Mechanical Property of Asphalt Pavement Recycling with Using Prototype Asphalt Plant Reduction Scale

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ABSTRACT: The hot recycled asphalt mixtures, can fit among alternative materials for working with very hard asphalt and gains feedstock with environmentally friendly and inexpensive. One of the main problems to be solved in practical activities of recycling asphalt concrete is the need for frequent addition of a new stone aggregates the milled material framework for obtaining grain size of asphalt mixture obtained (recycled). This paper presents the mechanical behavior of recycled asphalt mixtures in the laboratory determined first and later in the field, using a small-scale prototype plant, hot machining. This is a new equipment in reduction scale that the type is circular mixer containing heating plates at the bottom, and called J1000, which details are given in the paper. A laboratory study and field study was developed about the asphalt concrete dosage that containing asphalt pavement recycling, asphaltic cement (AC) of polymer, lime and grinded tire rubber, without the addition of new stone material. Two results of the mix dosage are presented and the first being obtained in the laboratory and the other obtained in the prototype asphalt plant in reduction scale, and it contains aggregates usually used to pavement construction in Três Rios city, RJ/Brazil. The results of the asphalt binder characterization and the short time aging using drying oven RTFOT, the recycled mix grading, tensile strength and resilience modulus. It shown that the prototype asphalt plant in reduction scale is able to produce recycled asphalt mixture with satisfactory quality, and can be used in tropical countries.

KEY WORDS: Guidelines, abstract, title, text, figures.

1 INTRODUCTION

In Brazil, the years of 1985 and 1986 were considered as landmarks when it comes to the attempt to introduce the processes of hot asphalt mixes recycling, with works at Anhanguera Highway (SP), with the use of cold milling and hot recycling in central plant, and at Dutra Highway, with the usage of preheated equipments, milling and recycling, completely *in situ*. There are no evidences, at least in the expansion of normatives from 1988, that such process, of great environmental interest in the most technologically developed countries, has gained space in the country, except from the non-documented sporadic experiences in urban roads, with the introduction of milled materials in a mixing plant, or roads, with recycling *in situ* (Balbo and Bodi, 2004).

In the attempt to reduce environmental passives and incorporate the advantages of a polymer to the asphalt binder, the present study brings as an innovation the dimensioning of a plant prototype in reduced scale, named J-1000, which produces asphalt mix from the recycling of asphalt concrete by the dry process.

Modern companies, notoriously the ones which operate complex systems and with a strong potential to environmental impacts, have been trying to reach and maintain an Environmental Management System (EMS), adequate to its economical purposes, aiming, thus, a safeguard regarding to its own commercial, financial and legal interests which may determinate major difficulties to the consolidation or maintenance of its positions at the market, undermining its growth and even its survival (DNIT, 2006).

The Federal Constitution enacted in 1988 contemplates the environmental issue, bringing to the article 225 the following affirmation: "all have the right to an ecologically balanced environment, which is an asset of common use and essential to a healthy quality of life, and both the Government and the community shall have the duty to defend and preserve it for present and future generations."

In Brazil, studies and researches have been developing and innovating techniques of alternative aggregates to the incorporation of asphalt, hence, allowing these to be used on works of paving all over the country. In the state of Rio de Janeiro the technique incorporates alternative aggregates in asphalt production, and it has especially been used in several works of state roads, obtaining satisfactory results which have been motivating correct environmental researches, searching for new technologies and alternative aggregates to paving engineering.

The aim of this work is to present the technological advance of a plant prototype in reduced scale, developed to machine recycling from hot asphalt concrete (milled). Hot recycling uses the Milled Asphalt Product (MAP), which comes from roads or streets with irregularities in their pavements, by adding AsphaltIC Cement (CAP) and rubber from unserviceable tire (dry process), without the necessity of adding other mineral materials and filler. This technology has advantages for its low consume of energy, facility of installation and operation, machining of asphalt recycling as well as the mix temperature conservation, presenting thus satisfactory results. It is a sustainable technique in favor of city halls all over Brazil.

2 RECYCLED ASPHALT MIXES

When an asphalt pavement in use becomes structurally damaged, there is the necessity to restore its cargo capacity through the addition of new thicknesses added of layers or through the cut of whole or part of the damaged concrete by a specialized equipment (miller) and execution of a new layer of asphalt concrete.

Milled materials of asphalt mixes are especially present in big and average cities, when urban pavement restoration concerns to important demands such as the raising of the road platform grade, which would cause undesirable situations especially with doorstep, sidewalks and gutters, besides other interferences. It is possible that it might have occurred and it has been occurring, not officially, a reuse of milled materials in a small part of the preparation of new asphalt mixes (Balbo and Bodi, 2004).

