STUDY OF NATURAL ADDITIVES TO REDUCE THE PRODUCTION AND PLACEMENT TEMPERATURES OF THE HOT ASPHALT MIX.

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ABSTRACT

The technological innovation in highways goes directed to get better energetic and environmental efficiency.

The study of Cuban natural additive, such as the waxes from the sugar cane and henequen and natural zeolite deposit a working, they constitute potential sources for the reduction of the energy demands in the asphalt industry in Cuba.

The paper exposes the sugar cane wax evaluation, as additive incorporated into asphalt binder to modify the high temperatures viscosities, as initial stage to develop the investigations related to warm mix asphalt.

Keys words: additives, sugar cane wax, warm mix asphalt, modified asphalt.

1. INTRODUCTION

The main investigations in the asphalt researchers are wrapped up in the last years are directed to the preparation of asphaltic mixtures to smaller temperature to achieve energy and emissions reduction of powder and smoke without the mechanical benefits of the mixtures are affected in hot.

One of the work lines to achieve these results is referred to the employment of additives that act about the viscosity from the asphalt to high temperatures.

Inside the additives that are mentioned in the literature are different waxes: natural, paraffinic, 100 % synthetic not paraffinic, partially synthetic not paraffinic, amides of fatty acids, polyethylene, etc, with them is possible to lower the viscosity of the asphalt and therefore the temperature during the process of blended and compactness about 20 ºC maintaining or improving the properties to service temperature.[1, 2, 3].

In our country the natural resources exist to develop the investigations related to the mixtures semi hot such as the waxes coming from the sugar cane and the henequen which constitute potential sources for the energy reduction of demands in the asphalt industry in Cuba.

The first part exposed in this work is related to the evaluation the raw cane wax like additive to modify the viscosity from the asphalt to the high temperatures following the work lines outlined in the international community.

In Cuba the cane wax is marketed fundamentally for the pharmaceutical production of PPG. Cuba has eight extractor plants of raw cane wax that require maintenance and intensive repair and they could contribute in harvest from 4 000 to 5 000 ton. of wax raw that is to say, of 40 to 50 times the quantities of raw wax to refine for PPG [4].

This would facilitate a surplus for their application in the construction industry in the development of investigations of having proven applicability and that they substitute important imports besides that develop products of the industry of the Cuban construction for example the waterproof cement IMPERCEL, CERAMOLD to remove from the molds in the prefabricate industry and of course their employment in the development of the semi hot mixtures.

2. WORK METHODOLOGY

The study to determine the behavior of the properties of the asphalt modified with wax cane raw was divided in two stages:

1. Determination of the best percentage of cane wax to add to the asphalt according to the behavior of the Brookfield rotational viscosity.

2. To study the rheologycal behaviour of the asphalts modified with the cane wax.

The first stage consisted on adding percentages of waxes to two samples of conventional asphalt 60/70 employees habitually in the production of hot asphalt concrete and to measure its behavior to the rotational viscosity with the purpose of establishing the good percentage and the temperatures to which it can mix and compact in an appropriate way considering the recommendations of viscosity settled down in the method SUPERPAVE[5].

The second stage consisted on evaluating the rheologycal behavior of the asphalts modified with cane wax before and after subjected to the processes of aging of the action of the air and the temperature simulating the phenomena that happen during the process of production of the mixture. Fig. 1 shows an outline of the experimental plan developed in the study:

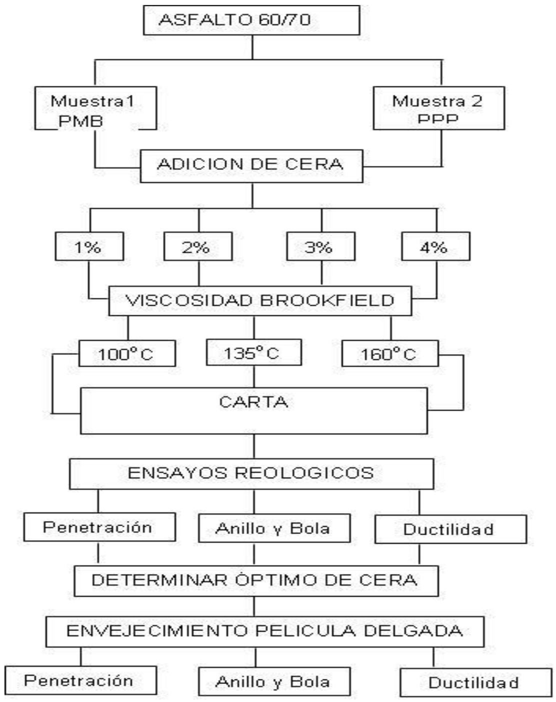

Fig 1 - Experimental plan for the investigation of the behavior of the asphalt with wax cane raw additive.

