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Using cool pavements to mitigate urban temperatures in a case study of Rome (Italy)

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Abstract

The urban density and the design of built and natural environments of cities play a crucial role in defining sustainable patterns. Urban heat islands (UHI) are phenomena tightly associated with the development of cities and urban expansion. Its effect is defined as the increase of the urban air temperature compared to surrounding rural areas. One of the main technology aimed at reducing the urban air temperature is the adoption of cool materials. As a matter of fact, the increasing of solar reflectance of urban materials can lead to reduce the built surface temperatures and mitigate the urban heat island intensity. Its features have vast impacts and implications on energy efficiency, environment and at last on human comfort and health. Measured temperatures were used to calibrate a model of a densely populated neighborhood in Rome inputted in ENVI-met software. The actual temperature field was evaluated in comparison with proposed areas consisting in the adoption of high albedo pavements application. Simulation results showed a significant reduction of air temperature closely correlated with the road solar reflectance.

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Keywords: urban heat island; validation model; ENVI-met; urban requalification; microclimate countermeasures; cool pavements

1. Introduction

The well-being and quality of life depends on the climatic conditions of the urban environment. This has a great importance due to the fact that about 50 % of the world's population lives in urban areas [1–3]. This is why it is

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necessary to study the features of the local urban climate. Locally, the presence of an urban area changes the air temperature and humidity, the profile and the structure of the wind circulation schemes [4]. It is the phenomenon of the so-called urban heat island (UHI), which is the effect defined as the increase of the urban air temperature compared to surrounding rural areas [5]. The high rate of urbanization will lead to a bigger exposition to the heat island phenomenon. It follows that the district heating generated from the heat island effect in the city has a very significant impact on human life. It increases the consumption of energy for summer cooling, it reduces the levels of comfort, it increases the concentration of pollution, threatens human health and affects the urban economy. Another cause that concerns the formation of urban heat island is linked to the geometric aspects. As a matter of fact, tall buildings provide bigger surfaces for the absorption of solar radiation that leads to an increase of cooling demand: This phenomenon takes the name of "urban canyon effect". Another consequence produced by buildings is the obstacle to the wind that inhibits cooling by natural convection [6–20]. Every year European projects are aimed at studying the urban climate of the cities, in order to support the population to the climate change. Some of these projects are related to the urban heat island mitigation techniques such as the use of cool materials. These materials have a high reflectance to solar radiation with a high coefficient of emissivity. Low absorption of solar radiation and high infrared emission minimize the surface temperature of these materials, thus decreasing the amount of heat released into the atmosphere during the nighttime and the building cooling demand [21–29].

This study aimed to improve the thermal comfort of a Roman district: Flaminio. After experimental and numerical analysis steps of the area, cool materials was implemented in order to mitigate the urban heat island effect.

2. Methodology

The work consists of the following steps, such as:

- Measurement and analysis of thermohygrometric conditions in the area through the use of a psychrometer;
- Modelling of the area through ENVI-met 4.0 and validation step with experimental data;
- Analysis of the cool material effects from the current situation (ante-operam) to modify area (post-operam).

3. Case study

The area chosen for the city of Rome is an urban site in Flaminio area. In detail, the measures undertaken in this study were conducted in the urban canyon represented by the blue rectangle in Fig. 1(a). The case study is a zone called “Flaminio District” placed in Rome at latitude 41°54'39"24 N and longitude 12°28'54"48 E. The “Flaminio District” enclosed in the yellow line (Fig. 1(a)) is an area of about 0.218 km^2. The study area is located in the north of the city and north-west of the Tiber River. The analysed area are grouped in the following building categories: Historical buildings, condominiums about 70’s, sheds for industrial use and some modern buildings.

The area taken into account is about 735,000 m^2, as shown in Fig. 1 and hereinafter referred as ante-operam. It is characterized by vegetation along the streets and around the river as shown in Fig. 2. This one is placed in the west side where the wind comes. The three-dimensional model recreate the distribution of structures, pavements and vegetation and it is composed by a mesh of 175 x 100 x 25 square cells. Each cell has a dimension of 6(x) x 7(y) x 3.5(z) meters.

The following Table 1 reports the main thermal properties of the material adopted in the ante-operam model. The solar reflectance considered for all surface was measured by an albedometer: The roofs are constituted of bituminous materials and measure an albedo of 0.10; the walls albedo measures are included in a range of values between 0.21–0.85; the asphalt have an albedo measure of about 0.11.

Table 1. Solar and thermal properties ante-operam of material in the urban model.

Urban Models	Thickness, m	Density, kg/m^3	Thermal Capacity, kJ/kgK	Thermal Conductivity, W/mK
Wall	0.40	2571	2.73	1.54
Roof	0.27	3770	2.60	0.96
Asphalt	0.01	1500	6.50	0.50