DESIGN STRATEGIES TO REDUCE THE HEAT-ISLAND IN THE URBAN SPACE. MADRID STADIUM CASE.

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ABSTRACT

This paper presents the results of a comparative study aiming to investigate the relation between microclimate and urban space design in Madrid. The scope of the work is establishing the effectiveness of mainly countermeasures against the urban heat island to ameliorate potential summer overheating in cities.
The work analyzes the air temperature monitoring in three locations in Madrid and compares these with the difference of urban design. The preliminary result strongly indicates an air temperature difference between the city location analyzed and the surrounding rural environment. Also, the work show appreciable differences between city locations each other.

1 INTRODUCTION

The unique microclimate of cities is the product of their complex built environment, their lack of cooling vegetative surfaces, and their increased anthropogenic activity. These combine to create a thermal contrast between urban and rural areas.
In the 1970, as consequence of energy crisis, as well as the boom of renewable energy and bioclimate architecture, the effect of urban spaces in the energy consumption has be taking into account in order to energy save. Now and day, due to the problem of climate change and the items of ecology and sustainability, the research on architecture and urban planning is more and more important. The control of micro-climate conditions in the cities is vital for the energy efficiency, reductions of emissions as well as to health and comfort for the citizens.
The city climate is defined as comparison with rural surrounding. From that comparison, it is possible to characterizing the city climate behaviour, although each city preserves the climatic conditions particular of region where settle. Also, in the same city, different climatic conditions could be verified. It could depend of morphology, sky view factor, use of green areas and urban design on the whole.
The features more pronounced are the increase of temperature, the reduction of daily temperature variation, the distributions of wind and the rainwater balance different compared with rural areas. The causes that generated this phenomenon are complex and generally related with the energy balance of city. The mainly factors that creating the urban heat island are:

- Reduced vegetation in urban regions: Reduces the natural cooling effect from shade and evapotranspiration.
- Properties of urban materials: Contribute to absorption of solar energy, causing surfaces, and the air above them, to be warmer in urban areas than those in rural surroundings.

- Urban geometry: the height and spacing of buildings affects the amount of radiation received and emitted by urban infrastructure.
- Anthropogenic heat emissions: contribute additional warmth to the air.

The Urban Heat Island intensity also depends on other factors like as city size, morphology, topography, human activity and regional clime (winds, temperatures, meteorology inversion, etc.).
In the urban spaces exists two type of Urban Heat Island: surface and atmospheric heat island. These two types differ in the ways they are formed, the technique use to identify and measure them, their impacts, and to some degree, the method available to mitigate them. Table 1 summarizes the basic characteristic of each of heat island.

Features	Surface UHI	Atmospheric UHI
Temporal Development	• Present all times of the day and the night • Most intensity during the day and in the summer	• May be small or no-existing during the day • Most intense during the night or predawn and in the winter
Pack intensity (Most intense UHI conditions)	More spatial and temporal variation: • Day 10º to 15ºC • Night 5º to 10ºC	Less variation: • Day 1º to 3ºC • Night 7º to 12ºC
Typical identifications method	Indirect measurement: • Remote sensing	Direct measurement: • Fixed water stations • Mobile traverses
Typical Depiction	Thermal image	Isotherm maps Temperature graph

Surface urban heat islands are typically present day and night, but tend to be strongly during the day when the sun is shining. The magnitude of surface urban heat islands varies with seasons, due to the change in the sun's intensity as well as ground cover and weather. As result of such variation, surface urban heat islands are typically largest in summer. To identify surface heat islands scientists use direct and indirect method, numerical modeling, and estimate based on empirical models. Researches often use remote sensing, and indirect measurement technique, to estimate surface temperature.

Warmer air in urban areas compared to cooler air in nearby rural surroundings defines atmospheric urban heat islands. Experts often divide these heat islands into two different types:

- Canopy layer urban heat islands**:**
  exist in the layer of air where people live, from the ground to below the tops of trees and roofs.
- Boundary layer urban heat islands:
  start from the rooftop and treetop level and extend up to the point where urban landscapes no longer influence the atmosphere. This region typically extends no more than one mile (1.5 km) from the surface.

Atmospheric urban heat islands are often weak during the late morning and throughout the day and become more pronounced after sunset due to the slow release of heat from urban infrastructure. The timing of this peak, however, depends on the properties of urban and rural surfaces, the season, and prevailing weather conditions. Researchers typically measure air temperatures through a dense network of sampling points from fixed stations or mobile traverses, which are both direct measurement methods.

