PERFORMANCE OF ASPHALT MIXTURES AT DIFFERENT TEMPERATURES AND LOAD, THEIR RELATION WITH THE ASPHALT LOW SHEAR VISCOSITY (LSV)

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ABSTRACT

The study and characterization of permanent deformation in a rational way has to develop laboratory test procedures that tried to reproduce the problem. The wheel tracking tests give an indication of the asphalt rutting resistance. This test simulated the traffic load in a pavement measures the variation of permanent deformations of an asphalt concrete along a period of time under extreme temperature and load traffic conditions. However, in practice the pavement temperature and traffic loads are not always so extreme. The asphalt binder rheological properties are important variable in the asphalt mixture rutting resistance performance. It has been recognized that the asphalt low shear viscosity (LSV) characterize the mixture rutting resistance. In this work the rutting performance of three asphalt mixture (dense, micro and SMA) prepared with three different asphalt binders (conventional, multigrade and polymer modified) were measured in the wheel tracking test at different temperatures (50, 60, 70 and 80 ºC) and load levels (520, 700 and 900 N). Additionally LSV measurements were made in the bitumen binders. A relationship to predict the asphalt rutting performance by known the bitumen LSV was found.

Keywords: Rutting, performance, Low Shear Viscosity, Temperature, Load

1. INTRODUCTION

A poor mixture performance is not a desirable situation because produce a waste of materials, the need to remove the asphalt and to rebuilt the new one with the cost in workmanship and inconvenient to the user of pavement. Nowadays the design and characterization of mixtures take into account the asphalt performance related to the common types of failure (rutting, fatigue and cracking).

The new laboratory test procedures, like wheel tracking test (WTT), tried to reproduce pavement conditions by studying and characterizing the asphalt rutting performance. The WTT measures the variation of permanent deformations of an asphalt concrete along a period of time under extreme temperature and load traffic conditions; however, in the field application, the pavement temperature and traffic loads are not always so extreme.

The prediction of asphalt performance is important during the design process; it is useful to relate this performance with the bitumen properties. The ASTM D 6373 standard classifies the bitumens considering the temperature conditions that would happen in pavements based on their rheological properties. These properties are associated to the most common pavement failures (rutting and cracking). Regarding rutting the parameter $G^*/\sin\delta$ is used; original and aged conditions are considered for a proper bitumen selection. It has been proved that the $G^*/\sin\delta$ is not appropriate to classify all binder, particularly the modified ones (Stuart et al. 2000, Bahia et al. 2001a, Dongré and D'Angelo 2003); nevertheless the idea of characterization of rutting performance from the bitumen rheological properties (original and aged) is an important concept in the standard. Nowadays other rheological properties are used to characterize permanent deformations; the Low Shear Viscosity (LSV) it has been recognized as a parameter strongly related to the asphalt rutting resistance (De Visscher and Vanelstraete, 2009). The LSV measurement is specified in CEN/TS 15324:2006; however a criterion using this rheological property for rutting mixture designs was not developed.

Otherwise CEN/TS 15324:2006 is also used to calculate the temperature at which the asphalt binders present a viscosity of 2000 Pa.s. This equiviscous temperature, as it is called, is considered as a performance indicator for the partial contribution of the binder to the rutting resistance of asphalt at elevated pavement temperatures. It must be noted that in the standard the LSV of 2000 Pa.s can be applied on original as well as aged bitumen. Nevertheless it is not clear why the same limit is used for both asphalt conditions.

In the other hand the loading limits are commonly exceeded with the consequents rutting problems in the pavement. Design of asphalt mixtures to resist the higher loads carried by trucks is a real challenge. Bahia and co-author (2009) studied the response of binders and mixtures to increased stresses under repeated loading at pavement temperatures. They said that load limitations are needed and the limits should be based on analysis of asphalt sensitive to stress increase.

The performance of most widely applied types of asphalt including dense, micro and stone mastic asphalts (SMA) were studied in this work at different temperatures. The main objective was study the LSV limit criterion related to rutting resistance. The relationship of asphalt mixture rutting performances obtained from Wheel Tracking Tests (WTT) results and the LSV of original and also aged asphalts was analysed. In addition the performances of asphalt at different load levels were studied.

