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Influence of Rubber Fine Powder on the Road Bitumen Properties

Nasr-Eddine Bouhamou

LCTPE, Civil Engineering Department, University of Mostaganem, Mostaganem, Algeria

Abstract: Rubbery waste at the end of the cycle often constitutes a threat for the environment because of their encumbrance and low biodeterioration. The purpose of the research presented is to develop the rubber fine powder as a pavement. It is interested primarily in the behavior of two types of bitumen 40/50 modified by the addition of two varieties of rubber fine powders of different grading, resulting from the crushing of the rubbery products intended for the clothes industry of soles of shoes. The objective of the experimentation is to study the influence of the added polymer on the physical properties of the ordinary road bitumen with the incorporation of the fine powder. The experimental approach is carried out using the two tests of characterization of the bitumen i.e. the softening point test and the penetration test which remain the most used to define and classify the road bitumen. It will be noted however, that the experimental investigation which is based on several tests according to the type and the content of fine powders, leads on a whole of interesting correlations.

Key words: Bitumen, rubber fine powder, development, penetrability, softening point.

1. Introduction

Rubbery waste at the end of the cycle thrown in nature constitutes a true threat for the environment because of their encumbrance and their low biodeterioration what encourages to be valorized as building materials with very useful properties such as the rubber fine powder (crushed rubbery elements) [1].

This article presents the summary of the results of tests using the valorization of the rubber fine powder in rolling layer by incorporating the fine powder resulting from crushing the rubbery elements at the end of the cycle such as the vehicle carpets and shoe soles in the road bitumen.

The objective of this study is to arrive to a new composite material "bituminizes rubber" with higher rheological and mechanical properties.

2. Historical Overview on Modified Bitumen

The Bitumen Modified with Polymers "BMP" are bitumen binders whose properties were modified by the use of a chemical agent, which, introduced into the basic bitumen, modifies their chemical structure and their physical and mechanical properties [2].

In what follows, it is recalled the historical route of the use of rubber in its granulated form in mixture with the bitumen:

- 1840: First experiments of incorporation of the natural rubber to the bitumen in Great Britain
- 1938: Bencovitz and Boe published in the review "ASTM" an article on the addition of sulphur to the bituminous mixtures.
- 1960: Realization, in the United States of America, of the first layers of roadways containing bitumen modified by the rubbers incorporated in the form of latex.
- 1970: Significant development of the modified binders in Europe in particular in Germany then in Austria and Italy and appearance of motorway roadways equipped with bituminous surfacing containing polyethylene.
- 1972: First applications In France, on a bridge with orthotropic plates with a BMP.
- 1982: Tests carried out jointly between the LCPC

Corresponding author: Nasr-Eddine Bouhamou, professor, research fields: cement.

of Paris and that of Clermont Ferrand (France) on the valorization of pneumatic waste in road field.

Currently, the bitumen rubber finds its full application in the road field and particularly, on the roadways that are heavily loaded such as the surfaces of operations and parking, on the slabs of bridges and on the inclined roads.

3. Classical Bitumen Shortcomings and Perspectives

The traditional bitumen, as it is currently used, present rheological deficiencies related to its physicochemical structure. This influences its behavior under the effect of the stresses due to the traffic and climate conditions which are relatively hard, without omitting other economical and environmental requirements [3].

The major shortcomings of the ordinary bitumen are summarized as follows [4]:

∗ low rutting resistance in particular under heavy traffic and high temperatures, ∗ strong risk of thermal cracking especially at low temperatures,

∗ medium adhesiveness in particular at the time which becomes gradually weak.

Currently, the bitumen constituting the binder of the road coatings is subjected to a set of loads and stresses making paramount the search and the improvement for some of its characteristics that are compatible with the following aimed objectives:

- reduction in thermal susceptibility in particular in the range -10 C/+60 C,
- rise in the adhesiveness and the cohesivity,
- improvement of the elastic behavior,
- increase in resistance to the ageing,
- rise in the fatigue strength and in the permanent deformations.

4. Materials and Test Procedures

4.1 Characterization of Material Used

The used binders are two types of pure bitumen of rank 40/50, one coming from the melters of the coating station belonging to the TOTAL group at Ouargla (Algeria) and the other from the refinery of NAFTAL manufacturing unit located in Touggourt (Algeria).The usual characteristics of the two bitumen are summarized in Table 1.In the same way, two varieties of rubber fine powders were tested, ie: a fine powder (F) and a coarse fine powder (G) coming from the Company of Application of Elastomers "SAEL Oued-Smar, Algiers". These fine powders are used for the manufacture of soles of shoes and the carpets of vehicles [5].

