Microclimate improvement through redesign of open urban areas with bioclimatic criteria in a city centre

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The morphology of the urban centres, the urban design, the canyon's geometry and the constructive materials are important factors which affect the parameters of the local microclimate.

In the present study the microclimatic conditions inside the urban canyons of a city in North Greece, Serres, are proposed to be improved through redevelopment of an array of streets and open areas in the city centre.

The paper presents the measurements that addressed the problem of the microclimate condition in the area and also the design and construction solutions that are proposed to eliminate the problem.

A number of measurements were carried out during hot summer days. The analysis and observations of the above data were useful for understanding how the urban morphology influences the intensity of urban heat island and the microclimate inside an urban centre

The redevelopment of an array of streets and open areas in the city centre aims at the bioclimatic and qualitative aesthetic upgrade of the area, strengthen of the local market and environmental improvement of the area. The proposed interventions include increase of vegetation, of shaded open spaces and introduction of water surfaces. The surface temperatures will decrease as cool materials will replace the existing ones. Ventilation of the area will be improved through special systems like ventilation towers and open spaces fans at selected locations.

Keywords: urban *microclimate, redesign of open spaces, bioclimatic redesign*

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. 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 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 [1, 2]. Redesign of open spaces with bioclimatic criteria can improve microclimate and thermal comfort conditions [3, 4].

In the present study the microclimatic conditions inside the urban canyons of a city in North Greece, Serres, are proposed to be improved through redevelopment with bioclimatic criteria of an array of streets and open areas in the city centre.

This paper presents the measurements that addressed the problem of the microclimate condition in the area and also the design and construction solutions that are proposed to eliminate the problem.

2. SITE DESCRIPTION

The Serres city is located at North Greece, at 41°05′North and 23°33′E, in North. The city experiences intense heat problems during summer period and presents thermal episodes of high air temperature that exceed 40 ºC. The study area is located in the central part of the city which is consisted by a densely urban structure (Figure 1). The buildings are characterized by four to five floors height and are built in the decade of 1970's. The ground floor of the blocks is for commercial use (shops), while the rest of the floors are residences. The site has about 14 building blocks and 10 streets, with a similar geometric configuration of the urban streets throughout the area. The ratio height (H) of the buildings to width (W) of the road in the urban canyon is H/W= 1.4 in average.

Figure 1. View of urban geometry and streets' configuration in area

The area was a basic part of the socio-economic development of the city that declined over the years. The oldness of the buildings, their insufficient maintenance in parallel with the lack of sufficient space to accommodate the increasing needs of the residents, especially for parking and green open spaces, resulted at degradation of living conditions in the area. Additionally, during summer, the area suffers from discomfort conditions due to overheating and wind calm.

The aim of the proposed redesign of the area is the improvement of living conditions, aesthetic upgrade of the urban neighborhoods in the intervention area and the improvement of summer comfort conditions in the area by applying bioclimatic means.

3. MICROCLIMATE SURVEY

3.1 Monitoring details

A series of measurements were taken in the study area in order to investigate the microclimatic conditions inside the streets and to compare it with the sub-urban area.

Continuous measurements of microclimatic parameters were taken during the summer period in 2011, specifically the air temperature (T), the relative humidity (RH), the wind speed (WS) and the wind direction (WD). Mini weather stations for monitoring the air temperature and relative humidity were

placed in 6 fixed Measurements Points (MP) in the study area, at 4.5m height, and recorded the microclimatic data every 5min (Figure 2). The location of the monitoring equipment took into account the geometric and the morphological characteristics of the region. The wind speed and direction was recorded with an ultrasonic wind sensor of 2-axis, with low start speed in 0.01m/sec. This low start speed makes it appropriate for measuring wind speed in densely urban centres, where the wind speed can be extremely low due to urban configuration and geometry. Measurements every 10min, at two locations were performed, firstly at the 4th measurement point (4th MP, B Street) for 6 days and afterwards at the 1st point (1st MP, A Street). The monitored data that are presented in this paper were performed between 27 July and 24 August 2011.

