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Procedia - Social and Behavioral Sciences 195 (2015) 2769 – 2776

Procedia Social and Behavioral Sciences

World Conference on Technology, Innovation and Entrepreneurship

Influence of Natural Rubber on Creep Behavior of Bituminous Concrete

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Abstract

The aim of this experimental work is to show the possibility of improvement of bituminous binders by natural crumb rubber. In this study, we propose the modification of a 35/50 bitumen by natural crumb rubber (NR) at the different contents (2%, 4%, 5%, 6% and 8%). The powder rubber used for the manufacture of rubber asphalt binder has been provided by the Algerian company SEAL "Application of Elastomers Corporation". The influence of natural crumb rubber (NR) on the creep behavior of bituminous concrete was studied. The results show an improvement on the creep behavior of the different mixtures considered in this work.

Peer-review under responsibility of Istanbul Univeristy.

Keywords: Bitumen ; polymer ; naturel rubber ; creep ; Marshall test.

1. Introduction

The hydrocarbon mixture, choice of coating material for the majority of roads, is composed of an inorganic backbone which is held together by organic glue.

This organic adhesive consists of pure or modified bitumen, is referenced by the term "binder". Although this represents only about 5% of the mass of the final material, bituminous binder very significantly influenced the

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Peer-review under responsibility of Istanbul Univeristy.
doi:10.1016/j.sbspro.2015.06.391

mechanical performance of road structure. It is normal research effort has been made to produce more efficient binders, and often referred to by the generic name "modified binders" (Ould Henia, (2005).)

The asphalt modification may be accomplished by two processes, the first being the modification of bitumen (wet process), the second involves the direct addition of the modifier in the asphalt concrete mixing operation (process sec) (Haddadi, 2007).

In this study, we use bitumen modification process (wet) for the production of modified bitumen asphalt natural rubber (NR), for a road surface to study its influence on the mechanical properties (Cheriet, 2010; Magramane, 2009).

2. Materials and Methods

2.1. The bitumen

The bitumen used in this study is class (35/50). Table 1 shows the results of its characteristics.

Table 1. Bitume Charactéristics

Bitumen		35/50	Specifications
Penetrability at 25°C (1/10 mm)		40	35 à 50
Softening point (SP) (°C)		52,25	50 à 58
Bukly density (g/cm3)		1.029	-
Ductility at 25°C (mm)		> 1000	> 1000
IPLCPC		0,545	-
After RTFOT	Penetrability at 25°C (1/10 mm)	24	-
	Softening point (°C)	58,25	>48
	Residual Penetrability %	67	>50
	Δ SP (°C)	6	<9

2.2. The aggregates

We used in this study three granular fractions (0/3, 3/8 and 8/15). These aggregates come from El-Hachimia career in Boumerdes. A chemical analysis was performed on aggregates. The results showed that the gravel 3/8 and 8/15 from the same parent rock, having a high carbonate content ($CaCO_3$), it is limestone. After various tests (Los Angeles test, Micro Deval test, cleanliness, Flakiness Index ...), selected materials have good intrinsic characteristics.

2.3. Instrial weste

Rubber powder used in the manufacture of asphalt rubber binder has been provided by the company Algerian SAEL "Company of Elastomers Application". This crumb comes from hydraulic nozzles joints (Magramane, 2009).

2.4. Bituminous concrete formulation

The granulometric curve, meeting specifications, is obtained for the following proportions:
• 38% of sand 0/3
• 30% of the fraction 3/8

• 32% of the fraction 8/15

The optimum bitumen content obtained was 5.57% giving the best Marshall characteristics. This content will be the reference in this study.

2.5. Modified bitumen

The modification was performed in the laboratory of roads of faculty of civil engineering of USTHB (Algeria). The modification is carried out with mechanical stirrer at the speed of 600 rpm for 2 hours at a temperature of 195 °C ± 5 °C [1]. The industrial waste contents in percent used to prepare different bitumen concrete are 0, 2, 4, 5, 6 and 8.

2.6. Marshall Test

The Marshall test according to EN 12697-34, was conducted on cylindrical specimens height 63.50 mm and 101.60 mm diameter, compacted at 50 blows per face. Overwriting was conducted at the speed of 0.850 mm/s after keeping the specimens in a water bath at 60 °C for 30-40 minutes. Five (05) specimens were tested in each case (Afnor, 1992).

