Experimental study of surface temperatures inside urban canyons during summer period.

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Abstract

The microclimatic conditions inside the contemporary cities are influenced by the phenomena of urban heat island and urban canyon. The morphology of the urban centers, the canyon's geometry and the construction materials are important factors that affect the intensity of the UHI and the parameters of the local microclimate.
The surface temperatures are of prime importance as they modulate the air temperature of the lowest layers of the urban canopy layer, they are central to the energy balance of the surface and they form the energy exchanges that affect the comfort conditions of city dwellers. Paved surfaces contribute to sunlight's heating of the air near the surface. Their ability to absorb, store and emit radiant energy has a substantial affect on urban microclimate.
In the present study the thermal behaviour of typical construction materials in an urban center of North Greece, Serres. is investigated. A number of experimental procedures were carried out during hot summer days, in order to investigate the thermal behavior of construction materials which are used on buildings' envelope, for covering pavements and open spaces. The thermal fluctuation during the day and the surface temperatures differences between different materials is analyzed. Since the paved materials affect the conditions inside the urban centers, it is significant to research their thermal behavior.

Keywords: Topic - Urban design, planning and sustainability; Method - Instrumental observations

1. Introduction

The thermo-physical properties of covered and construction materials in contemporary cities and the urban geometrical characteristics affect the microclimatic conditions inside the urban centers [1].
The radiant balance of the urban space, the convective heat exchange between the ground and the buildings, the air flowing above the urban area and the heat generation within the city [2], [3] increase the air temperature in the city and the difference in values of air temperature between urban and rural areas [4]. The urban heat island (UHI) phenomenon, it is responsible for 1 to 6^{o}C higher air temperatures in the city than the surrounding suburban and rural areas [5], [6].
In order to limit the effect of heat island and improve microclimate conditions, various mitigation techniques have been proposed involving the use of highly reflective materials, use of cool sinks and increased plantation [5], [7]. Trees and green areas have a large effect at moderating the microclimate and also contribute at cooling the cities [8], [9] as evapotranspiration from vegetation foliage reduces air temperature and increases humidity [10]. Vegetated areas are known to be comparatively cooler during daytime than most other urban elements [11]. Mitigating the heat islands effect is therefore a key element to achieving sustainability in a city and it can be done by improving the urban microclimate [4].

The current study investigates the thermal behavior of construction materials inside the urban centre. The investigation took place in a city at the North Greece, which is assumed as one of the warmest cities during summer in the North Greece.

2. Methodology

2.1 Site description

The investigation was conducted in Serres city (Greece), located at 41°05′North and 23°33′E, in North Greece, in an altitude of about 61m above the sea level. The city has intense heat problem during summer and presents thermal episodes of high air temperature that exceed the 40 ºC. The study area is located in the central parts of the city which contains a densely urban structure. The buildings are characterized by four to five floors height and are built in the decade of 1970's. The major amount of the wall's façade is beige in color and about 35% of them are covered by windows. The streets are covered by asphalt and the pavements are covered mainly by light colour, conventional pavement (concrete) tiles.
The selected site has a similar geometric configuration of the urban streets throughout the area. The ratio Height of the buildings to Width of the road in the urban canyon is H/W= 1.4, in average.

In the densely built study region there are only three restricted open spaces (a green area in a crossway road, a park and a playground area), which are covered by green, soil and tiles.

2.2 Description of monitoring campaign

The present study focuses on measurements of surface temperatures of the roads, the pavements and the vertical surfaces, so as to observe the phenomenon of urban heat island and the interaction between them and the air temperature inside the urban canyons.)

The field surveys involved measuring of surfaces' temperature and microclimatic monitoring (air temperature, wind speed, humidity). The measurement of surface temperatures took place in 6 different Measurement Points (MP), which located into the A, B and C streets (Figure 1).

A portable station recorded at 1.8m height the air temperature, the relative humidity, the wind speed and wind direction and the solar radiation. A thermal camera, an infrared thermometer and a surface temperature probe was also employed to measure surfaces temperature of the asphalt's road, the pavements' tiles and the vertical walls of buildings' ground floor, at the height of 1.8m.