The material generated in the cut (figure 1) can still be reused by recycling. From the environmental point of view, the reuse of materials makes unnecessary the exploration of new raw materials sources, still fulfilling the basic premises of environmental management, besides eliminating costs.

Figure 1: Milled material pile in the region of Três Rios/ RJ, Brazil.

It is understood by paving recycling the process of reusing old and damaged asphalt mixes in order to produce new mixes, taking advantage of reminiscent aggregates and binders, which come from milling, with the add of renewing agents, asphalt foam, CAP or new Petrol Asphalt Emulsion (PAE), and when necessary there is also the add of hydraulic agglomerates (Bernucci *et al.*, 2006).

Complete recycling, including old CAP of the removed materials from concretes and from pavement asphalt layers, would result in several savings concerned to the investments of road infrastructure, such as materials and energy in the production of materials, besides, it would also protect environmental aspects such as the preservation of raw material, even the minimization of existing fissures reflection to layers of reinforcement placed over the already existing pavement (Peres and Balbo, 1998).

Milling is the operation used to cut asphalt concrete of the roads, its part or its whole, through the use of special machines (milling machines), or even through the attachment of another layer of pavement, as a way to restore the quality to the rolling surface, or of the improvement the support layer, as shown in figure 2. Recycling in asphalt concrete has been very used in works of paving either in Brazil or all over the world, motivating frequent studies in the area which have been contributing to excellent constructions that aggregate the milled. Therefore, it is necessary to at least investigate rationally how to employ such material, taking into consideration its potentialities.

Recent laboratory studies made previously show that, in terms of conventional dosage parameters and test of wheel tracks formation in laboratory, the increase of 10% of milled material to new asphalt mixes did not incur in alterations in at the potential plastic material deformation, enabling its indication, in the worst case, as partially recycled material, in order to be employed in pot-hole filling operations (Garrido and Balbo, 1997).

Figure 2: Miller and milling service on a road (Bernucci *et al.*, 2006).

Usually the aggregates of an old mix maintain its physical characteristics and of intact mechanical resistance, whereas the asphalt binder, its characteristics are modified, becoming more viscous in such condition. It is possible to totally reuse the crushed or cut by the milled material and recover the binder characteristics with the addition of renewing or recycling agents. Recycling can be made (Bernucci *et al.*, 2006):

- hot, by using CAP, renewing agents (RA) and heated aggregated milled;
- cold, by using PAE, emulsified renewing agent (ERA) and milled aggregates to the ambient temperature.

It can be done in (Asphalt Institute, 1989):

- plant, hot or cold – the milled material is taken to the plant;
- *in situ*, hot or cold – the milled material is mixed with a binder in the own place of the cut, it can be heated (CAP), or cold (PAE) by an equipment specially conceived to this purpose;
- *in situ*, with asphalt foam. In this case a part of the base can be incorporated to the old concrete, with or without the adding of hydraulic binders, forming a new base which will be concreted by a new asphalt mix as rolling layer.

The techniques used to recycling, are mainly constituted of a history of experiences in the country. There are specifications such as DNIT 033/2005 a, and DNIT 034/2005 b which refer to the requirements which will be submitted to recycling in plants or *in situ* recycling.

3 ASPHALT PLANTS

Engineering market in its totality has been progressing in terms of technology and technique, improving the already used methods and conquering innovative methods. The growth of paving engineering area, the execution of works all over the world and also in our country has been resulting in a growing demand of its execution, which has been bringing new instruments, paving equipments, which have been highlighted with cutting-edge technology.

3.1 The equipment developed

In a figure 3 to 5 are presented some general aspects of the prototype in a reduced scale denominated J-1000, which was developed to previous researches of asphalt recycling, considering the total of reusing of the milled material. This equipment consists, basically, of a unique cylindrical piece, settled on a hot plate whose temperature can increase to even about 160ºC, as can be seen at figure 3.

Due to the fact that it is a prototype equipment, the capacity of production is limited to 1 ton/hour of milled material. In its interior there is a system of driving rods of different shapes, as shown in figure 4, which produces the homogenization of the mix. The prototype plant has advantages of easy locomotion and installation on work sites, enabling the production and handling of the asphalt mass to be produced. The prototype is fed by electrical energy.

Figure 3**.** General aspect and Interior of the Prototype in reduced scale.

Figure 4. View of the mixing pallets and homogeneous aspect of the mix obtained by the equipment J-1000.

In the sequence of the operations, the sample of the milled material is at first introduced with the equipment previously turned on, being homogenized and heated at the same time. At this stage of the heating, it is possible to verify that part of binder that involves the milled aggregate starts to se detach from the mix.

