Performance of Cold Mix Asphalt (CMA) with Addition of Recycled Asphalt Pavement (RAP)

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ABSTRACT

According to the National Transportation Confederation (Brazil), in 2014 almost half of the roads of the country has been classified as regular, bad or horrible. Therefore, it is necessary to constantly make repairs and rehabilitations, generating costs and solid wastes. The use of Recycled Asphalt Pavement (RAP), which is incorporated into new layers during the rehabilitation, offers a sustainable alternative to this problem. Moreover, the use Cold Mix Asphalt (CMA) instead of Hot Mix Asphalt (HMA) saves energy, showing an economic and environmental friendly alternative. In this proceeding, four different types of mixtures with cationic asphalt emulsion were evaluated, one with virgin aggregates and the others containing different amounts of RAP. Parameters from the main Brazilian specifications and the Superpave requirements were observed. Then, the following tests were carried out: Marshall's Stability and Flow, Splitting Tensile Strength of Cylindrical Specimens and Resilient Modulus. Results showed that the addition of RAP on the cold mix asphalt with ordinary emulsion is more advantageous when the content of RAP is equal to 7.5%.

Keywords: RAP, Superpave, Asphalt Emulsion, Dosage Marshall.

1. INTRODUCTION

1.1 The Highway Network in Brazil and in the World

From the 1,720,756 km of highways in Brazil nowadays, only 211,468 km are paved (12.3%). The density of road infrastructure is 24.8 km per 1.000 km² of area, which is very low compared to other countries. The US, for example, has 438,1 km per 1.000 km² of area. [1] In addition, 57.3% of the public paved roads have deficiencies in the pavement surface, traffic signalization and geometric design. These inadequacies can raise the operational cost of trucking, for example, by up to 91.5%. The average increase in Brazil is 24.9%. [1]

After the construction, a road will always be subject to deformation mechanisms such as rutting and cracking. As a result, many parts of the road reaches the end of their service life, needing to be totally or partially remade.

According to the National Transportation Confederation (Brazil), in 2014 almost half of the roads of the country has been classified as regular, bad or horrible. Among the possible causes for this precariousness is the lack of updating of the design method used by Brazil, since it does not incorporate an analysis of the behavior of the pavement in the field, and the lack of adoption of new and more efficient materials.

Therefore, many studies are trying to develop new technologies for projecting and implementing pavements, which combine reuse of materials, increase of the durability and reduce of energy consumption.

1.2 Cold Mix Asphalt

It is known that asphalt can be classified, by temperature of mixing, into: Hot Mix Asphalt or HMA (190-150ºC); Warm Mix Asphalt or WMA (100-140ºC); Half-Warm Mix Asphalt or HWMA (60-100ºC); and Cold Mixes (0-40ºC). [2] The binders that can be used for cold mixes are the emulsified or cut-back asphalt. This last is less usable for being polluting, flammable and potentially explosive. [3]

In addition to the reduced environmental impact, a major advantage of using CMA instead of HMA is that the percentage of recycled aggregate used is generally higher, up to 100%. [4] There are two main technologies for cold recycling: cold-plant recycling, where the milled aggregate is mixed close to the site and then returned to where it will be paved, and *in-situ* recycling, or cold-in-place recycling, where the aggregate is milled, mixed and launched simultaneously. [5]

It is noticed that the use of cold asphalt is not only economically friendly [6], [7], for having reduced energy consumption and CO^2 emission, but also more durable, showing good results even after 15 years of service. [6] In general, the best results with respect to economy, CO^2 emission and energy consumption are obtained when working with thin layers of RAP, i.e., less than 7.5 centimeters. [8]

In the development of CMA technology with emulsion, several factors must be controlled, i.e.: the workability of the mixture, which should permit launching and compaction with normal equipment (pavers and roller); the development of good strength must be rapid to allow traffic without unnecessary delay; the gradation of the aggregate must have sufficient voids to accommodate the binder and water; and lastly, to prevent run-off during construction, a minimum viscosity of the emulsion is required. [9]