3. EXPERIMENTAL PROCEDURE

3.1 Materials characterization.

3.1.1 Wax of raw cane of sugar

The samples of this wax were obtained of the warehouses of the Sugar Cane Investigations Institute (ICIDCA) and they were characterized with the basic rehearsals of identification.

Table 1. Wax fractions composition.

Fraction	M.U	Content
Oil	%	33
Resins	%	15
Wax	%	55

Table 2. Determination of Melting point of the wax. ASTM D87[6].

Sample	M.U	Melting Point
No. 1	^oC	79.4
No. 2	^oC	78.8
No. 3	^oC	73.7
Average value	**^oC**	**77.3**
Standard deviation	**^oC**	**3.1**

Table 3. Wax Chemical indexes.

Index	M.U	Content
Acidity index	mg KOH/g	32
Saponification index	mg KOH/g	98
Iodine index	mg I_2/g	28
Free fatty acids	%	11.6
Alcohols content C_{22} - C_{32}	%	16.4

The cane wax is constituted by chains with a number of carbons that varies between 14 and 60 because they are a mixture of free fatty acids, triglycerides, fatty alcohols, aldehydes, ketones, ésters, terpenes and resinous material of high molecular weight. It can be considered it presents a half molecular weight because in their composition they are made up of under and high molecular weight.

The cane wax is a vegetable origin non paraffinic type as long as the paraffinic compounds are formed with the time and the cane wax is obtained of an active vegetable[7].

3.1.2 Asphaltic cement.

The asphaltic cement employee in the production of asphaltic mixture for the paving of the avenues in Havana city is only taken place by the Ñico López Refinery which is giving a single type of penetration asphalt classified as asphalt 50/70.

For the development of the work we were sampling the asphalt in two of the plants that produce mixture for the paving of the city: the Bernardi Mobile Plant (BMP) and the Bernardi Plant of the Popular Power Urban Roads Enterprise (PPP).

The two asphalt samples were characterized with the basic rehearsals to determine the asphalts consistency.

Table 4. Consistency of the asphalts.

	PENETRATION		DUCTILITY		SOFTENING POINT	
	PMB	PPP	PMB	PPP	PMB	PPP
VIRGIN	74,1	65.9	150	150	49	46

Table 5. Penetration index of the asphalts.

	PENETRATION INDEX	
	PMB	PPP
VIRGIN	-1.3	-0.8

Table 6. Consistency changes of the asphalts for aging in the oven of movement thin film.

Sample	**Penetration**		**O.P (%)**	**Acceptable value PG-3 Article 211**
	Virgin 60/70	**Aging**		(Original penetration %)
PMB	74,1	35,1	47,4	50 minimum
PPP	65,9	32,7	49,6	
	Softening		**Δ T° A y B**	**Acceptable value PG-3 Article 211**
	Virgin 60/70	**Aging**		ΔT °C A y B
PMB	46	57	11	9,0 maximum
PPP	49	51,5	2,5	
	Ductility		**Acceptable value PG-3 Article 211**	
	Virgin 60/70	**Aging**	**Ductility, cm After aged**	
PMB	150	129	50 minimum	