After the filler is added to the mix (cement or lime), the unserviceable tire grounded rubber and last, the CAP-polymer that was heated to the temperature of project in an attached device to the equipment J-1000. All the compounds are mixed by a short period of time, about thirty minutes, in order to guarantee the mass homogeneity, shielding it, to keep the adequate temperature, which is unloaded of the equipment by gravity through a device of discard located in the inferior side of the plate.

In the tests executed, in field (trace I) and at the laboratory (II), specimen were molded, which were submitted to tests of Resilience Module (RM) and Traction Resistance by Diametrical Compression (TR) which followed the procedures approached by the methods of test of the National Transport Infrastructure Department (DNIT 135/2010 a; DNIT 136/2010 b), with the specimens to a temperature of 25ºC, presented at item 5. Besides the elaboration of the specimens, a small repair with the mix (trace II) was done, as shown in a figure 5, a good appearance of the material can be observed.

Figure 5. Aspect of the recycled mix compacted and leveraged from the device of mass discard.

Figure 6 and 7 show the asphalt mixtures recycling plants in real scale in two different sizes, still under final construction at the company SOMA’s Engineering, in the city of Três Rios in the Rio de Janeiro at Brazil. The machining ability is to recycle asphalt mixtures like a real asphalt plant (60 ton / hour to 100 ton / hour, respectively) that having the same basic characteristics of the prototype, while some observations have been corrected, as the energy of support that the prototype is electric and conventional asphalt plant is gas.

Figure 6. Asphalt mixture recycling plant in real scale – Type I

Figure 7. Asphalt mixture recycling plant in real scale – Type II

4 METHODOLOGY

The method adopted in this work consisted on the elaboration of two traces of asphalt concrete containing milled material, unserviceable tire grounded rubber, AC-polymer and filler (lime), being considered the grading of the used materials line “C” with the use of mold and Marshall socket, according to the specifications of the extinct National Highway Department DNER-ME 043/95 (DNER, 1995) applying 75 blows by face and temperature of compaction of 160ºC.

For the first trace it was initially made the study of dosage in the laboratory and then the dosed mix (test II) was executed in field, by using the equipment J-1000. At test I it was used a lime filler and AC-polymer, besides the milled and the grounded tire rubber. The second test was the same, but it executed in field, using the prototype J-1000. Through the elaborated specimens it was possible to analyze the volumetry and mechanic behavior of the mix developed, considering the tests of tensile strength and resilience modulus.

5 RESULTS

At table 1 are presented the values of aggregate’s gradings, of the mix referring to test I and II, which contains the milled, unserviceable tire rubber and lime (filler) in DNIT line “C”, where it is possible to observe, with the graphic of figure 8, a good grain size framework in this line. In the graphic presented at figure 8, it is observed that the gradings curve obtained for the mix is lightly distinct of the average curve of line “C”.

Table 1**.** Aggregate’s Gradings– Test I and II.

% Passing #		Milled		Rubber		Filler		DNIT Faixa C		Gradings curve
(pol.)	(mm)	Gradings	(%)	Gradings	(%)	Gradings	(%)	min.	max	
1 1/2"	38	100,00	94,00	100,00	3,00	100,00	3,00	-	-	100,0
1"	25	100,00	94,00	100,00	3,00	100,00	3,00	-	-	100,0
3/4"	19	100,00	94,00	100,00	3,00	100,00	3,00	100	100	100,0
1/2"	12,7	88,00	82,72	100,00	3,00	100,00	3,00	80	100	88,7
3/8"	9,5	79,00	74,26	100,00	3,00	100,00	3,00	70	90	80,3
n.º 4	4,8	54,00	50,76	100,00	3,00	100,00	3,00	44	72	56,8
n.º 10	2	30,00	28,20	100,00	3,00	100,00	3,00	22	50	34,2
n.º 40	0,42	12,00	11,28	46,00	1,38	100,00	3,00	8	26	15,7
n.º 80	0,18	6,00	5,64	7,00	0,21	100,00	3,00	4	16	8,9
n.º 200	0,075	2,00	1,88	1,00	0,03	89,00	2,67	2	10	4,6

