The Modification of Bituminous Binders by Means of New Generation Polymers

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Michele Agostinacchio
Full Professor of Roads, Railways and Airports
University of Basilicata - Italy
agostinacchio@unibas.it

Saverio Olita
Assistant Professor of Roads, Railways and Airports, Ph.D.
University of Basilicata - Italy
olita@unibas.it

Synopsis

This paper deals with the qualitative and quantitative assessment of the improvement of rheological properties of bitumen modified with the addition of different kinds of new generation polymers, in order to find a polymer which would give the binder itself highest performances, similar to those already measured for the SBS (styrene-butadiene-styrene).

In particular, the following polymeric materials were used for the purpose: radial SBS polymer with high, medium and low molecular weight; olefin co-polymer alpha and ter-polymers with dienes - EP(D)M - high, medium and low viscosity; thermo-plastic polymers obtained after polymerisation of ethylene by means of different processes as: VLDPE, LDPE, LLDPE, HDPE and two EVA typologies.

Using these polymers, after assuming a traditional bitumen with a 70/100dmm gradation as reference, a 5% in weight modification was carried out by means of a mixer with a mixing head able to prepare a homogeneous and quick solution of polymers into the bitumen.

The rheological analysis was conducted at different temperatures with the HAAKE Rheostress 150 rotational rheometer and with advanced interpretative tools as the Black Diagrams and the Cole-Cole diagrams, the results being an interesting comparison of the performances of the different binders, with significant conclusions on the use of such polymers for traditional bitumen modification.

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Several factors can influence the duration of flexible pavements and, amongst them, fundamental is the role played by the adopted bitumen.
In order to express a judgment on the suitability of bitumen it is fundamental to characterize binders in Laboratory, before using them and this analysis, was based in the past, only on the execution of empirical tests, as the Dow penetration test at 25°C, the ball and ring test etc., which, even though they did not allow a complete evaluation of the rheological behaviour of the binder, were sufficient to drive the road constructions technicians in the choice of the most appropriate bitumen for the different uses.
In any case it must be said that the traditional test procedures if used for modified bitumens with polymeric materials show severe deficiencies.
Indeed the results significance, obtained with these tests, is uncertain and not always to bituminous binders respecting the traditional acceptance requirements, correspond sufficient performances in use. As a consequence there is a rational approach for the bitumens characterization.
It is furthermore known that that the chemical and structural composition of bituminous binders has an immediate reflection on their rheological properties which, on their side, do influence the behaviour of the superstructure of asphalt concretes. Therefore it can be assumed that, by means of the control of the rheological properties of bituminous binders the behaviour of the superstructure can be driven towards defined performance levels during the design process.
Rheological investigation on bituminous binders have been introduced by the performance standards arranged into the American research program S.H.R.P. (Strategic Highway Research Program) which analyzed, amongst others, the theme of the characterization of binders from a chemical and physical point of view. The apparatus allowing these analysis are: rotational, flexural and extensional rheometers.
After this introduction, the principal aim of the present work is the qualitative and quantitative evaluation of the rheological properties of bitumens, after the addition of different polymers (elastomers and plastomers) of new generation which can be nowadays found on the market.

EXPERIMENTAL ANALYSIS

Reference binder

The experimental investigation has been conducted by using a “as it is” bitumen of medium gradation, from a market point of view seen as a 70/100, characterized by a 25°C penetration equal to 64dmm, by a ball and ring temperature of 47°C and by a Fraass breaking point of –8°C.
Furthermore the binder was classified according to the Standard AASHTO MP1 - SHRP 1001 - (Performance-Graded Asphalt Binder), determining the corresponding performance grade of PG58-22.
The details of the rheological characteristics of the base bituminous binder are reported in Tab.1.

Polymers

The polymeric materials used in this study belong to the family of dienic polymers and copolymers, to the family of monoolefin polymers and copolymers and to the family of thermoplastic polymers obtained from the polymerization of ethylene.
Among the dienic polymers and copolymers there are the butadiene polymers and copolymers to whom the three blocks SBS elastomeric copolymers belong. The morphology of these copolymers is characterized by a phase separation which refers to an SBS copolymer (S = polystyrene block, B = butadienic block) with a low percentage of polystyrene.
It is made of three spheroidal polystyrene elements, corresponding to a discontinuous phase dispersed in the continuous polibutadienic matrix.
Copolymers in blocks adopted as good thermoplastic gums from both mechanical and workability points of view should have a composition falling in a rather restricted area of molecular weights. Therefore for the investigation purposes 3 typologies of SBS with radial structure with different molecular weight were chosen.
Between the monoolefin polymers and copolymers the olefin alpha copolymers with dienes (saturated elastomers) are included, obtained copolymerizing ethylene with an alpha-olefin (polypropylene) in presence of catalysts working as an anionic mechanism coordinated. The use of these catalysts allows to obtain amorphous copolymers, when these contain less than 75-80% of ethylene moles. These polymers constitute a class of saturated elastomers, which show a combination of physical and chemical properties of great interest.
Moreover, after the introduction of rare insaturations along the chain of the copolymer, which can be realized executing the copolymerization of ethylene and of propylene in presence of small quantities of a diene,

generally isoprene, thermopolymers are obtained EP(D)M directly vulcanizable. In the study 4 different typologies of EP(D)M were analyzed characterized from a different value of viscosity or a different molecular weight.

