RECYCLING OF BASE COURSE WITH CEMENT

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ABSTRACT: Despite the enormous amount of tests dedicated to pavement rehabilitation in Brazil every year, the pavement field's ability to predict the performance of different rehabilitation techniques remains very limited yet. Some types of recycling appear every year but the problems are frequently associated with techniques and materials that should be used in particular considering their mechanic behavior. The recycling technique was implanted in the 80s and recently equipments that can recycle until 500 mm of asphalt pavement were introduced. Two kinds of recycling asphalt pavement have preponderated in the last five years: foamed asphalt and recycled base course with cement. This last technique is very easy and the costs almost attend the economics expectative of govern. However, the standards and proceedings recommend that the traffic liberation occurs after 7 days. Therefore, this is a big obstacle for using this technique. The time enough to get the necessary performance is the critical element for adopting the stabilization with Portland cement even if the cost is lower when compared with other techniques. This paper shows the research studying the recycling of the asphalt pavement with Portland cement behavior in terms of time to increase the compressive strength, indirect tensile and creep static. An extensive number of tests were made after 3, 6 and 12 hours of mixing the materials with Portland cement.

KEY WORDS: recycling, rehabilitation techniques, cement stabilization, full depth, static creep test, indirect tensile test.

1 INTRODUCTION

Economics and environmental factors have motivated a new generation of solution on road management. When the theme is pavement's rehabilitation, we can certainly find in the matrix of solution an alternative for the recycling solution. However, why has recycling technology been a solution preferred by managers? Certainly, the word environment is the main force that moves this process [1].

In the developing countries, considering for example, Brazil, there are not material's encases type stones, gravel, sand and lateritic soils but in the moment, the environmental conscience is the main motive to introduce one more solution in the decision matrix to rehabilitation phases. The matter in many cases is not the scarcity of materials but the environmental preservation. In other words, recycling is the better form to preserve the environment, for example, the aggregate reserve.

Secondly, there are the following issues: economics, considering the energy reduction around the process of aggregate production and respective volume that is not necessary to be transported; time, considering that there is a time reduction during the construction when compared with traditional construction; safety, because of the time of reduction of the construction, in case that it is not possible to close the roads. Maybe this is a good motivation to use recycling technology.

An additional advantages and benefits of the recycling, the materials and energy are conserved, and air quality problems resulting from dust, fumes, and smoke are eliminated.

Then, considering these facts, the recycling process is environmentally desirable and has a good motivation to be considered in the matrix decision on the planning of roads rehabilitation.

Another motivation to use recycling with cement is associated at experience with soil cement bases has been used since 1950 in the State of São Paulo. More than ten thousand km were built using this technology in many roads. This kind of base has had an excellent performance for more than 30 years, where traffic is 5×10^7 equivalent axle of 80kN. Considering this experience, there is a good motivation to use bases recycled with Portland cement.

On the order hand, the roads in São Paulo State, where an intervention is necessary, were built with simple line and the traffic is approximately five thousands vehicles per day. Then, the big problem is how to do the intervention considering that there is not another way to deviate the traffic. The interval of time between closing and opening the roads is very important. The practices have taken 3 days in case of pavement recycling when stabilized base with cement is used. However, this time is very long and accidents can happen because, when the pavement is being recycled, the traffic is generally transferred to the shoulders.

Thus, the main goal of this paper is to study the behavior in terms of mechanical strength concerning time and to observe the possibility to open the traffic 24 hours after the end of the compaction's works.

2 OBJETIVES

The objectives of this research are as follows:

- The first objective of this research is to obtain the variation of the compressive strength and indirect tensile stress versus the early curing time;
- The influence of variation of water content in the strength during the first times of curing;
- The influence of plasticizer additive in the mix resistance and density during the firsts times of curing;
- To compare the strength obtained in sample's laboratory with the stress that occurs in the field, obtained through the Elsym5 program, in terms of compression and tensile stress.

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3 RECYCLING BASE COURSE WITH PORTLAND CEMENT CHARACTERISTICS

In terms of philosophical conception, a recycling base course with Portland cement (RBCPC) can be considered a type of cementitious base stabilization. The main difference between this kind of base and the cement-stabilized soils is in the field's proceedings.