The grading curves of the two rubber fine powders, fine (F) and coarse (G) are shown in Figure 1.

4.2 The Bitumen Modification Procedure

The bitumen rubber is manufactured in the laboratory by dispersion of the fine powder in the basic bitumen under agitation at hot state. After having carried the bitumen at a temperature 170/180C, under mechanical agitation (propeller), the modifying agent (fine powder) is gradually added until to the required content. Several factors are fixed firstly during the manufacture of bitumen-rubber as shown in Figure 2.

- temperature of the mix : 175 ±05 ℃
- agitation velocity: 1000 tr/min
- agitation duration: 2,0h ±15 mn.
- dimensions of the container: Φ10cm, H15cm.
- Bitumen quantity ≈ 500g

4.3 Principle and Description of the Apparatus

The experimental approach is carried out using the two characterization tests of the bitumen; these are the softening point test and penetrability test. In spite of the simplicity of these two tests, they remain the most used to define and classify the road bitumen.

The determination of the characteristics of the bitumen such as penetrability with 25C (PEN25) and the softening temperature is made in the same manner as for the ordinary pure bitumen. However it should take attention for the bitumen with high contents of polymer for which it is recorded notable fluctuations of the results related to the instability of the mixture.

Table 1 Characteristics of basic bitumen.

Tests	Standart	Bitumen of Total	Bitumen of Naftal
Relative density à25 ℃	EN 1526	1,025	1,053
Penetrability à25 ℃ (0,1mm)	EN 1426	44,10	46,30
Softening point (℃)	EN 1427	43,8	42,85

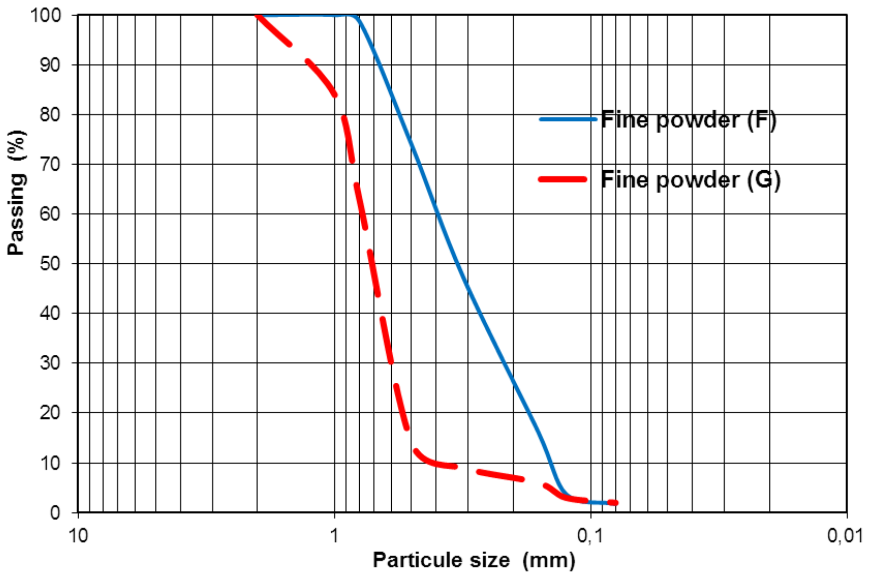


Fig. 1 Grading curves of the fine powders (F) and (G).

