochrones of the complex modulus at 1 Hz

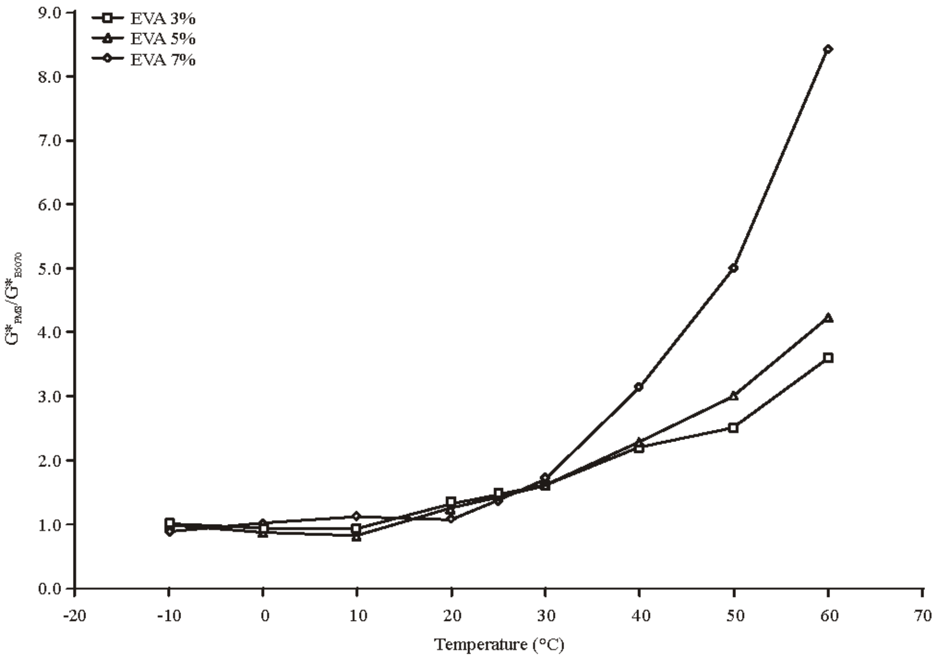

Fig. 5: Changes in complex modulus following EVA modification at 1 Hz and different temperature

When the polymer content increases, the behaviour of the modified bitumen tends towards an elastic solid behaviour. This evolution is interpreted by the decrease of the phase angle and a diminution of its thermo-mechanical susceptibility.

Sample with 3% EVA content: In this case, the modification is not significant effect on the improvement regarding the mechanical performance. The modified binder with 3% of polymer remains a viscoelastic liquid as the base bitumen. The phase angle increases monotonically when the complex modulus decreases (decreasing frequency and increasing temperature). However, it's thermo-mechanical susceptibility is lower because the angle is less rapid growth.

Sample with 5% EVA content: In this case, the binder is in the range of tested temperatures, as a body to creep parabolic, phase angle tending to a plateau.