Initially, it is important to consider the following definition in this research:

- Soil-cement: mixture of soil and Portland cement, in general 6% to 9% in weight, to be used in the base layer and with defined potential to support tensile strains in a flexible pavement or as a sub-base for rigid pavement. It can be produced in the plant and transported to the road or it can also be made in the road;

- Soil treated with cement or cement-modified soil: in this case, the cement is used in a small proportion; approximately 3% in weight, with the objective of modifying some undesirable behavior such as expansion or contraction. Again, it can be produced in the plant and transported to the road or mixed in the place it is going to be used. The main difference is the structural function;

- Recycling base course with Portland cement corresponds to mixing the cement in the place, including the asphalt layer, base layer, Portland cement and with or without addition of soil or aggregate. In many cases, it is common to add more stone or soil objecting to complete the thickness specified in the design. Figure 1 shows the typical structure normally recycled in SP State. We can observer that the mill depth is around of 5 to 10 cm and while the quantities of stabilized crushed stone is approximately 10 cm.

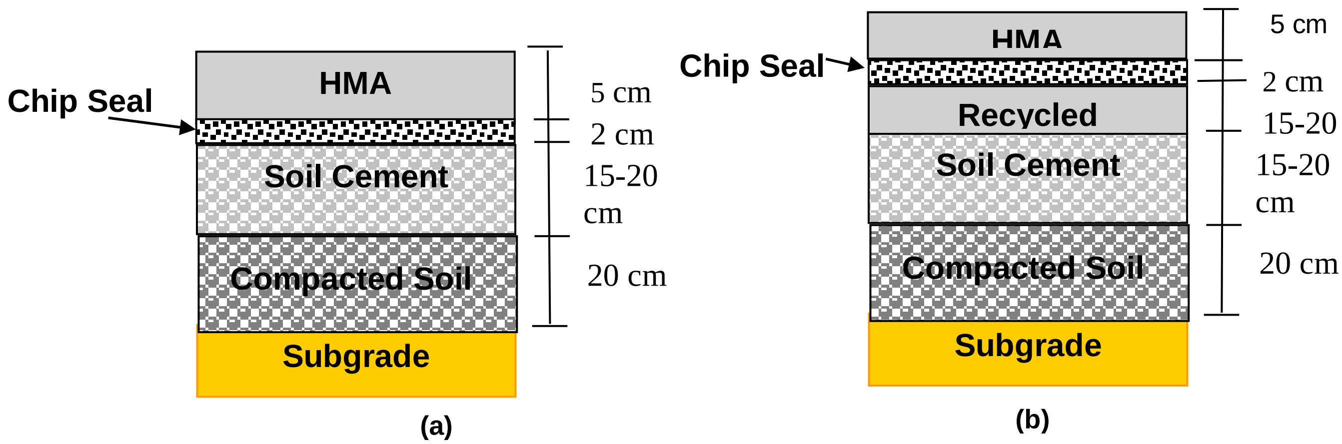

Figure 1 Typical Structure (a) before recycling (b) recycled in São Paulo State.

Recycling is only one of the several rehabilitation alternatives available for asphalt pavements.

The theme recycling when associated at pavement consist in the reuse of pavement material became a very simple but powerful concept. Recycling of existing pavement materials to produce new pavement materials results is considerable savings of money, energy and at the same time, the materials.

In terms of literature, full depth reclamation (FDR) has been defined as a recycling method where the asphalt pavement layer and a fixed quantity or total of the base material is treated to produce a stabilized base course. The process to be considerate a cold mix recycling and can be made with different types of additives such Portland cement, fly ash, lime, asphalt emulsion or chemical agents and all mix obtained is transformed in new base.

The process of construction can be resumed in four main steps: milling, introduction of additive and water (if necessary), addition of material, in case of in-place material is not sufficient to provide the necessary depth and compaction.

The bibliographic review states that in USA [1], since 1915, more than 100 thousands miles of equivalent 7.5m wide pavement bases have been constructed, using cement-stabilized soils and in the State of São Paulo, this number is over 10 thousands km, approximately 50% of the total road pavements in the State.

The stabilized bases with cement technology are an excellent alternative to attend the low cost construction because of the mechanical and hydraulics peculiarities of the lateritic soils and their abundance in the south of Brazil. Cement has been found to be effective in stabilizing clays and sand lateritic soils, according with Nogami & Villibor classification [2]. Its applications started in the 50s and today it is the best practice, when it is necessary to introduce more traffic lines.

However, in the rehabilitation programs, when in the matrix solution the way appointed is the removal of the asphalt layer and base, an alternative that has been indicated in many cases, is the recycling with cement Portland.

While the soil cement base solution has been indicated with 6% to 9% of Portland cement, considering the positive aspect of lateritic soil, the technique of recycling base course with Portland cement has been made with 3% of Portland cement.