2. NOMENCLATURE

D_{105}: permanent deformation at 105 min of rutting test [mm].
D_{120}: permanent deformation at 120 min of rutting test [mm].
f: frequency [Hz].
L_i: Load level considered as input data [N]
LSV: Low Shear Visacosity [Pa.s].
$LSV_{60\,°C}$: Low Shear viscosity at 60 ºC [Pa.s].
Rr: Rutting rate calculated from the WTT [μm/min].
t: time [min].
T_i: temperature considered as input data [ºC]
WTT: Wheel Tracking Test.
ε_p: permanent deformation [mm].
η_∞': limiting viscosity [Pa.s].
η': viscosity data [Pa.s].
η_0': zero shear viscosity (ZSV) [Pa.s].

3. EXPERIMENTAL

3.1. Materials and mixtures

Three asphalt gradations were studied in this work; dense grade (D-20), micro (M-10) and Stone Mastic Asphalt (SMA-10). These were made using different proportions of two coarse aggregates (6-20 and 6-12 mm), two crush sands (0-6 and 0-3 mm), hydraulic lime, filler and cellulose fibres. Table 1 shows the main characteristics of gradations and asphalts including optimal asphalt content (O.A.C), density (D) and air voids (A.V.).

Table 1. Properties of gradations

	D-20	M-10	SMA-10
Aggregate Proportions[%]			
6-20 mm	40	-	-
6-12 mm	12	75	75
0-6 mm	45	-	-
0-3 mm	-	16	15,5
Filler	2	8	8
Hydraulic lime	1	1	1
Cellulose fibres	-	-	0,5
Design properties			
O.A.C. [%]	5,0	5,3	6,0
D [gr/cm^3]	2,437	2,380	2,400
A.V. [%]	3,5	4,9	3,3
O.A.C.: Optimal Asphalt content; D: density; A.V.: Air Voids			

Three bitumen binders currently used in Argentina (Conventional (C), Multigrade (M) and Polymer Modified (PM)) were used in each gradation to make different asphalts. Table 2 presents their main characteristics including penetration, softening point (R & B), Brookfield viscosity at 60 ºC and torsional recovery test results. The different mixtures are identified by gradation and type of asphalt binder used.

Table 2. Principal bitumen properties

Bitumen		C	M	PM
Modification		-	Multigrade	SBS
Argentinian classification		CA-30	-	AM3-C
Penetration at 25 °C	[dmm]	55	60	64
Softening Point	[ºC]	51,8	58,3	95,5
Brookfield Viscosity at 60^{o}C	[Pa.s]	297,6	1224	-
Torsional Recovery	[%]	-	-	77,2

3.2. Testing Program

For each gradation the performance of different asphalt mixtures were studied in the WTT at 50, 60, 70 and 80 ºC with a load level of 520 N; they were selected keeping in mind the temperature range where rutting occurs. Additionally the performance of asphalts at load levels of 700 and 900 N at 60 ºC were studied to compare the different behaviours.

For each gradation twelve samples, 300 mm wide and 50 mm high, were cast. They were compacted to the design Marshall density using roller compactor equipment (UNE EN 12697-33 2003). The densities were controlled to verify a minimum of 98 % of the design density; then the specimens were tested in pairs at each temperature.
In addition the LSV of each asphalt binder, on original and aged condition, was measured at the same temperatures (50, 60, 70 and 80 ºC). The Rolling Thin Film Oven Tests (RTFOT, ASTM D 2872) was used to generate the asphalt binder ageing. In PM asphalt was also done a modified RTFOT (at 180 ºC) considering that the ageing of this asphalt after the standard method was not necessarily enough. Different studies show how the standard RTFOT (ASTM D 2872) produce an inadequate ageing of some polymer modified asphalt (Bahia et al. 2001b y Jia et al. 2005). One of the main problems is that this kind of asphalt does not roll inside the bottle during the test due to their high viscosity at the test temperature (163 ºC); then, it is not generated a thin asphalt film and therefore the ageing is inadequate, unlike what happens in the mix plant. In addition modified asphalts are usually exposed to severe temperatures during the mix process.