Tab.1: Rheological characteristics of the bituminous binder used

BITUMINOUS BINDER		70/100 PG58-22
Traditional parameters	Penetration at 25°	64 dmm
	Softening point (PA)	47 °C
	Penetration Index	-1,41
	Fraass failure point	-8°C
SHRP parameters	Dynamic Viscosity at 135°C (ASTM D4402)	0,38 Pas
	DSR	
	G*/sinδ (T=**58**°C)	1,87 kPa
	G*/sinδ (T=**58**°C, post RTFOT)	5,72 kPa
	G* · sinδ (T=**22**°C, post RTFOT+PAV)	3405 kPa
	BBR	
	$S(t)_{60}$ T=**-12**°C	136 MPa
	m_{60} T=**-12**°C	0,44
	LST Temperature	-17 °C
	LmT Temperature	-25 °C

Thermoplastic polymers and copolymers obtained after polymerisation of ethylene, with processes very diversified from each other, are available on the market in a numerous and variegated series.
In the experimental phase 6 different typologies of ethylene copolymers were tested.
In conclusion the polymeric materials selected for the changes of the reference bitumen are the following:

1. EP(D)M high viscosity, called **EP(D)M a**;
2. EP(D)M medium viscosity called **EP(D)M b**;
3. EP(D)M low viscosity called **EP(D)M c**;
4. VLDPE very low density polyethylene called **PE a**;
5. EVA type 1 copolymer of ethylene and vinyl acetate called **PE b**;
6. LDPE low density polyethylene called **PE c**;
7. EVA type 2 copolymer of ethylene and vinyl acetate called **PE d**;
8. LLDPE linear polyethylene at low density called **PE e**;
9. HDPE polyethylene at high density called **PE f**;
10. SBS radial at high molecular weight called **SBS a**;
11. SBS radial at medium molecular weight called **SBS b**;
12. SBS radial at low molecular weight called **SBS c**.

Bitumen modification

The specimens of binder which were to be subjected to tests were manufactured changing the "as it is" bitumen with the addition of a percentage of polymer equal to 5% in weight, through a mixer SILVERSON L4R at high performances (Fig.1a), at the temperature of 180°C and for a varying duration from 3 to 5 hours as function of the chemical-physical properties of the modifier.
The mixer adopted has a duplex mixing head (Fig.1b) with two working heads located in the opposite directions; in particular the upper one pushes the materials to the bottom of the mixing container. The upper disintegrating head is designed to reduce solid materials into small fractions, in order to expel them from the lower part. The lower working head at the same time attracts the partially disintegrated solids and reduces them in finer fractions. This combined use of the two heads makes the duplex an optimal machine for the modification of bitumens with polymers.
In particular the heads work in this way:

- Phase 1 - The high rotor blades velocity applies a strong intake, which attracts bitumen and polymer to the bottom of the tank inside the working head (Fig.1c);
- Phase 2 - The centrifugal force produced by the rotating blades pushes the material towards the external area of the working head where it is subjected to a strong shear action due to the rotor blades and to the internal wall of the stator (Fig.1d);
- Phase 3 - Phase 2 is followed by an intense hydraulic shear of the materials during the forced expulsion at high velocity through the holes of the stator. The pulverized polymers come back to the bituminous

mass provoking a strong recirculation (Fig.1e);
- Phase 4 - The expelled products from the head are projected quickly at high velocity towards the wall of the tank and at the same time, because of circulation, some other material enters the working head (Fig.1f).

The effect of the radial expulsion and of the vertical intake inside the working head produces a circulating flow without turbulence under the surface of the bituminous mass. The materials contained into the tank pass some hundreds of times into the working head during the mixing procedure, until a progressive and uniform homogenisation with the complete elimination of aeration.

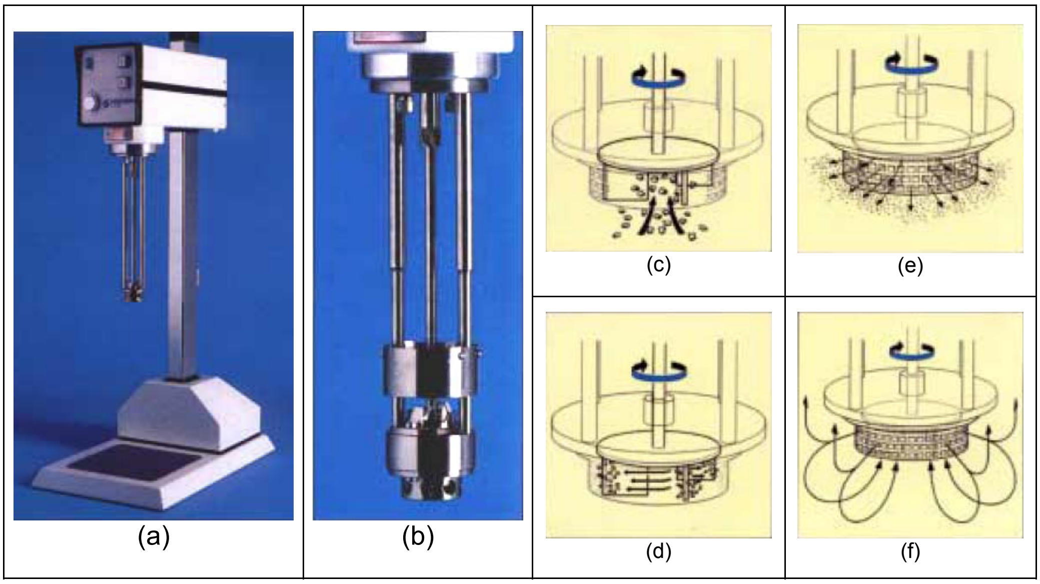


Fig.1: Silverson L4R Mixer

Rheological test is oscillatory conditions with DSR

From the specimens object of the investigation, heated in electric oven at a temperature between 140 and 160°C chosen as function of the nature of the modifier used, about 1g was taken and it was put onto the lower plate of the rheometer Haake RS150 (Fig.2) equipped with a geometry of sensors with parallel plates of 25mm with a gap fixed at 1mm. The test procedure followed respects the AASHTO Designation TP5: "*Test Method for Determining Rheological Properties of Asphalt Binders Using a Dynamic Shear Rheometers (DSR)*", based on the product SHRP 1007.