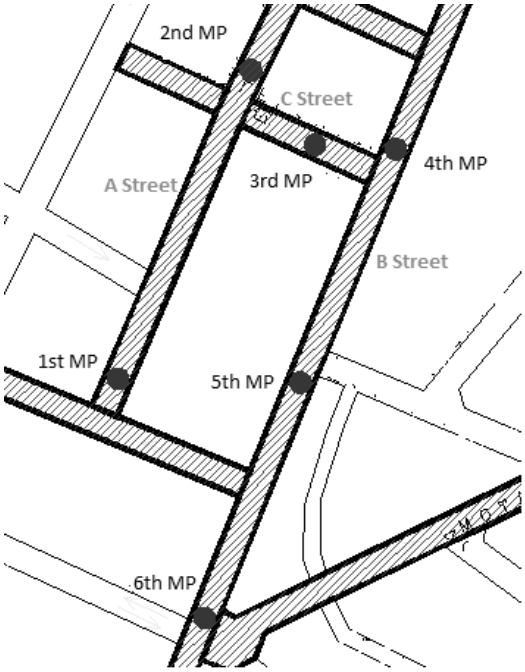


Figure 2. View of the selected stations of fixed measurements

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

3.2 Microclimate analysis

The daily fluctuation of the average air temperature during the days that the experimental measuring took place is presented at Figure 3. Each curve corresponds to a fixed station (MP) 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 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. 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 [5].

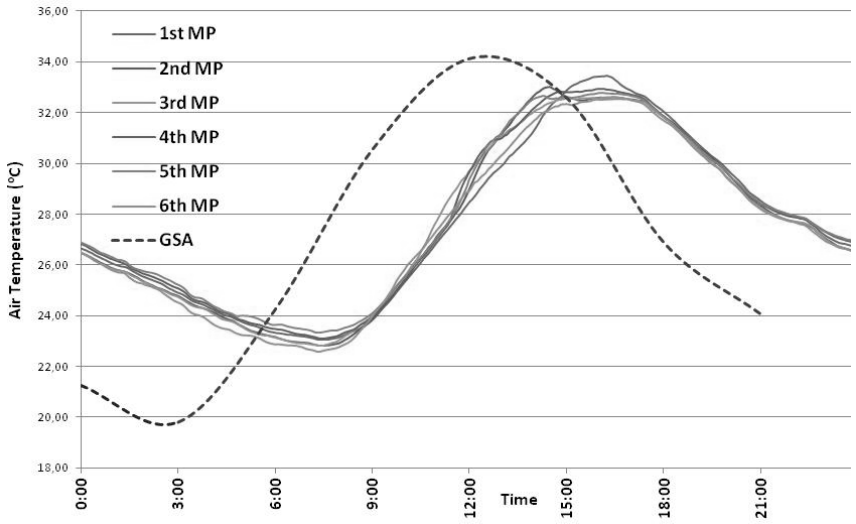


Figure 3. Daily fluctuation of air temperature for the six MP inside the urban streets and GSA in the suburban

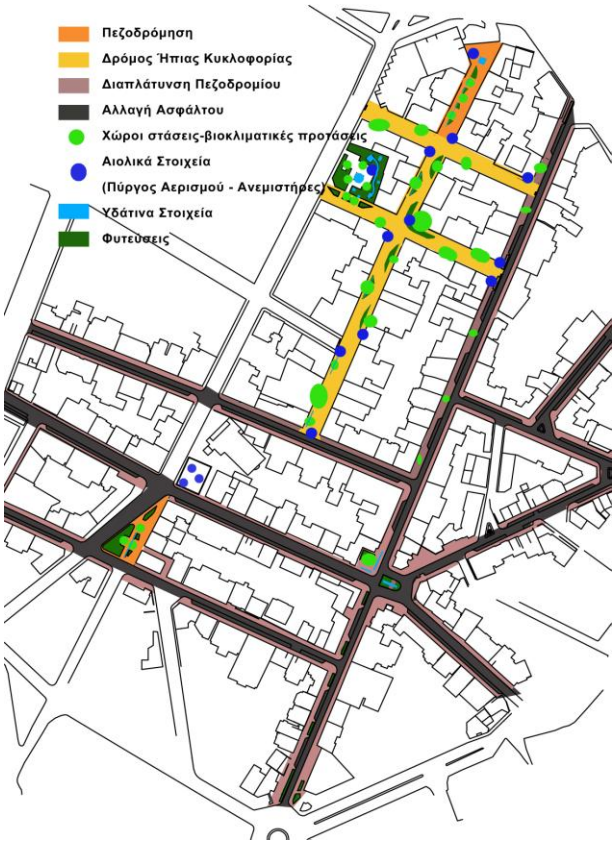
During the morning hours the wind speed was increasing, reaching at 14:00 the mean maximum hourly wind speed for the recorder period of about 0.6m/s in street B and 0.7 m/w, at 15:00 in street B.
The maximum wind speed that recorded during the experimental period was 1.5m/sec in both A and B streets (with SW direction for street A and NE direction for street B). During afternoon time, the wind speed was decreasing.
The measurements confirmed that overheating with poor ventilation conditions was characterizing this area of the city centre.