3.3. Test Procedures

3.3.1. Frequency sweep test

A DSR Paar Physica SM-KP with a Rheolab MC-100 was used to evaluate the rheological behaviour of the asphalts. The equipment has a thermo stabilizer to allow the temperature to set in a range from 0 to 90 ºC through a water recirculation system that surrounds the asphalt sample.
The frequency sweep test method was used to obtain the asphalts LSV. The frequency sweeps were done in 40 to 80 ºC temperature range at 10 ºC steps. The Plate-plate configuration was used in all DSR tests. A 25 mm diameter and 1 mm gap sample geometry was used. The frequency sweeps were done from 0.5 to 10 Hz. The frequency sweep test was done inside the linear viscoelastic region of the studied asphalts.
Master curves for reference temperatures of 50, 60, 70 and 80 ºC were built using the frequency-temperature superposition principle trough the frequency sweeps at different temperatures. The Cross model is used to fit the complex viscosity data as equation 1 indicates.

$$\eta' = \eta'_{\infty} + \frac{\eta'_0 - \eta'_{\infty}}{1+(k.f)^n} \tag{1}$$

where η': viscosity data; η_0’: ZSV; η_∞’: limiting viscosity; *K* and *n*: model constants; *f*: frequency in Hz. As recommended by De Visscher (2004), the LSV was calculated at a frequency of 0.001 Hz for each reference temperature.

3.3.2 Wheel tracking test (WTT)

The WTT was used to characterize the asphalt rutting performance. The device consists in a loaded solid rubber wheel, 207 mm diameter and 47 mm wide. The loaded wheel describes a simple harmonic motion with a total travel distance of 230 mm and a frequency of 21 cycles per minute over a sample of asphalt concrete. Rutting depth was measured one minute intervals through a LVDT during 120 minutes. The collected data are fitted with the potential model as equation 2 indicates. The first ten data collected were not taken into account because they significantly affect the fit.

$$\varepsilon_p = a.t^b \tag{2}$$

where εp: permanent deformation data; t: time; a and b: model constants. The rutting performance was evaluated through the Rutting rate (Rr); this parameter represents the rate of chance in rut depth determined over the last part to the rut depth-time curve. It is calculated as eq. 3 indicates where D_{120} and D_{105} are the deformations at 120 and 105 minutes respectively.

$$Rr = \frac{D_{120} - D_{105}}{15\text{ min}} \left[\frac{\mu m}{\text{min}}\right] \tag{3}$$

4. TEST RESULTS AND DISCUSSION

4.1 Asphalt performance analysis at different temperatures

Table 3 shows the rutting rate (Rr) of each asphalt mixtures studied (D-20, SMA-10, M-10) and the corresponding LSV measures on the original and aged (in RTFOT) asphalts performed at temperatures of 50, 60, 70 and 80 ºC.

Table 3. Test results

Bitumen	T [ºC]	LSV original [Pa.s]	LSV Aged [Pa.s]	D-20	*Rr* M-10 [µm/min]	SMA-10
C	50	1012,4	2674,5	3,9	4,2	3,4
	60	252,5	559,3	9,6	14,8	11,2
	70	83,2	159,5	23,4	37,9	24,0
	80	34,3	58,4	-*	-*	-*
M	50	3631,1	15267,4	2,4	1,8	2,1
	60	947,5	3199,4	3,4	3,2	3,3
	70	308,1	863,9	6,7	10,4	8,4
	80	120,5	288,5	14,1	30,0	16,7
PM	50	7669,9	21881,6[1]	2,3	1,4	1,8
	60	2459,3	6471,5[1]	3,0	1,8	1,9
	70	911,3	2220,4[1]	3,5	2,6	3,0
	80	383,1	867,9[1]	4,9	4,1	3,8

* not measured
[1] obtained by means of modified RTFOT

It must be noted that the LSV of aged PM bitumen indicated in Table 3 corresponds to modified RTFOT performed at 180 ºC, while in other binders (C and M) it was used the standard temperature (163 ºC). To validate the use of a higher temperature a PM asphalt mixture was made at 180 ºC, temperature that all PM mixture were made; then the asphalt was recovered following the ASTM D 1856 (2003) methodology in order to compare with both aged PM in standard (163 ºC) and modified (180 ºC) RTFOT. Table 4 compares the LSV values of aged PM asphalts with the recovered from PM asphalt mixture one. As expected the LSV values for aged PM in standard RTFOT are lower than the PM recovered while the LSV values of PM aged at 180 ºC are closer to the recovered one. Thus, the modified RTFOT gives a better representation of the real ageing that occurs in the PM mixture process, mainly as temperature increases; see last columns in table 4.

