THE INFLUENCE OF ALBEDO ON THE URBAN MICROCLIMATIC STREET CANYON

FATIHA BOURBIA[1], YASMINA BOUCHAHM[2] AND OUARDA MANSOURI [3]
University of Constantine, Algeria
[1]*Email: someg1@hotmail.com*
[2]*Email: ybouchahm2@gmail.com*
[3]*Email: wmansouri_2006@yahoo.fr*

Abstract: In city, when temperatures run higher than those in suburban and rural areas, this generate a phenomenon called Urban Heat Island (UHI), this effect occurs, primarily because growing numbers of buildings have supplanted vegetation and trees. The main causes of the different microclimatic conditions in cities are linked among other parameters to urban geometry which influences incoming and outgoing radiations as well as surface material properties, such as color and texture. In hot climates the elevated surface temperatures of materials directly affect, not only the urban microclimate, but also thermal comfort conditions in urban open spaces. In order to evaluate the microclimate variation of urban street canyon compared to the variation of walls and ground surfaces materials, series of field simulation are used by software tool , Envi-met v3.0, in down town of Constantine, Algeria.

1. Introduction

An urban area settlement is composed of a mosaic of individual buildings and other land use units, the form and disposition of which are highly complex. Each new building or group of buildings constructed will create an internal climate and cause some change to the local external environment. This makes environmental designers responsible not only for the internal conditions of the buildings but also for the external climatic environment created by those buildings. Most of the literature reviewed shows that the first control mechanism against the climate is the city layout

[1]. The update researches suggest that careful planning; design and attention to the climatic forces can significantly improve the urban environment from both the human comfort and the energy use perspective. This improved microclimate will have direct impact on the thermal performance and energy usage of buildings.

Open spaces in cities have a large variety of forms and surface characteristics. The microclimate of these spaces is influenced by several parameters such as the urban geometry, the vegetation, the water levels and the properties of surfaces [2]. The inappropriate uses of these parameters cited contribute to the harshness of the environment and makes the temperature in the urban environment higher than the suburbs. This phenomenon called the urban heat island [3]. Based on experimental observations and other research results, such as [4, 5, 6&7], it can be concluded that the air temperature differences between clusters are mostly influenced by the urban geometry and the surface thermal characteristics (albedo). Many researchers, e.g. [8], take the position that, at the micro scale, explicit considerations of urban geometry are more important than the albedo effect; namely the street to buildings height and width relationships and their orientations. While an increasing number of authors like [9] and many others suggest that the surface characteristics are more crucial and could be the most significant factor in controlling the outdoor thermal comfort and reducing the thermal gains in the urban environment and in particular by reduction of the absorbed solar radiation. The role of building materials and geometry are decisive for the reduction of thermal gains and overheating. The orientation of the streets, the H/W ratio together with the type of materials, used, defines the surface temperature of the material. Higher surface temperature increase the ambient temperature, convection intensity is higher. According to [10], a white surface with an albedo of 0.61 was only 5°C warmer than ambient air whereas conventional gravel with an albedo of 0.09 was 30°C warmer than air. Another experimental study conducted using 93 commonly used outdoor pavement materials showed that the light colored tiles were cooler than dark colored titles [8].

The properties of surfaces, which characterize construction materials, in particular the reflectivity or “albedo”, influence significantly the external thermal environment. Research indicated that the material of clear color and smooth surface present lower temperatures than those of dark color and rough surface, this facilitate the classification of these materials according to two categories “cool” and “heat”[11]. Other studies estimated the effect of the albedo used in roofs on the attenuation of the urban heat island and the reduction of the energy consumption of the buildings in the urban centers [12].

The aim of this research is to evaluate the microclimate variation of an urban street canyon against the variation of walls and ground surface material in down town of Constantine - Algeria (semi arid climate). To meet this objective, series of simulation are used using Envi-met v3.0 (M. Bruse, 2004, ENVI – met modelling).

2. Software characteristics

Envi-met, v3.0 is a three-dimensional microclimate model developed by Michael Bruse, it is designed to simulate the climatic variation and the surface-plant-air interactions in urban environment with a typical resolution of 0.5 to 10 m in space and 10 sec in time. The typical areas of application are; Urban Climatology, Architecture, Building Design and Environmental Planning.
ENVI-met is scientific software, based on different research studies and projects. Therefore the program is constantly under development.