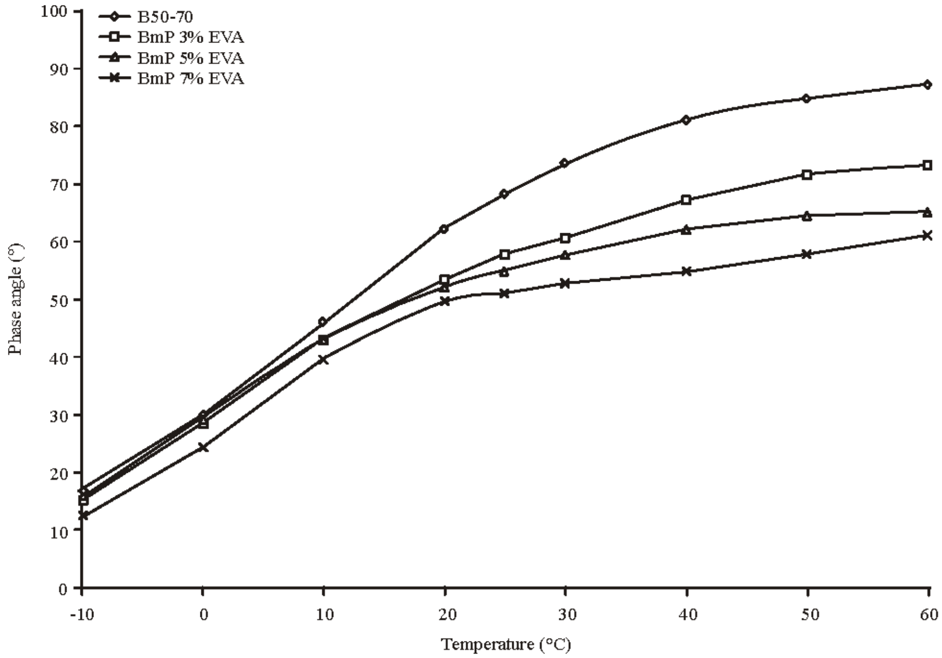

Fig. 6: Isochrones of the phase angle

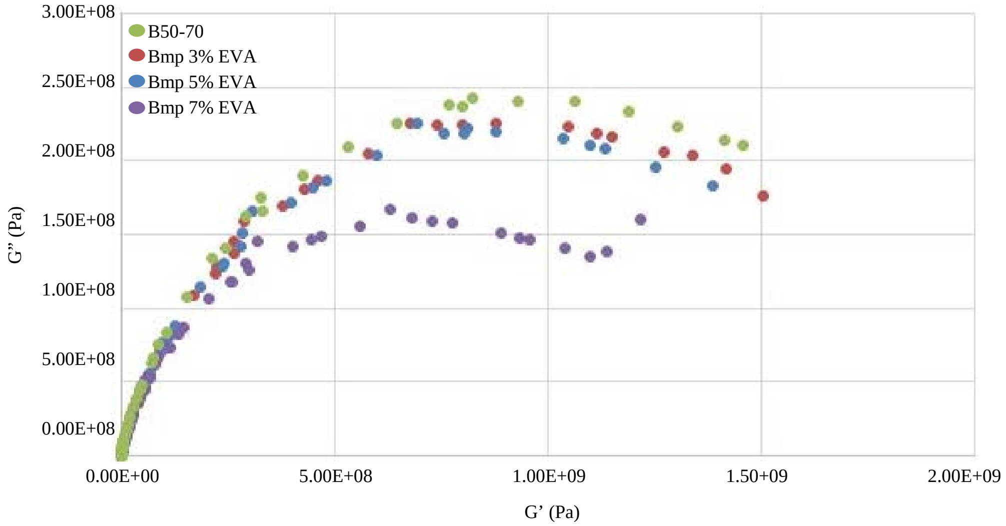

Fig. 7: Representation in cole-cole space

Sample with 7% EVA content: The modified binder have a high content of polymer, therefore, the continuous phase is constituted by the swollen polymer by bitumen oils, the rheological behaviour is fundamentally different from that of the bitumen and depends on the polymer.

The rheological measurement gives strong variations between temperatures and the time-temperature equivalence principle isn't applicable correctly and completely. These discontinuities between isothermal curves are related to different microstructures in polymer modified bitumen.

Structure parameter: The structure parameter R estimated overall the thermal susceptibility of bitumen, more R is high least the bitumen is susceptible. It is defined by the following equation (Di Benedetto *et al*., 2001):

$$R = \log \frac{|G^*_\infty|}{|G^*_{45°}|}$$

where, $|G^*_\infty|$ is maximum value of the complex modulus when the frequency tends to infinity (the temperature tends into

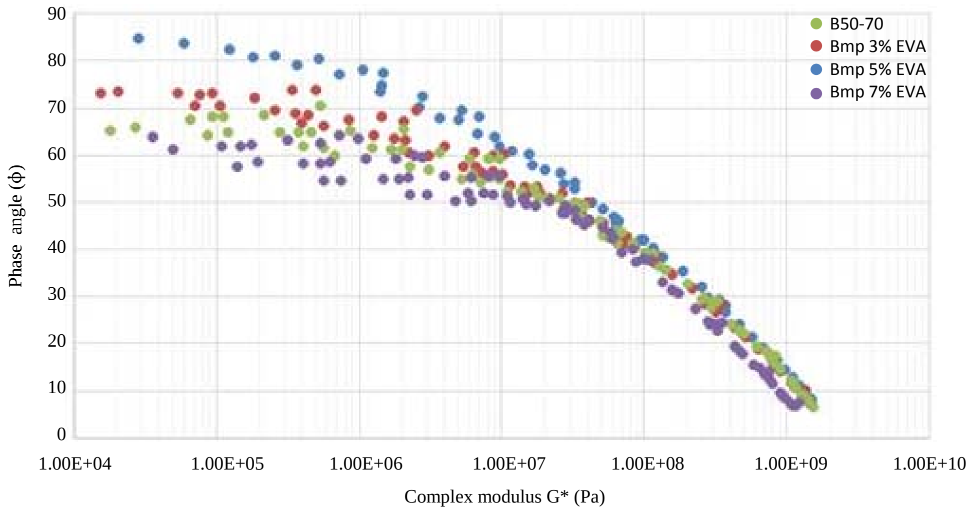

Fig. 8: Representation of the measurements in black space

Table 3: Values of R

Bitumen 50-70	Bitumen + 3% EVA	Bitumen +5% EVA	Bitumen +7% EVA
1.53	1.68	1.74	1.63