Table 4. LSV [Pa.s] of PM aged bitumen

T [ºC]	RTFOT (1)	RTFOT (2)	Mix recover (3)	(1)/(3) [%]	(2)/(3) [%]
50	24952,9	21881,6	35824,8	69,7	61,1
60	5169,0	6471,5	9103,7	56,8	71,1
70	1367,7	2220,4	2766,8	49,4	80,3
80	445,0	867,9	982,5	45,3	88,3

(1):RTFOT at 163 ºC - 85 min.; (2):RTFOT at 180 ºC - 85 min.;

Figure 1 shows the variation of rutting rates (Rr) with temperature for the different asphalts. Beyond the type of asphalt the response to rutting is similar respect to kind of bitumen and thermal susceptibility. As expected, it is clearly seen that the Rr increases as the temperature increases when considering one type of binder. Respect to the rutting susceptibility is observed that this clearly depend on the bitumen independently of asphalt type. It is observe higher rutting susceptibility for conventional asphalts follow for M and PM asphalts. Also it is important to mention that, depend of binder; it seems modify the temperature threshold for which a fast increase in rutting takes place. The threshold is below 50 ºC for C, close to 60 ºC for M and higher than 80 ºC for PM. In figure 1 also can see the different aspect of some samples after the WTT.

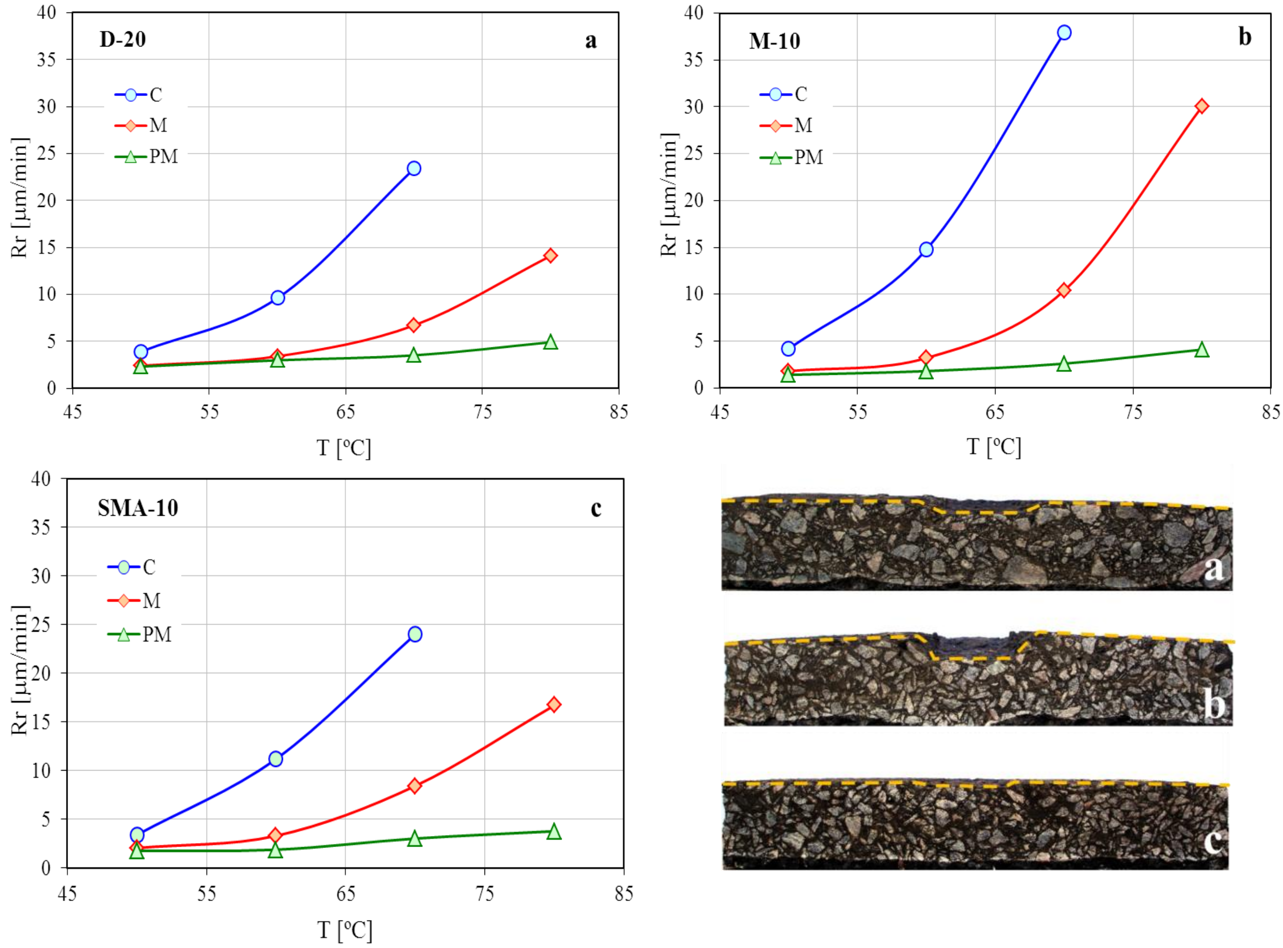

Figure 1. Rutting rate (Rr)-Temperature relationships for the different bitumens (Conventional, Multigrade, Polymer Modified) and asphalts (D-20, M-10, SMA-10) studied and pictures of samples after WTT; a) D-20 C at 60 ºC, b) M-10 C at 60 ºC, c) SMA-10 PM at 70 ºC

Nevertheless, if the *Rr* measurements (WTT) are represented as a function of the bitumen LSV (original or aged) determined at each test temperature, see Figure 2, all asphalts follow a similar tendency. It was observed how improves the rutting performance in the WTT (minor *Rr*) when the LSV is increased. In addition the figure 2 