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ANALYSIS OF THE PROPERTIES OF ASPHALTIC CONCRETE USING RECYCLED AGGREGATES OF CDW

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Abstract. This study aims at investigating the feasibility of the partial replacement of aggregates of asphaltic concrete by recycled aggregates from construction and demolition waste (CDW). It was adopted as parameter a project design mixture of an asphalt concrete used in the construction of Itaueira-Canto do Buriti state highway (Piaui). Two project mixtures were used: in the first 38% of the natural aggregate were replaced by the recycled aggregate and in the second, 70%. We carried out the characterization of the aggregates through physical, chemical and mechanical testing analyzing them based on specific reference standards of paving. We performed assays related to the asphaltic mixture with CDW determining the apparent specific mass, the volume of voids, the relationship bitumen/voids and mechanical testing of traction resistance by diametric compression and Marshall Stability. The results indicate that the recycled aggregate, in a defined proportion, can partially replace natural aggregate in flexible pavements.

Introduction

The Construction Industry is recognized as one of the most important activities for the economic and social development, but on the other hand, still behaves as major generator of environmental impacts [1]. In most countries of the world, is widely used the asphaltic coating layer as road pavements and urban, among others. In Brazil, more than 95% of the roads are paved with asphaltic coating, and it is also used in the majority of urban roads [2].

The aggregate that is used in asphalt mixtures is usually obtained from crushing rocks like basalt, granite, gneiss, limestone, among other types and that are exploited and turned into gravel with various sizes and specific grade [3]. The construction and maintenance of asphalt pavements require large amounts of aggregates, which usually account for more than 90% of the weight of asphalt mixtures [4].

The production and sale of asphalt binder by Petrobras for the application in infrastructure in Brazil registered a record in 2010, having been produced 2.763 million tons of asphalt, an increase of 32% compared to 2009, which leads to estimate a consumption of approximately 35 million tons of aggregates extracted from natural reserves to use in hot mixtures [5]. Moreover, in 2011 the production of CDW (Construction and Demolition Waste), increased 7.2% over 2010, reaching 33 million tons in Brazil [6], which is disposed mostly in municipal and private landfills, and irregular areas of "send-off".

The increasing consumption of natural aggregates and increasing production of CDW have led to the consolidation of recycling techniques. The use of recycled aggregates in asphalt mixtures has been an interesting topic for the protection of the environment and sustainable development [3].

Joining forces with Resolution No. 307 of CONAMA (National Council of the Environment), which sets forth guidelines for effective reduction of environmental impacts caused by the CDW, in 2010 Brazil approved the National Policy on Solid Waste (NPSW) which defines how the nation should dispose their waste, encouraging recycling and sustainability. In this context, waste recycling is critical to implement a model of sustainable development capable of meeting the needs of the whole population of the present without compromising the ability of future generations to survive [7].

Thus, this work aims at the recycling of the CDW as aggregates for production of hot machined asphaltic concrete (CAUQ). There were two mixture projects where in the first was replaced 38% and in the second 70% of the natural aggregate by recycled aggregate.

Materials and Methods

The present research had as its parameter the design mixture of an asphaltic paving type AC (asphaltic concrete) following the specifications of the National Department of Transport Infrastructure (DNIT – ES 031/2006), which was performed by Construtora Success S/A , stretch between the towns of Itaueira and Canto do Buriti (Piaui).

Asphalt Binder: The Petroleum Asphaltic Cement (PAC) used in this research was provided by Construtora Success S/A, which was acquired from the Northeastern Lubricants and Petroleum Derivatives Company - LUBNOR, a Petrobras refinery, located in the city of Fortaleza - CE. We used the PAC 50/70, which presented its features within the specifications of the National Petroleum Association (NPA).

Aggregates: The natural aggregates, Brita 19 mm (B-19), Brita 9.5 mm (B-9.5) and Brita powder (BP) used in the implementation of the highway were acquired from the construction company own mining, located in the city of Angical - PI and the washed sand (WS), extracted from the Salinas Creek, located at the place of execution of the stretch, Itaueira - PI.

The recycled aggregates from CDW were collected in four (4) work sites located in different districts of the city of Teresina and consisted of waste concrete, asphalt, tiles, bricks, grout, slabs, ceramic tiles and stones, discarding plaster, wood, glass, metal and plastic fittings. The CDW collected was crushed in a Remanso crusher (also owned by Construtora Success, located on the road connecting Teresina to Palmeirais), on granulometry similar to natural aggregate, which was named as: recycled residue 19 mm (RR-19), recycled residue 9.5 mm (RR-9.5) and Powder Residue (PR).