4. BIOCLIMATIC DESIGN PRIORITIES

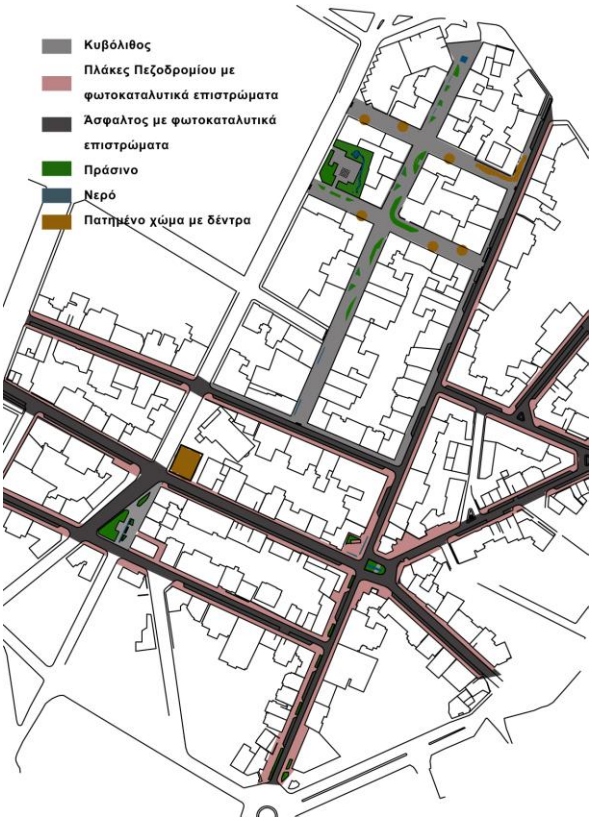
The bioclimatic interventions that were planned for improvement of microclimate and outdoor thermal comfort conditions during summer in this part of the city and consequently of improvement of indoor thermal comfort and improved energy performance at the surroundings buildings – lower air temperature of the external environment contributes to reduction of the hours that air-conditioning is used at buildings and at higher efficiency of the A/C units) are the following (Drawing 1, Drawing 2):

- Shading of external places: due to street orientation at North-South axis and solar access at pedestrian level during part of the day, permanent shading elements were designed, mainly at sitting places that are created at selected places but also at open spaces (e.g. park). Extensive vegetation is also used for shading that apart from other cooling benefit it contributes to psychological realm and aesthetic improvement of the area.
- Air temperature reduction: with extensive use of vegetation with native species – shrubs and trees - along the streets that act as a natural conditioning system through its evapotranspiration phenomena.
- Surface temperature reduction: with replacement of conventional floor cover materials with cool materials at pedestrian streets and pavements and replacement of asphalt with photocatalytic asphalt at streets.
- Enforcement of air ventilation in the outdoor spaces: outdoor fans are located at selective places to increase air circulation through the streets and create comfort sitting places during hot days.
- Introduction of direct evaporation: through the natural evapotranspiration of vegetation and several water installations, like fountain - jet, water-curtains, spray-systems (Figure 1). According to literature,

a developed deciduous tree evaporates 1.460 kg of water during a sunny summer day' while 'it is estimated that water jets, spray and water-curtains, for mean summer climate conditions, result at 150-200 W/m^2, with evaporation rate on a wet surface depending on air velocity and vapor content of the air.