3. Site descriptions

The investigation was conducted at Constantine City (Algeria) located at (36°17' North and 07°23' East). The altitude is about 687m above the sea level. This city is characterized by semi arid climate, hot and dry in summer with an average maximum temperature as high as 36°C occurring at about 3.00 pm and a humidity of about 25% where the winter is cold and humid. In addition the sun radiation intensities over this region is very high with a great number of sunny hours and clear skies. All these contribute to the climatic harshness of this region (Constantine). The wind direction comes relatively from the North with an average speed reaching 2.1m / s. The study area is located in the central parts of the city which contains a very dense urban structure with a typically European design and a narrow street canyon (Fig. 1). The site considered has an average of five-storey buildings and smaller courtyards with no vegetation. The Sky View Factor (SVF) of the streets is ranging from 0.12 to 0.58, as shown in Table. 1. Also the diversity of sky view factor and the street orientation has an effect on the street microclimate, and consequently the different temperature values [13].

In order to evaluate the effect of the albedo on the urban climate and more precisely on surface temperature which directly related to the mean radiant temperatures and ambient temperature, a series of modeling were performed for the three stations (A, B and C) carefully selected as shown in Fig. 2, during the summer for the month of July, representing the hottest period, when we take a multitude values of albedo which varied from 0.2 to 1.

Fig. 1: View of the selected site of study, showing the studied stations.

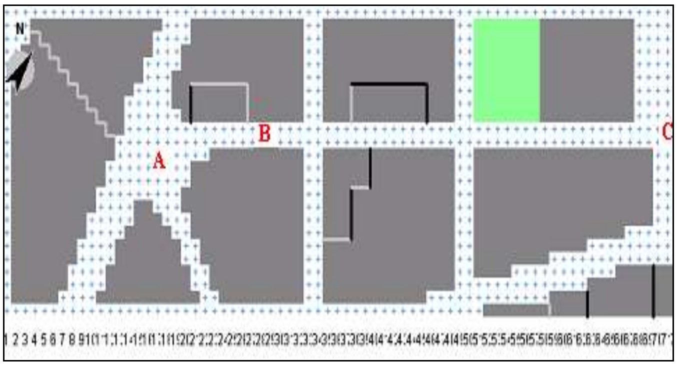
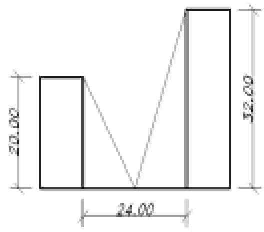
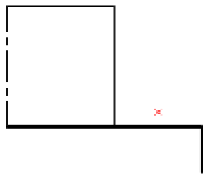


Fig*. 2:* The selected stations (A, B and C) for the simulation study by Envi-met v3.0

TABLE 1: Photo fish-eye for the three stations chosen (A, B and C), representing three different geometry.

Fish eye photographs	Description (H/W)
Station A 	 **Station A (SVF=0.23, H/W=1)**
Station B 	 **Station B (SVF=0.12, H/W=4.6)**
Station C 	 **Station C (SVF=0.58, H/W=2.6)**

4. Analysis And Results

In order to examine the influence of the material albedo on the street microclimate, the geometrical and the orientation parameters were fixed while the value of the reflectivity of materials has been changed respectively from 0.2, 0.4, and 0.6, 0.8 to 1. at calm wind. The modeling was carried out using Envi-met software [14]. The results are read by Léonardo program. An example of this output is shown on Fig. 3 which illustrates the surface temperature for an albedo of 0.2, at 10.00h.

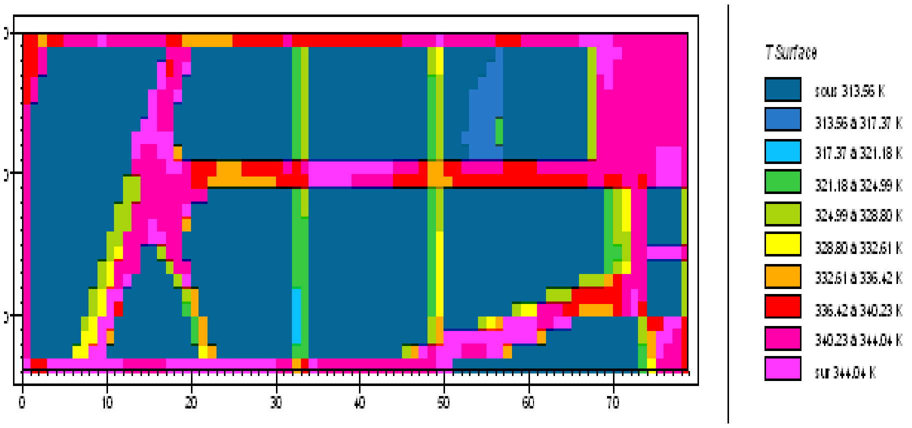


Fig. 3: Surface temperature for an albedo of 0.2 at 10.00h.

