RHEOLOGICAL STUDY OF ASPHALT MODIFIED WITH TATAJUBA'S WOOD

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Abstract. *The incorporation of polymeric materials in pavements is becoming increasingly common due to the gain of structural strength and reuse of discarded material in nature. In pavement is commonly used coating consisting of mixed ligand based oil and asphalt cement aggregate as pebble, sand, stone materials and cements. So there may be the inclusion of other materials that take years to deteriorate as post-consumer plastics, elastomers from tires and rubbish, wood, bricks, replacing or composition of paving materials. Among such materials are elastomers styrene-butadiene-styrene (SBS), styrene-butadiene rubber (SBR), natural rubber (NR) and the polymer that comprises all the elastomers mentioned, from tire retreading is the leftover, or that is, ground rubber from scrap tires. The main objective of this study is the evaluation of asphaltic layer with waste wood. In which follow the following steps: (1) shear mixture of sawdust, wood type tatajuba (bagassa guianensis), red quartz sand (RQ) and ground tire rubber (CR), (2) to prepare nine specimens of hot mix asphalt (HMA) second dosage Marshall in small scale, with composite tatajuba/quartz sand/CR dosage 20/2/10 by weight, (3) rheological characterization by Haake RS 6000 of parallel plates, scanning electron microscopy (SEM) and strength tests the maximum radial compression of the specimens to obtain the parameters of Marshall. The results showed that wood type tatajuba was inserted into the polymeric structure of rubber modifying the structure and rheological properties of the material in the composite increase of stability in mechanical testing, the intermediate values of relationship bitumen/voids in sample 3CP8. Thus, the applicability of the composite studied is satisfactory and environmentally friendly when it comes to the reuse of materials that replace natural fields.*
Keywords: *Tatajuba, HMA, SEM.*

1. INTRODUCTION

Tatajuba, "*Bagassa guianensis*" is a great upland tree that grows up to 60 m tall and can reach a diameter of 1.90 m, a species of Moraceae, edible fruit, slightly sweet. This type of tree usually occurs in very dense vegetation and among various species of trees, palms and shrubs. Madeira relatively heavy and of good quality, yellow heartwood when freshly cut, changing to yellow-burned when exposed to light for some time, the sapwood is pale yellow and distinct from the core, irregular grain, shrinkage during drying exceptionally small for a wood weight. It is resistant to insects and marine worms, thus has great potential for use in construction and outside deck. It has been cultivated as a source of cellulose, the species has a disjunct distribution, occurring predominantly in the Amazon state of Para is very rare in Rondonia. Currently, there is an intense exploitation by logging companies, because the quality of wood, Silva *et al.* (2008).

For the wood industries, it is appropriate and necessary waste recovery in helping to reduce storage areas, lower handling costs, reduced production costs and more efficient use of raw materials.

The study by Gomes and Sampaio (2004), the wood waste produced in one of the companies mentioned, is up to 15,000 cubic meters per year and 30% of the timber is stored in warehouses.

In flooring is commonly used coating consisting of mixed ligand-based oil and asphalt cement aggregate and pebble, sand, stone materials and cements. Replacement or composition of paving materials, may be the inclusion of other materials that take years to deteriorate as post-consumer plastics, elastomers from tires and debris from construction (Al-Hadidy and Qiu, 2009), among the materials already studied elastomers are styrene-butadiene-styrene (SBS), styrene-butadiene rubber (SBR), natural rubber (NR); Al-Hadidy and -Qiu (2009), Larsen *et al*. (2009), Yu *et al.* (2009), Lesueur (2008), Sengoz (2009), Zhang and Yu (2010), Gorkem (2009); and the polymer that comprises all elastomers cited, from tire retreading is the leftovers; Fang (2008), Xiao (2008), Shen (2008); or of ground rubber from scrap tires.

The aim of this study is to evaluate rheological coating with a mixture of asphalt modified by ground tire rubber, wood type *B. guianensis* and aggregates plus wood waste for use in flexible pavements.

2. MATERIALS AND METHODS

The asphalt was used CAP 50/70 (A) produced by Petrobras in its refinery located in Fortaleza, Ceará (Lubnor) and was tested as Furol Saybolt viscosity, density, softening point, penetration and flash point, whose Results are available in Tab. 1, Coelho (2009).