2 THE URBAN HEAT ISLANDS IN THE URBAN SPACES

The urban heat islands have as principal consequence an increment of temperature in urban spaces compared with the rural areas. The First consequence is the increments of use of mechanical cooling in the building enables a reduction internal temperature and restore de comfort level for the occupants. The heat islands effect could be produced during the day as well as in the night with a temperature increase that could be reach 10ºC.
The cooling of buildings is a very important problem because, especially in hot and dry clime, could produce waste energy and GWP gases emissions more important than for the heat. In the last two decades, the energy consumption for cooling as increased significantly, mainly for European countries.
The increases of peak temperature and the extension of daily functional hours from 8 to 12 hours represent an important cost increase due to electrical consumptions and the need to use equipment with more power in order to ensure the comfort conditions.
The increases of temperature have warmer consequence for the people health as well as for the environment. The NOx gases emitted in the combustion process are the precursor for the troposphere ozone (O3) a toxic gas, mainly responsible of photoquimical smog creations. The production of O3 is happening with sunbeam and it's bigger in summer and in the hotter hours of the day.
There is a strong relationship between microclimatic conditions and use of open spaces. The environmental conditions imposed on people using open space, may improve or ruin their experience of them. Thus by integrated social and environmental objective, it will be possible to increase use of outdoor spaces and revitalized cities, strengthening social interaction between citizens, by allowing for such interaction to take place.
Jan Gehl (1987) defines the goodness of a place, in term of the protection offers from negative aspects of climate and exposure to the positive one. Similarly, Ralph Erskine (1988) define the social spaces as the place to spontaneous activity to take a place mentioning the strong influence of climate to it, whereas Finnish Reima Piëtila (1988) speaks of architecture and climate as being a dynamic couple.
The recent research has show that the response to microclimate, may be unconscious, but they often result in an different use of open space under different climate conditions. Although the comfort conditions vary with metabolic function, clothing and psychological adaptation, the outdoor conditions affect significantly the users. Temperature, humidity, winds, lighting and sunbeam exposition are de mainly factors that conditioning the urban spaces quality (4).

3 STRATEGIES TO REDUCE THE URBAN HEAT ISLAND EFFECTS

Urban climate of each region is influence by regional characteristic, e.g. urban scale, geographical features, land-use, sea breeze and artificial heat release etc. Thus effective countermeasures in each region are different according to the regional characteristic. The applications of them depend of a lot of factors. Some of them could be incorporated in the city planning design strategies.
Countermeasures against effect of heat island are generally intended to modify the energy balance mechanism in urban space. The different energy balance between urban surfaces and surrounding areas depend on ratio between sensible and latent flux. The rural areas,

mainly cover with vegetation, are characterizing for evapotranspiration, unlike urban spaces are cover with artificial surfaces, have low latent energy flux.
The use of trees and green spaces is the first and more effective countermeasure against the urban heat island. Trees and vegetations help cool urban climate though shading and evapotranspiration. Leaves and branches reduce the amount of solar radiation that reaches the areas below the canopy of trees or plants. Shading reduces surface temperature below tree canopy. These cooler surfaces, in turn, reduce the heat transmitted into buildings and the atmosphere. Evapotraspiration cools the air by using heat for the air to evaporate water and, generally, change the latent flux of energy balance of the areas.
The urban temperature distribution depends on urban radiation balance. The solar radiation incident on urban surfaces is absorbed and transformed as sensible heat. Roofs, facades, roads, squares and etc. represent an important heat accumulation mass, which re-emitted the heat as longwave and with time lag. The intensity of wave depends on sky view factor, material characteristic as albedo, emissivity, inertia etc. (6-7)
The composition of artificial surface is very important in the formation of urban heat island. For example the roads represent about 16% of urban surface in the typical city development, and rise until 23% in the regular grid like social-housing neighborhood. The extension of horizontal surfaces exposed to sunshine, joint with absortance and the high thermal capacity of the materials employed, has an important impact.
The urban morphology is responsible for lowering the porosity of the city and limiting air flow through it. The relationship between urban morphology and the urban-rural temperature difference has been show to display an inverse linear association under the idealized urban heat island conditions outlined above, for a range of mid latitude, developed cities. Morphology has fundamental importance to the timing and magnitude of the heat island effect.

4 OBJECTIVE OF RESEARCH

The reduction of urban heat island is fundamental strategies for the energy save and improve exterior space comfort.
The urban population of Europe is predicted to increase from 73% of the total population in 2000 to 80% in 2030 (United Nations,2005) and temperature increases of 0.1–0.5 1C per decade are expected across the UK and Europe during the 21st century (Hulme etal.,2002; IPCC, 2007a). While the use of mechanical cooling in buildings enables a reduction in internal temperatures and restores the comfort level for occupants, it is not a desirable solution overall.
The varieties of elements that influence the urban heat island effect are complex and interacts each other in no linear way.
The scope of this research is investigated the impact of physical characteristic of urban land use in outdoor air temperature.
The used data are:

- Meteorological data collected in 3 stations of Madrid
- Selection of suitable area extension for the analysis
- Selection of urban design measures that influence the urban heat island effect, that could be associated with quantifiable indicator

Through these is be possible:

- Establish the urban heat island magnitude in the different stations
- Investigate the relationship between microclimate conditions and land use

5 THE URBEN HEAT ISLAND IN THREE NEIGOURHOOD IN MADRID

The urban heat island could be quantified in temperature different between two observatories, one in urban space and the other rural, ΔT_{u-r}. In this work different temperature collected in three stations of Madrid will be compared.