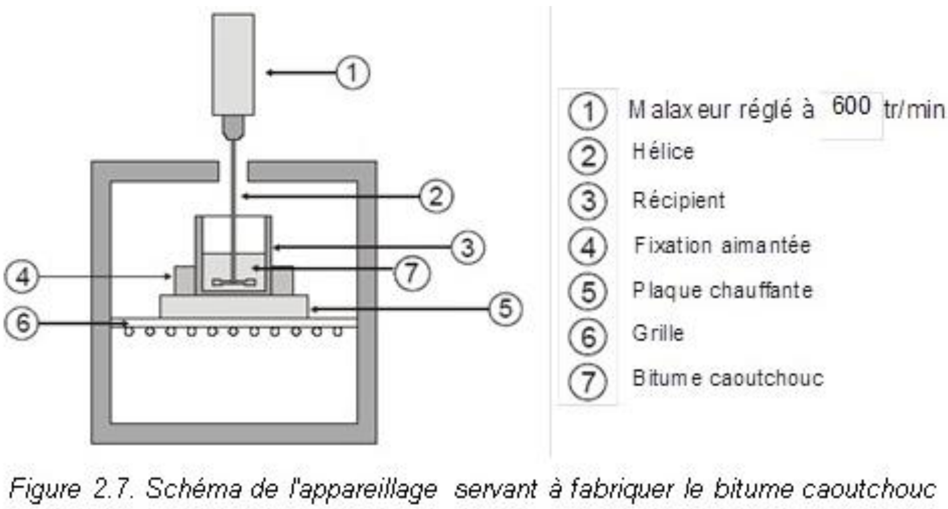


Fig. 2 Bitumen-Rubber mixture principle scheme.

4.3.1 The Penetrability Test

This test is performed to know the bitumen hardness on the basis of penetrability in a bitumen sample evaluated with the tenth of millimeter of a standardized needle supporting a mass of 100 g lasting 5 seconds at a temperature of 25 ℃ [6].

The more the bitumen is hard, the weaker is the penetrability. This test explains the commercial name of the bitumen and gives its classification (Figure 3).

4.3.2 The Softening Point Test

This test consists in measuring the softening point; a copper ring filled with bitumen on which is placed a

Fig. 3 Penetrability test apparatus.

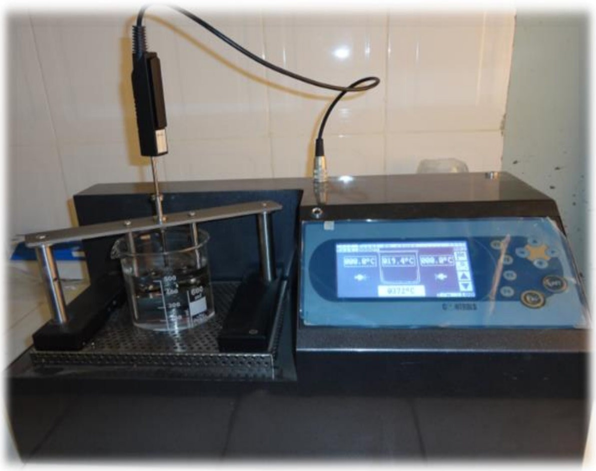


Fig. 4 Softening point digital apparatus.

steel ball, is immersed in water, one raises the temperature of 5 ° C per minute, the temperature of softening is that when the ball drag away the bitumen being in the ring at the bottom of the container (or on a fixed depth).This test informs about the consistency of the bitumen (Fig. 4) [7].

5. Results and Analysis

The tests and analyses have allowed quantifying the variation which occurred on the basic bitumen properties. The comparison between the pure bitumen (reference) and the modified with the fine powder, according to various contents, showed the influence of the latter on the intrinsic characteristics of the binder. The fine powder content varies in the interval of 0% (bituminizes pure) and 15% (extreme value).

5.1 Influence Fine Powder on the Characteristics of the Bitumen

Table 2 contains the various results obtained from the two tests: penetrability and softening point relating to the two bitumen Total and Naftal modified by the two varieties of fine powders: fine (F) and coarse (G). Each value showed in the Table 2 corresponds to an average of at least two values.

5.1.1 Influence of fine powder (F) on Penetrability

A significant reduction in penetrability is recorded when the content of fine powder increases, which shows that penetrability and the content of fine powder are inversely proportional for the two types of bitumen.

The reduction in penetrability is similar for the two tested bitumen, the most significant reduction is localized in the interval of fine powder [0-5%], where this one is 29% for bitumen of NAFTAL counters of 23% for the bitumen of TOTAL

The interval of fine powder content [5-10%] corresponds to a quasi-constancy of the values; variation lower than 6% for the two bitumen.

Table 2 Characteristic of bitumen-fine powder.