Table 4: WLF coefficients C_1 and C_2

WLF coefficients	B50-70	3% EVA	5% EVA	7% EVA
C_1	17.60	15.63	20.14	17.80
C_2	132.15	114.35	141.90	121.11

Table 5: Parameters of the model after calibration

Parameters	E_0 (MPa)	E_∞(MPa)	δ	k	h	β	τ
B	0	2150	4.101	0.275	0.645	31.5	0.00035
EVA 3%	0.00253	2000	3.739	0.277	0.634	206.4	0.00032
EVA 5%	0.00409	1950	3.286	0.283	0.617	545.2	0.00026
EVA 7%	0.00595	1800	2.898	0.201	0.577	1829.1	0.00017

Table 6: Thermal susceptibility parameters

Parameters	A_0	A_1	A_2
B 50-70	-2.62698	-0.382154	0.0021626
3% EVA	-2.48039	-0.395299	0.0020958
5% EVA	-2.34968	-0.396538	0.0019898
7% EVA	-2.41422	-0.424267	0.0023811

lower values). For all the binders, the maximum is about 3.109 GPa and can be obtained by the intersection of the Black curve with the abscissa axis and $|G^*_{45°}|$ is Value of the complex modulus when the phase angle is equal 45°.

Table 3 presents the structural parameters R. It is noted that the parameter R increases with the addition of polymer. However, the most significant increase comes after the addition of 3%, confirming that the base bitumen is the most susceptible.

WLF coefficients: Table 4 indicated values of WLF coefficients. The C_1 is much more constant than C_2. It might be interesting to understand how these constants can reach the physico-chemical state of materials.

Modeling the behaviour of the copolymer modified bitumen in the linear viscoelastic domain: The identification of model parameters is done from the master curves for a temperature of 15°C. The parameters obtained after calibration are shown in Table 5 and 6.

The calibration step shows that many parameters of the Huet modified model changes with polymer content. Some of these parameters (E_0, E∞, δ and τ) increases linearly and others parameters h, k and β increases more quickly following an exponential law. These changes seems to be linked with phase change of microstructure (from 3-7% polymer content).

To evaluate the effect of the polymer addition on the behaviour of bitumen, the following plots shows the evolution of two parameters of the Huet modified model (E_0 and) to the polymer content.

At first, plotted the evolution of the initial modulus E_0, such as E_0 represents also the static modulus when $\omega\tau \rightarrow 0$. It is observed that the evolution of the static modulus E_0 can be linked with polymer content (Fig. 9a-b).

The parameter β increases quickly after addition of 7% EVA polymer. One assumes that the evolution can be interpreted with phase changes of microstructure (Fig. 2c).

The parameter β represent the characteristic time which depends on the temperature changes. It is observed that the parameter τ decreases slowly with polymer content (Table 5).

Regarding the evolution of the parameters, it considered that the Huet modified model can reproduce the contribution of the polymer content.

From the calibration parameters of the Huet modified model, one represents in the Fig. 10, the relaxation time of the different tested binders.

At the lower temperature, the relaxation time from Huet modified model has not changed with addition of the