The simulation results reveal a link between surface temperature and the albedo; In general lower temperatures are observed on surface with higher albedo.

We observe for the three stations that during the day, the relation is inversely proportional between the values of albedo and the surface temperature, for almost 12 hours period, by recording a maximum surface temperature value (Station A and C) of 69.17°C for an albedo of 0.2 against a value of 54.72°C for an albedo of 0.8 at 16.00h, the difference was reaching 14.45°C see Fig. 4 and 5.

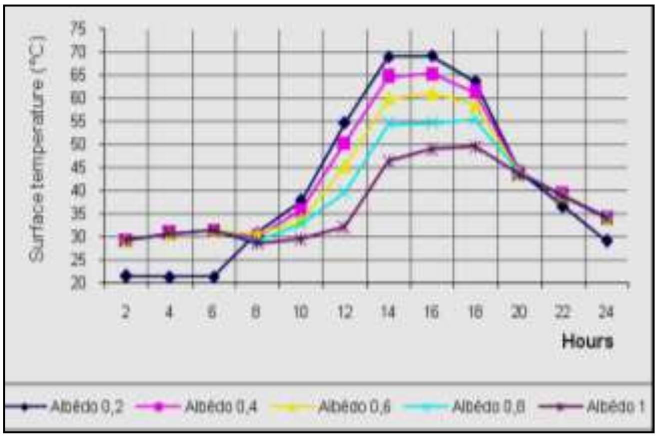


Fig.4: Surface temperature (Station A)

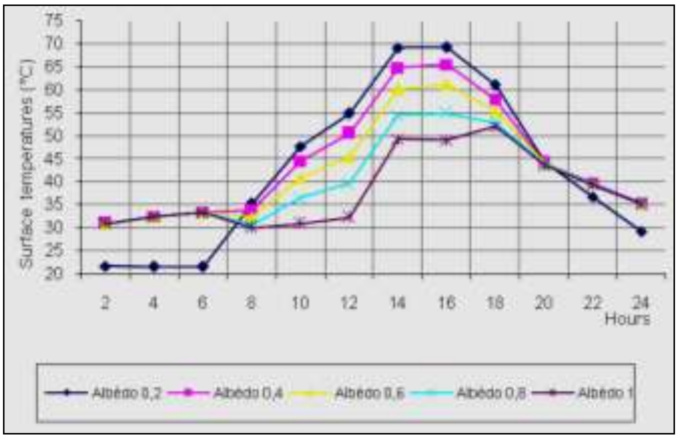


Fig.5: Surface temperature (Station C)

Concerning the station B, it has a lower temperatures to those of station A and C, the peak was recorded at 14.00h with 61.36°C value for an albedo of 0.2, while lower surface temperature were observed up to 49°C for an albedo of 0.8. But at 16.00h the differences are maintained according to the same order only with less value, recording a value of 51.86°C for an albedo of 0.2 and 48.94°C for an albedo of 0.8, see Fig. 6. This diminution in surface temperature is mainly due to the geometry of station B, which has a higher H/W ratio (canyon) who offers more freshness in the semi-arid climate [15]. The station C present identical results to the station A where their geometry is nearly identical (open spaces). The maximum difference

(15°C) between surface temperatures was observed for an albedo of 0.2 and 0.8 at 16.00 h.

