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Evaluation of the application of cool materials in urban spaces: A case study in the center of Florina

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ABSTRACT

In the last years there is a strong interest for application of bioclimatic techniques and practices in urban neighborhoods and open spaces. This paper presents a bioclimatic study of an open space in an urban area by the use of simulation tools giving emphasis on the replacement of conventional materials with cool materials. Routes linking traditional monuments in the Greek city of Florina are characterized of decreased human thermal comfort conditions during summer time. The employment of computational fluid dynamics has contributed in the understanding of what interventions should be made on urban populated routes in order to meet defined thermal related targets during the warmest day of the year. The proposed replacement of conventional materials by "cool" ones would result in the reduction of the mean surface temperature by 3.52 °C while the mean maximum air temperature would be reduced by 1.39 °C during noon of the warmest day.

1. Introduction

It is widely approved that densely urban developments in conjunction with the use of inappropriate external materials, the increased thermal energy emission related to human related and the lack of green areas, increase environmental temperature, leading to significant environmental impacts and increased energy consumption (Fintikakis et al., 2011). Open spaces within urban developments are complicated due to thermal energy exchange between structures, shadowing and wind flow complication in comparison to general flow. Cool material and other practices (water surfaces, green roofs) are used to mitigate urban heat island effect (Gartland, 2008). The main problems that result from bad thermal conditions in settlements include decreased human thermal comfort, decreased air quality, increased heat illnesses and increased energy and water use.

Experimental measurements within urban developments are needed in order to identify the thermal situation. In the Greek territory there are intense thermal phenomena mainly during the summer period (Dimoudi, Kantzioura, Zoras, Pallas, & Kosmopoulos, 2013; Livada, Santamouris, Niachou, Papanikolaou, & Mihalakakou, 2002). These are observed in open urban areas all around country. Surface temperatures in relation to microclimatic conditions (wind, temperature, radiation) must be analyzed in order to better select rehabilitating strategy of open developments.

Simulation tools must be employed (Stavrakakis et al., 2011) in order to depict the present situation around the opencast area, usually during the warmest day of the hot period. Materials identification and constructions configuration must also be taken into account in the simulation process. New materials and bioclimatic techniques are then proposed and simulated in order to show their impact at the thermal urban environment. The aim of this procedure is to realize the microclimatic conditions improvement due to the rehabilitating bioclimatic techniques and practices. The selection of the appropriate measures depends on the targets that will be defined for achieving an improved thermal environment (e.g. thermal comfort).

Due to the complicated urban environment in terms of materials, reflection, emission, wind flows around buildings, altitude differences etc., the simulation tool must be selected very carefully. It must be able to simulate three dimensional flows with solar radiation taken into account. This inevitably leads to general codes of computational fluid dynamics tools (e.g. PHOENICS software tool) but with increased demand of computational resources. Other tools may be useful for the assessment of individual parameters, as surface materials and trees may influence thermal comfort (Matzarakis, Rutz, Mayer, 2006) but they would not assess the wind flow effect in geometrical detail.

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This paper presents a bioclimatic study of an open urban complex space in a city of North Western Greece, Florina, giving emphasis on the replacement of conventional materials with cool materials. The has been carried out in the framework of MSc thesis. The studied area includes the routes linking traditional neighborhoods by the river side of the city. Experimental measurements, simulation tool verification and the simulation based assessment of the proposed redevelopment measures are presented. All simulations have been carried out by the ANSYS CFD software package.

The thermal targets of this study were defined in accordance with the 'Programme for Bioclimatic Redevelopment of Public Open Spaces – Study Guideline' (http://www.cres.gr/kape/Scientific_Guide_19_7.pdf). These concerned the following parameters that should be improved:

1. Mean maximum summer temperature during noon of the warmest day
2. Mean surface temperature during noon of the warmest day
3. Wind field during the typical summer day

2. Bioclimatic thermal problem

Urban climate, compared to the surrounding suburban and rural environment, varies in terms of solar radiation, characteristics of rainfall and air temperature. According to Oke (1973), almost every urban center in the world is warmer 1–4 °C than neighboring non-urban rural areas, and this enforces urban heat island effects. Also, Gilbert (1991) states that the air temperature on sunny days can be from 2.0 to 6.0 °C higher in urban compared to suburban locations.

To examine the weather conditions in the city of Florina meteorological data of the period of 1st of January 2009 to the 31st of December 2010 were used from the meteorological stations of Florina that is located in the urban complex of the city. Hourly data were available and the meteorological parameter that was examined was the air temperature (°C). From Table 1, it was concluded that August of 2010 was the hottest month of the two year period.

Table 1
Monthly mean temperatures (°C).

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2009	1.9	2.6	6.2	12.0	17.2	20.0	23.3	22.2	18.1	12.6	8.6	7.3
2010	2.9	4.5	7.6	12.2	16.9	20.0	22.3	24.3	18.0	11.0	11.7	4.2

3. Bioclimatic interventions

The open urban complex that was studied belongs to the commercial and social center of Florina city, and it is heavy populated during the week. The urban summer time microclimate in this area is mainly affected by the presence of conventional surface tiles and asphalt all over the linking routes. The ground surface of the river side routes of Florina is covered by Greek (flagstone) (Fig. 1).

The rehabilitation strategy of the area targets to conserve human activities and improve human thermal conditions in the open urban complex. Bioclimatic interventions could be divided into two main directions:

- the river side streets
- the linking streets of the river

The main bioclimatic interventions are characterized by increasing vegetation, green roofs and by installing cool asphalt and flagstones.

In order to improve thermal microclimate in the area new cool materials must be used that may reduce surface temperatures of buildings, streets and sidewalks. The proposed materials have relatively high reflectivity of solar radiation and increased emission

Fig. 1. River side routes in Florina.