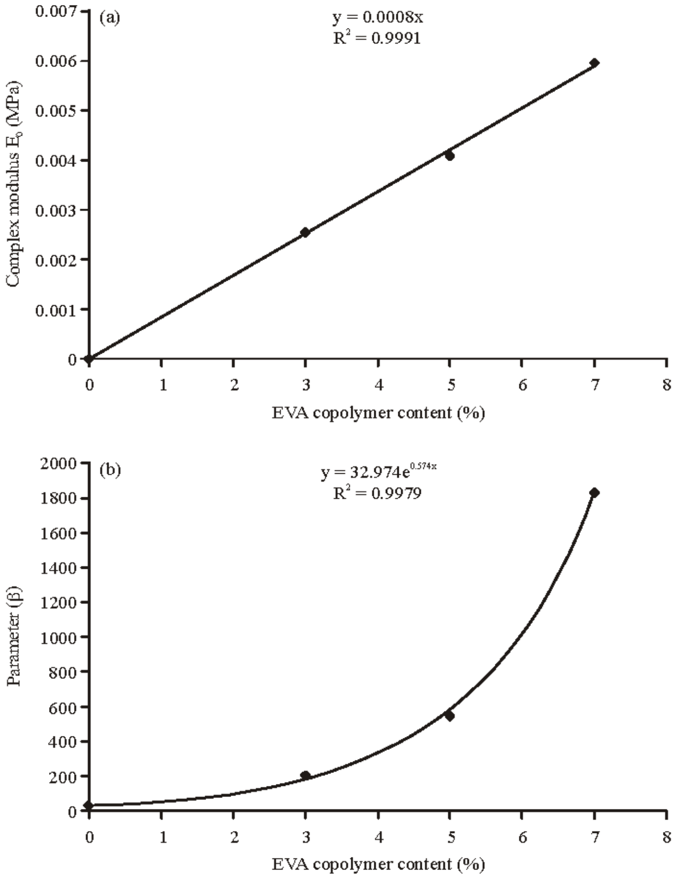

Fig. 9(a-b): Relation between parameter (a) E0 and (b) Beta with EVA copolymer content