shows that *Rr* drastically changes in the region of low LSV values. Considering the temperatures range, the different types of asphalts and the gradations studied, it is observed that notable changes in rutting resistance appear when the original bitumen binder has LSV values lower than 500 Pa.s, see figure 2 left. Similarly strongly changes in the rutting behaviour take place for aged bitumen LSV values lower than 1000 Pa.s. Based on this observation, the CEN/TS 15324:2006 LSV value of 2000 Pa.s can be taken as a safer threshold for the aged asphalt condition.

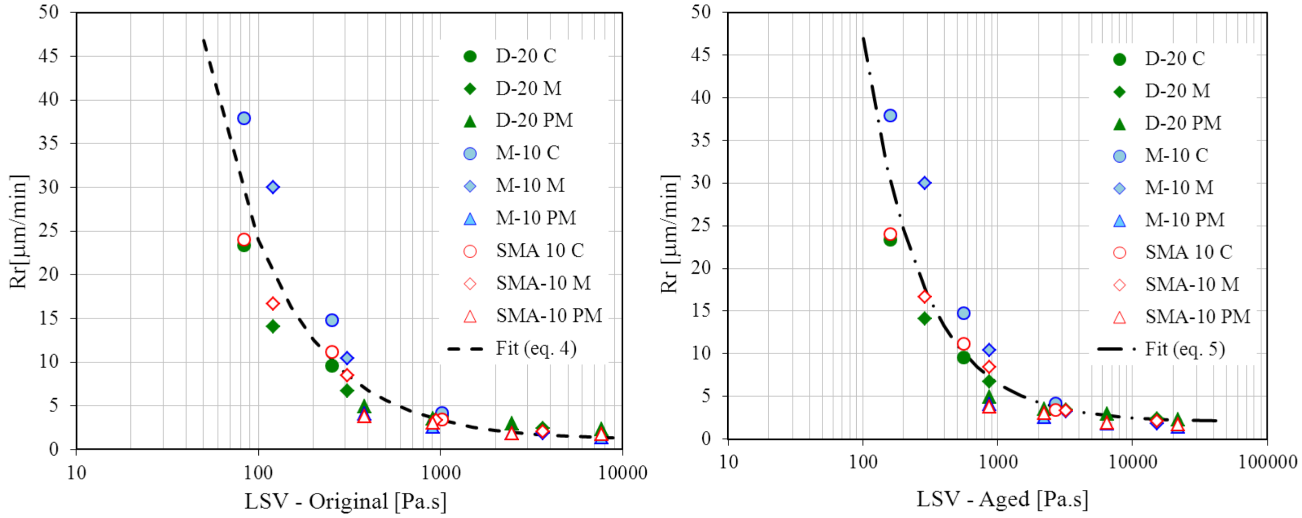

Figure 2. *Rr* of D-20, M-10 and SMA-10 asphalts vs. bitumen LSV (left: original, right: aged)

From the analysis of results, it is interesting to note that the changes in rutting performance (*Rr*) for the lower region of LSV values were observed independently of asphalt type and kind of used binder; in addition the same behaviour was observed with the original or aged bitumens. The obtained results indicate that the LSV values of 500 and 2000 Pa.s represent limits related to the partial contribution of binder in the mixture rutting resistance for the original and aged conditions respectively. However, it must be keeping in mind that each original bitumen binder (C, M or PM) has a LSV value of 500 Pa.s at different temperatures; similar for the 2000 Pa.s in the aged bitumens (see Figure 3). By means of LSV-T curves it is possible to obtain each temperature associated to LSV of 500 and 2000 Pa.s for the original and aged binder respectively (T_{500} and T_{2000}). Table 5 shows the T_{500} and T_{2000} values for the bitumens studied. This temperature can be associated with the maximum pavement temperature at which asphalt can be submitted without compromising its rutting resistance.