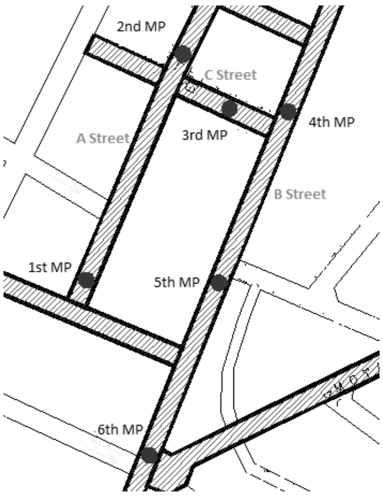

Figure 1: View of the Measurements Points

The experimental procedures were carried out during the midday hours from 13:00 to 16:00 at hot summer days. The measurements took place at the six measurements points, in both sides of the road. The experiments that are presented in this paper were performed between 27 July and 24 August 2011. High temperatures were prevailed during this summer period.

Figure 2: View of the street (left) and the pavement tiles (right)

3. Result and Discussion

3.1 Surface Temperature

During the experimental procedures with the portable station the surface temperature of the asphalt, of the light color tiles that cover the pavements and of the buildings' facades on 1.8m height were measured (Fig. 2). The measurements took place in both sides of the road, from 13:00 to 16:00 hours, twice.

At 13:00 the asphalt was under insolation conditions in the A Street and B Street, while it was shadowed in C Street. At the afternoon, the asphalt was shadowed in all streets of the study area.

The pavement tiles, at midday were insolated in the one side of the road in all measurement points, while the other side was shadowed. At the afternoon, both pavement sides of the 2nd MP, the 4th MP, the 5th MP and the 6th MP were shadowed. Instead, in the 1st MP and 3rd MP the shadow conditions were reversed compared to previous measurement.

The green cover and the pavers in the islet of 6th MP were insolated during the two cycles of the measurements procedures. This is due to urban geometry of the area that permits the entrance of solar radiation in the open space.

Table 1 presents the average temperature of asphalt, tiles and facades, during midday (13:00) and afternoon (16:00). The temperature of asphalt at the midday reaches 44^{o}C, while at afternoon it is shadowed and the temperature fluctuates from 32.5^{o}C to 38.0^{o}C. The temperature of buildings' façade is between 29^{o}C to 37.1^{o}C at midday and 30.6°C to35.7°C at afternoon.

It is notable that the average difference between the surface temperature of green and pavers in the islet is 8.6^{o}C at midday and 11,32^{o}C at afternoon accordingly. The higher difference at afternoon is due to thermal capacity of pavers that storage the heat before emitting it to the environment.

Figure 3 illustrates the surface temperature variation of a wall covered with brown-red tiles as compared to the prevailing air temperature measured at the street, at the same height. This course of measurements was conducted 4 times per day, in the morning, noon, afternoon and evening.

	Asphalt	**White tiles of pavements (right side)**	**White tiles of pavements (left side)**	**Building façade (right side)**	**Building façade (left side)**

	13:00	16:00	13:00	16:00	13:00	16:00	13:00	16:00	13:00	16:00
1st MP	35.4	38.0	33.6	36.8	35.7	36.2	32.7	35.8	32.5	34.1
2nd MP	37.7	34.0	29.9	30.2	32.8	30.9	29.1	30.6	29.8	30.7
3rd MP	33.4	32.5	31.0	30.5	40.8	33.8	31.2	31.2	37.1	32.0
4th MP	44.3	36.8	36.2	32.4	31.0	34.2	34.1	32.6	30.9	31.9
5th MP	42.6	33.8	33.2	31.3	33.2	31.8	32.3	31.4	30.9	31.6
6th MP	43.5	33.8	40.0	33.2	32.0	32.4	32.2	31.3	31.7	31.7

Table 1: Average Surface Temperature of materials (contact thermometer)