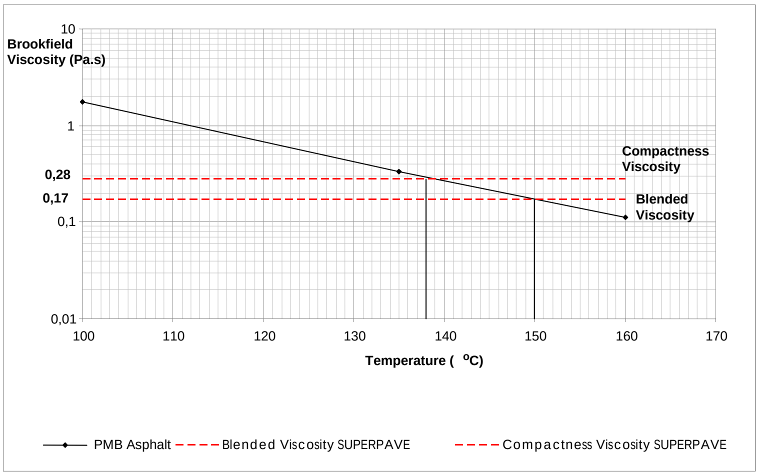

Fig 2 - Letter viscosity-temperature for the PMB asphalt sample.

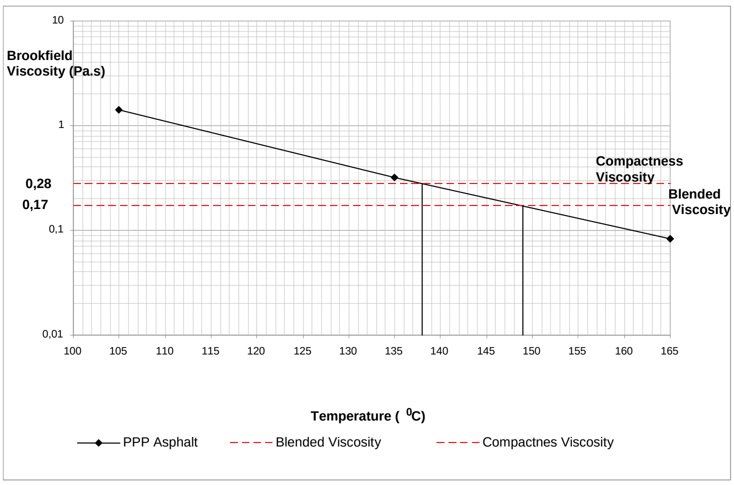

Fig. 3 - Letter viscosity-temperature for the PPP asphalt sample.

3.2 Preparation of the mixtures asphalt / cane wax.

Considering the ranges of additions found in the revised literature was considered to prove 4 different percent from addition embracing from 1% until 4%, varying one to one the quantities to add.

We weigh 500 grams of asphalt in each recipient and we heat until reaching a temperature among 90 ^{o}C and 100 ^{o}C so that the temperature of the asphalt went superior to the wax temperature of coalition (78-80) ^{o}C. The quantities of wax required for each determination were previously weighed and later added to the asphalt, staying the hot mixtures on an electric iron with manual agitation during 5 minutes.

In the preparation of the samples was appreciated for 4 % addition a slight increase of volume, formation of foam and coloration change in the asphalt.

3.3 Brookfield rotational viscosity measuring[8, 9].

The viscosity measurement was carried out for three points of temperatures (100 ^{o}C, 135 ^{o}C and 160 ^{o}C) to conform the temperature-viscosity curves of the asphalts modified with the wax to different percentages (1% to 4%) being elaborated the letter viscosity-temperature where the different curves are included for each considered addition. The influence of the additive was determined it has more than enough viscosity and the temperature.

They were signalled in the letter the temperatures stockings settled down by the design method SUPERPAVE for the blended one (0.17 ± 0.02 Pa.s) and the compactness (0.28 ± 0.03 Pa.s).

According to the modification of the asphalt coming from the Bernardi Mobile Plant represented in the graph 4 we can appreciate that the contents of additions of 1% to 3% reduce the viscosity values regarding the virgin asphalt in the blended temperatures and compactness (135 ^{o}C and 160 ^{o}C). However in relation to 1% the contents of 2% and 3% begin to increase the viscosity lightly for the compactness temperature (135 ^{o}C) although for the temperature of blended (160 ^{o}C) the addition of 2 % diminishing the viscosity. The addition of 4% increases the viscosity above the virgin asphalt PMB in the compactness temperature although it doesn't maintain same tendency in the temperature blended.

The viscosities measured to 100 ^{o}C showed random variations in relation to the percent of addition that which could be due to that to that 100 ^{o}C the asphalt begins to behave as a liquid very viscous.