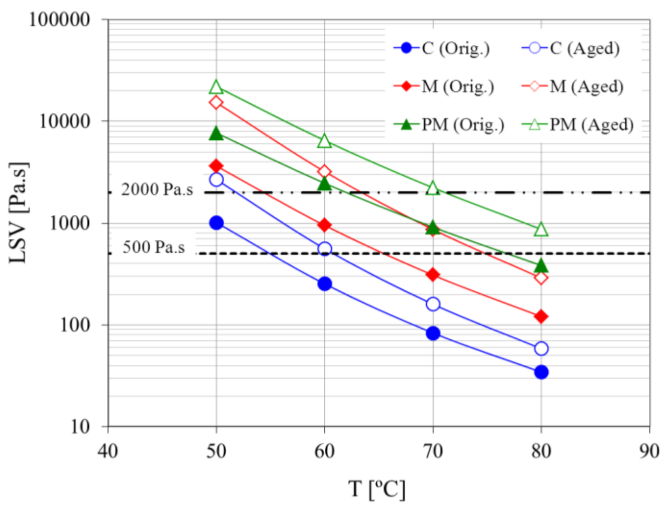

Figure 3. Bitumen's LSV vs. Temperature (Filled dots: original, void dots: aged)

Table 5. High temperatures related to T_{500} y T_{2000} concepts

Criterion	Bitumen		
	C	M	PM
T_{500} (original) [ºC]	54,8	65,5	76,8
T_{2000} (aged) [ºC]	51,7	63,4	73,0

The CEN/TS 15324:2006 uses the LSV to obtain the Equi-Viscous Temperature (EVT), associated to rutting resistance. A LSV value of 2000 Pa.s is used to calculate the EVT. The standard fixes this LSV value for original and aged bitumen as well. Considering the result obtained in this work it is not logical take the same limit for both conditions. If the limit of 2000 Pa.s is applied in Figure 2 left (*Rr* versus original LSV), in most cases the test results fall outside; thus this limit appears as a rigorous threshold for original bitumen.
The relationships between *Rr* and the original and aged asphalt LSV represent a powerful tool to estimate the asphalt rutting resistance at a specific temperature if the LSV in the same condition is known. Thus, the *Rr*-LSV relationships were obtained fitting the data by a non-lineal regression as equations 4 and 5 indicate.

$$Rr\,[\mu m/\min] = 1{,}06 + \frac{2287{,}9}{LSV_{Original}} \quad (R^2 = 0{,}87) \tag{4}$$

$$Rr\,[\mu m/\min] = 2{,}04 + \frac{4494{,}5}{LSV_{Aged}} \quad (R^2 = 0{,}86) \tag{5}$$

The results show that the original and aged bitumen properties must be taken into account for a correct binder characterization. Note that in many practical situations it is not possible to obtain a sample of the original bitumen and only a pavement or mix plant sample is available for the analysis. As a consequence, it is relevant to relate the asphalt rutting performance to the aged bitumen properties.

4.2 Asphalt performance analysis at different load levels

One of main objectives of this work was to study the asphalt rutting response to increasing loads. The Table 6 shows the rutting rate (*Rr*) results of studied asphalts with different load levels at 60 ºC measured in the WTT including the results to 520 N previously shown.

Table 6. Rr results at different load levels

Load	Asphalt	*Rr* [µm/min]								
		D-20			M-10			SMA-10		
[N]	Bitumen	C	M	PM	C	M	PM	C	M	PM
520		9,6	3,4	3,0	14,8	3,2	1,8	11,2	3,3	1,9
700		14,8	4,3	3,0	24,4	5,2	2,0	23,9	4,8	1,9
900		40,2	7,1	4,1	-	6,0	3,2	-	7,8	2,9

Figure 4 shows the *Rr* results as a function of load level. As expected, the Rr increases as the load level increases and consequently a worse rutting performance was observed. In addition, it can be seen in Figure 4 that the asphalt load sensitivity depends on type of bitumen; the C asphalts showed the major load sensitivity followed by the M and PM asphalts. In Figure 4 also can be noted that the load sensitivities were similar in the different gradations mixed with the same binder. It is interesting to note the case of PM asphalts, it can be seen slight changes on *Rr* when considering the load increment from 520 to 700 N, while the behaviour is clearly different when the load increases from 700 to 900 N.