The tests were conducted at 45 and 60°C and every test was repeated four times, as prescribed in the Designation AASHTO TP5.

The following tests were performed:

1. Flow curves and viscosity curves - These preliminary measurements were adopted to examine the properties of the flow of the binder with the variation of the sliding and stress conditions. In particular the viscosity curve represents the behaviour of the dynamic viscosity as function of the sliding level dγ/dt. There are different ways to obtain this parameter: one can operate in CR mode (controlled rate) or in CS mode (controlled stress), moreover, in both cases, one could operate the control of the changing parameters through the ramp or steps method (Steady State). For these methods the data referring to the single experimental point are represented by a couple of values constituted by the rotational speed and the torque. In the investigation it was used the CR Ramp method was used, fixing the temperature at 135°C±0.2 with dγ/dt variable from 0.1 to $100s^{-1}$.
2. Stress Sweeps – the tests of stress sweeps have been conducted in order to determinate the linear viscoelasticity interval in running of oscillating shear. In this series of tests the shearing stress was varied from 0.1 to 10000Pa, at a frequency of 10rad/s and at the temperatures of 45 and 60°C;
3. Frequency sweeps: the tests of frequency sweep, at 45 and 60°C were conducted applying a constant value of the shearing stress, included in the interval of linear viscoelasticity and varying the frequency from 0.01 to 100 rad/s.

Black Diagram - Cole Cole Diagram - Rutting Factor

The viscoelastic parameters of bitumens can be studied using the Black Diagrams, which represent the complex modulus G* as function of the phase angle δ and the Cole Cole diagrams which represent G' as function of G'', being G' the accumulation modulus and G'' the loss modulus. In particular G' is directly proportional to the energy stored in a deformation cycle, while G'' is proportional to the energy dissipated under the form of heat in the same deformation cycle.

Fig.2: Haake Rheostress 150 DSR

The just mentioned diagrams allow moreover to evacuate the elasticity of the binder as function of G'', thus with the variation of the dissipated energy. The fundamental parameters, to evaluate the performances of "as they are" and of modified bitumens, must therefore include G', G'', δ and tgδ at the different temperatures.
Moreover the thermorheological behaviour of bitumens can be classified as simple or complex, respecting the Black curve or the Cole Cole curves. In particular, in order to realize a thermorheological simple behaviour, the data G* and δ are to be located on the same curve, while a behaviour is thermorheological complex when the Black curve is not unique anymore.
The same idea can be repeated for the Cole Cole curves, where significant is the importance of the value of the angle δwhich indicates the elastic and/or viscous behaviour of bitumen considered.
The parameter G*/sinδ, proposed by SHRP as indicator of the answer to permanent deformations, was also determined in order to furnish a further parameter for the classification of the different binders tested.
In order to reduce the probability of arising of permanent deformations in the conglomerate manufactures with the examined binder, the parameter G*/sinδ has to present a minimum value, at the fixed temperature of test, equal to 1kPa for the not aged binder.

ANALYSIS OF EXPERIMENTAL RESULTS

Stress Sweeps tests

A binder, in order to be defined with a linear visco-elastic behaviour, has to obey the homogeneity and validity conditions of the superposition principle.
In order to verify this condition the stress sweeps test is applied, with whom the value of tension that can be applied in the frequency sweeps test can be determined.
This method requires the monitoring of the complex modulus with the variation of the shearing stress: the range of the stress within which the linearity condition is verified is that in correspondence of which there is a decrease of the value of G* lower than 10% of its initial value.
The results of the tests are interpreted with respect to the linear viscoelasticity theory and therefore the strains obtained in the oscillatory running tests, should be taken into the linear area, whose limit is fixed in correspondence of the deformation for which there is a 5% reduction of the complex modulus.
From the results of all the specimens analysed, the area of visco elastic-linear behaviour was included within 100 and 900Pa, for which the shearing stress value chosen for the frequency sweep tests was assumed equal to 400Pa (Figg.3 and 4).
At 45°C the experimental results show that the **PE a** (VLDPE very low density polyethylene) is that with the higher chemical affinity with the bitumen analysed, because of the value significantly higher of the complex modulus along all the interval of variation of the shearing stress.
Polymers **PE b** (EVA type 1 copolymer of ethylene and vinyl acetate), **PE c** (LDPE low density polyethylene) and **PE d** (EVA type 2 copolymer of ethylene and vinyl acetate) give the binder a value of the complex modulus even lower than it has when not modified (70-100).
On the contrary, for the modified bitumen with the different typologies of SBS values of G* comparable with those of **PE e** (LLDPE linear low density polyethylene), **PE f** (HDPE high density polyethylene) and 3 modified specimens with **EP(D)M** with varying viscosity had been obtained.

At 60°C, it is still the modified bitumen with **PE a** to show the best rheological answer, immediately followed by that modified with the polymer called **SBS c**.