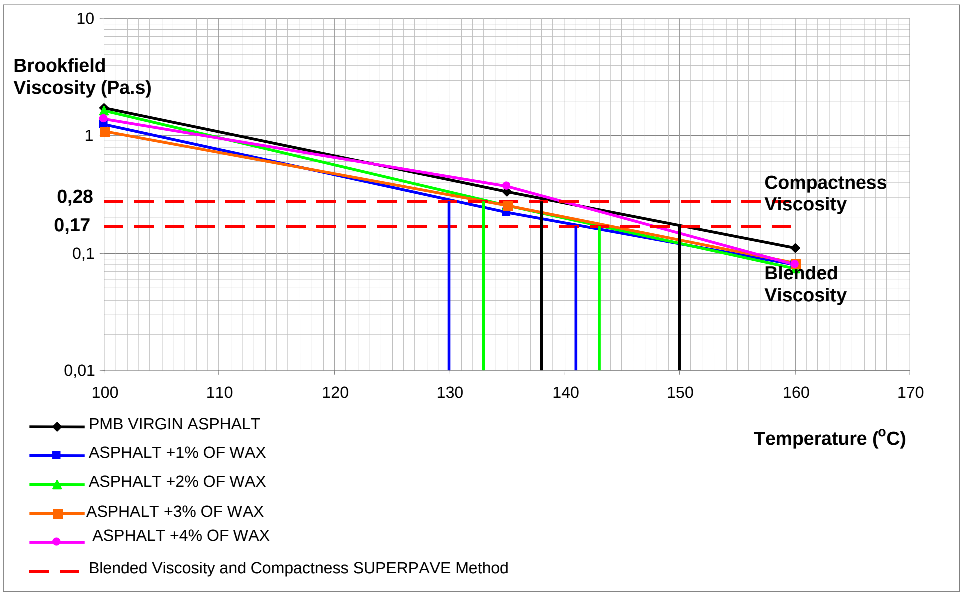

Fig 4 - Letter viscosity - temperatures for the asphalt PMB with different contents of wax.

Of the results of the rehearsal of viscosity it can settle down that the good of addition is between the 1 % and 2 % of wax.

If the intersection marked by the horizontal line of the viscosities recommended by the SUPERPAVE method is determined the blended temperatures of the virgin asphalt diminish from 150 ^oC to 141 ^oC and 143 ^oC respectively for the asphalts with 1% and 2 % of addition and producing a reduction between 9 and 7 grades of temperature. The letter viscosity temperature of the second asphalt sample taken of the Popular Power Plant is represented in the Fig 5. In this case we decided to displace the range of temperatures in 5 ^oC for the measuring of the viscosity. A very even behavior is appreciated between the additions of the 1 % and 2 % of wax and in a same way those corresponding to the 3 % and 4 %.

The 1% and 2% additions reduce the viscosities regarding that of the virgin asphalt in the three measured points of temperature similarly to the first sample. In the 3 % and 4% additions of although for the compactness temperature (135 ^oC) the viscosity continues being smaller than the virgin asphalt and it begins to be increased the same one in connection with the addition of 2% of wax having for the blended temperature (165 ^oC) with superior viscosity respect to the virgin asphalt. Therefore the measurement in this second sample corroborate that the best of addition of cane wax is between 1% and 2%.