Rehabilitation under high traffic must be analyzed considering two aspects: minimum potential strength required and minimum time to perform it.

The minimum strength can be obtained using the software, determining the strains and stress in each layer in function of the weight's trucks. However, the necessary time to obtain the strength compatible with the stress that occurs in the field only can be known through the experimental study in laboratory.

4. MATERIALS

Two kinds of materials were used in this research: HMA pavement layer uniformly crushed cold milling an existing pavement and granular roadbase. In both cases, they come from granite stone. The L.A. Abrasion was 25,1% while the sand equivalent for fine aggregate fraction was 66%. The mix gradation used in this research coincides with the model used in some pavement rehabilitation [3]. The proportion used is 40% milling HMA and 60% granular roadbase. Figure 1 shows the distribution of the gradation curves studied and two materials originals curves.

In terms of gradation curve as shown in Figure 2, both materials, cold milling, an existing HMA, and granular roadbase, are very similar.

The milled material was a HMA with 5,2% of binder. Its original thickness was about 50 mm.

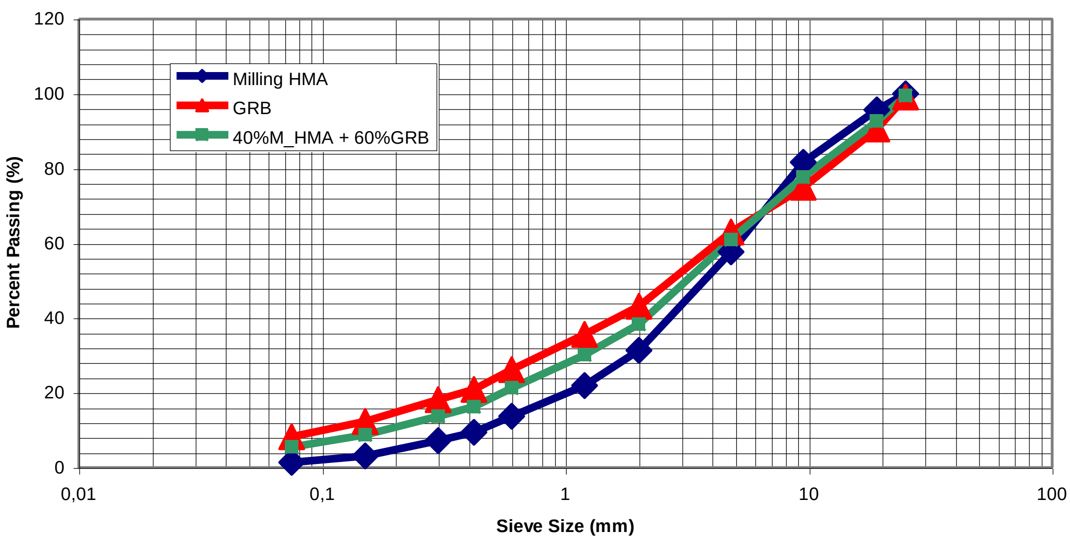

Figure 2. Gradation of aggregates that were studied

5 EXPERIMENTAL RESEARCH

Considering that the main objective of this research is to determine the time necessary for the mixture to obtain the necessary resistance to support the light and the heavy traffic, all tests were made in the early time after the Portland cement has been mixed with the aggregates and water.

The routine in recycling base course with Portland cement used in Brazil is to use only 3% of cement in weight. However, this quantity has shown that it isn't enough to result some homogeneous mix, resulting in premature distress in the new pavement. So, the research studied 2 mixes: with 3% and 5% of cement.

It was studied too, the influence of reduction of water content considering the effect of the weather when the temperature is very high. Finally, a doubts that persist in the technical staff, is the influence of plasticizer.

Initially, it was determined the moisture condition value optimal in the Proctor test, in the Modified Energy, according with DNER [4]. It was obtained 6% and 7%, respectively, to mixes with 3% and 5% of cement.

The equipment used to produce the cement mix was a concrete mixer and the time necessary to mix the base was 3 minutes.

In sequence, the mixture was compacted in a CBR cylinder, with 150 mm of diameter, in the Modified Energy. Three specimens from the same mixture were prepared for testing, in both cement percentages and tested after 6, 9, 24, 48 and 72 hours moist curing at Moist Rooms.

The specimens were tested and the compressive strength, indirect tensile stress (ITST) and creep static were determined. The cylindrical specimens used in creep test were capped when were 9 hours old or more (Figure 3). Merighi and Fortes (2005) presented some illustration about these proceedings.

In Figure 4 is showed the apparatus used to apply indirect tensile stress. Some details of this is presented in Figure 5 and 6.