The material was characterized according to national specifications and obtained the results shown in table 1, which were compared to the minimum required by the standard DNIT-ES 031/2006.

Table 1 – Characterization of the Aggregates

Characteristic	**Method**	**Limits[DNIT-ES 031/2006]**	**Recycled Aggregate**	**Natural Aggregate**
Real Relative Density [g/cm³]	DNER-ME 084/95 -	-	RR-19: 2.445 RR-9.5: 2.369 PR: 2.381-	B-19: 2.748 B-9.5: 2.808 BP: 2.697 WS: 2.600
Apparent Relative Density [g/cm³]	DNER-ME 081/98 -	-	RR-19: 1.469 RR-9.5: 1.423 PR:1.610 -	B-19: 1.500 B-9.5: 1.495 BP: 1.486 WS: 1.500
Los Angeles Abrasion [%]	DNER-ME 035/98	50% max	RR-19: 42% RR-9.5: 38%	B-19: 14% B-9.5: 14%
Absortion of the Coarse Aggregate [%]	DNER-ME 081/98	-	RR-19: 3.8% RR-9,5: 4.8%	B-19: 0.6% B-9.5: 0.7%

Shape index	DNER-ME 086/94	0.50 min	RR-19: 0.90 RR-9,5: 0.88	B-19: 0.80 B-9.5: 0.56
Durability [%]	DNER-ME 089/94	12% max	RR-19: 10% RR-9.5: 9.5%	B-19: 6.0% B-9.5: 6.5%
Adhesion to Betumen/Binder	DNER-ME 078/94	-	Fair	Fair

Mixture: We used the track "C" of the service specification DNIT ES-031/2006, because it was adopted for the implementation of the AC on roads. The mixture 01 comprises the trait composed only of natural aggregates adopted for implementing the highway and mixtures 2 and 3 are composed partly of recycled aggregate, totaling 38% and 70%, respectively. The blends that showed an amount of fines (fillers) low adopted the Portland Cement (PC), so that there were fitting in the granulometric limit chosen (Fig. 1). The proportions of aggregates at 100% weight were:

Mixture 1 – 15% B-19; 30% B-9.5; 25% BP; 28% WS; 2% PC

Mixture 2 – 10% RR-19; 28% RR-9.5; 30% BP; 30% WS; 2% PC

Mixture 3 – 14% RR-19; 28% RR-9.5; 28% PR; 30% WS

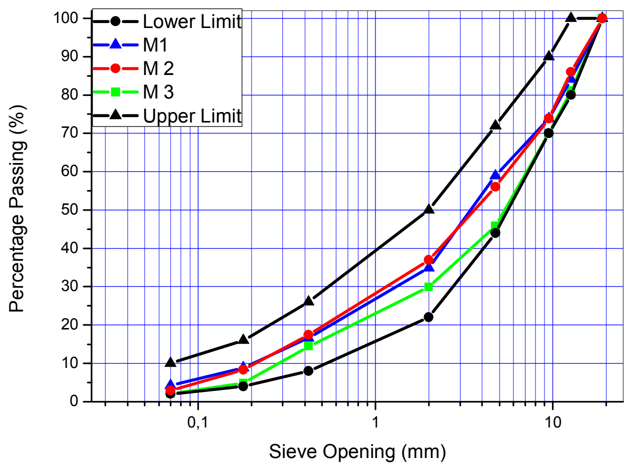

Fig. 1 – Granulometric Curves of the Mixtures and Limit C of the Standard DNIT ES-031/2006

In preparing the mixture, we followed the Marshall method, as determined by the standard DNER-ME 043/95. First, were heated separately the PAC 50/70 at 165 °C and the aggregates at 175 °C, and then manually mixed to obtain homogeneity of the mixture. The samples were compacted by the Marshall method, resulting in regular cylindrical bodies-of-evidence with 100 mm diameter and 63.5 mm in height. In the compression were adopted 75 blows per face and mixture temperature at 145 ºC. To each mixture were used five different percentages of binder in order to find the level to which the mixture would meet all the requirements imposed by the standard DNIT-ES 031/2006, for bearing layer (Table 2).