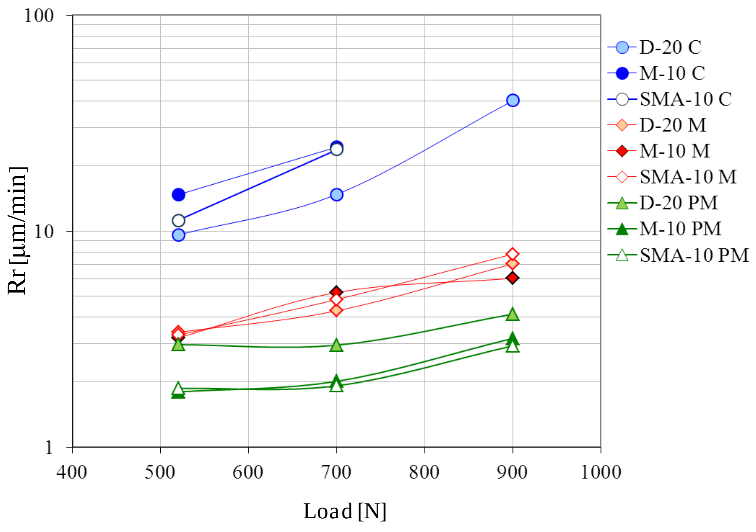

Figure 4. *Rr* of D-20, M-10 and SMA-10 asphalts vs. Load

Bahia and coauthors (2009) studied the load sensitivity of different bitumens in the multiple stress creep recovery test (ASTM D 7405) at two temperatures: a moderate one representative of the middle of a summer and the other the high temperature of bitumen performance grade (PG). They found that most of the binders did not show variations at the moderated temperature in their response to load increments; however at the high temperature of PG the bitumens showed a greater sensitivity to the applied load. Considering the high temperature (T_{high}) obtained for C, M and PM bitumen (see Table 5) it is possible to explain the different asphalt sensitivities observed in Figure 4. The tested temperature of asphalt in WTT (60 ºC) was higher than the T_{high} of C bitumen (54.8-51.7 ºC), similar to the M bitumen (65.5-63.4 ºC) and lower than the PM bitumen (76.8-73.0 ºC); it is reflected on a high, moderated and lower load sensitivity at the WTT temperature (60 ºC).

4.3 Comparative analysis of asphalt performance results

Table 7 shows all together the asphalt *Rr* results at different temperature and load levels. The Table 7 also shows interpolated values of *Rr* at temperature of 64 ºC; only this interpolated value is shown for simplicity. However, in fact, the *Rr* values at different temperatures were interpolated to observer which one was near to the *Rr* measured in WTT with the load of 700 N. From the analysis of results can be defined that:

I. The changes observed in *Rr* when it is considered a load increment from 520 to 700 N represent an equivalent effect to increase the temperature from 60 to 64 ºC.
II. The changes observed in *Rr* when it is considered load increment from 520 to 900 N represent an equivalent effect to increase the temperature from 60 to 70 ºC approximately.

It is important to note that these equivalencies can be applied on the different gradations (D-20, M-10 & SMA-10) and bitumen binders (C, M & PM) studied.

The load-temperature equivalence can be used as a tool in the selection of binder to consider overload in pavements. Previously it was stated a maximum bitumen binder temperature (T_{high}) associated with the LSV. This temperature can be associated with the maximum pavement temperature at which asphalt can be submitted without compromising its rutting resistance. If overloads can be considered in the selection of bitumen binder, the necessary T_{high} can be increased between 4 or 10 ºC.