Table 1. Physical characteristics of the CAP 50/70

Tests	Methods	Results
Penetrtion (0,1mm)	DNER - ME 003/93	58
Viscosity type Saybolt in 160 ºC	DNER - ME 004/94	92
Real density (g/cm³)	DNER - ME 193/96	1.03
Softening point (ºC)	ABNT - NBR 6560/85	52
Flash Point (ºC)	DNER - ME 148/94	<340

The aggregates gravel and white sand pit, were extracted from a deposit located in the municipality of Santo Antonio do Taua in Para State, Brazil. Pebble (S) passing through the square mesh sieve No. 4 and white sand (Ab) of passing cava through sieve No. 40.

The aggregate red quartz sand (AQ) was extracted from Nova Timboteua in Para State, Brazil. The passing aggregate AQ in square mesh sieve No. 200.

The ground rubber tire (B) was extracted from retread used tire, stuck in square mesh sieve No. 80.

Wood type tatajuba (*B. guianensis*) (T) was comminuted through the mill with mortar / pestle motorized model MA-590, at a frequency of 6 Hz and a time of 71 minutes. The wood grain showed in passing square mesh sieve No. 100.

The rheological characterization of asphalt with T/AQ/B was made in a HAAKE, model RheoStress 6000, plate/plate with 35mm in diameter, sensor type PP35, thermal controller of the type RS 6000, a temperature of 180°C. In Tab. 2, the test doses of rheology in percentage of weight represented by ${}_{d}R^{e}$ (d, percentage of asphalt in the asphalt mix, and percentage of T/AQ/B in the mix with ligand).

Table 2. Strength test of rheology of compound A/B/AQ/T

(%)	${}_{7}R^{3}$	${}_{7}R^{4,5}$	${}_{7}R^{6}$	${}_{7,5}R^{3}$	${}_{7,5}R^{4,5}$	${}_{7,5}R^{6}$	${}_{8}R^{3}$	${}_{8}R^{4,5}$	${}_{8}R^{6}$
A	70.0	60.9	53.8	71.4	62.5	55.6	72.7	64.0	57.1
T	6.3	8.2	9.7	6.0	7.9	9.4	5.7	7.6	9.0
B	7.9	10.3	12.1	7.5	9.9	11.7	7.2	9.5	11.3
AQ	15.8	20.6	24.3	15.0	19.7	23.4	14.4	18.9	22.6

The Tab. 3 depicts the weight percentages of each aggregate constituent, in which we ${}_{a}C^{b}$ (a, represents the percentage of T and b represents the percentage of CAP 50/70 during the mix for each specimen tested). Figure 1 represents the aggregate grading curve compared with the track "C" specification DNIT 031/2004 - ES, rolling to coat with 4.5% to 9% of asphalt.

Table 3. Particle size of aggregates

Material (%)	Sieve (n°)	Opening (mm)	${}_{2}C^{7}$	${}_{3}C^{7}$	${}_{4}C^{7}$	${}_{2}C^{7,5}$	${}_{3}C^{7,5}$	${}_{4}C^{7,5}$	${}_{2}C^{8}$	${}_{3}C^{8}$	${}_{4}C^{8}$
S	4	4.8	51.36	51.09	50.29	51.33	51.06	50.26	51.84	51.03	50.22
Ab	40	0.42	44.94	43.60	42.80	44.88	43.54	42.73	44.28	43.47	42.66
B	80	0.18	0.19	0.30	0.40	0.19	0.30	0.40	0.19	0.30	0.40
T	100	0.15	2.01	3.01	4.01	2.02	3.02	4.03	2.03	3.03	4.05
AQ	200	0.075	1.01	1.51	2.01	1.01	1.52	2.02	1.02	1.52	2.03

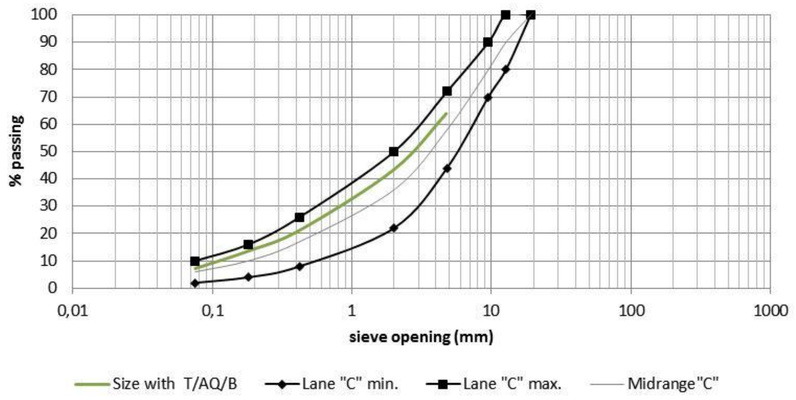

Figure 1. Aggregate grading curve

Initially it was made pre-mix B/AQ in weight fraction of 100/30 and T/AQ/B in weight fraction of 20/2/10, both mixed by a helical rod embedded in a high torque stirrer microprocessor model Q250M1 at a speed of 200 rpm for 12 min. and subjected to ultra-thermostatic bath model 521/3DE to 140ºC. Figure 2 shows the equipment used in the mixture.