Table 2 – Limit Values of Standard DNIT-ES 031/2006

Characteristics	**Assay Method**	**Bearing Layer**
Percentage of Voids, %	DNER-ME 043	3 a 5
Relationship Betumen/Voids	DNER-ME 043	75 a 82
Stability, minimum, [Kgf], [75 blows]	DNER-ME 043	500
Resistance to Traction by Diametric Comp. at 25º, minimum, Mpa	DNER-ME 138	0.65

Results and Discussion

Aggregates: It is observed in Table 1 that the recycled aggregate used has lower density values and absorption higher than natural aggregate. Gouveia et al. (2008) concluded that the absorption of the aggregate, as a function of density, is directly related to the percentage of interstices (pores) of the crystal mass of the particles. Thus, it can be concluded that the recycled material is much more porous than natural aggregate, which results in a lower density and higher absorption than the virgin material (natural). A porous aggregate will absorb a larger quantity of asphalt binder to give cohesion to the mixture, thus the recycled aggregate will consume a greater amount of PAC than the natural aggregate.

The standard DNIT-ES 031/2006 specifies that the wear resistance of the coarse aggregate be equal to or less than 50%. Observing Table 1, in the abrasion test to Los Angeles, the recycled aggregate had a higher wear compared to the natural aggregate, which leads to the conclusion that the natural aggregate is much more resistant than the recycled one, but the latter is still within the limit allowed by the standard.

The standard DNER-ME 086/94 determines the shape index, which characterizes the shape of the particles. Bernucci et al. (2008) states that this ratio varies from 0 to 1, being the aggregate considered of optimal cubicity when f = 1.0 and lamellar when f = 0.0. The standard indicates the minimum limit of 0.5 for flexible pavements. Thus, the CDW is more cubic than conventional aggregate, showing better interlocking between grains compressed.

Mixture: After making bodies of evidence, some volumetric parameters were calculated in order to define the dosage that meets the minimum requirements of the DNIT specification (Table 2) and that has a better cost-benefit, with a lower percentage of binder, as the PAC is the most costly component of the mixture. It was calculated the apparent specific mass of the mixture (G_{mb}) (Fig. 2a), the void volume (V_v) (Fig. 2b) and the ratio bitumen/voids (RBV) (Fig. 2c). The bodies-of-evidence composed of natural aggregates showed higher apparent density, lower voids volume and higher bitumen/voids relationship than the bodies-of-evidence with recycled aggregates, due to the low porosity of the natural material when compared to the recycled material.

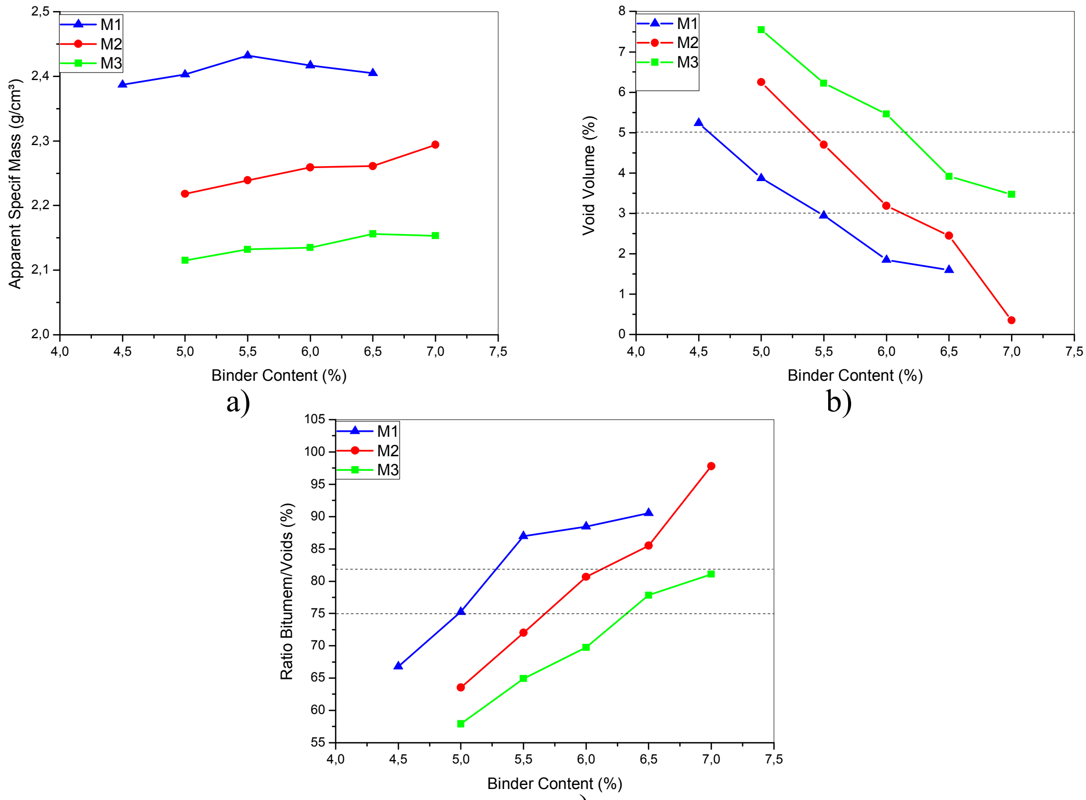

Fig. 2 - a) Apparent Specific Mass of the Mixtures, b) Volume of Voids of the Mixtures c) Relationship Bitumen/Voids of the Mixtures.