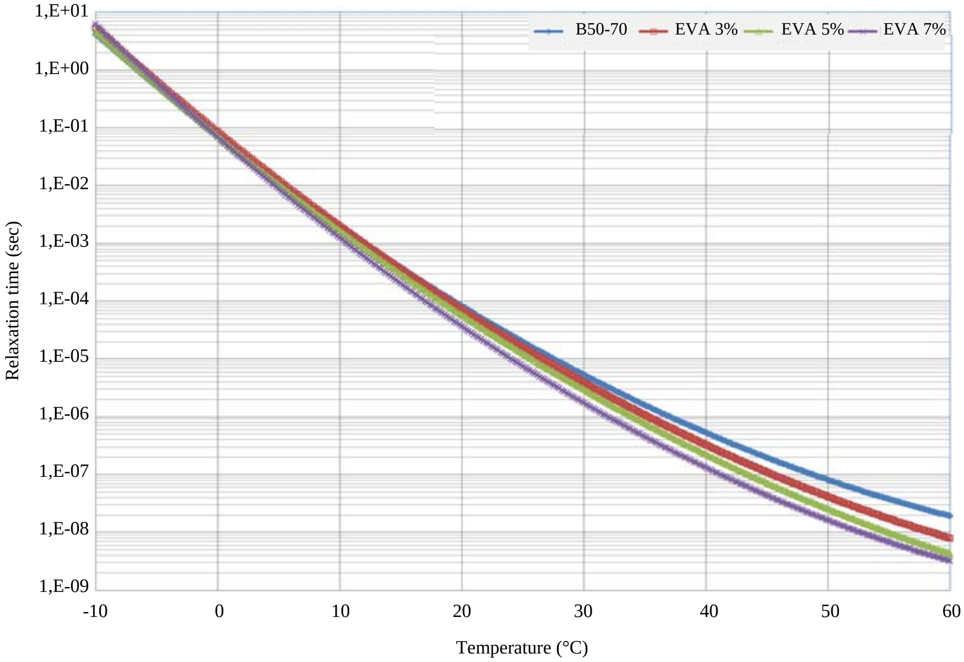

Fig. 10: Relation between relaxation time and temperature for different binders

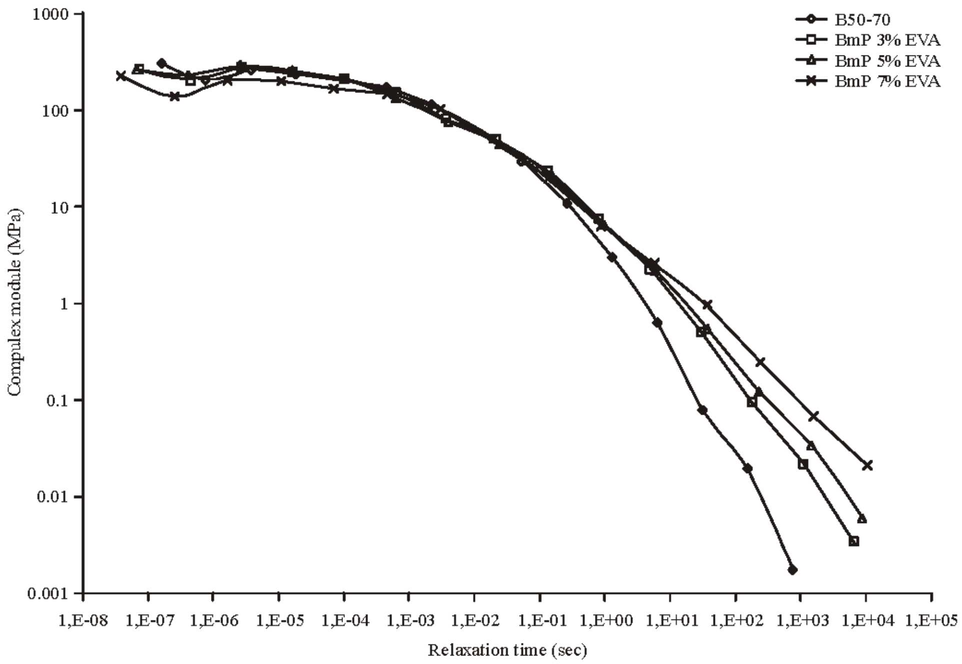

Fig. 11: Relaxation spectrum of different co-polymer modified polymer from Prony series model

copolymer modified bitumen. However, for higher temperatures, the difference is more pronounced with 5-7% EVA polymer.

The results can be interpreted with the phase change of the microstructure observed on microscopy after addition of 7% EVA polymer.

Prony series model: The second model used in this study is an extension of the standard generalized Maxwell model. An extra isolated spring (E_0) is added in parallel and gives the possibility (depending of the value of E_0) to reproduce an arrheoditic behaviour (solid body as vulcanized polymer). Mathematically, this model can be written as a Prony-series:

$$E' = E_0 + \sum_i^n E_i \cdot \frac{(\omega\tau_i)^2}{1+(\omega\tau_i)^2}$$

$$E'' = E_0 + \sum_i^n E_i \cdot \frac{(\omega\tau_i)}{1+(\omega\tau_i)^2}$$

The parameters E_0, E_i and τ_i can be determined from complex modulus measurements. The parameter ω is the pulsation of the oscillation ($\omega = 2\rho/T$) and T is the period of the oscillation. The method used in this study is inspired from the multidata method (Cost and Becker, 1970; Tschoegl, 1989).

In a first step, the precedent equationsare written as a linear system by assuming the set of relaxation time τ_i. Firstly, the selected relaxation times are determined following spaced points (in logarithmic time). But a second procedure is needed where the selected relaxation times can vary slightly to reduce the error and improve the fit (Hammoum *et al.*, 2009).

This calibration performed on EVA copolymer modified bitumen at different polymer content, is shown in Fig. 11. In this case, fifteen elements of the Prony Series are used. It appears that the effect of EVA copolymer is reproduced on the mechanical behaviour at low frequency (or high relaxation time).

The prony series model doesn't reproduce the mechanical effect of EVA copolymer at high frequency (or low relaxation time).

CONCLUSION

To increase the performance of binders by improving the rheology, it uses an addition of polymer. The objective is to obtain an "perfect" binder. In the literature, different research works demonstrate that the resistance to permanent deformation, the cracking resistance and the resistance to fatigue should be important while susceptibility to time loading should be limited. For this purpose, researchers have set the objective to find more performance additives, less expensive and easy to incorporate into bituminous mixes.

These improvements must be sustainable which it seems that the modified binder must have good resistance to aging, easy for coating the aggregates and during laying process on site.

The results obtained with classical tests show an overall modification of the modified bitumen. Indeed, the penetration of bitumen decreases against the softening point increases with the addition of polymers. The degree of influence varies depending on the added quantity of the modifier.

The observation of the microstructure made by UV fluorescence microscopy shows the spatial distribution of the polymer are extremely important to the extent that it exists, a close relationship between the microstructure of a modified binder at different contents and its physical properties.

Rheology is an approach particularly suitable for the study of viscoelastic materials such as bitumen in order to understand and to predict their behaviour under mechanical loading.

This characterization was able to differentiate the base bitumen and modified bitumens to highlight the effect of the nature and quantity of the polymers used on the rheological behaviour of the bitumen.

The main rheological properties of the binders were presented. The analysis of the viscoelastic behaviour showed the decrease of the temperature susceptibility after the addition of the polymer. The results of complex modulus such values of the phase shift confirm this trend.

Two rheological models have been used to describe the rheological properties of EVA polymer modified bitumen. The modified Huet model has represented the effect of polymer addition.

Bitumen modification with others polymers will be evaluated with the same methodology to quantify the contribution of the polymer and to predict the rheological response. In the same time, the performance depends also of polymer content and the base bitumen which are important for the performance of polymer modified bitumen.

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