5.1 Methodology

The work is based on the comparison between air temperature and the urban design characteristic in the three stations selected.
The meteorological data are be collected by SIM (Sistema integral del Ayuntamiento de Madrid), a network developed in order to control the air quality data.
In order to check the effect of growth of the city of Madrid on the annual evolution of temperature, a trend study of hourly temperature data are be analyzed. The work was been performed analyzing the hourly average temperature collected during summer season (June, July and August) and winter season (January).
Related de context boundary, this research considers 250m radius with respect to measurement point as the study area, and material surface upper 10% of total surface
The research is focusing on countermeasures available in open spaces because are the mainly work could be carried out in the rehabilitations of built areas. For this reason the work was been limited on land use analysis as principal responsible of urban heat island. The table.1 shows the design parameters and indicators selected.

	Criteria	Indicator
Green space	Green area	% (m^2/m^2)
Land use and materials	Dark surfaces area	% (m^2/m^2)
	Clear surfaces area	% (m^2/m^2)
	Average Albedo of paved area	%

Table.1 Urban design criteria

5.2 Stadium cases description

The stadium cases are:
Plaza de España (station 1)
The station of Plaza de España is located in the city center and the values measured are representative of urban city center. The built environment is characterized on high density, the vegetations presence is reduced and the human activity is very strong due manly to the traffic.

Fig. 3 Plaza de España. Source: Google Earth

Municipal Acoustic Centre of Madrid (station 2)
The station 2 is localized near the Manzanares River, closed to M-30 road. The areas are less density and the important presence of open and green spaces.

Fig 4 Centro Municipal de Acustica. Source: Google Earth

District Council of Moratalaz (station 3)
Moratalaz is residential neighborhood located on South-East of Madrid, closed to A3 highway. The built space is composed of 5 floors block and green space between block.

Fig. 5 Junta Municipal de Moratalaz. Source: Google Earth

5.3 Temperature data analysis

This study considers temperature data collected in July and August for the summer and January for the winter.
The first analysis is focused on daily temperature trend analysis for the three stations. The average values of hourly air temperature are be represented on figure 6, 7 and 8.

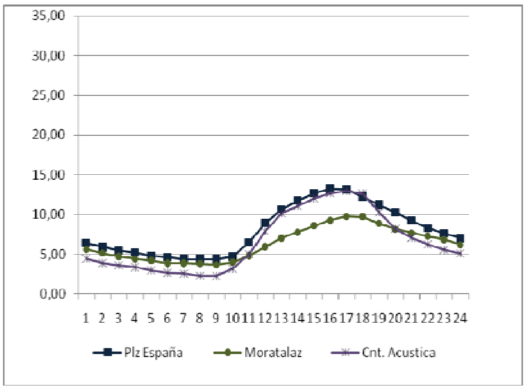

Fig.6 January

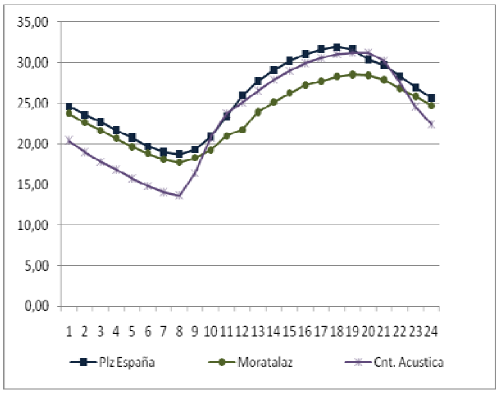

Fig.7 July

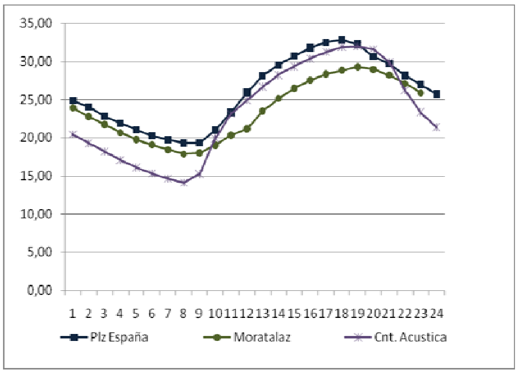

Fig.8 August

Station	July	August	January
Plaza de España	11,9	11,97	8,58
Centro de Acústica	16,44	16,68	9,99
Ayuntamiento de Moratalaz	9,7	10,2	5,38

