The influence of urban design in microclimate inside the urban canyons

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Abstract

The urban microclimate is mainly influenced by increased building density, the canyon geometry, the use of materials and the lack of green and open spaces. The urbanism in the last decades has dramatically influence the sustainable development of the contemporary cities. Also, the urban design plays an important role on the configuration of microclimatic conditions.

This paper describes the measurements and analysis of an experimental campaign performed in urban street canyons in a city of North Greece. A number of field experimental procedures were organized during summer 2011 aiming at the investigation of influence of built environment to microclimatic conditions. The present study is focused on the experimental investigation of air temperature, wind speed and wind direction, in different heights along street canyons. The measurements of these microclimatic parameters were carried out during summer, under hot thermal conditions. Also, data from the local meteorological station were used to compare the climatic conditions inside the urban center and in the suburban area. The data analysis investigates the configuration of microclimatic conditions inside the urban canyons and the intensity of urban heat island.

The extracted conclusions indentify the influence of urban design to the sustainable conditions inside the urban centers.

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

1. Introduction

The local climate of an urban area can be greatly affected by the urban thermo-physical and geometrical characteristics, anthropogenic activities and heat sources present in the area. The urban environment modifies micro-climate in numerous ways [1]. So, there is a growing interest in microclimate issues as they represent important factors in achieving sustainability inside the cities, where a big amount of the population is living.

The urban growth has caused significant changes in 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]. The main consequence of these effects is the difference in values of air temperature between urban and rural areas [4]. This called urban heat island (UHI) phenomenon, it is responsible for 1–6oC higher air temperatures in the city than the surrounding suburban and rural areas and is the most obvious climatic manifestation of urbanization [5], [6].

The phenomenon is present in many cities around the world [4], [5]. The urban microclimate is mainly influenced by increased building density with the canyon geometry, the use of materials with inappropriate optical and thermal properties, the lack of green spaces, increased anthropogenic heat and increased air pollution [7],[8],[9]. So, the main differences between the urban and rural microclimatic conditions that affect human comfort result from differences in air temperatures and wind speeds [10],[11].

The aim of the current study was the investigation of microclimatic conditions in a densely constructed urban complex consisting of different building blocks in the centre of a city. The investigation took place in a city at the North Greece, which is assumed as one of the warmer cities during the summer in the North Greece. Particular emphasis was given in air temperature, wind characteristics, as these characteristics are affected by the canyon geometry, orientation, weather conditions [12] and thermal properties of the constructive materials.

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 study area is located in the central parts of the city which contains a densely urban structure. The ground floor of the blocks is for commercial use (shops), while the rest of the floors are residences. The buildings are characterized by four to five floors height and are built in the decade of 1970's. The streets are covered by asphalt and there of them there pavements 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.

Figure 1: Urban geometry and streets' configuration of the study area

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. These areas could be to reclaim so as to configure better microclimatic conditions inside the urban canyons. Also, there are a church and a small school building which have lower height of the other blocks and a yard around.

Analysis of the climatic data for a period of 30 years (1973-2004) from the cities in North Greece, documents that the city of Serres is characterized by the highest air temperatures in summer period in N. Greece. The city has intense heat problem during summer and presents thermal episodes of high air temperature that exceed the 40 ºC.

2.2 Description of monitoring campaign

The aim of the present study was to investigate the microclimatic conditions inside the streets in a densely populated area in the city centre and to compare it with the sub-urban area.

A number of experimental procedures were organized in the study area. The field surveys involved detailed microclimatic monitoring by two different operation programs, one with a fixed measurements net and one with a set of portable equipment.

The first program included continuous measurement of microclimatic parameters and specifically the air temperature (T), the relative humidity (RH), the wind speed (WS) and the wind direction (WD). The mini weather stations for monitoring the air temperature and relative humidity were placed in 6 specific fixed Measurements Points (MP) in the study area (Figure 3). The location of the monitoring equipment took into account the geometric and the morphological characteristics of the region.

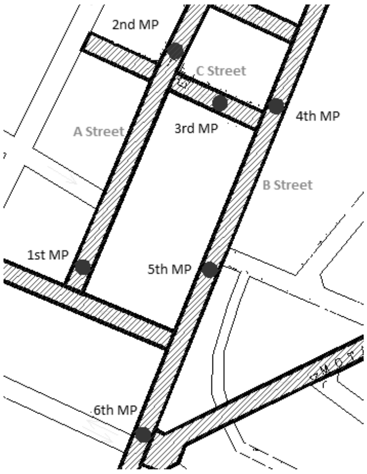

Figure 2: View of the selected stations of fixed measurements

The fixed weather station for air temperature and humidity was placed at 4.5m height and recorded the microclimatic data every 5min.

The sensor for recording wind speed and direction was an ultrasonic wind sensor of 2-axis, with low start speed in 0.01m/sec. This advantage makes it appropriate for measuring wind speed in densely urban centers, where the wind speed can be extremely low due to urban configuration and geometry. The sensor was firstly placed for 6 days at the fourth measurement point (4th MP, B Street) and afterwards at the first point (1st MP, A Street). It recorded data every 10min.

In order to evaluate the microclimatic conditions within the urban street, a series of measurements were collected by a portable weather station. The portable station recorded at 1.8m height the air temperature, the relative humidity, the wind speed and wind direction and the solar radiation. The experimental procedures with the portable weather station were carried out during the midday hours from 13:00 to 16:00 at hot summer days.

Also, data from the local meteorological station were used to compare the climatic condition of Greater Serres Area (GSA) and microclimatic condition of the study area. The meteorological station is located in South-East suburban area of the city, in a not densely populated area.

The experiments that are presented in this paper were performed between 27 July to 24 August 2011. High temperatures were prevailed during this summer period.

