Evaluation of Ceramic Plates as a Thermal Insulator for the Decreasing aging of Asphalt Mass

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ABSTRACT

Clays have a wide variety of applications due to their physical and chemical properties. The objective of this research was the morphological, physical and chemical characterization of residues from the clays used in the industry for the purpose of being used in the protection of the storage condition and transportation of asphalt. For this, three samples ARM (filter-press cake) and MIX (blending process steps) both from waste sanitary ware process, and ARGILA 1 (*in natura*) were sintered, different characterizations were carried out: SEM, EDS and temperature variation and absorption tests. The results have shown that temperature's variation to MIX was 6 ºC degree after 24 hours of testing, since it presents a larger surface area and external surface with open pores, as observed by SEM analysis and absorption testing. Thus, the ceramic plates made from MIX would reduce both the oxidation process and the temperature drop of the asphalt mass and provide an environment of stability in the interaction between the asphalt plant and the application point of the asphalt.

Keywords: waste, asphalt, degradation, quality control.

1. INTRODUCTION

The concern with the quality of the extensive highway network in Brazil and the World has taken researchers to investigate the process improvement, as well as the quality of the asphalt mass produced. Great contributions were made to add to the asphalt products that could improve the quality and extend the properties of petroleum asphalt cement (PAC), after the formation and application of the asphalt mass, with the consequent increase of the useful life of the highways and the reduction of the cost of maintenance, as Susanna *et al.* [1] notes in the study on deterioration trends of asphalt pavement friction and roughness from medium-term surveys on major Italian roads. In parallel to the effort and research success, the regulatory agencies apply quality control through technical standards, establishing acceptance parameters of the product. However, asphalt useful life problems persist and are responsible for the high rate of highways degradation, incurring considerable losses to users and public bodies.

In this context, Silva [2] studied the phenomenon of aging of asphalt, in which it represents a type of degradation responsible for the appearance of cracks that do not permit the use of highways. Silva *et al.* [3] established parameters that made it possible to identify the percentage of aging in each stage of the process and presented the following data: 60% of aging due to asphalt machining and 40% of aging due to storage, transport and application of asphalt on the pavement.

According to investigations on the negative effects of temperature drop and asphalt exposure to ultraviolet radiation, as main mechanisms for the development of the phenomenon of aging, the effective control of the influence of these parameters in the course of the machining process and application is necessary. Lamothe *et al.* [4] noted the temperature effect on degradation of hot mix asphalt, during winter and spring. Thus, this research work presents a study that looks for the creation of a barrier in order to reduce the oxidation process and the temperature drop of the asphalt mass and provide an environment of stability in the interaction between the asphalt plant and the application point of the asphalt.

The methodology makes use of the waste from the Duratex S. A. sanitary ware process in the manufacture of plates that function as thermal insulation and can be used as surface materials of the asphalt transporting vehicle. The starting point for achieved the stability involves two distinct research lines, one directed at the modeling the behavior of the asphalt mass in a controlled environment and the other the development of ceramic waste plates that act as thermal insulation. It must be emphasized that the percentage of loss of storage and transport could reach 20%, and the consequences of temperature dropping are the viscoelastic loss of the PAC and its aging, as well as the need to determine the time and the maximum distance transport between mass asphalt process, application of asphalt on the pavement and compaction in the in order to limit the harmful effects of early aging.

2. MATERIALS AND METHODS

2.1 Characterization of ceramic waste

Chemical characterization testing to ARM and MIX were conducted in the company's laboratories CAF Quimica, in accordance to the Brazilian standard NBR 10004:2004 – Classification system for solid waste – leached and solubilized, Brazilian Technical Standards Association (ABNT) [5]. Leaching procedures were based on the NBR 10005:2004 – Procedure for obtention leaching extract of solid wastes [6] and the solubization tests were based on the NBR 10006:2004 – Procedure for obtention of solubilized extraction of solid wastes [7].

2.2 Characterisation of the materials used

Water absorption tests were carried out on the ceramic plates after calcination. Dried samples were weighed and immersed in water for 24 hours at 100 °C degree. The dry mass and wet mass ratio resulted in the percentage of voids content.

The scanning electron microscopy observations were made on a Jeol model JSM 7100F with an energy of 1.31kV, with increase of X150 and X600. With the scanning electron microscopy equipped with and energy dispersive X-ray spectrometer (SEM/EDS) technique, it was possible evaluate the morphology of the sample, with the main focus being to identify the microscopic structure, the porosity and the mean particle or pore size of the samples. In parallel, the chemical composition of the samples can be identified. Also, based on the images of samples, computer image processing was used as an additional method of sample analysis to measurement spatial distribution of the porosity.