Tests	%	Fine powder (F)		Coarse powder (G)	
		Bit. Total	Bit. Naftal	Bit. Total	Bit. Naftal
Penetrability (0,1 mm)	0	44,00	46,33	44,00	46,30
	5	35,67	35,67	39,33	40,67
	10	33,67	34,67	37,33	40,00
	15	30,33	30,00	32,67	34,00
Softening point (℃)	0	43,80	42,85	43,80	42,80
	5	47,25	45,50	48,20	48,50
	10	47,70	46,00	47,45	45,00
	15	49,90	51,00	45,95	43,40

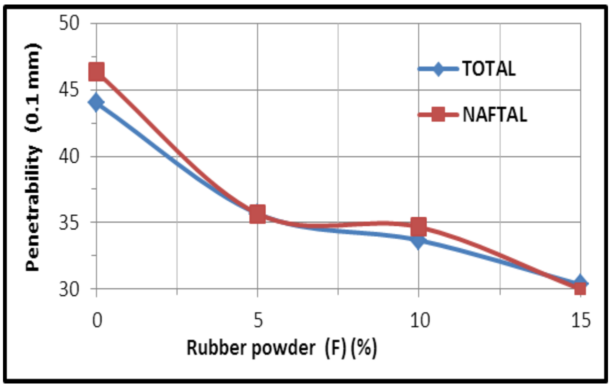


Fig. 5 Effect of powder (F) on bitumen penetrability.

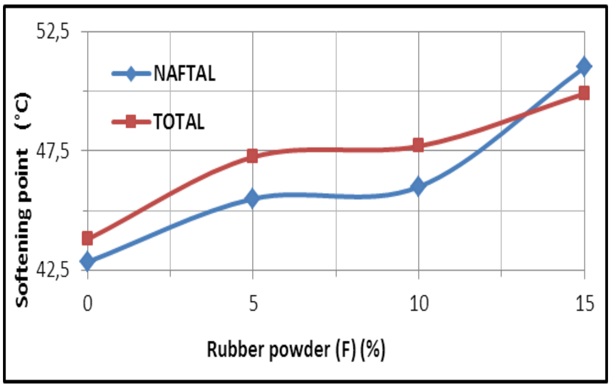


Fig. 6 Effect of powder (F) on bitumen softening point.

In general, the incorporation of 15% of the fine powder (F) in the case of the bitumen of total and that of Naftal make fall the penetrability respectively of 45% and 54%, which is very significant.(Figure 5).

5.1.2 Influence of fine powder (F) on softening

the softening point and the fine powder content are proportional; an increase in fine powder led to an increase in the softening point for the two types of bitumen.

The increase in the softening point between 0 and 15% of fine powder (F) varies of 14% for the bitumen of TOTAL against 19% for bitumen of NAFTAL what reflects a relatively limited influence of the fine powder (F) on the softening point (Figure 6).

The variation of the softening point in the interval of fine powder 5-10% is practically negligible.

5.1.3 Influence of Powder (G) on Penetrability

It is observed an almost linear reduction in penetrability according to the content of fine powder (G) for the two bitumen.

The most significant penetrability variation is recorded in the range of 10-15% of fine powder, this one is approximately 18%.

The reduction in penetrability in the range 5-10% is almost 7%. A clear reduction affects penetrability when the content of fine powder passes from 0 to 15%, this one is approximately 36% (Figure 7).

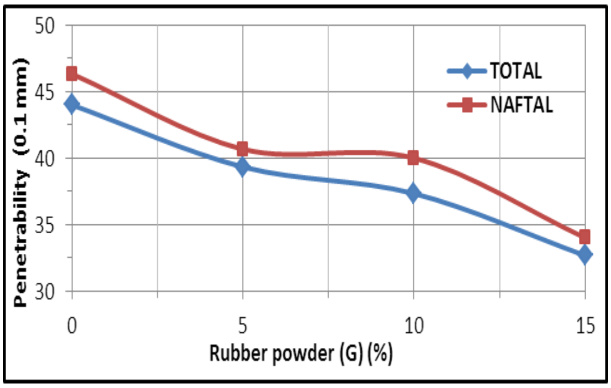


Fig. 7 Effect of powder (G) on bitumen penetrability.

