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Urban pavements used in Brazil: Characterization of solar reflectance and temperature verification in the field

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ABSTRACT

This paper presents the results for the solar reflectance and temperature of 20 types of pavements used in Brazil for roads, parking lots, squares and sidewalks. New and aged pavement samples were tested. Some asphalt mixtures and Portland concrete mixtures were developed in the laboratory, with the addition of colored pigments in different percentages. The standard method ASTM E1918 and the procedure E1918A were used to measure solar reflectance of the pavements in the field. The difference between the surface reflectance values for surfaces with a lighter (white Portuguese mosaic) and darker (Reference CPA asphalt mixture) appearance was approximately 48%, and the corresponding difference in the measure surface temperature was 18.4 °C. A correlation between the solar reflectance and the temperature measured in the field is reported. The results obtained can be used as a reference to design public spaces, contributing to reducing the urban heat island (UHI) and improving the thermal comfort of the users.

1. Introduction

The urban heat island (UHI) phenomenon is characterized by high air temperatures in densely constructed areas in comparison with the surrounding rural areas. One of the main causes of the formation of a UHI is the use of large quantities of industrialized materials (bricks, concrete, asphalt mixtures, stones and others) in urban zones to replace natural terrain and green areas. These materials absorb a high percentage of shortwave solar radiation during the day and irradiate it to the environment more easily than surfaces normally found in low density sub-urban areas or rural regions (Romeo and Zinzi, 2005; Solecki et al., 2005). Some consequences of UHIs in large cities are discomfort, diseases related to excessive heat, an increased energy demand in buildings for the cooling of environments and an increase in the ozone concentration in the troposphere (Romeo and Zinzi, 2005; Ashie, 2008; Xu et al., 2012; Rosenfeld et al., 1995; Mirzael and Haghighat, 2010).

High temperatures of urban pavements increment the ambient temperature within the cities and the temperature difference between the rural and urban area (Santamouris, 2015). Conventional impervious pavements have dark surface and large thermal inertia. During summertime they tend to absorb and store solar radiation and block the evaporative cooling, contributing to the development of UHI (Hui, 2016).

Over the years, different strategies for the mitigation of UHI have been proposed, including: the planting of trees for shade and an increase in green areas in cities, and the use of reflective surfaces known as 'cool' surfaces for buildings and pavements (Akbari et al., 1997; Rosenfeld et al., 1998; Synnefa et al., 2007; Synnefa et al., 2006; Santamouris et al., 2011; Akbari and Matthews, 2012; Carnielo and Zinzi, 2013; Santamouris, 2013). In many densely populated cities the installation of green areas presents a challenge and the use of reflective surfaces for buildings and pavements is a viable solution in the short term. In these locations paved areas can easily represent 20% of the area available for urbanization (Ashie, 2008). In addition, most of the paved areas are under the control of the public authorities (roads, sidewalks, squares, etc.), which facilitates the application of this type of strategy by the government as a measure to mitigate the UHI.

Santamouris et al. (2012) reported a study on the application of reflective pavements in an urban square in Athens (Greece), totalizing 4500 m^2. It was estimated that on a typical summer's day the use of cool pavements would reduce the air temperature in the square by 1.9 °C. At the same time the temperature of the surfaces in the square will be reduced by 12 °C. A study by Georgakis et al.

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(2014), also carried out in Athens, indicated that the use of cool (highly reflective) materials for pavements and walls in an urban canyon could reduce the surface temperatures by 7–8 °C at ground level and the ambient air temperature on a street inside the canyon by up to 1 °C. These and other studies (Santamouris, 2013) have demonstrated the potential for the application of cool pavements to improve the climatic conditions in cities. This potential has encouraged new research projects to develop methods for the characterization of conventional pavements used in cities and also to study the performance of other materials typical of each region (Li et al., 2013; Lin and Ichinose, 2014).

In Brazil, the main material used for the paving of roads in large cities is a mixture of asphalt and petroleum-derived components. A publication by Kinouchi et al. (2004) presented a type of coating of high albedo and low brightness, based on the application of paint with low reflectance in the visible spectrum (20%) and high reflectance in the infrared region (83%). The results showed that the maximum surface temperature of the painted samples was approximately 15–17 °C lower than that of the conventional asphalt mixture. However, the use of paints is associated with the drawback of wear due to the circulation of vehicles. One alternative available to eliminate the wear problem is the use of cold pigments (high infrared reflectance) as a replacement material for the asphalt mixture. This option was studied by Synnefa et al. (2011) and the mixtures produced reached reflectance values of 27–55% (high values considering that a conventional asphalt mixture normally reaches 4–5%). The simulations carried out showed that in an urban environment the use of these materials can reduce the air temperature by up to 5 °C.