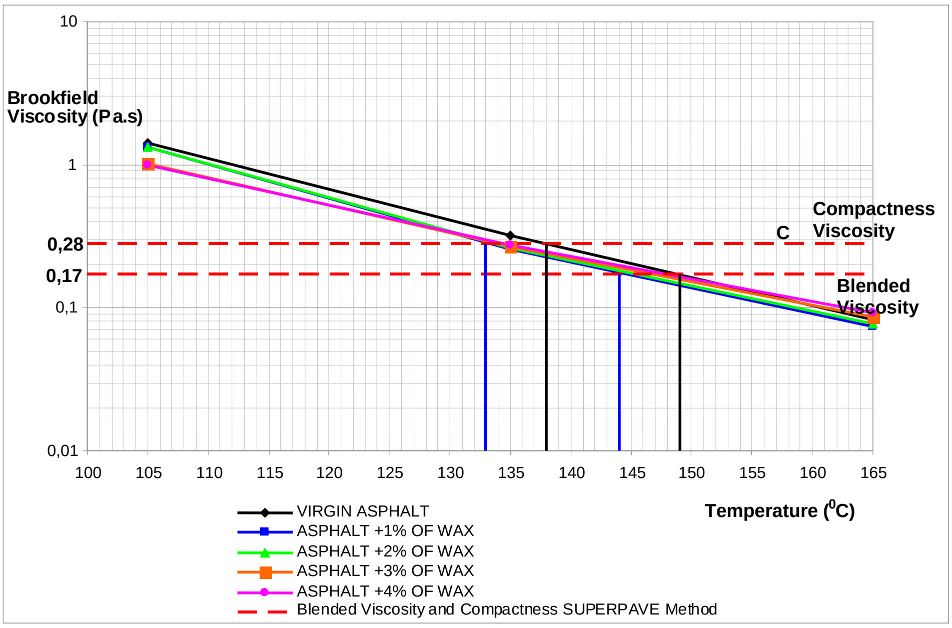

Fig 5. Letter viscosity - temperature for the asphalt PPP with different contents of wax.

The variations in the temperatures according to the viscosities recommended by the SUPERPAVE design method diminished for the temperature of blended of 149 °C for the virgin asphalt to 144 °C for the contents of 1% and 2 % of wax and for the compactness temperature a decrease of 138 °C necessary took place for the virgin asphalt to 133 °C for the asphalt with 1% and 2 addition % what bears to a reduction of 5 grades of temperature.

In both rehearsed asphalt samples the reductions obtained in the temperatures of work of the mixtures are in the order from the 5 °C to 9 °C of temperature.

Making a detailed revision of the consulted literature in general lines we thinks about that the technique of addition of waxes for the mixtures semi hot produces a reduction of the temperature between 20 °C and 30 °C however presented works of the experimentation of different authors in different countries show similar results to the one obtained in our experimentation.

Regarding this matter we can mention the works developed in Spain inside the mark of the project PHOENIX where the viscosities measuring in the asphalt modified they diminish very little in relation to the patron asphalt 60/70 used for the superior temperatures at 130 °C[10]. Regrettably they don't expose the type of wax employee in the study. With similar results they are the works developed in Portugal with additions of 4% of SASOBIT (Fischer Tropsch wax) that achieve reductions of the temperature between (7-9) °C in the Brookfield viscosity measuring [11]. As well as, the experimental works developed in Argentinean with a Fischer Tropsch wax where the reductions of viscosity regarding the normal asphalt are minimum, being obtained a temperature reduction of 5 °C[12].

In all these works are obtained temperatures reductions of the order of the 20 °C according to the studies carried out on the mixtures elaborated with this modified binder and in compactness tests to different work temperatures.

The results of the evaluation of the rheologycal properties of the asphalts modified with wax starting from measurement of the properties that affect the consistency of the asphalts were represented in the Fig. 6 for their best visualization.