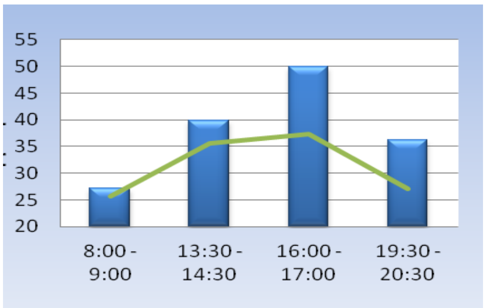

Figure 3: Variation of surface temperature of a brown-red tile covered wall (bar) and air temperature (line) during the July 15t.
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4. Conclusions

The surface temperatures during the midday and afternoon are influenced by the urban geometry, the streets' orientation and the shadowing. The materials' temperature in the A Street increases during the second cycle of the experimental procedures at afternoon. Contra wise, in the B and C Streets the temperatures, in a big majority, are decreasing due to shadowing.

Also, it is conducted that the temperature of green and soil is considerably lower than pavers. These two types of covering are located at the same place with the same shadowing and heat conditions. Although, the average difference between the surface temperature of green and pavers in the islet is 8.6^{o}C lower at midday and 11.32^{o}C lower at afternoon than pavers. Urban vegetation is credited with providing numerous benefits, such as mitigating the urban heat island and improving thermal comfort and air quality. So, landscaping, specifically the incorporation of planted areas in the urban fabric, can modify the microclimate of an area.

Thus, construction and surface covering materials and the green areas existence are important factors that influence the thermal balance and the local urban microclimate.

5. References

1. Lau, S. S. Y., Yang, F., Tai, J., Wu, X. L., & Wang, J., (2011), The study of summer-time heat island, built form and fabric in a densely built urban environment in compact Chinese cities: Hong Kong, Guangzhou. International Journal of Sustainable Development, Vol. 14(1-2), pp. 30-48

2. Mihalakakou, P., Flocas, H.A., Santamouris, M., Helmis, C.G., (2002), Application of neural networks to the simulation of the heat island over Athens, Greece, using synoptic types as a predictor, Journal of Applied Meteorology, Vol. 41 5, pp. 519–527.

3. Santamouris, M., Mihalakakou, G., Papanikolaou, N., Assimakopoulos, D.N., (1999), A neural network approach for modeling the heat island phenomenon in urban areas during the summer period. Geophysical Research Letters, Vol. 26 3, pp. 337–340.

4. Gaitani, N., Spanou, A., Saliari, M., Synnefa, A., Vassilakopoulou, K., Papadopoulou, K., (2011), Improving the microclimate in urban areas: A case study in the centre of Athens, Building Services Engineering Research and Technology, Vol. 32(1), pp. 53-71

5. Santamouris, M., (2007), Heat island research in Europe - State of the art, Advances Building Energy Research, Vol. 1, pp. 123–50.

6. Livada, I., Santamouris, M., Niachou, K., Papanikolaou, N., Mihalakakou, G., (2002), Determination of Places in the great Athens area where the heat island effect is observed. Theoretical & Applied Climatology, Vol. 71, pp. 219–230.

7. Gaitani, N., Michalakakou, G., Santamouris, M., (2007), On the use of bioclimatic architecture principles in order to improve thermal comfort conditions in outdoor spaces. Building and Environment, Vol. 42 1, pp. 317–324.

8. Santamouris, M., (Ed.), (2001), Energy and climate in the urban built environment, The role of green spaces (pp. 145–159), London: James & James Science.

9. Dimoudi, A., (1996), Urban design, In M. Santamouris & D. Assimakopoulos (Eds.), Passive cooling of buildings (pp. 95–128). London: James & James Science

10. Dimoudi, A., Nikolopoulou, M., (2003), Vegetation in the urban environment: Microclimatic analysis and benefits, Energy and Buildings, Vol. 35(1), pp. 69-76.

11. Zoulia, I., Santamouris, M., Dimoudi, A, (2009), Monitoring the effect of urban green areas on the heat island in Athens, Environmental Monitoring and Assessment, Vol. 156(1-4), pp. 275-292.