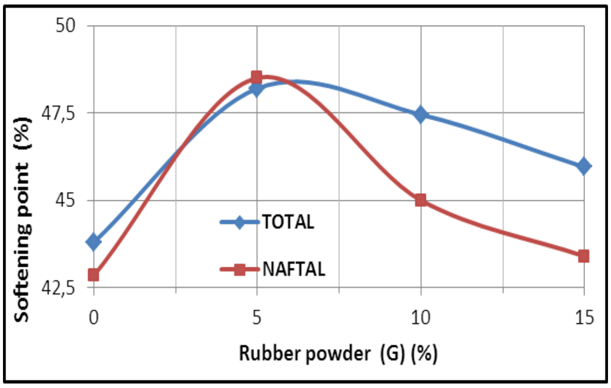
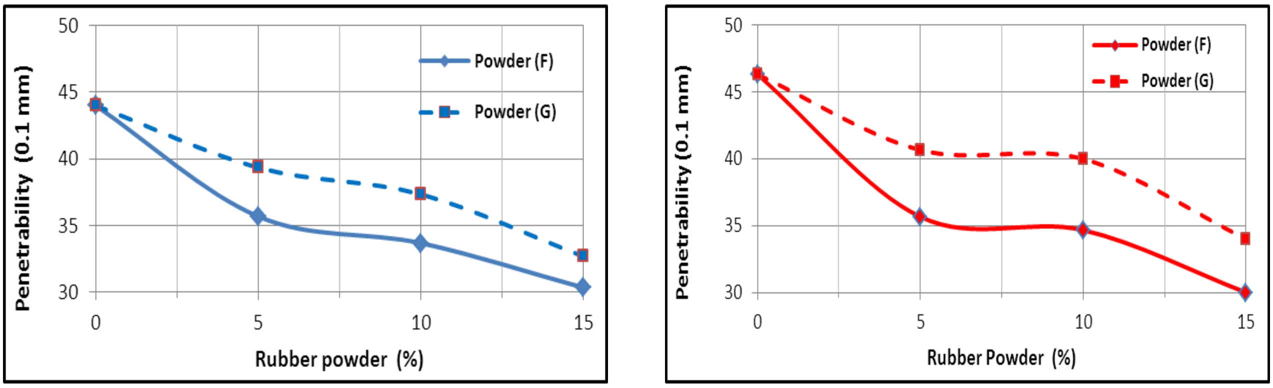


Fig. 8 Effect of powder (G) on bitumen softening point.

5.1.4 Influence of Powder (G) on Softening

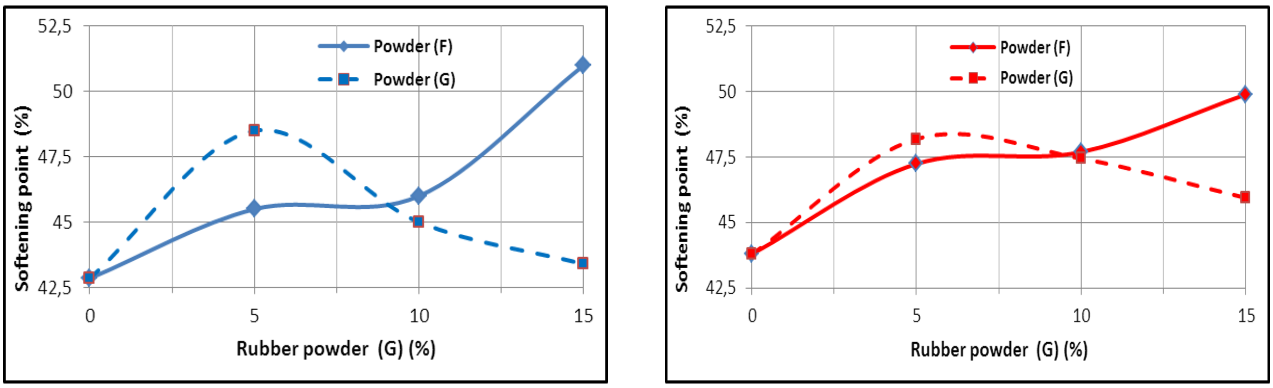
An appreciably bell-shaped curve reflects the variation of the softening point of the bitumen according to the content of fine powder (G) (Figure 8).

The softening point increases in the interval 0-5% at about 11% then decreases in a less accentuated way.



(a) TOTAL bitumen (b) NAFTAL bitumen

Fig. 9 Effect of powders (F) et (G) on bitumen penetrability.



(a) TOTAL Bitumen (b) NAFTAL bitumen

Fig. 10 Effect of powders (F) et (G) on bitumen softening point.

A maximum value of the softening point is recorded at about 6% of fine powder (G).

Comparison between the two fine powders [8, 9].

5.2.1 Penetrability

The fine powder (F) has a more significant influence on penetrability than the fine powder (G).

As an example, at 5% of fine powder, the reduction in term of penetrability is approximately 12% for the fine powder (G) whereas in the case of the fine powder (F) this reduction exceeds 24%.