Another important factor is the curing time and temperature, to guarantee asphalts with sufficient hardening to receive traffic, without premature aging. Cold emulsion blends, when properly designed and at complete cure, even without the addition of cement, are known to be comparable in stiffness to hot blends (at the same bitumen grade). [10]

1.3 Objective

The objective is to evaluate and compare cold mixes within its mechanical properties obtained from the Marshall's Stability and Flow, Splitting Tensile Strength of Cylindrical Specimens and Resilient Modulus tests. To do this, four different mixtures of dense cold mix asphalt were made.

2. MATERIALS AND EXPERIMENTS

2.1 Materials

The mixes used asphalt emulsion (RL-1C) as binder, a mixture of recycled asphalt pavement (RAP) and virgin coarse aggregates, and hydrated lime (CH-III) as filler. The emulsion RL-1C, which is classified as a cationic slow-setting asphalt emulsion (DNIT 165/2013), was provided by a distributor. It was chosen according to Brazilian standard's recommendation for dense CMA [11].

As for the asphalt emulsion properties, the following tests were carried out: Saybot-Furol viscosity, residue by evaporation, determination of pH and determination of sifting. The results are given in the Table 1. The virgin aggregates were basaltic and classified according to its size as: crushed stone, grit, and crusher dust. In Table 2 is shown the characterization of the aggregates.

TABLE 1 Properties of the asphalt emulsion

Type	Standard	Specification limit	Value
Specific gravity (kg/m³)	DNER-ME 193/96	----	1,010
Saybot Furol viscosity, 25º C (sSF)	ABNT NBR 14491:2007	Max. 90	82.17
Saybot Furol viscosity, 50º C (sSF)	ABNT NBR 14491:2007	----	16.41
Residue by evaporation (%)	ABNT NBR 14376:2007	Max. 60	60.46
Sifting (%)	ABNT NBR 14393:2012	Max. 0.1	0.0
PH Value	ABNT NBR 6299:2012	Max. 6.5	3.34

TABLE 2 Characterization of the virgin aggregates

Type	Standard	Specification limit	Value			
			Crushed stone	*Grit*	*Crusher dust*	*Hydrated lime*
Los Angeles Abrasion loss (%)	DNER-ME 035/98	Max. 40	22.40	23.35	----	----
Sand equivalent	DNER-ME 054/97	Min. 55	----	----	57.26	----
Specific gravity (kg/m³)	ABNT NBR NM 53:2009 (coarse)/52:2009(fine)	----	2,971	2,976	2,976	2,600

The RAP was obtained from a deposit of milled asphalt, which was located at the kilometer 83 (north way) of the BR-163 highway. The location of the deposit and the gradation of aggregates is shown in Figure 1 below.