The creep static test was performed according to Merighi and Fortes presented in their article of 2004 [5].

Figure 3: The capped specimens.

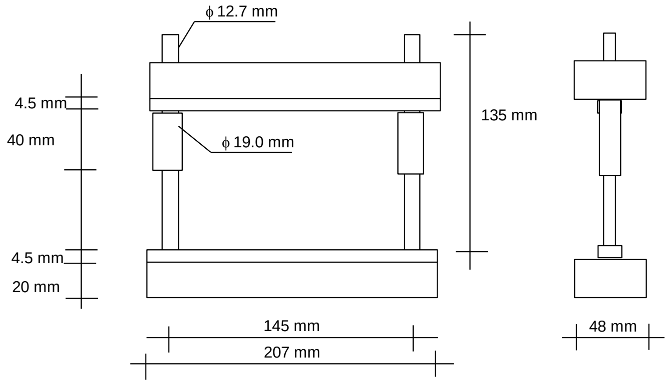

Figure 4: Apparatus used in Indirect Tensile Stress

Figure 5: Some details of the Indirect Tensile Stress Apparatus

Figure 6: Indirect tensile stress test.

6. MECHANICAL ANALYSES

For this purpose, a structural analysis was carried out for the typical structure used in São Paulo and the program used was ELSYM5 model. The single axle considered for this analysis had a total load of 80, 60 and 40 kN, and tire pressures, respectively of 0.56; 0.42 and 0.28 MPa. The distance between dual wheels was considered 0.33 m and between the centers of dual wheels is 1.80 m.

In these analyses, to eliminate or to mitigate this cracking effect were considered, and a double layer of 10 mm seal coat surface treatment was devised to be laid onto the recycled material surface.

In Table 1, the results of maximal flexural stresses for compressive stress in the top, and tensile stress at the bottom of the base layer of the mentioned pavement cases were presented. It was considered as a representative value of Elastic Modulus, 500 MPa, because the difference found was very small.

For this research, it was considered the following partial structure, because the proposal is to open the traffic 24 hours after finishing the works and to put the final HMA layer after 3 days.

Table 1. Parameters and strength obtained according with ELSYM5 analyses.

LAYER	THICKNESS (mm)	ELASTIC MODULUS (MPa)	POISSON COEFFICIENT (ν)	COMPRESSIVE STRESS (MPa)			TENSILE STRESS (MPa)		
				TOTAL LOAD (kN)			TOTAL LOAD (kN)		
				100	80	60	100	80	60
Seal Coat	20	500	0,35	-	-	-	-	-	-
Recycling Base	180	50	0,25	0,68	0,55	0,41	0,07	0,06	0,40
Sub base (Lateritic Soil)	150	200	0,40	-	-	-	-	-	-
Subgrade		80	0,40	-	-	-	-	-	-

7. RESULTS AND ANALYSES

The compressive strength values (MPa) and their respectively average are shown in Table 2.

Table 2. Characteristics of specimens.

CHARACTERISTICS		CEMENT = 3%	CEMENT = 5%	CEMENT = 5%	CEMENT = 5% + 0,3% PLASTICIZER
Compressive strength (MPa)	6	0.39	0.31		
	9	0.43	0.29		
	24	1.29	1.63	1,44	1,16
Time (hours)	48	1.93	2.62		
	72	2.48	2.67		
Indirect Tensile stress (MPa)	6	0.04	0.03		
	9	0.06	0.04		
	24	0.09	0.15	0,07	0,05
Time (hours)	48	0.13	0.28		
	72	0.16	0.35		
Water (%)		6	7	5	5
Permeability (cm/s) – 24 hours		1.4×10^{-5}	5.0×10^{-7}		
Permanent Deformation (mm)		0.06	0.05	0.05	0.4
Elasticity Modulus (MPa) (24 hours)		45	56	50	46

Figure 7 illustrates the variation of the compressive strength versus the curing time for early strength. Initially, the compressive strength is very low. Until 9 hours old, it is not possible to observe differences between the mix with 3% of cement or 5% of cement, but, after 24 hours, the sample with more quantities of cement begins to show more strength.

Figure 8 summarizes the variation of the indirect tensile stress versus the curing time. Again, in the initial strength, the difference between the two mixes is the minimum, but after 24 hours, it increases. Naturally, the mix with more cement shows more strength. After 24 hours, the strength is about 0.15 MPa for the mix with 5% of cement, while the other mix strength is about 0.09 MPa.

