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Studying the effect of "cool" coatings in street urban canyons and its potential as a heat island mitigation technique

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ABSTRACT

Surface temperature measurements carried out during summer period, at canyons' facades, pavements and street inside a deep urban canyon, in the center of Athens. At the same time experimental data of air temperature were collected through extensive monitoring in the center of the urban canyon.

CFD simulations performed in order to calculate surface temperature in buildings' facades and at street level as well as air temperature inside the canyon. On the first part of this study comparison carried out between the measured and calculated values for a) surface temperature for the initial coating and b) the air temperature in the center of a deep street urban canyon. The calculated data have been thoroughly analyzed and used as well for the CFD model validation. The second task of this work was the calculation of the surface and air temperature, inside the deep urban canyon, by using a "cool" coating and the possible mitigation of the heat island effect in the specific urban area.

The use of "cool" coatings, providing high reflectivity of solar radiation on the materials used on pavements and walls inside a canyon, estimated able to decrease surface temperature up to 7–8 °C at ground level. The decrease on walls' surface temperature estimated close to 2–3 °C. Ambient air temperature inside the urban street canyon may decrease up to 1 °C. The reduction of absorbed solar radiation may lead to the energy consumption and thermal comfort conditions in cities and fight the increased heat island effect.

1. Introduction

"Cool communities" strategies reroof and repave in lighter colors and new materials in order to reduce air temperature in cities and decrease the increased heat island effect. Planting trees is also an effective way to cool communities, mainly effective if they shade buildings, though savings are significant if they merely cool air by evapotranspiration. It was estimated that 50% of the temperature decrease could be arise from planting trees and 29% could be the benefits from the lighter-colored roofs and 21% from the light-colored pavements (Rosenfeld, Akbari, Romm, & Pomerantz, 1998). In the same study it was indicated that "cool communities" strategies, can lead to air temperatures' reduction in LA as much as 3 °C (Rosenfeld et al., 1998).

Advanced reflective materials for roof and pavements, the "cool materials", considered as one of the solutions in the fight of the heat island effect (Akbari, Menon, & Rosenfeld, 2009; Fintikakis et al., 2011; Santamouris et al., 2012; Stavrakakis et al., 2012; Synnefa et al., 2007).

In the study of Fintikakis et al. (2011) the bioclimatic interventions proposed for the retrofitting of the historic center of the city of Tirana, Albania, were the following: a) extended use of shading and solar control in the area, b) use of high size trees and c) use of light colored materials. By the means of CDF tools it was examined the contribution of these bioclimatic interventions to ambient temperature, during summer period, and to surface temperature. It was concluded that the above mentioned retrofitting can contribute significantly to the improvement of thermal comfort conditions and to the quality of life of urban citizens.

A project carried out to optimize the rehabilitation of specific urban zone in the dense urban area of Maroussi, in Athens, Greece (Santamouris et al., 2012). The project dealt with the rehabilitation of a zone of 16,000 m^2, using new high reflectivity pavements, green

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spaces and earth to air heat exchangers. The repaving consisted of colored asphaltic material presenting a reflectivity close to 0.35 in the place of paving surfaces consisted of black asphalt for roads and dark concrete tiles for pavements with albedo lower than 0.4. The initial colored concrete pavements with reflectivity of 0.78 replaced with natural reflective materials, marbles, and concrete pavements colored with higher reflectivity paints. Computational analysis indicated that the use of cool pavements may lead to a decrease of both the peak ambient temperature and the surface temperatures in the build area.

A general computational methodology was developed for assessing and mitigating urban heat island in the study of Stavrakakis et al. (2012). A validated fluid dynamic model was used for prediction of the microclimate in the urban sector and advanced rehabilitation techniques in order to improve pedestrians' thermal comfort as well as to reduce areas of high temperatures. As advanced rehabilitation techniques considered the use of "cool" materials, shading devices, vegetation, water and plant surfaces. It was concluded that the architectural interventions suggested lead to an improvement in thermal comfort by at least 20%, representing an adequate mitigation of UHI in the urban domain (Stavrakakis et al., 2012).

In this study a bioclimatic intervention was tested by the means of a coupled CFD model and measurements from a real state experimental procedure, carried out in the center of Athens. Aim of this study was to examine if materials "cool" colored painted can contribute to the decrease of surface temperatures and be an urban heat island mitigation technique.

The first task of this study addresses the calculated values for surface temperature and air temperatures inside the street canyon, provided by CFD simulations. The simulations carried out based on the orientation of the street, the geometrical characteristic of the street (Height/Width), and the initial coating of the external facades of the experimental site. Computational results compared to field data in order to validate the CFD model used. Secondly, by the means of the computational fluid dynamics model for different "cool" coatings i) air temperature was calculated inside the urban canyon and ii) surface temperature in the canyons facades and at ground level.

2. Description of the measurements

Measurements of several meteorological parameters were performed, during summer period, in the center of Athens. Measurements performed during the 4th-5th and 6th of September 2001; and lasted twelve hours per day (09:00LT-20:00:00LT).