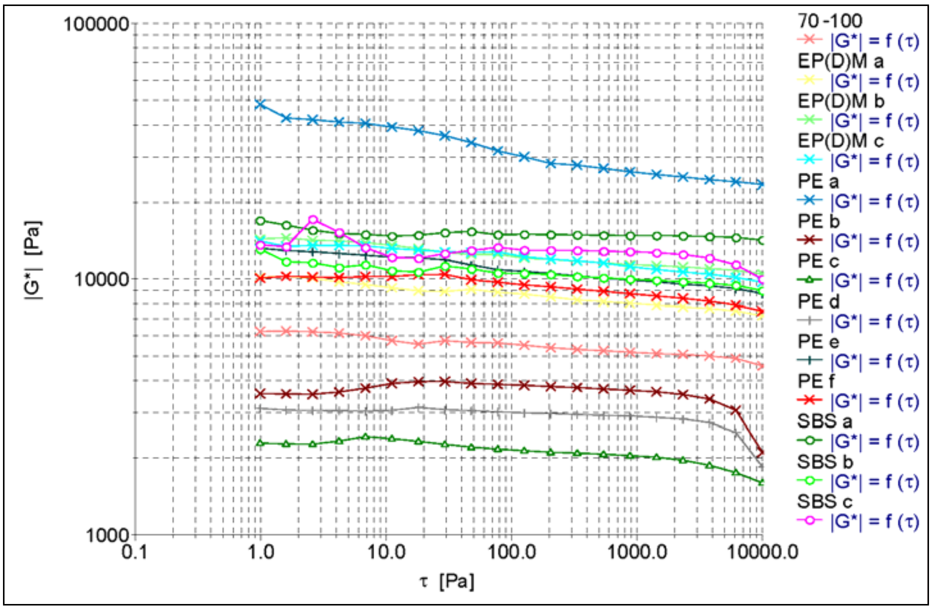


Fig.4: Stress Sweeps a 45°C

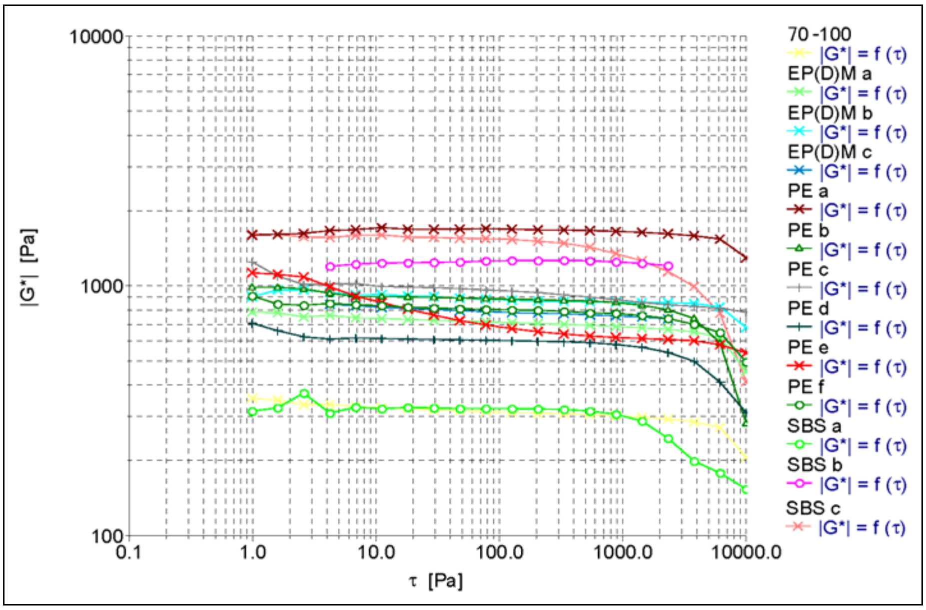
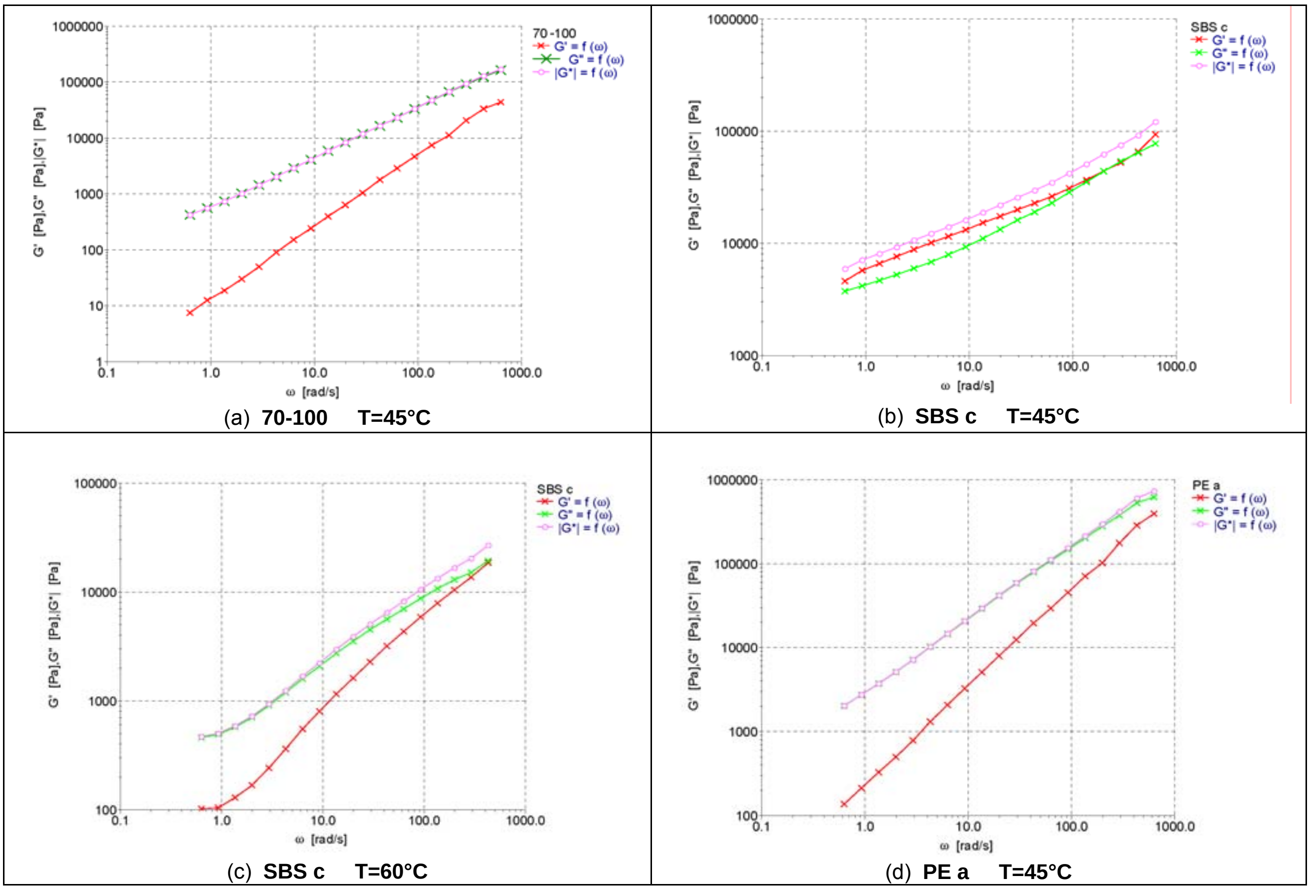