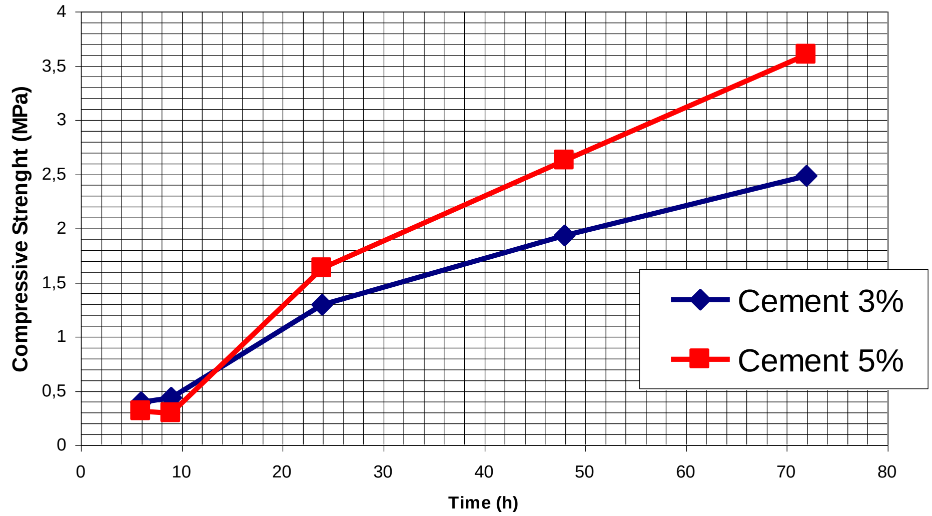

Figure 7. Effect of curing time on the compressive strength.

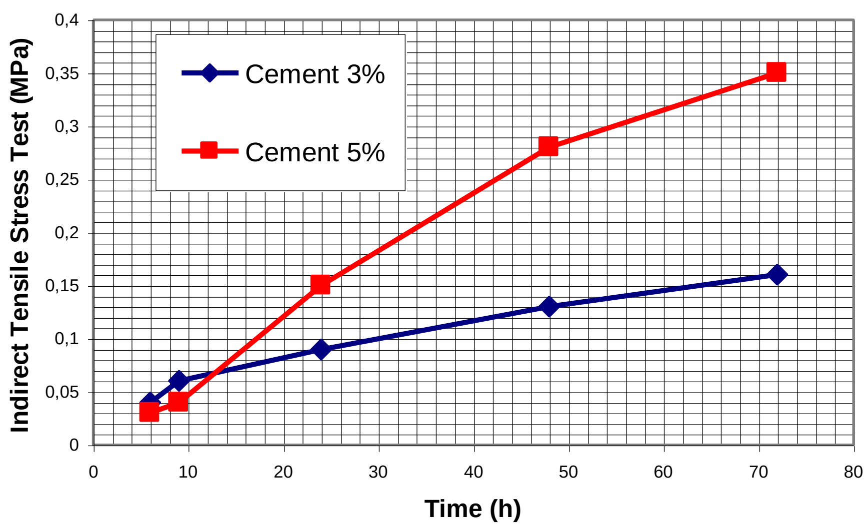

Figure 8. Effect of curing time on the indirect tensile stress.

In fact, the results clearly show that the tensile stress is the load's limit factor. The base would be able to support the compressive stress until 80 kN but not the tensile stress, limiting the maximum load in 40 kN.

Despite being a practical current, to do base recycling with 3 % of cement, it is very important to define which percentage improves the best performance. This study was developed in the laboratory because it is possible to keep homogeneous samples, but in the field, it is almost impossible to be carried out, and the 3% percent of cement mixed with equipment usually makes many areas without cement. The consequences can damage the pavement very much.

8. CONCLUSIONS AND RECOMMENDATIONS

The main problem using the stabilization with Portland cement is the time enough to get the necessary performance, even if the cost is lower when compared with other techniques.

This technique is very easy and the costs almost attend the economics expectative of the government. However, the standards and proceedings recommend that the traffic liberation occur after 7 days. Therefore, this is a big obstacle for using this technique.

The research results encourage to use this technique because the compressive and indirect tensile strength are enough to support until 4 ton per axle, so it's possible to open the lane to light traffic after 24 hours.

Adequate curing of this kind of base is very important. Curing compound (emulsion) must be applied consistently and before the surface begins to dry.

The compressive strength and indirect tensile were good tools for determining cement content in soil-cement.

The creep testing result demonstrated that permanent deformation resistance is very high, so it reduces the probability to present damage in the early ages.

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