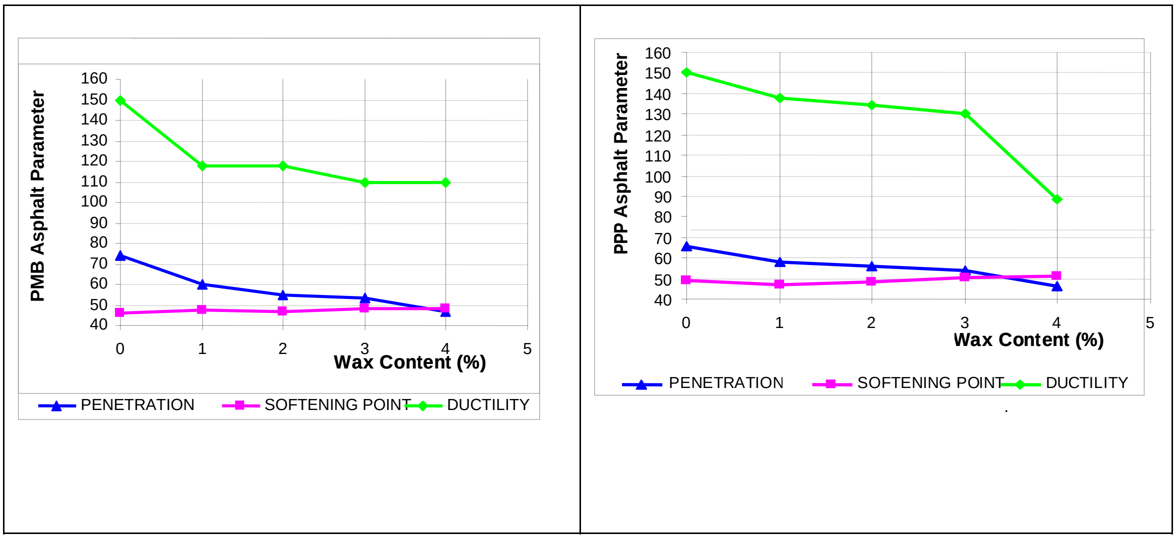

Fig 6. Representation of the rheologycal properties of the two asphalt samples modified with different wax additions.

We can appreciate that the ductility falls with the content of wax although it maintains values above 100 cm and it doesn't arrive to the break. Alone it suffers an accented deformation except for the addition of 4% in the asphalt coming from the Popular Power Plant (PPP) where the value of ductility broke in of 88 cm. The penetration values diminish and those of the temperature of softening are increased. It indicates a hardening of the asphalt with the increment of the contents of wax that which is better in relation to the type of asphalt employee. This presented high values of penetration above the classification range and temperatures of softening below the prospective ones in our pavements.

However in spite of these beneficial variations in the penetration parameters and temperature of softening the calculated penetration indexes (Table 7) for the asphalts modified with this wax they stay in the order of the -1 for what continues being an asphalt of great susceptibility to the temperature.

Table 7 - Results of the penetration index of the asphalts with different content of wax.

Wax Content (%)	Penetration Index (PI) PMB Sample	Penetration Index (PI) PPP Sample
0	-1,3	-0,8
1	-1,4	-1,6
2	-1,7	-1,4
3	-1,4	-0,9
4	-1,7	-1,1

The asphalts modified for the 1% and 2% addition were subjected to the aging for the action of the air and the temperature in the thin and later measured on movie oven the consistency parameters. The results for rehearsal are shown in the following graph, before and after the aging.

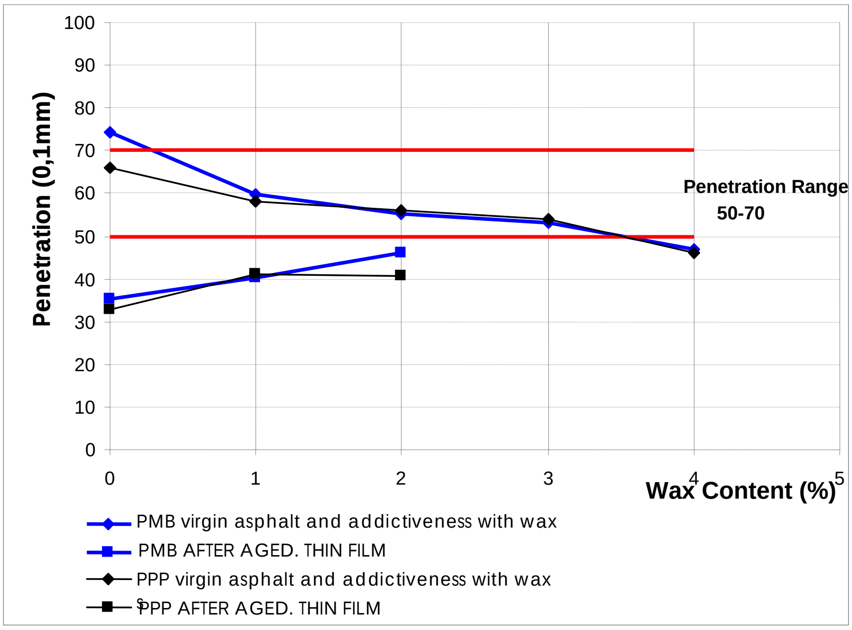

Fig 7 - Results of the Penetration test of the additivates asphalts before and after aged.