2.3 Laboratory simulation tests

Boxes were made of these materials (ARM, MIX and ARGILA 1) with the same dimensions (height, length, depth and thickness). The asphalt mass was produced in the laboratory [made from the mix of a percentage of petroleum asphalt cement 50/70 (5,1% by wt) and aggregate], according with to the Brazilian National Department of Transport Infrastructure (DNIT) [8]. The composition of the aggregates was weighted according to range IV C of Asphalt Institute [9] – gravel 0 (13,3%), gravel 1 (30,4%), stone dust (51,2%). These materials were then transported to a vertical cylindrical reactor, blended at 170 ^{o}C degree, and the asphalt mass was inserted into the boxes (80% V) at the same temperature and monitored the temperature internally and externally by means of thermocouple. The thermocouples were connected to a Programmable Logic Controller (PLC) connected to the computer, recording the temperature during the first 12 hours, the result was collected every 1 hours and, after 12 hours, the result was collected when completed 24 hours.

3. RESULTS AND DISCUSSION

3.1 Characterization of ceramic waste

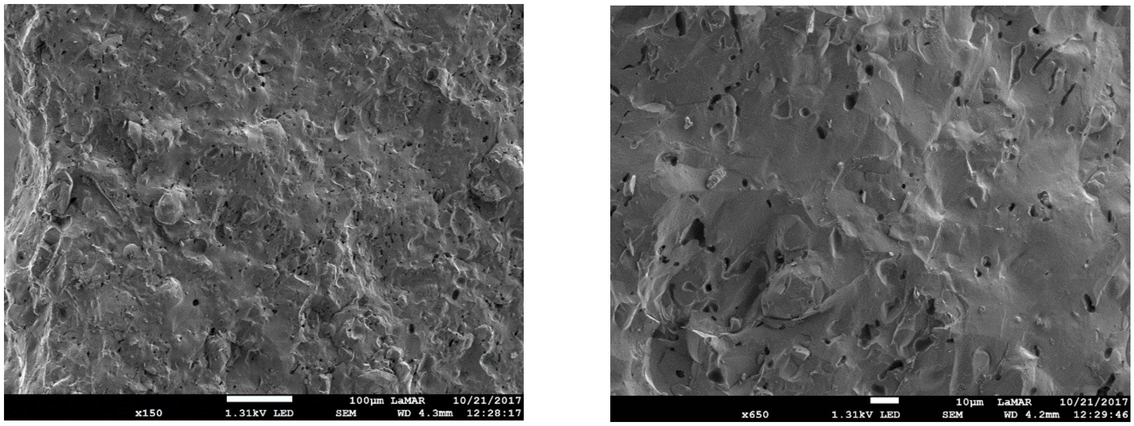
The results showed that the contents of heavy metals of concern are below the limits established by the NBR, in accordance with the annex F (leaching) and annex G (solubilisation). No pesticide and organics (benzenes and other polycyclic aromatic hydrocarbons) have been detected for both. It is therefore concluded that the ceramic waste is classified as CLASS IIA - NON-INERT WASTE.

3.2 Characterisation of the materials used

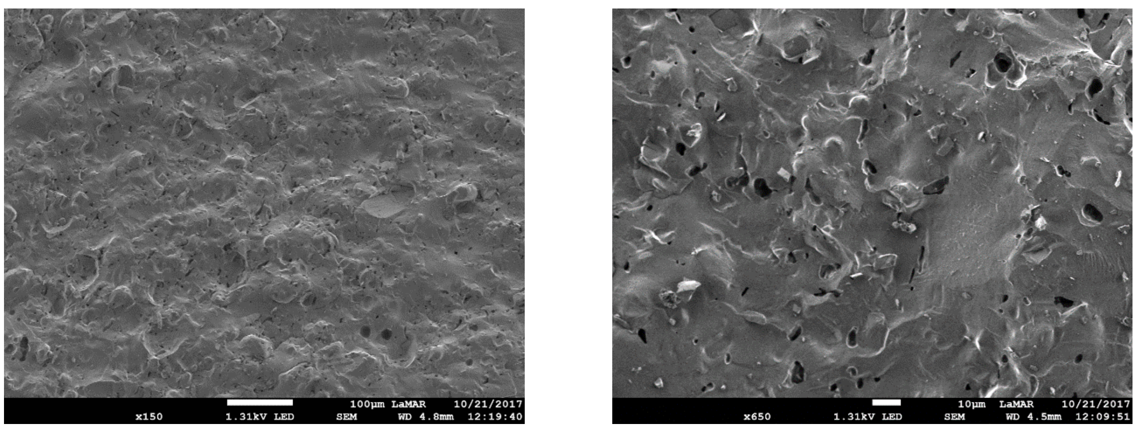
The pore diameter from MIX are between 10 µm and 45 µm. However, ARM and ARGILA1 are in the range of 10 µm. Also, the total pore area obtained by image analysis from ARM and ALGILA1 were about 10%, which is smaller than the total pores area measurement by MIX (60%). Also, by EDS it was possible to observe that the samples had the same chemical composition (not shown here). The elements found were O, Si, Al, K, Na, Ca, Fe, Mg and Ti. Other elements were not detected.

Figure 1 SEM micrographs at low and high magnification of the samples (ARGILA 1, ARM and MIX).

