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Experimental testing of cool colored thin layer asphalt and estimation of its potential to improve the urban microclimate

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ABSTRACT

Urban Heat Island refers to the temperature increase in urban areas compared to rural settings, exacerbating the energy consumption of buildings for cooling. The use of highly reflective materials in buildings and urban structures reduces the absorbed solar radiation and contributes to mitigate heat island. This paper presents the results of a study aiming to measure and analyze the solar spectral properties and the thermal performance of 5 color thin layer asphalt samples in comparison to a sample of conventional black asphalt. Computational fluid dynamics (CFD) simulation is used for evaluating the thermal and energy impact of applying the samples in outdoor spaces (roads). The spectrophotometric measurements showed that the colored thin layer asphalt samples are characterized by higher values of solar reflectance compared to the conventional asphalt, which is mainly due to their high near infrared solar reflectance. From the statistical analysis of the surface temperatures it was found that all the colored thin layer asphalt samples demonstrate lower surface temperatures compared to conventional asphalt. The maximum temperature difference recorded was for the off-white sample and was equal to 12 °C. The CFD simulation results show that surface and air temperatures are decreased when applying the color thin layer sample.

1. Introduction

The urban microclimate is mainly influenced by increased building density with the canyon geometry, the use of materials with inappropriate optical and thermal properties and the lack of green spaces, increased anthropogenic heat and increased air pollution [1,2]. The Urban Heat Island (UHI) effect, with temperatures in urban areas higher by several degrees compared to the surrounding rural areas, has been documented in over 30 cities worldwide [3–10]. The UHI has the effect of increasing the demand (and peak demand) of energy for cooling and energy prices, accelerating the formation of harmful smog, as increasing energy demand generally results in greater emissions of air pollutants from power plants and higher air temperatures also favor the formation of ground-level ozone, and causing human thermal discomfort and health problems by intensifying heat waves over cities [1,2,11–18].

The surface temperature is of prime importance as it modulates the air temperature of the lowest layers of the urban atmosphere, it is central to the energy balance of the surface, helps to determine the internal climates of buildings and has an impact on the energy exchanges that affect the comfort of city dwellers [19]. Pavements (roads, parking spaces etc.) cover an important percentage of a city's surface and their thermal characteristics play a dominant role in the formation of the urban heat island effect. Paved surfaces contribute to sunlight's heating of the air near the surface and they can transfer heat downward to be stored in the pavement subsurface, where it is re-released as heat at night [20–22]. Asaeda [23] found that pavement heat flux in Tokyo is equal to about half the energy consumption rate of the city. Conventional pavements are usually impervious made of concrete and asphalt, with solar reflectance values ranging between approximately 4% and 45% [24,22], which can reach peak summertime surface temperatures of 48–67 °C [2,22,25,26], as reported from several experimental studies for hot summer climatic conditions.

One of the heat island mitigation strategies that has been proposed by researchers and has gained a lot of interest in the last years is the use of materials that present high reflectivity during the summer period [27,28]. Cool materials are characterized by high solar reflectance and infrared emittance values. These two

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