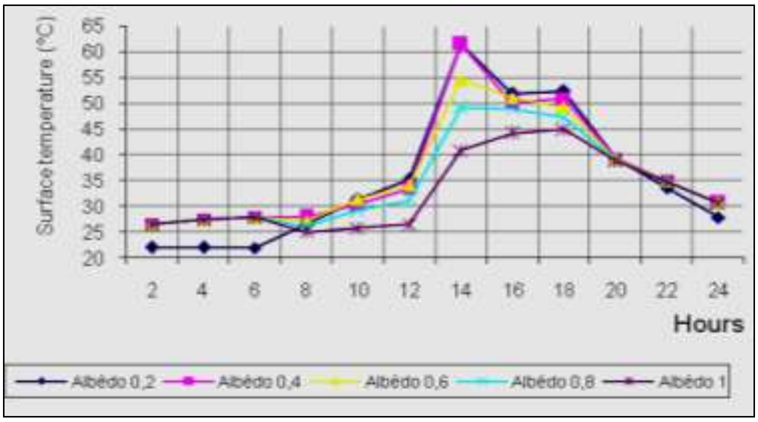


Fig.6: Surface temperature (Station B)

It is often Remarque, that in the urban environment, the building materials are not always chosen according to their surface color and texture. The most commonly construction material are asphalt, concrete. However, from this modeling, it was found that the material with light color is more suitable for lowering surface temperature, as well as the air temperature. Fig. 7 and 8 shows mean surface and air temperature respectively from sun rise to sun set at the chosen stations using different albedo. As expected, the material with higher surface temperatures gave rise to higher air temperature and material with low albedo resulted in the highest air temperatures inside the stations. However the case is reversed for the mean radiant temperature, the lower the albedo factor the lower the mean radiant temperature as shown in Fig. 9. This may be attributed to high reflectivity of the light surfaces, which may increase the amount of reflected radiation to the environment. This matches other results studies which reported higher mean radiant temperature at areas with higher albedo surfaces, compared to less reflective surfaces [16]. The difference in temperature is also affected by the canyon geometry. The high surface albedo coupled with high H/W ratio results in low surface, air temperature and mean radiant temperature. The Comparative study, between the mean ambient air temperatures in the canyon (Station B) for an albedo factor of 0.2 and 0.8, reveal a difference up to 1.92°C. Previous studies had shown that for every 1°C rise in temperature, 5% more cooling energy is needed [17]. Based on this, the increase in temperature inside the canyon (simulated) with low reflectance façade material can increase the cooling energy by nearly 10%.

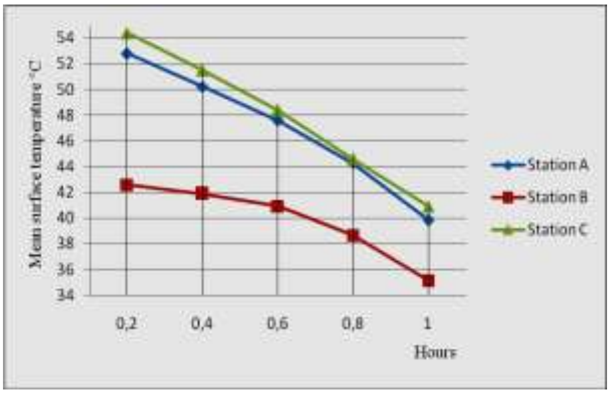


Fig. 7: Mean surface temperature for the selected stations (A,B and C) with an albedo of 0.2 to 1.

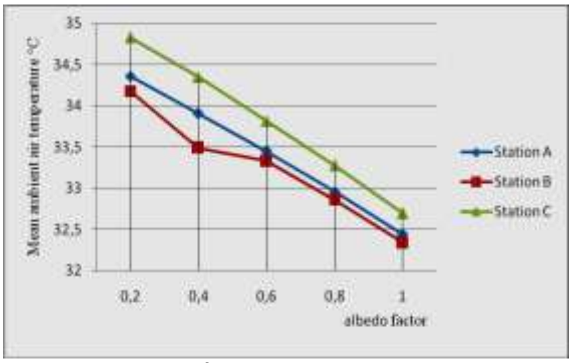


Fig. 8: Mean ambient air temperature for the selected stations (A,B and C) with an albedo of 0.2 to1.

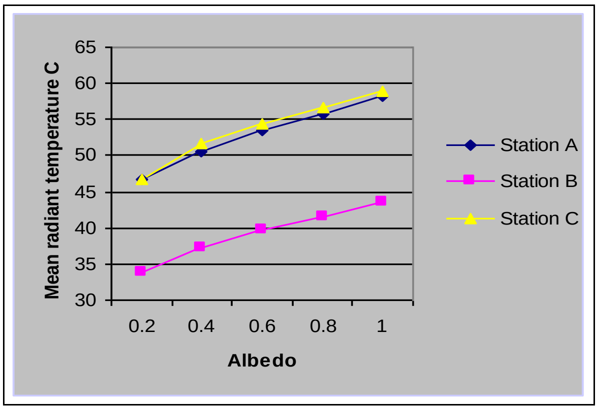


Fig. 9: Mean radiant temperature for the selected stations (A,B and C) with an albedo of 0.2 to 1.