Thus, it is clear that a reduction in the amount of solar radiation absorbed by surfaces of buildings and pavements contributes to improving the conditions of thermal comfort and to mitigating the UHI effect. However, in Brazil studies on the application of cool surfaces are still rare (Uemoto et al., 2010; Nakata and Souza, 2013; Souza et al., 2009) and information on the reflectance and thermal conditions of pavements produced with local raw materials is practically non-existent.

This paper reports the results for measurements of the solar reflectance and temperature of 20 types of pavement used in Brazil (conventional and alterative) for roads, parking lots, squares and sidewalks. Samples of new and aged pavements were tested. Some asphalt mixtures and Portland concrete mixtures were developed in the laboratory, with the addition of colored pigments in different percentages. Also, correlations between the reflectance values and the temperatures measured in the field are reported.

2. Materials

In this research the surfaces of new and aged pavements of different types (Portuguese mosaic, Portland concrete and asphalt mixture) were analyzed. The surfaces were divided into three groups considering the conservational state of the material:

(a) Aged surfaces: surfaces aged over 20 years, used in an open central square at UFSC (Federal University of Santa Catarina) and which have an aged appearance due to weathering and wear. These surfaces are:
- Sidewalk made of Portuguese mosaic (*petit pavê*) using basaltic rock (black);
- Sidewalk made of Portuguese mosaic (*petit pavê*) using calcareous rock (white);
- Sidewalk made of Portuguese mosaic (*petit pavê*) using rhyolite (red);
- Surface of aged dense asphalt mixture.

Fig. 1 shows the appearance of the aged surfaces in the field.

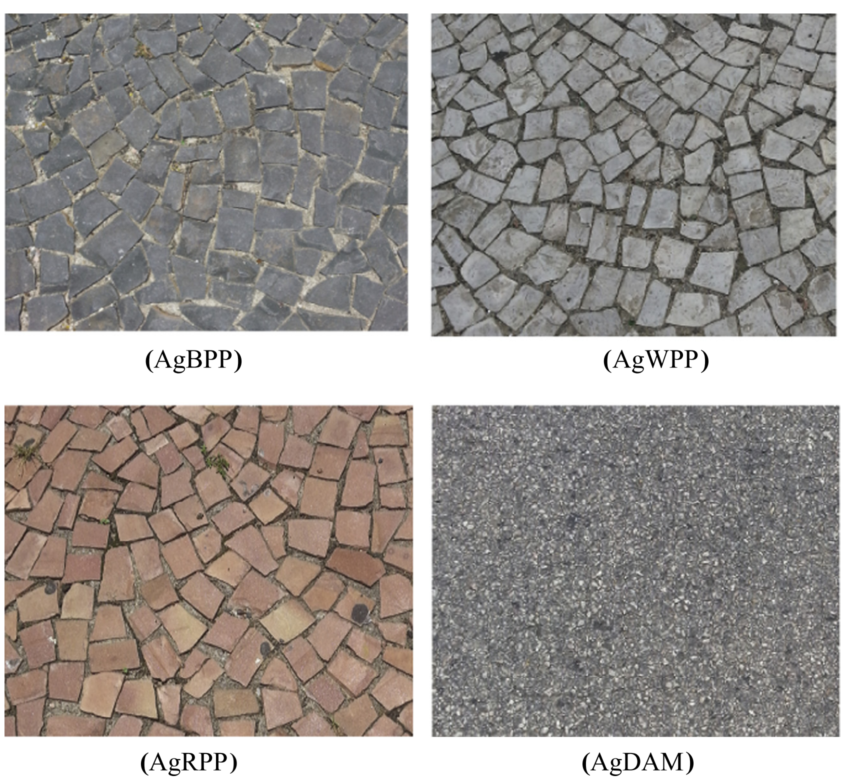

Fig. 1. Aged surfaces: Black *Petit Pavê* (AgBPP), White *Petit Pavê* (AgWPP), Red *Petit Pavê* (AgRPP) and Dense Asphalt Mixture (AgDAM). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)