Figure 2. Microprocessor and high-torque stirrer ultra-thermostatic bath

Mixes were made in molds made from metal for calculating the reduction of the diameter of the mold of Marshall specimens. In Fig. 3, the metal molds of the specimens.

Figure 3. Mini Marshall - Compactor (A) and molds (B)

We obtained the following dosage (D) equivalent to 20 g of the total sample divided into percentages of material, as shown in Tab. 4. The asphalt mix was performed according to standard DNER ME 043/95, a temperature of 180°C. Premixes were inserted CAP 50/70 wet.

Table 4. Dosage mini Marshall 2%, 3% and 4% of pre-mixes with Tatajuba

D (%)	${}_2C^7$	${}_3C^7$	${}_4C^7$	${}_2C^{7,5}$	${}_3C^{7,5}$	${}_4C^{7,5}$	${}_2C^8$	${}_3C^8$	${}_4C^8$
S	48.00	47.75	47.00	47.75	47.50	46.75	48.00	47.25	46.50
Ab	42.00	40.75	40.00	41.75	40.50	39.75	41.00	40.25	39.50
A	7.00	7.00	7.00	7.50	7.50	7.50	8.00	8.00	8.00
B	0.18	0.28	0.37	0.18	0.28	0.37	0.18	0.28	0.37
T	1.88	2.81	3.75	1.88	2.81	3.75	1.88	2.81	3.75
AQ	0.94	1.41	1.88	0.94	1.41	1.88	0.94	1.41	1.88

The specimens were tested on maximum resistance to radial compression standard based on the DNER ME 043/95, in press DL5.000 universal model, electromechanical, microprocessor, with a capacity of 5000 kgf (50 kN) to obtain the values of maximum force in Newton versus displacement obtained by the program of universal press to observe the total deformation in millimeters. In Fig. 4, the compression molding of reduced size, based on standard DNER ME 043/95.

Figure 4. Mini Marshall - Mold the radial compression

The test speed was 50 mm/min. for completion of the test was computed under a limit of 1226 N and limit displacement of 18 mm.

Samples showed the T/AQ/B before and after mixing the asphalt and aggregates traditional constituents. In order to examine the compatibility of the composite modified asphalt.

The equipment used was a scanning electron microscope (SEM) was used for morphological model LEO-1430. The samples were metallized with platinum coating and the time was 2.0 minutes. In the analysis of secondary electron images was due to the following conditions: electron beam current of 90 µA, accelerating voltage of 10 kV and constant working distance from 15 to 12 mm.

3. RESULTS AND DISCUSSION

Rheological analysis was performed with samples of different dosages, Fig. 5 indicates the different behaviors mediants dosages of Tab. 2, when analyzing the viscosity ($\eta(\dot{\gamma})$) as a function of shear rate and in Fig. 6 the complex modulus ($G^*(\omega)$) as a function of angular velocity.