The Marshall stability (Fig. 3a) and the traction resistance by diametrical compression (TR) (Fig. 3b) decreased with increasing substitution of natural aggregates by recycled aggregates, whereas the characterization of aggregates showed that the natural aggregate is more resistant than the recycled.

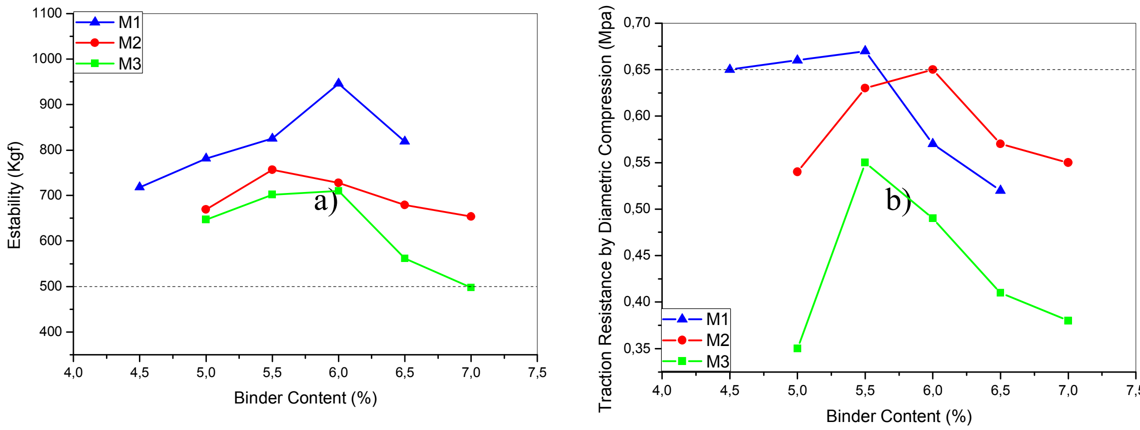

Fig. 3 - a) Stability of Mixtures b) Traction Resistance by Diametric Compression of Mixtures

The concentration of PAC that meets national specifications, in mixture 01, was 5.0%, whereas in mixture 02 (38% of CDW) was 6.0% and mixture 03 (70% of CDW), thus, there was no percentage that met the limits of the standard because the TR with all levels of PAC was less than 0.65 MPa (Table 3).

Table 3 – Values obtained from assays required by the standard DNIT-ES 031/2006

Characteristics	Mixture 1	Mixture 2	Mixture 3
Concentration of PAC	5%	6%	6.5%
Percentage of Voids, %	3.87	3.19	3.92
Relationship Bitumen/ Voids	75.25	80.65	77.82
Stability, minimum, (Kgf), (75 blows)	781.3	727.9	561.5
Traction Resistance by Static Diametrical Compression at 25º, minimum, Mpa	0.66	0.65	0.41

Conclusions

The characterization of aggregates showed that recycled aggregates have good features to meet the requirements on all items. It was observed, in most trials, that the recycled aggregate does not have characteristics as satisfactory as the natural aggregate, but the important thing is that it is within the limits allowed by the rules. Therefore, there is the feasibility of using CDW in the production of asphaltic concrete, provided that it be studied the maximum percentage of this material that can be employed.

The mixture 3, comprising 70% of aggregates of CDW, despite having good volume of voids (Vv), relationship bitumen/voids (RBV) and stability, did not meet the requirements of the standard DNER-ME 138 of traction resistance by diametrical compression in any of the traits used, being this design mix discarded for use in AC.

The mixture 2, comprising 38% of aggregates of CDW, showed that it is technically feasible to use CDW in flexible pavements, but should still be analyzed the economic viability since the recycled aggregate showed an absorption greater than the natural aggregate and the consumption of (PAC) was considerably higher. While in the mixture of natural stone aggregate the consumption of PAC was 5%, in the mixture with CDW was 6.0%. However, in regions where there is a shortage of natural stone aggregate, the use of aggregates of CDW becomes economically viable.

It should also be taken into consideration the environmental factors, since a percentage ranging between 50% and 70% of urban solid waste consist of CDW, the use of this material in asphalt coatings is an appropriate way to give a final disposition of this residue without causing further damage to the population and the environment [9].

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