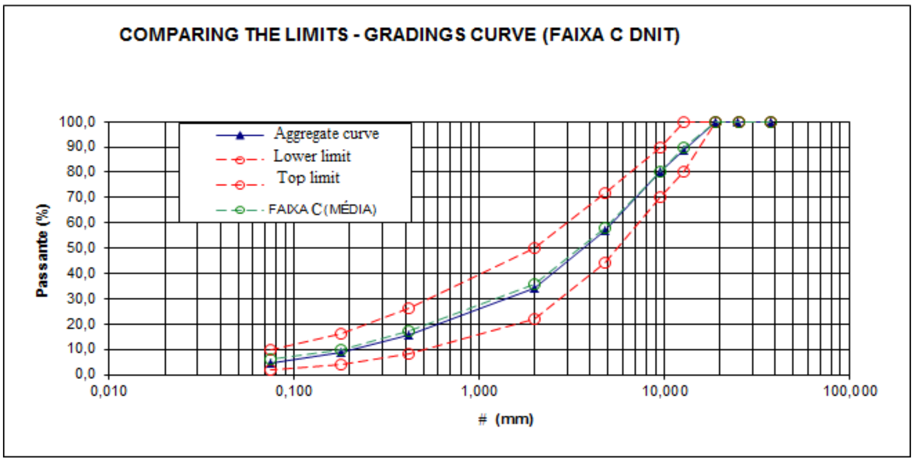

Figure 8. Gradings curve of the used materials – DNIT line “C” – Test I.

At table 2 it is presented the percentages of the aggregates used at the Marshall dosage to trace I and II, in which can be observed the high level of milled material as well as the variation from 3% of tire rubber level.

It is important to highlight that in general, when working with recycling of milled material, it is usually added a fraction of thin material, for instance, powder/ crushed dust. Nevertheless, in this work, the main focus is exactly the non-utilization of powder/ crushed dust in the recycled mix, an ecologic option by the grounded tire rubber. However, it was opted to compensate as an eventual fragility of the grain size composition of the mix with the adding of cement or lime.

Table 2. Percentage of the aggregates – Test I and II.

Percentage Aggregates		
Milled	Rubber	Filler
94%	3%	3%

The specimens molded at test I and II were submitted to tests of Tensile Strength by Diametrical Compression, which are presented at tables 3, with the respective results. In test I, molded with level lime (filler) of 3%, it was verified a variation between 1.32 and 1.34 MPa, that can be considered satisfactory values, and for such reason it was opted to make test II to compare the both. In test II, the specimens were molded with a level of 3% of hydrated lime (filler) and a level of 5.5% respectively of binder AC. The Tensile Strength varied between 2.23 and 2.37 MPa.

Table 3. Tensile Strength (TS) – Trace I and II.

Resilience Modulus (RM)							
Test I				Test II			
Test Piece	TS (MPa)	AC (%)	Filler (%)	Test Piece	TS (MPa)	AC (%)	Filler (%)
1	1.34	5.5	3	2	2.23	5.5	3
2	1.34	5.5	3	9	2.28	5.5	3
3	1.32	5.5	3	26	2.37	5.5	3

The resilience modulus obtained to test I, presented values between 4,163 and 5,624 MPa, as shown in table 4, which can be considered expressive values, as well as it was observed to the values of TS, due to the high level of filler used in these tests. At this point, it must be clear that the authors did not aim the procurement of an asphalt mix with such toughness, being a consequence of preliminary studies.

In test II, molded with dehydrated lime, it was presented values of resilience modulus of 5,747, 6,043 and 6,390 MPa, to the levels of 5.5% of AC-polymer respectively. These values can be considered relatively satisfactory, however, not very distinct from those obtained to asphalt mixes with AC-polymer and line “C” (DNIT). Thus, the resilience modulus behavior of the asphalt concrete of trace II can be considered satisfactory.

Table 4. Resilient module (RM) – Trace I and II.

Resilience Modulus (RM)							
Test I				Test II			
Test Piece	RM (MPa)	AC (%)	Filler (%)	Test Piece	RM (MPa)	AC (%)	Filler (%)
1	5,624	5.5	3	2	6,390	5.5	3
2	4,163	5.5	3	9	5,747	5.5	3
3	4,840	5.5	3	26	6,043	5.5	3

6 CONCLUSIONS

Mechanical and operational features of a prototype of asphalt concrete mixer with a warming system attached to it, denominated J-1000, have been presented here, which was specially developed to asphalt mixes recycling, being elaborated a test mix in the field, denominated test I.

The mix denominated test I, although it had been shown as homogeneous and it had been compacted in a satisfactory way, was designed with a high level of lime, generating great values to the Tensile Strength – between 1.32 and 1.34 MPa – and the Resilient Module – between 4,163 and 5,642 MPa. The mix test II, shown values to the Tensile Strength – between 2.23 and 2.37 – and the Tensile Strength – between 5,747 and 6,390. The both tests presented greats values for the test of Tensile Strength and Resilient Module like than others which the authors found the literature.

For this reason, it was developed a new mix called test I and test II, still restrict to the laboratory stage and field by using J-1000, containing milled, rubber and lime, and the values of Tensile Strength and Resilient Module obtained are compatible to the ones observed in the literature to this sort of mix. The authors comprehend that the prototype equipment developed is of a promising use in road engineering and the research will continue to be developed from the machining of others tests in the field and of the construction of experimental stretches.

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