In relation to the determination of the penetration for effect of the aging the asphalt changes penetration range from a 50-70 up to a 40-50 in the additions of the 1 % and 2 %. The percent of the original penetration in the additivates asphalts stays above 50 % specified. The behavior of the two studied samples is very similar in this parameter. The best percent in the original penetration is obtained for 2 % addition (83, 7 %).

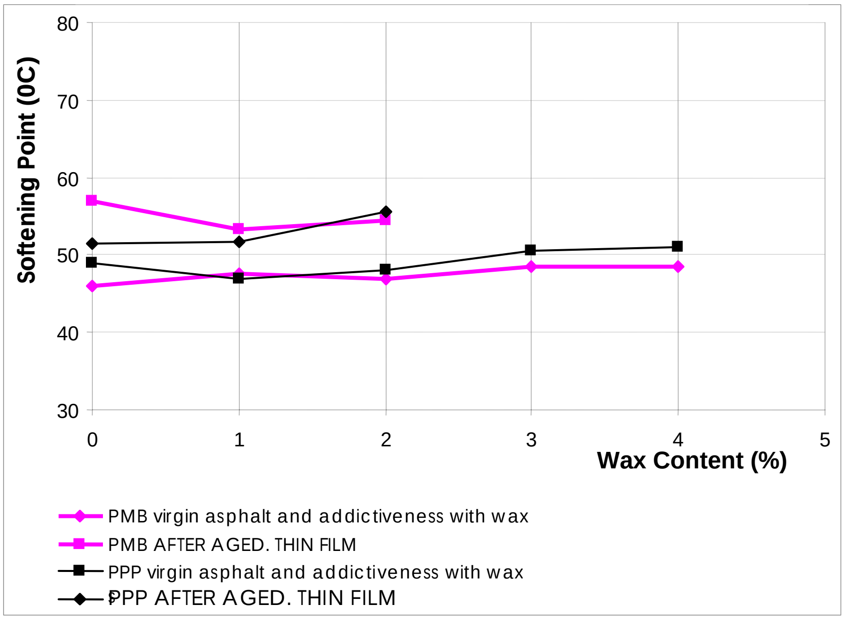

Fig 8 - Results of the Softening Point with Ring and Ball method of the additivates asphalts before and after aged.

The softening point after aged is increased to more temperatures that 50 ^{o}C, taking the biggest value of 55, 5 ^{o}C, for 2 % addition.

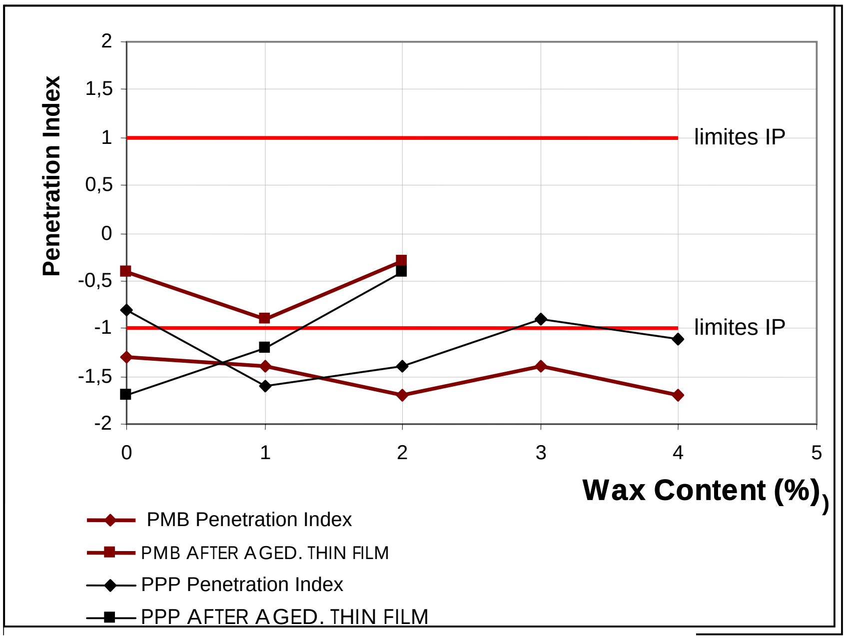

Fig 9 - Representation of the results of the penetration index of the additivates asphalts before and after aged.