Fig.5: Stress Sweeps a 60°C

Frequency Sweeps tests

The frequency sweep tests highlighted that the values of the loss modulus at 45°C for the “as it is” bitumen (70-110) are higher than those of the accumulation modulus along all the interval of frequencies (Fig.6a).
The same thing happens for all the modified bitumens, but for the bitumen modified with **SBS c**, for which one can distinguish a strong elastic behaviour: the curve of the modulus of accumulation is always above that of loss, apart from a very short part of the domain of the frequencies around 300rad/s, in which the viscous component is higher, even though for a very small quantity, than the elastic one (Fig.6b).
From the experimental results it can be found that, both for the “as it is” bitumen (70-100) and the modified ones and for both test temperatures, the modulus of accumulation and that of loss increase in a continuous manner with the increase of the frequency. Moreover, the bitumens analysed show a prevailing viscous behaviour both at 45 and 60°C. In particular at 60°C also the binder modified with **SBS c** loses the characteristics exhibited at 45°C acquiring itself an almost viscous behaviour along the whole area of frequencies (Fig.6c).



(a) **70-100 T=45°C**
(b) **SBS c T=45°C**
(c) **SBS c T=60°C**
(d) **PE a T=45°C**

Fig.6: Frequency Sweeps

Referring to the answer of the modified binders, as for the values assumed by G* in correspondence of low and high load frequencies, the optimal condition would be that of finding a binder which would produce at the same time high values of G' for low frequencies and low values of G' at high frequencies. Such a binder, the conditions being unaltered, would allow to realize a pavement with both a lower tendency to rutting at high temperatures and under severe loads at low frequency, and a high resistance against cracking at low temperatures, especially in presence of medium and high frequency loads.
The binder modified with **PE a** (Fig.6d) shows in this case its limit, since it exhibits the elastic variable component of the complex modulus with a high gradient compared to the load frequency. Indeed G' assumes the maximum value at high frequencies, while for low frequencies it presents a values of more than one order of magnitude lower than that assumed by the function G' relative to the modified binder with **SBS c**.
From the tests outcomes moreover it is found that the binders modified with **SBS a** and **PE c** are to be discarded, since the relative function G'(ω) assumes values everywhere comparable to those of "as it is" binder.
The binder modified with **SBS b** e **PE f** reach maximum values comparable to those assumed by **SBS c**, but lower for the low frequencies. In conclusion, all the modified binders have a function G' subparallel to that of the "as it is", but with a higher slope and with position moved toward up or with values of G' higher. Therefore, choosing whichever specimen, we would have, the conditions being the same, a lower tendency to permanent deformations and on the contrary a higher tendency to cracking for high frequencies compared to the "as it is" one.
At the temperature of 45°C, the best performance is given by the bitumen modified with the radial SBS with low molecular weight (**SBS c**), which, apart from producing an increase of G' at high frequencies of few tens of Pa compared to the "as it is", causes and increase of G' for low frequencies of about two orders of magnitude (See Figg.6a e 6b).
At the temperature of 60°C the binders modified with the SBS elastomers with low and medium molecular weight can be distinguished, as confirmation of the known suitability of this particular kind of synthetic polymer fore the modification of road bitumens.

Analysis of Black Diagram

Analysing the Black diagrams it can be noticed that the not modified bitumen exhibits a simple thermorheological behaviour, with the dynamic complex modulus G* that decreases with the increase of the

phase angle δ (Fig.7a).
In the binders modified with **PE f** e **SBS c** it is found a complex thermorheological behaviour, indeed to every value of the phase angle correspond two values of the complex modulus, with a difference between them up to one order of magnitude.