During the test, the load and deformation are recorded until failure.

Marshall Quotient (QM) is an indicator for the resistance to permanent deformation, shear stress and also to rutting of bituminous mixes (Hinislioğlu al. (2004; Nguyen, 2006). High MQ values imply high stiffness mix and therefore a great ability of the mix to fail by cracking as its tensile strain is low (Whiteoak, 1991).

2.7. Static creep

The creep test in simple uniaxial compression can be performed on all types of bituminous materials. It has been correlated with rutting experiments conducted on actual road structures.

It complements the classical formulation tests and allows to conform the influence of formulation parameters and manufacturing parameters on the stability of the bituminous concrete to creep.

This behavior is strongly influenced by the weather conditions.

The apparatus used in this work is shown in Fig. 1. This device has been developed in the laboratory of road in faculty of civil engineering of the USTHB (is used to measure soil consolidation and is designed by the manufacturing company of test apparatus CONTROLS).

Fig. 1. Apparatus used for soil consolidation

Particular conditions of creep test

The recording of the initial deformation after loading 15s was chosen arbitrarily. The number of 15s is about the same average stopping time for the bus in a bus stop

- Tested mixtures: bituminous concrete 0/15 (pure and modified at 4% and 8% of NR).

- Test temperatures: + 25 ° C, + 40 ° C, + 60 ° C.
- Constraints Applied cuts: σ0 = 0, 14 MPa.
- Type of specimens: Marshall Specimen compacted at 50 blows per face.
- Difference in thickness maximum tolerated according to several generators: 0.1 mm
- Storage time of specimens: 24 h after manufacturing, it is put at the temperature of the test for 4 hours.
- Interval readings: recording deformations is carried out using a computer equipped with a data acquisition system every five seconds for two hours.
  - Charging time: 1 hour.
  - Discharging time: 1 hour.

3. Results and discussion

3.1. Marshall test on modified bituminous concrete

MQ values were calculated for the different bituminous concretes and are shown in Fig. 2.

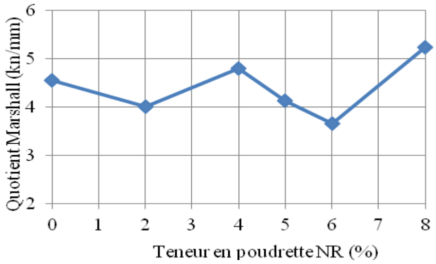

Fig. 2. Quotient Marshall according to NR content

Fig. 2 shows that the highest values of the ratio MQ are obtained for 4 and 8%. MQ (8%) is highest than MQ (4%). Other contents of NR give values of MQ lower than the reference bituminous concrete (0% NR). So for these contents, bituminous concretes manufactured are the most resistant to permanent deformation.

3.2. Static creep

Fig. 3 to 5 show the influence of temperature on the static creep behavior for each percentage of NR.
Bituminous concretes BB(0%), BB(4%) and BB(8%) were tested at three temperatures: 25 °C, 40 °C and 60 °C and an applied stress of 0.14 MPa.

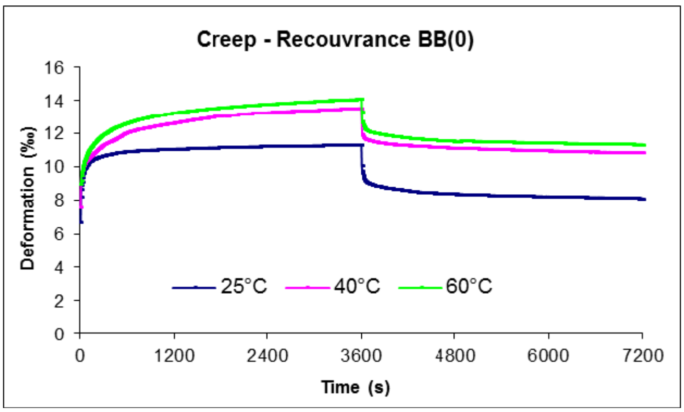

Fig. 3. Curves creep-recouvrance at different temperatures for 0 % of NR.