This graph represent the values of the penetration index (PI) and we can appreciate that in the aged asphalts the penetration index even maintains the negative values although they improve and they reach values bigger than -0,5 that it is the minimum limits settled down in the specifications for the case of warm regions or warm climates. The best values in PI after aged are obtained for 2 % of addition of wax.

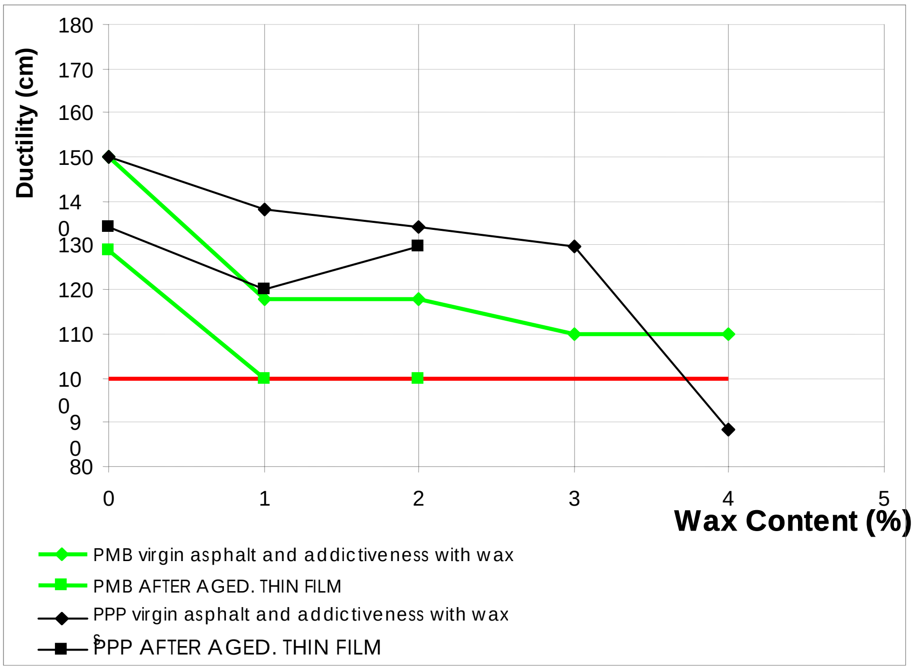

Fig 10 - Representation of the results of the ductility of the additivates asphalts before and after aged.

The values of the ductility of the aged asphalts with addition they stay above 100 cm as it establishes the specification although remarkable difference in this parameter is appreciated in the behavior among the two samples.

4. CONCLUSIONS.

1. The virgin asphalt used for the development of the work has been characterized as an asphaltic cement of great susceptibility to the temperature with a great content of slight fractions that evaporate easily for the action of the air and the temperature. This asphalt isn't ideal for their employment in paving under the conditions of climate warm and high temperature of Cuba.

2. The raw wax of cane used in this study presents a point of inferior coalition to 80 ^oC what facilitates its break up in the asphalt to the work temperatures.

3. It was possible to elaborate the curves temperature/viscosity of the virgin asphalts and modified with cane wax using a rotational viscometer being able to obtain the influence with which contributes the additive with the temperature to the viscosity.

4. The reductions of the temperatures of work of the mixtures with additions between the 1% and 2 % according to the viscosities recommended by the SUPERPAVE design method are in the order from the 5 ^oC to 9 ^oC.

5. The best content of addition of cane wax raw according to the results of the viscosity measurement and rheologycal evaluation of the addictive asphalts is considered the 2 % addition.

6. The obtained results are in agreement to that expressed by the international literature with the employment of other types and it is of hoping the reductions of temperature reach the 20 ^oC when the compactness tests are evaluated in the mixtures elaborated with the addictive asphalt in the studies that will be carried out after this work.

5. RECOMMENDATIONS.

1. To include studies with the refined wax of cane since the wax raw employee presents only a 55% of wax in its composition with that which one will be able to value the effect that could present the composition of the wax refined in the characteristics of consistency of the asphalt.
2. To continue the studies of asphaltic mixtures using the raw wax of cane like modifier.

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7. ABSTRAC DESCRIPTION

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