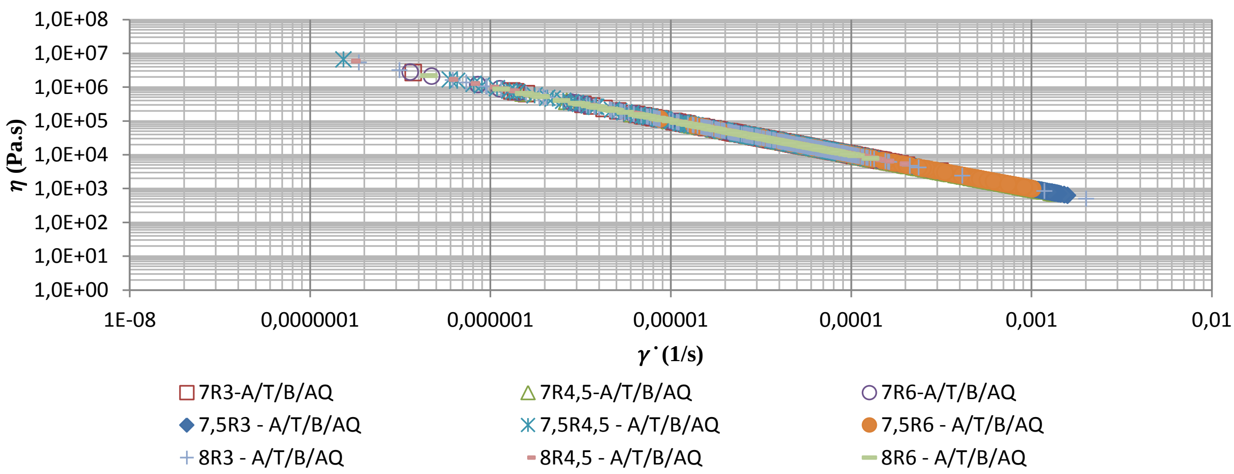

Figure 5. Viscosity ($\eta(\dot{\gamma})$) as a function of shear rate, samples $_7R^3$, $_7R^{4,5}$, 7R6, $_{7,5}R^3$, $_{7,5}R^{4,5}$, $_{7,5}R^6$, $_8R^3$, $_8R^{4,5}$ e $_8R^6$

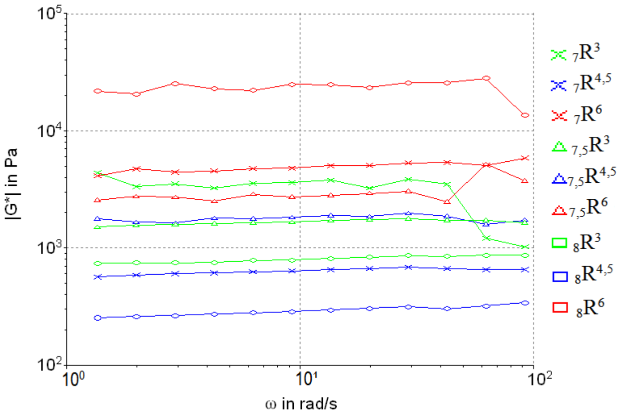

Figure 6. Complex modulus ($G^*(\omega)$) as a function of the angular velocity of the samples

The results for Fig. 5 and Fig. 6 show the best performance against the gain of yield strength with increase of T/AQ/B and ligand.

At first, aggregates of the mixture and asphalt were not engaged by ligand, due to reduced particle size, a higher percentage of fines was at first absorbed by the CAP. Thus, the sample had to be subjected to heat of 180°C to a new mixture, then yes, it was made samples mini Marshall.

Figure 7 contains the results of bitumen/voids, bulk density and air voids in accordance with the percentages of wood.

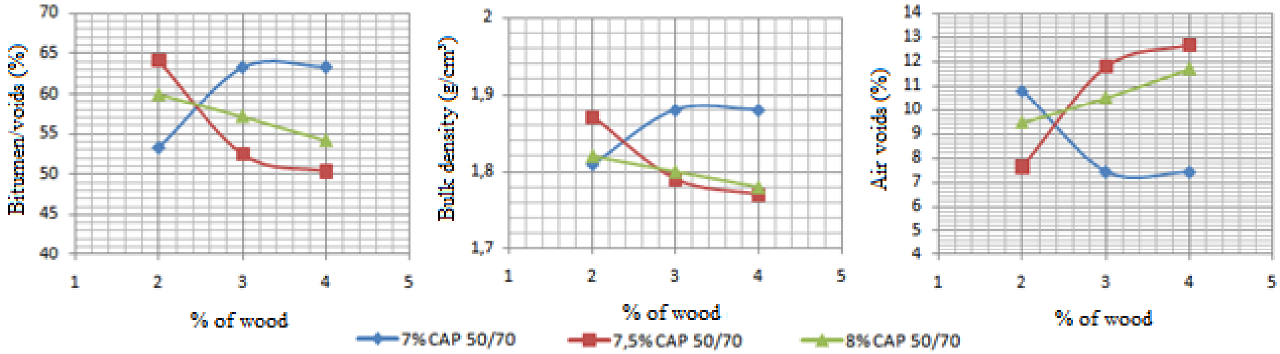

Figure 7. Volumetric parameters mini Marshall

The results of Marshall and mechanical parameters of compressive strength, in Fig. 8 and referring to specimens of Tab. 4 according to the percentage of wood.