The mobile meteorological station of the University of Athens (Fig. 1) was parted from: a) a vehicle and b) a telescopic mast PT8 Combined Collar Mast Assembly with extended height of 15.3 m, retracted height 3.43 m and maximum head load 15 kg. The experimental site was a deep street urban canyon, which is oriented in the center of Athens with the long axis in a NW'N-SE'S direction (33° from real North counter-clockwise). The urban street canyon was placed in the center of Athens, presenting longitude: 23°44′14.77″ East and latitude: 37°59′6.74″ North, UTC: +2. The in-canyon measuring point was located in the middle of a cross-canyon distance, 20 m from the North intersection. The mean buildings height was 23 m, the distance between buildings was 8 m and the distance between cross intersections of the street was 55 m. The geometrical characteristics of the street canyon were H/W = 3 and L/W = 6.9.

The first type of measurements was:

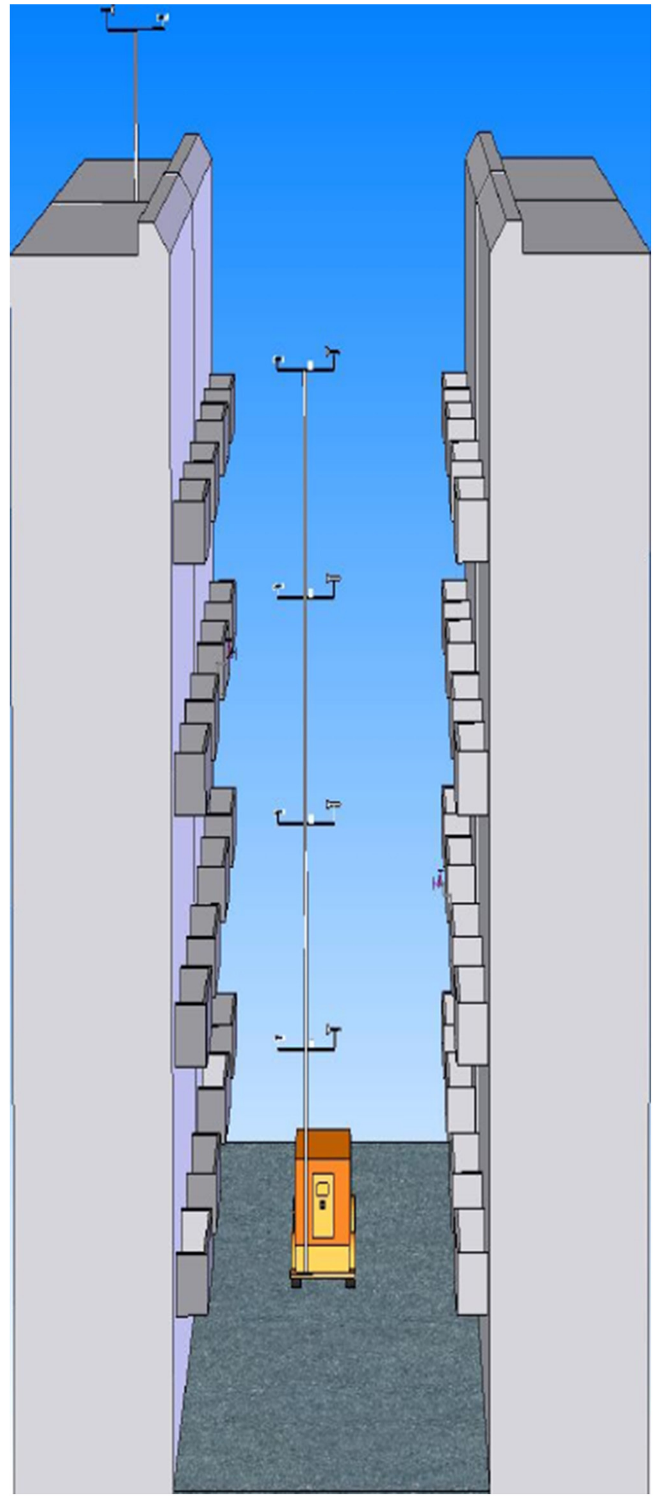

Fig. 1. Mobile Meteorological Station of the University of Athens.

a) Air temperature measurements in the center of the canyon. Miniature thermometers were placed on the telescopic mast at 3.5–7.5–11.5–15.5 m, measured air temperature every 30 s. The miniature screen formed housing for a range of temperature sensing elements, proving weather protection while allowing the free passage of air.
b) Wind speed and direction measurements in the center of the canyon. Anemometers were placed on the telescopic mast at 3.5–7.5–11.5–15.5 m height, measured and recorded wind speed and direction every 30 s. Pulse output anemometer 10 Hz per knot, for recording the air wind speed inside the canyon and W200 Porton Windvane, ±300° ranges for recording the wind