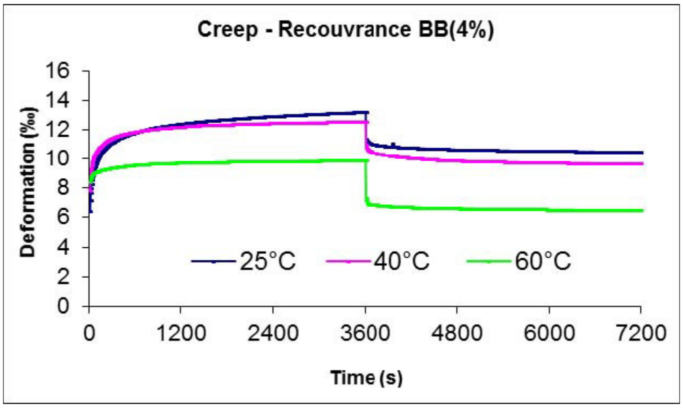

Fig. 4. Curves creep-recouvrance at different temperatures for 4 % of NR.

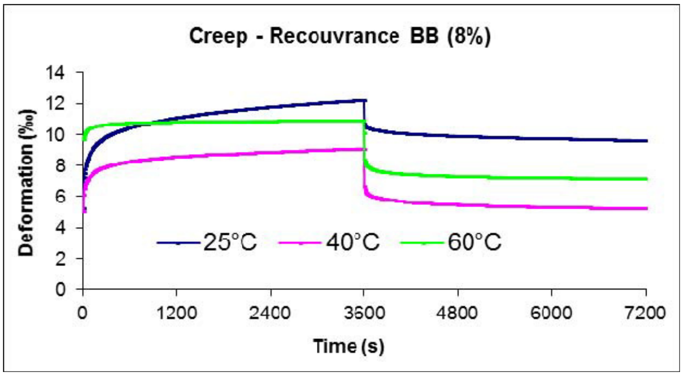

Fig. 5. Curves creep-recouvrance at different temperatures for 8 % of NR.

Fig. 3 to 5 show that:

- more the temperature increases more deformation increases in the reference mix; is also observed small variations in deformation between 40 ° C and 60 ° C.
- more the temperature increases more deformation decreases for modified mixes 4% NR; the deformations have a low variation between the temperatures 25 ° C and 40 ° C.
- For the modified mixes to 8% is noted that the recouvrance is not complete for temperature 25 ° C. By against at 40 ° C and 60 ° C the total recouvrance is, this phenomenon is due to the rubber elasticity.

Fig. 6 to 8 show the influence of the content on the behavior of bituminous mixtures (pure and modified) on the creep-recouvrance.