Table 3 daily termical range

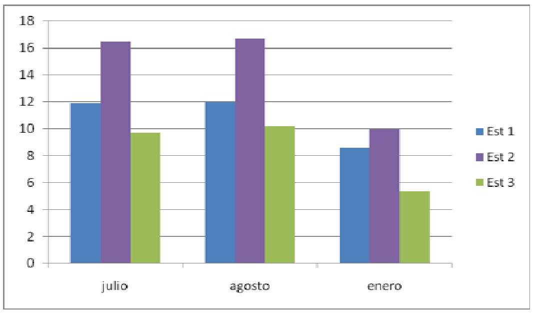

Fig.10 graph of daily termical range

The trend analysis will show that:

1. The air temperatures measured in Plaza de España are hotter than the other, and also the maximum and minimum pick are the hottest.
2. The minimum value is measured in the Acoustic Centre station, but in the hotter hours, the maximum temperature is similar at the temperature of Plaza de España.
3. The Moratalaz station collected halfway values between the temperatures of the other two stations and with less daily variation.
4. The temperature variations during the day have the same trend in the three stations. The maximum pick is from 6 to 8 p.m. and the minimum pick is from 8 to 10 a.m.
5. In January the trend of temperatures measured in the three stations is similar to the summer, although the daily variations measured is lower.

The second stage is focused on the analysis of temperature variations during the day. The maximum and minimum values are being showed on table 3 and figure 9.
The table 4 data show the difference of maximum and minimum temperature. The daily variation is more during summer than in winter months (figure 10) and the Acoustic Centre is the station with the widest variations. The analysis show the daily temperature swing is more in summer than in winter, is due to night cooling in summer.

5.4 Land use analysis

As mentioned before, the analysis area is unclosed in 250 m radius from station. The surface ratio is calculated and the result showed on table 5. The albedo assign to the surfaces is 15% for dark surfaces, 35% for clear surfaces and 20% for green surfaces.

Station 1: Plaza de España

Total area: 133.936 m^2					
Green Surface		Dark surface		Clear surface	
m^2	%	m^2	%	m^2	%
12.116	9,05%	32.726	24,46%	7.186	5,37%

Station 2: Municipal Acoustic Centre of Madrid

Total area: m^2					
Green Surface		Dark surface		Clare surface	
m^2	%	m^2	%	m^2	%
92707	42,54	32233	14,79		

Station 3: District Council of Moratalaz

Total area: 218.729 m^2					
Green Surface		Dark surface		Clare surface	
m^2	%	m^2	%	m^2	%
88.505	40,46%	46.441	21,23%	22.990	10,51%

For the Municipal Acoustic Centre was not possible obtain all of information, so just green surfaces and dark surface are analyzed.
The green surface in the city centre is lesser than the other two stations, and the un-built space is occupied mainly with road and parching. The ratio of green space in station 2 and station 3 is quite similar although the dark surface is higher in Moratalaz.

6 RESULTS ANALYSIS AND CONCLUSIONS

Researcher shows that there is an important relationship between heat islands effect and land-cover and canopy. In that work there are some result that confirms the relationship and other that differ of them.
The main effect of urban heat island is the reduction of temperature waver during the day. The atmosphere heat island is stronger during night then in daily hours, due to absence of the heat dissipation that increasing the minimum daily temperature.
Madrid urban heat island follows the general behavior, with maximum intensity during night and more frequently in winter. The station three, Moratalaz, show the low temperature daily variation, although the maximum temperature value, in winter as well as

in summer, is lesser than the other two. This could be caused by other factors as orientation, wind exposition or morphology, which are not taking into account in this work. The Plaza de España station shows high temperature daily variation. Temperature trend is increasing during the day, reaching the maximum value at 6 pm. The night cooling is very important, in summer temperature decrease 12 ºC and 8 ºC in winter. That shows the less intensity of urban heat island effects in opposition with the urban design parameter: poor green spaces, high density of buildings and high ratio of dark surfaces. The variation of daily temperature cold be strongly influenced by surface heat island, and that was not be demonstrated with the parameter analyzed.
The complexity of the urban context, the particularities of each case and the poor data analyzed are the reasons that explain the difficulty to obtain general result. For the three stadium cases, the only analysis of air temperature as meteorological data is not sufficient, because there are lots of other factors, like humidity and wind exposition, which could be taken into account.
Directly relations between air temperature and land-cover could not be establishing.
The study need taken into account more meteorological and physic parameters. For the future research meteorological parameter as humidity, wind and sunshine as well as design elements as orientation, topography, density of constructions and sky view factors could be taken into account and the result compared to rural case.

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