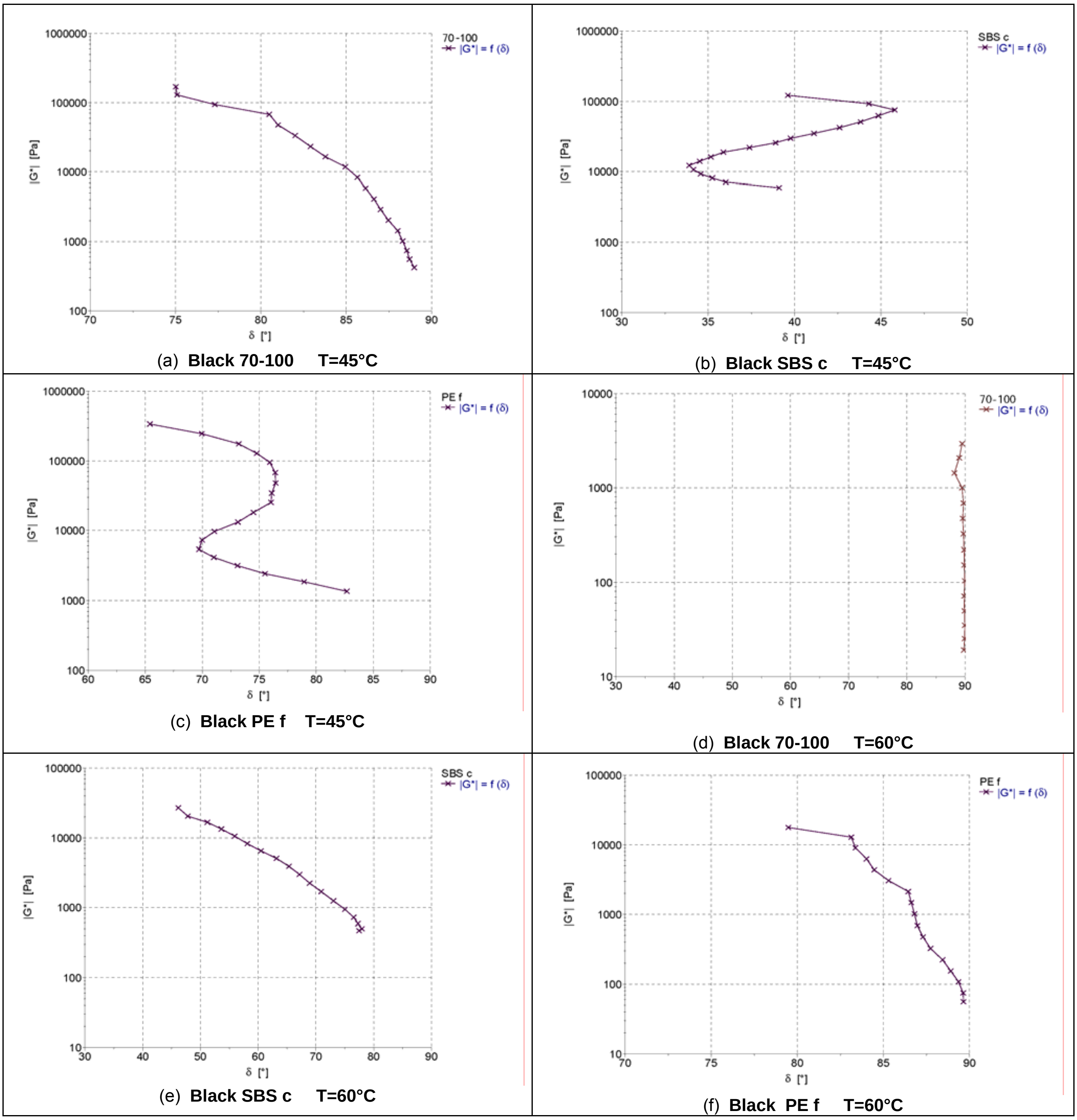


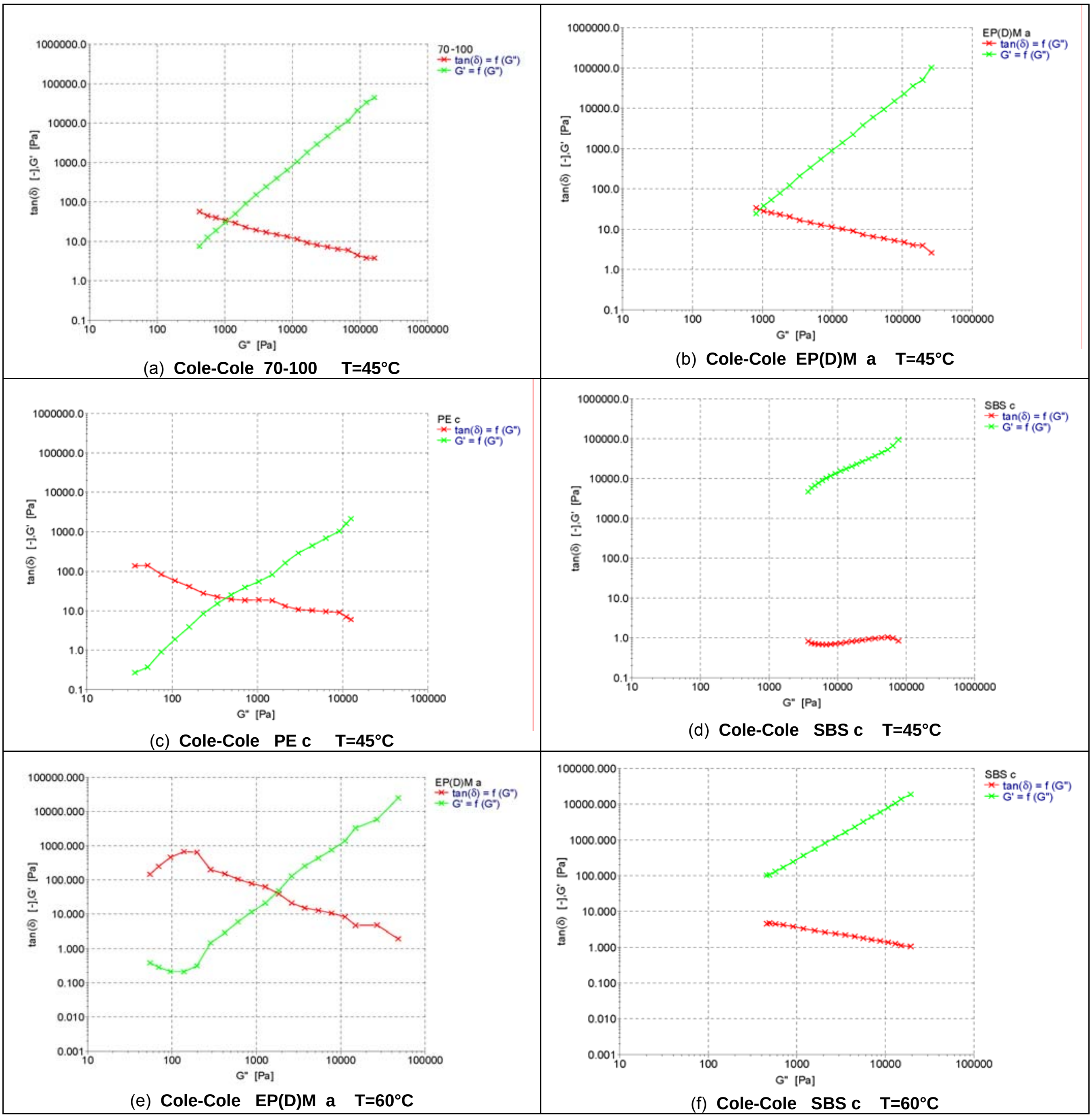
Fig.7: Black Diagram

In particular it can be noticed that, in the upper part of the curve and in correspondence of the highest values of G*, the maximum limit of δ equal to 45° is reached, which is shifted towards the area with viscous behaviour, while in the lower part the minimum δ limit of 35° is reached in area strongly elastic (Fig.7b).
The complex thermorheological behaviour of the binder modified with SBS radial at low density, confirms a right compromise between cracking resistance and rutting resistance.
Moreover, the Black representation is useful to individuate quickly, among the polymers proposed, those that determine an effective modification of the rheological behaviour, compared to the "Was it is" binder.
At the temperature of 45°C, apart from the binder modified with **SBS c**, only that modified **PE f** can be distinguished for a complex thermorheological behaviour (Fig.7c).
For the highest test temperature of 60°C, the "as it is" binder is, as expected, completely shifted towards the

viscous area with δ equal to 90° (Fig.7d).
At this temperature the styrene-butadiene-styrene elastomers are distinguished, in particular those with medium and low molecular weight, since only them, amongst all the specimens tested, present a function G* which moves from the vertical axle with δ equal to 90° in correspondence of the low frequency loads (Fig.7e).
The binders modified with the remaining polymers present a behaviour slightly different from that of the “as it is” binder, showing δ values of at low frequencies anyway higher than 80° (e.g. Fig.7f).

Cole Cole Diagrams analysis

Cole-Cole diagrams represent G’ as function of G’’, or rather the elastic component as function of the viscous component of the complex modulus. It is also useful to represent, in this diagram, the function tanδ, called tangent of loss, since it is proportional to the ratio between the dissipated and the stored in a deformation cycle energy, or rather to the ratio between the viscous and the binder elastic component.
The value of the “as it is” bitumen tanδ decreases as G’’ or rather the frequency increases, while the value of G’ increases as the frequency or rather G’’ increases (Fig.8a).
The decrease of the tangent of loss with the increase of G’’, or rather of the frequency, confirms that the viscous component decreases when the frequency increases, causing as a consequence an increase of the elastic component of the complex modulus.
This is highlighted by the Cole-Cole representation, in which the function G’ has positive slope, and therefore denotes a progressive recover of the decreases of the viscous part, represented in this case by tanδ.
It must be highlighted that it is always good to control the decrease of G”, represented by tanδ, in order to reduce the tendency to cracking.
It is also evident, in this representation, a particular point, where the two functions cross-over, thus where they assume the same value.
This means that there is a particular value of the load frequency in correspondence of which the tangent of loss is equal to the modulus of accumulation. This situation occurs when G” is equal to the square of G’, as a consequence of the definition of the tangent of loss.