5. Conclusions

The study was carried out on an urban axis presenting three stations of different geometry, in order to evaluate the impact of the reflectivity of the materials (albedo) on the urban microclimate.

The results of simulation established by Envi-met v3.0 revealed an opposite relation between the values of albedo and the surface temperatures. The more the reflectivity of material increases and the mean surface temperature decreases, by reflecting mainly the whole amount of solar radiations, therefore the absorption of heat is small, which keeps the surfaces of the street frontage cooler. The results had shown a difference up to 15°C between the material with an albedo of 0.2 and 0.8. The simulation reveals a strong link between surface temperature and surface albedo. The use of high surface albedo is important in the urban environment and especially in cities with hot climate. However the use of low surface albedo material causes a rise in urban temperature and the demand for cooling load in the building is getting greater.

As concluded the facade materials with low albedo values will significantly increase the air temperature within the canyons. Hence it can be concluded that the type of facade materials and their colour are among the significant factors causing urban heat island. This definitely provides a clear direction for urban designers on which area to concentrate in order to achieve good environmental quality.

Références

[1] ALI-TOUDERT. F.,” Dependence of outdoor thermal comfort on street design”. PhD Thesis, University of Freiburg (2005), Freiburg

[2] MILLS, G. “An urban canopy-layer climate model” Theoretical and Applied Climatology 1997; 57 pp 229-244.

[3] OKE.T.R, "Boundary Layer Climate" second ed. London: 1987

[4] SWAID, H., HOFFMAN, M.E., “Climatic impacts of urban design features for high and mid latitudes cities”. Energy and Building, 1990; 14 pp. 325–36.

[5] ROHINTHON, E. A., “hypothetical shadow umbrella for thermal comfort enhancement in the equatorial urban outdoors”. Architectural Science Review 1993; 36 pp 173–84.

[6] GOWARD, S.N., “Thermal behavior of urban spaces and the urban heat island”. Physical Geography1981; 2 pp 19–33.

[7] ARNFIELD, A.J., GRIMMOND, C.S.B., “An urban canyon energy budget model and its application to urban storage heat flux modelling”. Energy and Buildings 1998; 27 pp 61–8.

[8] ROSENFELD.ARTHUR.H, AKBARI.HASHEM, BRETZ.SARAH, FISHMAN.BETH.L, KURN.DAN.M, SAILOR.DAVID, TAHA.HAIDER, "Mitigation of urban heat islands: materials, utility programs, up dates". Energy and Buildings 1995; 22 pp 255-265.

[9] TAHA, H., “Urban climates and heat islands: albedo, evapotranspiration and anthropogenic heat”. Energy and Buildings 1997; 25 pp 99–103.

[10] TODHUNTER, P.E. “Microclimatic Variations Attributable to Urban Canyon Asymmetry and Orientation”. Physical Geography 1990; 11 pp 131-141.

[11] DOULOS.L, SANTAMOURIS.M AND LIVADA.I, " Passive cooling of outdoor urban spaces. The role of materials". Solar energy 2004; 77 pp 231-249.

[12] PRADO R.T.A, FERREIRA F.L, “Measurement of albedo and analysis of its influence on the surface temperature of building roof materials”. Energy and Buildings 2005; 35 pp 295-300.

[13] BOURBIA F., BOUCHERIBA F. “Impact of street design on urban microclimate for semi arid climate (Constantine)”. Renewable Energy, 2010; 35 pp 343-347.

[14] BRUSE.M.2004. Envi-met web site, www.envi-met.com

[15] BOUCHERIBA.F, Impact de la geometrie des canyons urbains sur le confort thermique exterieur - cas du Coudiat de Constantine. These de Magister 2005, Universite Mentouri de Constantine, Departement d Architecture.

[16] SHIRAISHI, Y., H. KAGAWA AND J. NAKANO, “Evaluation of Outdoor Thermal Environment for Sustainable Region Planning in Kitakyushu Science and Research Park”. PLEA 2005.

[17] RAJAGOPALAN PRIYADARSINI, WONG NYUK HIEN, CHEONG KOK WAI DAVID, “Microclimatic modeling of the urban thermal environment of Singapore to mitigate urban heat island” Solar Energy 2008; 82:727-745