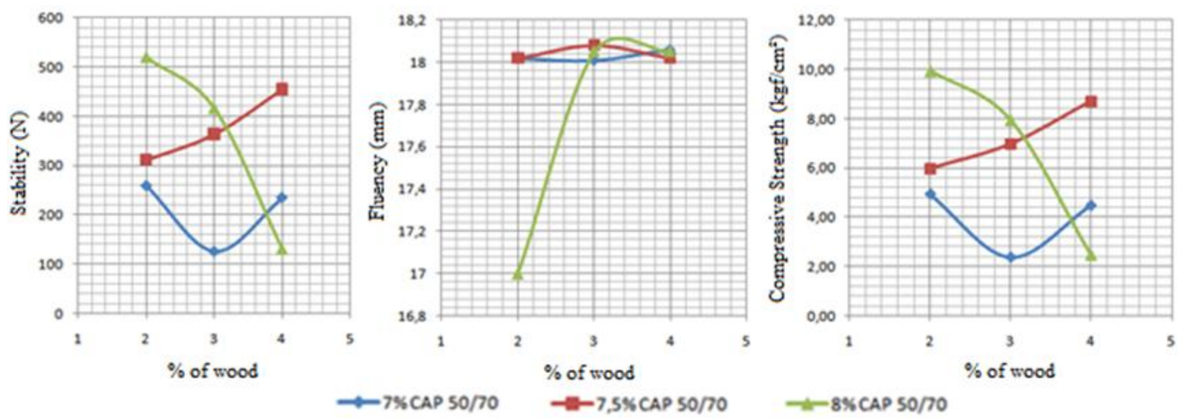

Figure 8. Mechanical parameters and resistance mini Marshall

The graphs in Fig. 7 and Fig. 8 show that higher the percentage of CAP 50/70 and a lower percentage of wood in the mixture of the compound T/AQ/B , the smaller the volume of empty and filled the greater the specimen with asphalt, and the greater the resistance.

In Fig. 9 images detected by scanning electron microscopy (SEM) to verify the adherence of the mixture studied.

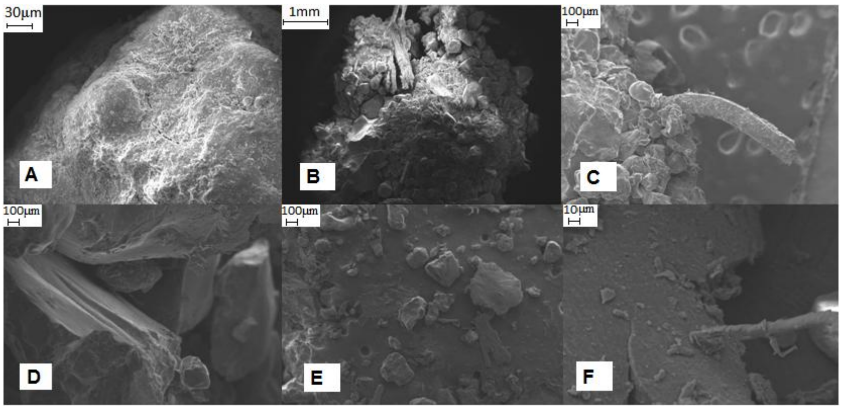

Figure 10. SEM – mini Marshall

Figure 9-A is the image of AQ, with approximation of 344x. In Fig. 9-B, we see the fractured surface of modified asphalt. Approximations, we can observe in Fig. 9-C adhesion between particles of wood type tatajuba with asphalt. Figure 9-F, shows the presence of *B. guianensis* bound structure of rubber. Figure 9-E is the fractured surface of modified asphalt in which we can view openings made after the test compression wood *B. guianensis*. Figure 9-D also features the presence of tatajuba, because it makes a tear in the rubber surface, both linked to the modified asphalt.

4. CONCLUSIONS

In the rheological analysis, the increase in yield strength versus low shear rates is larger when we mix weight percent T/AQ/B in the asphalt, as well as higher percentages of T/AQ/B in the asphalt, increase the stiffness of the material difficult flow between aggregates. That is, the strength values are higher mixtures made with the highest percentage CAP and smaller percentages of the compound T/AQ/B in the asphalt, better involvement of the ligand compound modified and aggregates. The insertion of *B. guianensis* wood on asphalt improves physical contact between the particles formed and aggregates of the compound constituted of rubber.

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