Examining the Cole-Cole diagram of the “as it is” bitumen at the temperature of 45°C, it can be noted that for tanδ =G’ roughly equal to 33Pa (cross over) there is a value of G’’ equal to 1000Pa, experimentally highlighting that in the cross over point G” is equal to the square of G’ (Fig.8a).
Therefore, every time that in a Cole-Cole diagram a cross-over occurs, the viscous component is strongly predominant on the elastic one, since G” is equal to n times G’, with n just equal to G’.
This condition gives benefits in the case when the cross-over occurs at high frequencies, in this way solving the cracking problem at high frequencies and low temperatures. In fact, unfortunately, this never happens, since the crossing of the two functions, if any, will always occur at low frequencies, situation which is to interpreted as a strong tendency to permanent deformations for the binders that present cross-over.
At the test temperature of 45°C, the cross over occurs for the binders modified with: **EP(D)M a** (Fig.8b), **EP(D)M b**, **EP(D)M c**, **PE e**, **PE c**.
Among the last ones it can be distinguished the binder modified with **PE c**, for which the cross occurs for G” almost equal to 400Pa, in correspondence of which the frequency assumes the value of about 20rad/s, value which can be considered low as function of the minimum and maximum values which define the range of variation of the frequency, or rather 0.1 and 100rad/s (Fig.8c). With this binder with a higher emphasis than the “as it is” one and the other cross-over case the inversion of the disposition of the curves for values of G” lower than that of the cross-over critical occurs.
Indeed, the curves relative to tanδ and to G’ are generally disposed so that the first is lower than the second, while in the case of **PE c** it can be seen how, before the crossing point the first is higher than the second. This means that for this sample, in correspondence of low values of the load frequency, the viscous component of the complex modulus is much bigger than the elastic one, and even higher than the characteristic one of the cross over. The phenomenon illustrated is justified because the chemical characteristics of the polymer analysed, reacting with the “as it is” bitumen, induce a quicker decrease of the elastic performances with the decrease of frequency, with a flexural point in correspondence of the cross-over.
At the temperature of 45°C the binder modified with the **SBS c** shows a rheological behaviour, through the reading of the Cole-Cole diagram, which strongly moves away from the “as it is” one. (Fig.8d).
The curve G’ is always higher than the tangent of loss, because of its significant elastic nature, along all the frequencies domain. Moreover it can be noted that the functions G’ and tanδ change continuously, the distance between each other being constant, assuming for low and medium temperatures an elastic behaviour and at high frequencies an intermediate behaviour between viscous and elastic, as confirmed also by the analysis of the corresponding black diagram, from which it can be found that at high frequencies the phase angle reaches the value of 45°C, which means an equally split complex modulus between the elastic component and the viscous component.