Drawing 1. Overview of the proposed interventions in the area

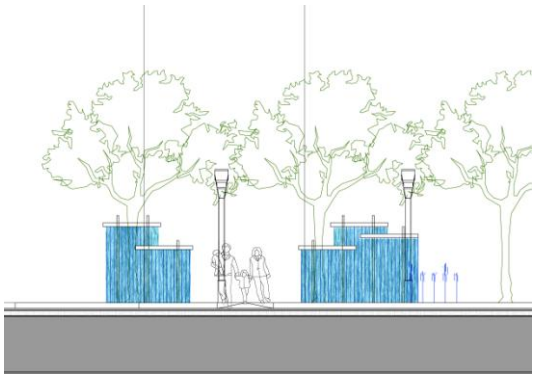


Drawing 2. Mapping of the use of new materials

The bioclimatic interventions in the area also include:

- Increase of access in the area for pedestrians and people with special needs and encouragement of "soft movement means' (e.g. bicycle, low traffic speed routes); reduction of space for car movement through reduction of streets width and increase of pavement width and creation of 'low speed traffic routes'. This is achieved with:
  - bioclimatic transformation of an array of streets into 'low traffic speed routes', with use of bioclimatic elements like water surfaces, shaded areas and qualitative urban equipment,
  - increase of the width of existing pavements and transformation into pedestrian places for walking with use of bioclimatic elements.
- Improvement of outdoor public spaces for people use and predominance of natural elements and materials that is friendly to the environment. The bioclimatic redevelopment of the outdoor public spaces in the studied area concern parks, a playground, a school courtyard and street junctions.
- Extensive plantation along the streets with deciduous trees that offer increase of the shaded areas and air temperature reduction due to evapotranspiration during the summer period, they contributes to psychological realm and aesthetic improvement of the area.
- Use of water elements as extensively as the available space in the area allows it, in order to promote natural cooling means (Drawing 3). The water elements combined with the vegetation contribute to aesthetic upgrade of the area.

- Creation of a cycling path in the area and connection with the planned cycling route in the city.
- Ensuring parking places with controlled and structured way in recesses along the streets**.**
- The smooth traffic operation of the area is maintained, as cars' movement and the undisturbed access in all streets of the under redevelopment area is ensured**.**
- Consolidation of the security feeling and avoidance of violence spots, with provision at the design of the open spaces so that all corners are visible from passing persons and form adjacent streets. Adequate lighting, with energy saving features, is ensured in all places.



Drawing 3. Artistic intervention with water-curtains

The proposed interventions aimed at giving a flagship in the whole project, with cooling elements, like artistic water jets, at the entrance of the streets in the intervention area, wind towers, thematic parks, outdoor fans, so that they mark the bioclimatic redeveloped area. The aim is to obtain the area a distinguished identity, the 'bioclimatic neighborhood' that it will attract people for its bioclimatic character and become a cool shelter during 'overheating days' (Picture 1).

Picture 1. 3-D representation of the bioclimatic interventions in one street

5. CONCLUSIONS

The study area experiences higher air temperature by about 5.0°C to 5.5°C than the suburban area, during the afternoon and night time which result at overheating conditions in the outdoor spaces and indoors. This can be attributed to the geometry of the urban area that obstructs the air flow and ventilation of its streets and also at the use of cover materials with high thermal conductivity and heat capacity (e.g. asphalt and pavement tiles).

The wind speed in the area is low, reaching, during the experimental period, a maximum value of 1.5m/sec. During afternoon and evening hours the wind speed was decreasing. This increases the discomfort conditions in the area due to poor ventilation conditions and limitation to apply natural and night ventilation in this urban area.

The sustainability of the area will be achieved with the proposed architectural redesign. The interventions will improve microclimate and thermal comfort conditions in outdoor spaces but also will improve thermal conditions in the surrounding buildings. This will attract people outdoors and regenerate the social life of neighbourhoods in the area but also it will upgrade the economic value of properties.

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