3. Result and Discussion

A discussion is initially presented focusing on the microclimatic parameters of wind characteristics and air temperature, inside the urban canyons in the city's centre. The microclimatic data recorded in the study area are also presented along with the meteorological data of the GSA for investigating the correlation and the interaction between them.

The discussion focuses on analysis of thermal behavior inside the streets and the comparison between the microclimatic parameters of the urban centre and suburban.

3.1 Development of the air flow

In the A Street the main direction of the air flow is East (E) and South (S). The incidence amount is 28.5% and 27.9% respectively. The more intensive wind has South-West direction (SW) and the average wind speed is 0.7m/sec. Then follow the South (S) direction winds with average wind speed 0.58m/sec, which are the second appeared main direction winds in the street. The maximum wind speed that recorded during the experimental procedures is 1.5m/sec for SW direction.

In the B Street the main direction of the air flow is South-West (SW), in amount of 35.6%. The more intensive winds have North-East (NE) direction with average wind speed 0.5m/sec and the South-West (SW) and West (W) with average wind speed 0.45m/sec. The maximum wind speed is 1.5m/sec, North-East direction (Table 3).

Table 1: Wind flow characteristics in two streets, in study area

	main WD	more intensive wind		Max	
		WD	WS (m/sec)	WD	WS (m/sec)
A Street	E (28.5%)	SW	0.7	SW	1.5
B Street	SW (35.6%)	NE	0.5	NE	1.5

In the A Street, the wind speed is increasing from the 9:00 to 12:00h, during the measurement period. At 12:00 the average wind speed is about 0.6m/sec. For the next five hours the wind speed has high values and the highest wind speed is 0.7m/sec at 15:00. During the afternoon time the wind speed is decreasing (Figure 3).

In the B Street, the wind speed is increasing until 14:00h, where it is observed the higher wind speed (0.6m/sec) compared to the morning hours. In the afternoon, the wind speed is decreasing.

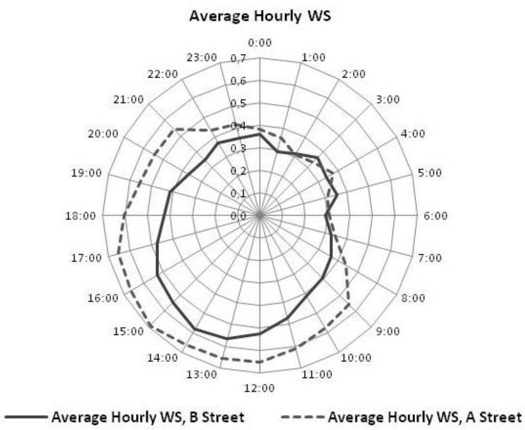

Figure 3: Hourly Average Wind Speed for the two streets

3.2 Air temperature distribution

The air temperature distribution was analyzed in order to investigate the impact of the street layout. At the Figure 4 the daily fluctuation of the average air temperature of all days that took place the experimental measuring is presented. Each curve corresponds to a fixed station and shows the daily fluctuation of the air temperature, every 5min. The curve named GSA shows the temperature fluctuation for the greater area of the city, based on every 3 hours data.

The maximum air temperature of GSA in suburban area is observed at 12:00 a.m., while for the stations inside the urban centre between 15:00 to 16:00h, three to four hours later than in the suburban area. The air temperature in GSA is decreasing after 12:00 until the 3:00 a.m., when it starts increasing. The temperature in the study urban area remains higher than GSA for more hours, because of the later appearance of the maximum temperature. At 15:00 p.m. the air temperature between the city's center and suburban is about the same, while at the next hours until 6:00 a.m. the temperature is higher inside the streets.

The air temperature in the study area is about 5.0°C to 5.5°C higher than the suburban area during the afternoon and night (between 3:00 p.m. to 6:00 a.m.), while at the morning and early afternoon (6:00 p.m. to 3:00p.m.) it is lower by up to about 7.0°C.

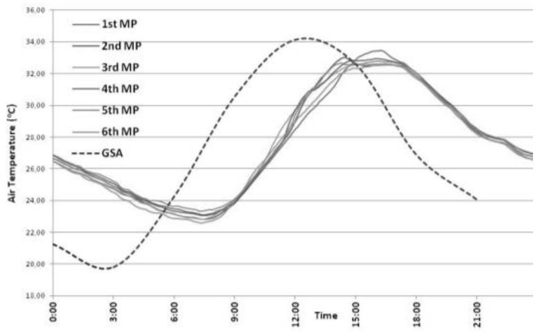

Figure 4: Daily fluctuation of Air Temperature for the six MP inside the urban streets and GSA in the suburban

4. Conclusions

According to the data analysis, the wind speeds inside the urban canyon in the study area are lower than in the suburban, GSA. Specifically, the wind speed in the pedestrians' level (1.8m) is the 1/3 to 1/4 of the suburban area. The wind direction differentiates according the geometry and orientation of the streets.

So, there is a serious reduction of the wind speed in the urban canyons and a limitation to apply natural and night ventilation in the dense urban environment. Ventilation contributes to the improvement of thermal comfort conditions in open urban spaces, restricts problems such as high ambient air temperatures due to urban heat island effect and contributes to the decrease of energy consumption or need for air conditioning during summer period.

The air temperatures in the study area are about 5.0°C to 5.5°C higher than in the suburban, during the afternoon and night time. This is due to the urban configuration that obstructs the air flow and city's ventilation and increases the intensity of the phenomenon of Urban Heat Island.

The above results indicate the influence of urban geometry to the microclimatic conditions in an area. The morphological characteristic of city's planning (width of roads, height of buildings etc) and the existence of open and green areas influence the air flow inside the urban canyons and the thermal balance in the local microclimate.

5. References

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