At 15% of fine powder, the difference in penetrability is more than 15% between the fine powder (G) and (F).

Between 10 and 15% of fine powder, the influence of the fine powders is tiny.

5.2.2 Softening Point

The almost superposition of the two curves relating to the two fine powders (F) and (G), in particular in the interval of fine powder 0-10%, shows that the two types of fine powder have the same effect on the softening point, at different degrees. The fine powder (F) is more influential. (Figure 10).

From 10%, the curves relating to the two fine powders diverge, the softening point relating to the fine powder (F) increases and that of (G) decreases.

The curve relating to the fine powder (F) increases which means that a more significant temperature is necessary to soften the bituminize-fine powder, which is logical.

The curve relating to the fine powder (G) decreases for the two bitumen, which is not normal. These results can be brought back to the chemical composition of the two bitumen.

The fine powder (G) presents an increase followed by a reduction in the softening point, the cap is located with the content 5.5%.

6. Conclusion

In the light of these first results obtained and from the tests carried out for the study of the influence of the two types of rubber fine powders of different grading on the bitumen physical characteristics, it is possible to draw the following conclusions:

- the increase in the content of rubber fine powder led to a significant reduction in the penetrability, the influence depends on the nature of the bitumen and the smoothness on the fine powder.
- the fine powder having the finest granularity has the most significant influence on penetrability as well as the softening, this is due to the facility of digestion of the fine powder by the bitumen.
- the reduction in penetrability is not constant, it is significant in the intervals of fine powder 0-5% and 10-15%. Between 5 and 10% the influence of the fine powder is negligible.
- the softening point of the bitumen is proportional to the rubber fine powder content; an increase in fine powder lead in general to an increase in softening.
- the effect of the fine powders on the softening is similar in the interval 0-5% of fine powder. Beyond, the softening point relating to the grained fine powder decreases, these results can be brought back to the temperature, the chemical composition of the bitumen and the time of interaction fine powder-bituminizes.

The grained fine powder presents an increase followed by a reduction in the softening point, the fine powder content between 5 and 6% seem to be the optimal value for the softening point.

The classification tests carried out on the built-in bitumen of rubber fine powders showed the noticeable improvement of the rheological behavior in particular through the increase in the temperature of softening and the reduction in the penetrability [8, 9].

The results obtained show the interest which the incorporation of rubber in the ordinary bitumen can take on since it makes it possible to improve their physical characteristics. However, it is necessary to announce the need for developing techniques of bitumen modification more powerful and practical to control the use of modified bitumen on an industrial scale.

References

[1] AIPCR. 1999. Emploi des liants bitumineux modifiés, des bitumes spéciaux et des bitumes avec additifs en techniques routières. - Guide technique - Association mondiale de la Route (AIPCR), comité technique des routes souples (c8), N°303 Mars 1999.

[2] F. Belabdelouahab, H. TROUZINE. 2014. Research and Enhancement of Used Tyres, Such as Material Innovative in Algeria, Physics Procedia, Volume 55, 2014, pages 68-74 – ELSEVIER.

[3] N. Ward. 2003. Caractérisation de nouveaux bitumes-caoutchouc. Mémoire de maitrise es sciences appliqués, Université de Sherbrooke 2003.

[4] N. Kebaili. 2012. Influence de la poudrette de caoutchouc sur les performances des enrobés bitumineux. Master génie civil, Université de Ouargla 2012.

[5] Norme Européenne (EN 15326): Bitumes et liants bitumineux -Mesure de la masse volumique et de la densité-Méthode du pycnomètre à bouchon capillaire. Mars 2007.

[6] Norme française NF EN 1426: Bitumes et liants bitumineux - Détermination de la pénétrabilité à l'aiguille. Décembre 1999.

[7] Norme française NF EN 1427: Bitumes et liants bitumineux - Détermination de la température de ramollissement, Méthode Bille et Anneau. Janvier 2000.

[8] N. Kebaili, F. Belabdelouahab. 2012. Valorisation de la poudrette de caoutchouc dans le domaine routier-Asphalte caoutchouté ACMA, International Symposium Aircraft Materials Fes Maroc 09-12 Mai 2012.

[9] F. Belabdelouahab, N. Kebaili. 2014. Influence of crumb rubber on the mechanical performance of asphalt concrete pavement for aircraft in the south Algeria, ACMA, International Symposium Aircraft Materials Marrakech Maroc 23-26 April 2014.