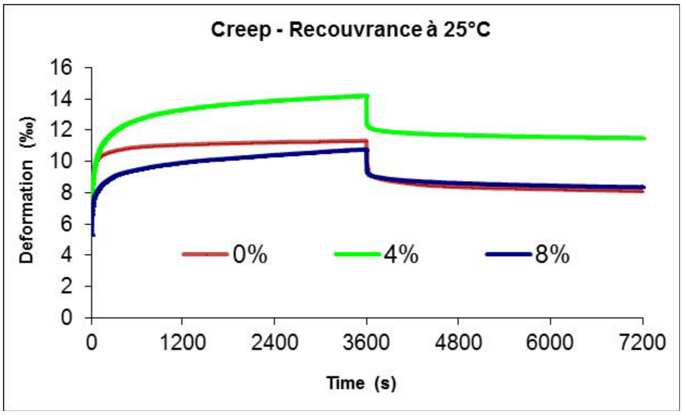

Fig. 6: Curve creep-recouvrance for different contents of NR at 25 °C

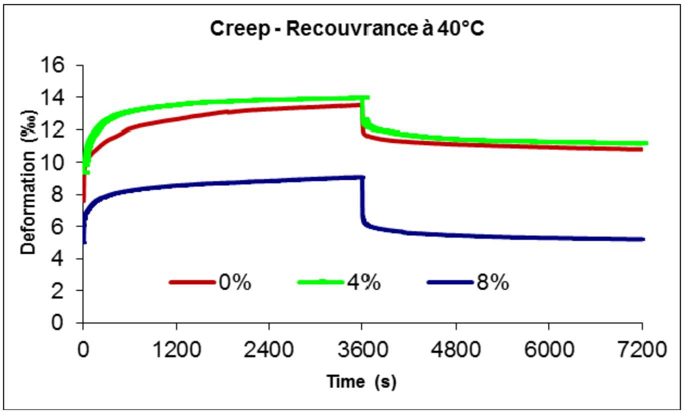

Fig. 7: Curve creep-recouvrance for different contents of NR at 40 °C

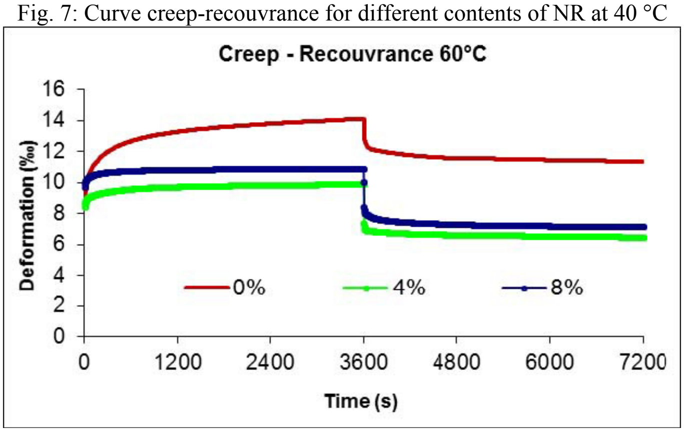

Fig. 8: Curve creep-recouvrance for different contents of NR at 60 °C

From the curves of the preceding Fig. it is noted that:

At 25 ° C,

- The recouvrance is not complete except for the bituminous mix for the pure bitumen.

- The bituminous mixtures with modified bitumen for 4% give the highest deformation.
- The deformations values with modified bitumen at 8% are lower compared to those of pure bitumen, for against for the part of recouvrance it is noted that the curves are almost identical. Therefore the crumb rubber influence the creep behavior.
- The strain rates (creep-recouvrance) for modified asphalt is lower than the reference bituminous concrete. So the natural crumb rubber mix relieves.

At 40 ° C:

- The recouvrance is not total for the bituminous concretes modified at 0% and 4%, but is complete for the bituminous concretes modified at 8% .This phenomenon is due to linear elasticity of the rubber .
- Modified bituminous concretes at 8% presents the lowest strain.
- The difference between the curves of modified bituminous concretes at 0% and 4% is low.
- The strain rates (creep - recouvrance) for the modified bituminous concretes are lower than the reference bituminous concretes. So the natural rubber crumb relieves the bituminous concretes.

At 60 ° C:

- The recouvrance is complete except for the refernce bituminous concretes.
- The reference bituminous concrete gives the highest deformation.

4. Conclusion

In this work bituminous concretes were obtained by mixing the modified bitumen and the aggregates (wet process).

The industrial waste contents used to prepare different modified bitumen are 0, 2, 4, 5, 6 and 8. Marshall test and static creep test were performed on the modified bituminous concretes.

The result of Marshall test show that the highest values of the ratio MQ are obtained for 4 and 8%. This indicate that the modified bituminous concretes with 4% and 8% of NR are highly resistant to permanent deformation (rutting) in asphalt concrete. MQ (8%) is highest than MQ (4%).

The creep test was performed for the unmodified bituminous concrete and modified bituminous concretes at 4% and 8% of NR. The test temperatures were 25 °C, 40 °C and 60 °C. The constraints applied was 0, 14 MPa. Marshall specimens compacted at 50 blows per face were used. The modification of the bituminous concretes by the natural crumb rubber NR (by wet process) improves creep resistance at temperatures of 40 °C and 60 °C. The results show that:

- For the unmodified bituminous concretes, deformation increases with increasing temperature.
- For the modified bituminous concretes at 4% of NR, deformations decrease with increasing temperature.
- For 8% of NR, deformations decrease at 40 ° C but increase at 60 ° C. Deformations at 60 ° C are lower than those of the unmodified bituminous concretes.

By combining the Marshall test results with those of creep test, the mixtures with 8% of NR seems most powerful. Therefore the incorporation of 8% of NR improves behavior to permanent deformation (rutting) of bituminous mixtures.

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