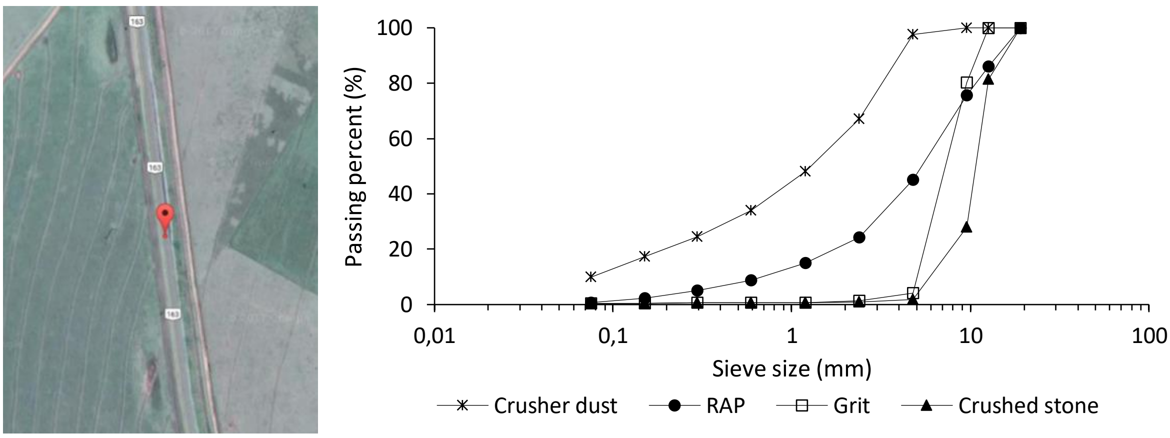

FIGURE 1 Location of RAP deposit and gradation curves for aggregates

In order to obtain a mixture with adequate gradation by the Brazilian and Superpave specifications, a correction in the curves were made by mixing the RAP with different amounts of aggregates (Table 3).

TABLE 3 Composition of mixes

Mixture	Coarse aggregates (%)			Fine aggregate (%)	Filler (%)
	Crushed stone	*Grit*	*RAP*	*Crusher dust*	*Hydrated lime*
Mix-1 (Control)	22.0	32.0	----	45.0	1.0
Mix-2 (7.5% RAP)	20.3	29.6	7.5	41.6	1.0
Mix-3 (15% RAP)	18.6	27.1	15	38.3	1.0
Mix-4 (30% RAP)	15.2	22.3	30	31.5	1.0

After the correction, based on the Superpave's optimum gradation, the following curves were obtained for the mixtures (Figure 2). Then, these curves were compared with the "D" grading envelope of DNIT's specification. We can notice that the curves slightly escape the limits only near the 1/2" sieve (12.5 mm).