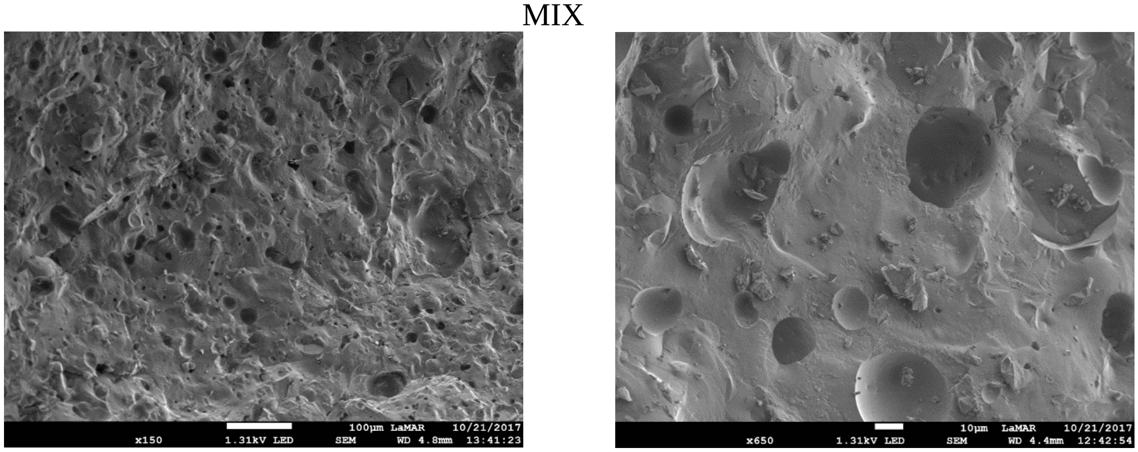
ARGILA 1



ARM



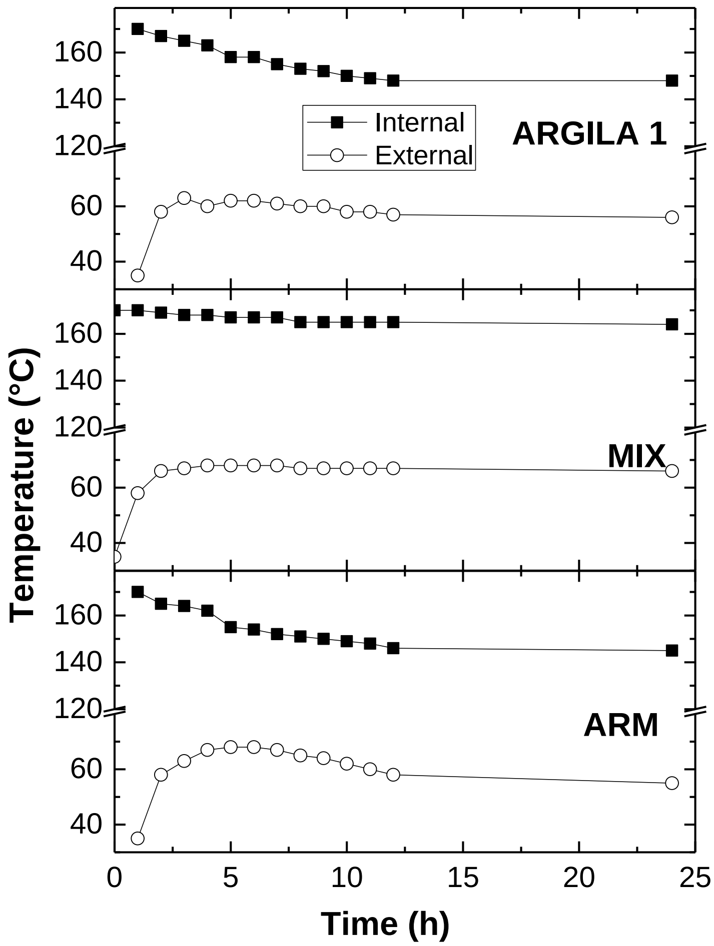
MIX



3.3 Laboratory simulation tests

The results of the internal and external temperatures monitoring of the boxes are plotted in Figure 2.

Figure 2 Graphs of the internal and external temperatures of the boxes



The decay of the internal temperature from ARGILA 1 and ARM were similar, whereas for MIX was less pronounced (170°C to 164°C). Probably this behaviour was due to the greater porosity of the MIX and the water absorption tests, the gain of percentage mass present in the sample was greater in relation to the others.

Ceramics, in general, due to the presence of porosity, are not good heat conducting paste. By the behavior of the MIX graph, it concludes that external surface has pores open and closed inside the ceramic plate, while ARGILA 1 and ARM have closed external and internal pore, as shown in figure 1.

It emphasizes that sintering is a non-equilibrium thermodynamic process, and ARGILA 1 and ARM have lower surface area than MIX, resulting in higher densification and volumetric contraction, as observed by the absorption tests.

4 CONCLUSION

The results showed that the MIX ceramic waste behaved as a barrier, avoiding more pronounced temperature decay as observed for ARGILA 1 and ARM.

The MIX variation was only 6 ºC degree after 24 hours of testing, since it presents a larger surface area and external surface with open pore, as observed by SEM analysis and water absorption tests. Thus, the ceramic plates made from MIX would reduce both the oxidation process and the temperature drop of the asphalt mass and provide an environment of stability in the interaction between the asphalt plant and the application point of the asphalt.

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