(a) **Cole-Cole 70-100 T=45°C**
(b) **Cole-Cole EP(D)M a T=45°C**
(c) **Cole-Cole PE c T=45°C**
(d) **Cole-Cole SBS c T=45°C**
(e) **Cole-Cole EP(D)M a T=60°C**
(f) **Cole-Cole SBS c T=60°C**

Fig.8: Cole Cole Diagram

Therefore, working in the field of linear viscoelasticity, the principle of superposition temperature-frequency is valid, which allows to state that the binder modified with the low molecular weight elastomers SBS shows characteristics higher elastic at high temperatures compared to those exhibited by the "as it is" binder and by all the other modified binders tested in this work.
At the temperature of 60°C the results just described for the temperature of 45°C (are confirmed Figg.8e and 8f).

Analisys of the Rutting Factor

The S.H.R.P. parameter G*/sinδ, proposed as indicator of the resistance to the formation of permanent deformations, both at the temperature of 45°C (Fig.9) and at 60°C (Fig.10) exhibits higher values in the modified bitumens with low and medium molecular weight SBS compared to the "as it is" one and to the other samples modified with PE and EP(D)M, but the binder modified with **PE a** (Figg. 9 and 10).
From this it can be found that the first ones have a resistance against permanent deformations, which can arise in an asphalt pavement definitely higher that the second ones.

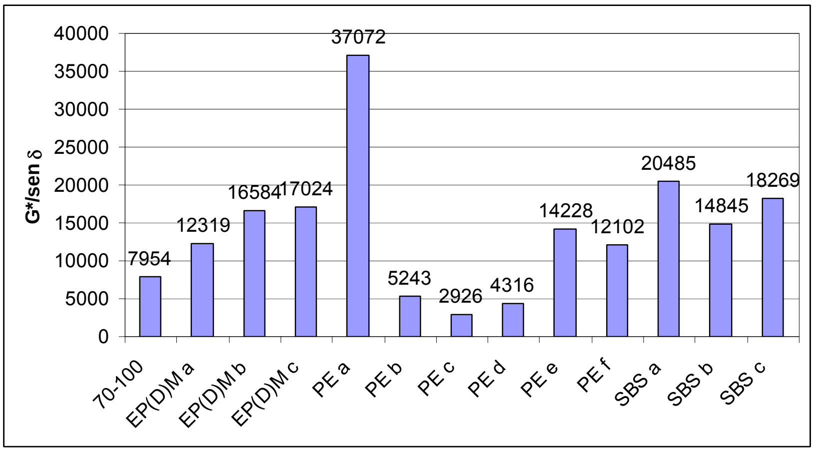


Fig.9: Rutting Factor a T=45°C

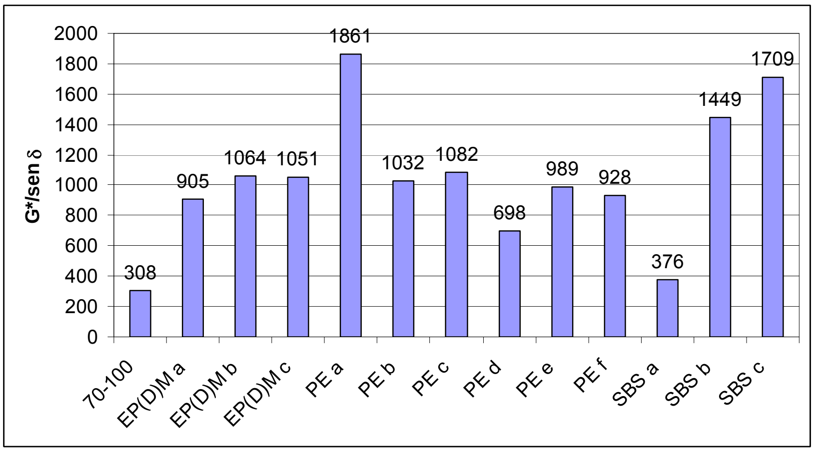


Fig.10: Rutting Factor a T=60°C

CONCLUSIONS

The objective of this research has been concentrated on the evaluation and comparison of the rheological characteristics of the bitumens modified with some new generation polymers. In particular the polymeric materials adopted in the research have been: radial SBS polymer with high, medium and low molecular weight: alpha olefin copolymers and thermopolymers with dienes EP(D)M at high, medium and low viscosity; thermoplastic polymers obtained after polymerization of ethylene with different processes as VLDPE, LDPE, LLDPE, HDPF and two EVA typologies.
Whit these polymers, assumed a “as it is” bituminous binder with 70/100dmm gradation as reference, a modification was performed in the measure of 5% in weight. As highlighted in the previous paragraphs, the rheological analysis conducted at different temperatures with the use of a DSR (Dynamic Shear Rheometer) highlighted that the polymers tested are not always good for the improvement of the performances of the binder.
As known, the last aim of the modification of the binders is the decrease of the thermal susceptivity of the binder, the improvement of the elastic properties at high temperatures (reduction of the tendency to rutting), the decrease of the fragility at low temperatures (reduction of cracking) and increase of the cohesion.
From this point of view the investigation, starting from advanced interpretation instruments such as the Black Diagrams and the Cole-Cole diagrams has allowed to establish that the VLPDE (**PE a**), plastomer currently adopted for food wrapping films, can be surely be adopted in the manufacture of bituminous asphalts for base and binder layers of high modulus pavements. On their own, the samples of bituminous binders modified with the different typologies of EP(D)M and of PE showing a very strong viscous behaviour along all the frequencies field, can be positively adopted for pavements subjected to high load frequencies and low temperatures.
Moreover, the investigation outcomes confirm that the low molecular weight radial SBS gives positive warranties from the point of view of the protection against rutting and cracking of conglomerates.

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