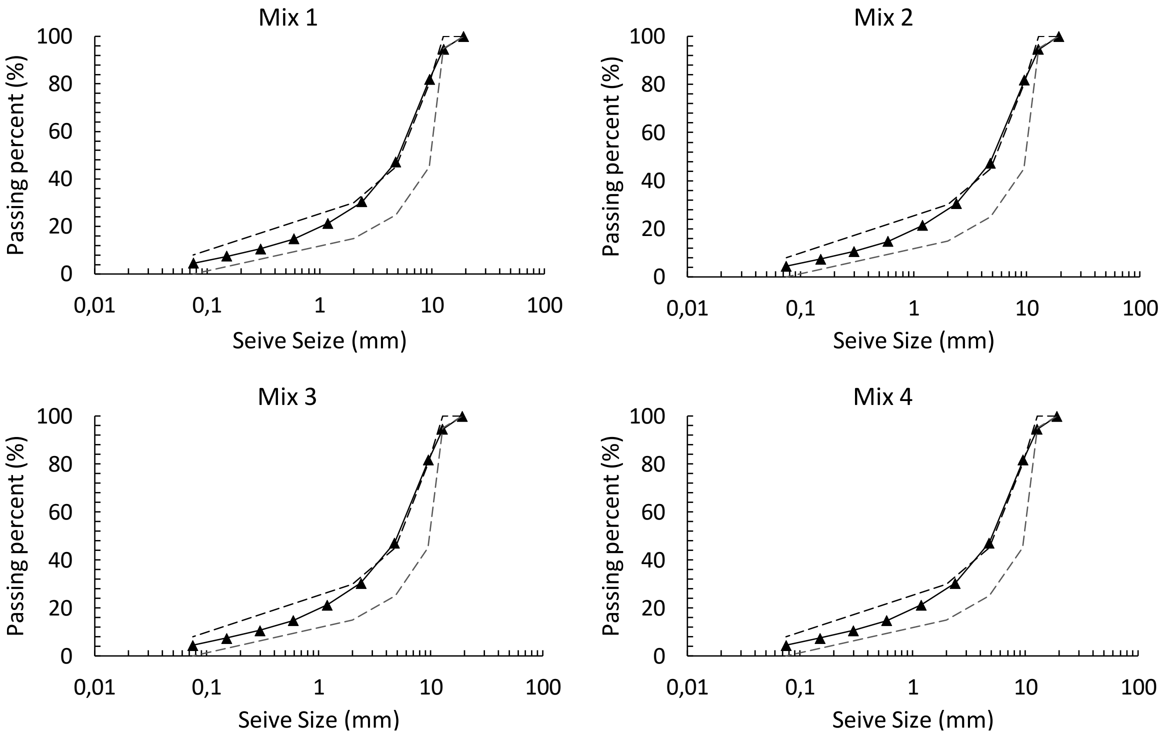

FIGURE 2 Gradation of mixes compared with DNIT's "D" grading envelope for cold mixes

2.1.1 Mix-Design Using Marshall Test

In this investigation, the mixtures were produced using the Marshall mix design for bituminous mixtures [11], according the standard DNER-ME 107/94. Since we considered low to medium traffic, the specimens were compacted with 50 blows. After the compaction, the specimens were cured at ambient temperature for no more than 60 minutes, because the emulsion was slow-setting. From this, we obtained as optimum binder content the values of 10.1% for mixtures 1, 2 and 3, and 10.6% for the mixture 4. The percentage of air voids chosen for these mixes was 7%.

2.2 Experiments

2.2.1 Splitting Tensile Strength of Cylindrical Specimens

The 12 samples (three for each blend) were prepared with the optimum binder content determined by the Marshall dosage. The test was performed in accordance with standard DNIT 136/2010. The procedure consisted in maintaining the temperature of the specimen at 25° C for 2 hours, then the material was taken to the Marshall press, positioned and the load was applied until the rupture. Then, the tensile strength value was calculated from the value of this load.

2.2.2 Resilient Modulus Test

Similarly, for this test, more 12 samples were prepared with the optimum binder content. It was performed in accordance with standard DNIT 136/2010. Accommodated at 25° C, the specimens were taken to a diametral compression of repeated load press. A load was then applied several times until the specimen was ruptured. The value of the resilient modulus is given by the ratio between this load and the elastic deformation measured by the Linear Variable Differential Transformer (LVDT).

3. RESULTS AND DISCUSSION

The results for the experiments are presented in the Table 4 below.

TABLE 4 Results of mechanical experiments

Mixture	Marshall's Stability (kgf)	Marshall's Flow (mm)	T.S. (MPa)	R.M. (MPa)
Mix-1 (Control)	564.8	4.33	0.181	2,934
Mix-2 (7.5% RAP)	489.6	4.32	0.162	2,274
Mix-3 (15% RAP)	610.9	4.60	0.159	2,280
Mix-4 (30% RAP)	419.9	4.33	0.137	2,278
Specification limits	Min. 150 kgf (50 blows)	Min. 2.0/Max. 4.5	----	----

3.1.1 Split Tensile Strength of the Mixtures

This property does not have a minimum value for CMA in standard, however, when compared to the minimum required for a HMA (≥ 0.65 MPa), all the mixtures presented lower values. For this reason, it is only considerable if applied in roads with low to medium volume traffic and in road repairs.

3.1.2 Resilient Modulus of the Mixtures

For this property, the bigger the value, the best is the behavior of the material. Therefore, all the mixtures with RAP presented similar resilient behavior, varying between 2.274 to 2,280 MPa.

4. CONCLUSIONS

In this work we evaluated cold mixes with RAP content ranging between 7.5% and 30%. Properties as Marshall's Stability and Flow, Split Tensile Strength and Resilient Modulus were tested. We observed that the performance of the CMA with 7.5% of RAP in mass provided the best results in general, except for Stability.

The development of more comprehensive mechanical tests would make the study even more interesting. The Fatigue, Creep and Lottman assays are cited here. The intention of this research is that these and other points can be reassessed, with similar trials and studies being promoted, so the national scientific collection about CMA develops. Therefore, would be created a greater degree of confidence in the use of this material in paving services.

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