Table 7. *Rr* result of D-20, M-10 and SMA-10 at different temperatures and loads

			Rr [µm/min]								
Asphalt			D-20			M-10			SMA-10		
		Load [N] / T [ºC]	520	700	900	520	700	900	520	700	900
Bitumen	C	50	3,9			4,2			3,4		
		60	9,6	14,8	40,2	14,8	24,4		11,2	23,9	
		64	**15,1***			**24,0***			**16,3***		
		70	23,4			37,9			24,0		
	M	50	2,4			1,8			2,1		
		60	3,4	4,3	7,1	3,2	5,2	6,0	3,3	4,8	7,8
		64	**4,4***			**5,4***			**4,8***		
		70	6,7			10,4			8,4		
		80	14,1			30,0			16,7		
	PM	50	2,3			1,4			1,8		
		60	3,0	3,0	4,1	1,8	2,0	3,2	1,9	1,9	2,9
		64	**3,2***			**2,1***			**2,3***		
		70	3,5			2,6			3,0		
		80	4,9			4,1			3,8		

*interpolate values

Summarizing, the asphalt concrete rutting performance is related to the binder rheological properties as well as the temperature and load conditions on pavement; but for asphalt design these variables are analysed independently. As a consequence, it seems interesting to obtain a model to predict rutting performance based on the LSV, temperature and load asphalt conditions. The *Rr*-LSV-Temperature-Load relationships were found fitting the data of all asphalts (different gradations and binders) by a non-lineal regression as equation 6 indicates. It can be seen in equation 6 that the LSV was considered at fixed temperature of 60 ºC and temperatures and load as ratios respect to 60 ºC and 520 N respectively.

$$Rr = 3587{,}3\,LSV_{60^\circ C}^{-1{,}05} \cdot \left(\frac{T_i}{60^\circ C}\right)^{6{,}69} \cdot \left(\frac{L_i}{520\,N}\right)^{2{,}31} \quad (R^2 = 0.89) \tag{6}$$

Regarding rutting prediction, it is important to mention that gradation and air void content can have a significant role in rutting performance. However these are more a problem of design, poor aggregated selection, or poor compaction of asphalt during the laying. The three kind of gradations tested in this work are well proved designs and present different characteristic between them, see table 1. The major influence on rutting observed here were consequences of temperature, load and bitumen properties. As can be seen in figure 2 the different gradation or air void contents did not have influence in the relation *Rr*-LSV.
To summarize, the rutting prediction model will not predict the behaviour of a poor gradation design or poor compacted asphalt that probably present rutting problems in the field. The prediction model is a tool to observe the influence of temperature and load that to be exposure the asphalt in the field and considering the bitumen characteristics for well design gradation.

5. CONCLUSIONS

The rutting performances at different temperatures ranged between 50 to 80 ºC and load levels (520, 700 and 900 N) of three types of mixture gradations (dense, micro and SMA), incorporating Conventional, Multigrade and Polymer Modified asphalts, were studied through the wheel tracking test (WTT). The Low Shear Viscosity (LSV) of original and aged asphalts was also evaluated in order to relate this rheological property with the rutting behaviour. The main conclusions are indicated as follows.
As expected for each asphalt binder, as the temperature increases the rutting performance decreases, obtaining higher rutting rates (*Rr*) in WTT.
The asphalt binder modifies the temperature threshold for which a fast increase in rutting takes place.
The rutting susceptibility of mixture depends on the asphalt binder type independently of mixture gradation.

The rutting performance in the WTT increased (minor *Rr*) as the LSV at the same temperature increased.
However, for all temperatures, types of gradations, and binder studied were observed similar relationships between rutting performance and the asphalts LSV (original or aged) measured at the same temperature.
Strong changes in *Rr* of the asphalt were found when the asphalt binder achieves LSV values lower than 500 and 2000 Pa.s for original and aged asphalt respectively. Considering that the changes in performance were observed independently of mixture type and kind of asphalt, these LSV values represent limits of the partial contribution of the binder in mixture rutting resistance. Based on these viscosity levels, maximum temperature of asphalt binders can be defined, below which the asphalt mixture rutting resistance is acceptable.
A model to estimate the asphalt mixture rutting resistance at different temperatures based on the LSV (original or aged) at the desired temperature was proposed. The *Rr*-aged LSV relationship can be specifically used when in situ pavement samples are only available.
Respect to rutting response to increasing load, as expected, the *Rr* increased as the load level increased. A worse rutting performance was observed.
The asphalt load sensitivity depends on type of bitumen; this sensitivity is similar in different gradations made with the same binder.
The asphalt load sensitivity is associated with the temperature at which it is exposed and can be related to the maximum temperature of bitumen obtained by the LSV limits previously stated.
Load-temperature equivalence was found. It can be used as a tool to consider pavement overload in the design bitumen selection considering the possibility of increasing the maximum binder temperature requirements (Trough the LSV) in 4 or 10 ºC.
A model to estimate the asphalt rutting performance based on the LSV of bitumen, temperature and load asphalt conditions was found.

6. ACKNOWLEDGMENTS

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