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Quality of the thermal environment of urban courtyards in arid and semi-arid cities. Case of the city of Ouragla

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Abstract.
This work deals with the quality of urban thermal environment in an arid context of the city of Ouargla, in the south-east of Algeria.
The focus has long been on interior ambiences, while city producers are being asked, in the light of new sustainability data, to make more tangible improvements by ensuring acceptable standards in urban living. . The present work is part of this perspective and aims to improve the microclimatic quality of outdoor spaces. The study examines the response strategies in terms of climate adaptation research, especially in the summer period, and tries to evaluate the thermal regulation measures relating to criteria for attenuating energy heating due to intense diurnal solar radiation, which continues with a rise in temperature at night caused by heat loss under the effect of nocturnal radiation. And this by essentially taking into account the impact of the geometric parameters which consist of the profile of the built form expressed by the ratio of the height of the geometric form to its spatial extent defining different configurations at court in relation to different solar orientations.
The objective is to assess whether such configurations can be the subject of models of organization of cities in an arid context.
Field experimentation led to interesting results from a scientific point of view and likely to shed new light on the contribution of traditional urban form to passive strategies.

Keywords. Urban configurations; urban courtyards; thermal environment.

1. Introduction

Often the city is conceived as a combination of built and unbuilt, in other words full and empty. **(Muret J-P, Alain Y-M, Sablet M-L, 1987; Colette P, 1994).**

When the first concern of man was to shelter, these solids constitute the first devices for modulating the elements of the climate and creating conditions of well-being inside.
(Olivier M, 1972).

However, the examination of the combined effects of the external and built climatic environment revealed different behaviors relating to different urban configurations revealing the influence of urban forms on the modification of the climate and refer to note:
- The shapeable aspect of the elements of the climate on this scale making it possible to join spatial coherence and quality of external atmosphere. **(Givoni B, 1998).**
- The role of interface occupied by these voids between architectural design and urban composition, on the one hand and external atmosphere on the other hand and encourage a revision of a design in correlation with micro climatic conditions where built form / external space induced and climatic environment act simultaneously in an interactive relationship. Limited to a concern for supplying energy at lower cost, following the energy crisis of 1973, the alternatives undertaken, on the scale of the built form and its outer envelope only, and which led to the assignment of the report undertaken between built form and its induced exterior space, have consequently affected the quality of its exterior environment, particularly thermal.

The energy crisis had to become less or less pressing as interest shifted towards the external environment and its quality of physical (light, sound, olfactory) and essentially thermal

atmosphere and the role of outdoor space as an important interface. **(Groleau D, 1993; Sundersingh S.D, 1990; Bouillot J, 1991; Sacre C, 1986).**
However, the various interactive reports (radiative and thermal) taking place at the level of the urban roof, at the origin of the variations appearing on a higher scale (scale of the urban dome), of the most raised is the formation of hot masses (urban heat island), and which involve the part attributed to design particularities in this action **(Landsberg, H.E, 1981; Escourou G, 1983, 1991; Givoni, 1998)** raises in exchange this question of control of microclimatic conditions in outdoor space in particular **thermal (Izard J.L 1986, 1993; Oke T.R and Nunez M, OkeTR, 1977, 1978, 1981, 1988).**
The relative analysis made it possible to record essentially the impact of the geometry of the built form defined according to its profile **(Knowles R, 1981; Oke T.R, 1988; Amfleld A.J, 1990)**, the different characteristics of the building materials **({ zard J.L, 1993; Croome D,** 1990; Lavigne P, 1994) and the effective contribution of vegetation .(**(Izard, 1993 ; Fathy, 1985 ; Camous et Watson, 1986 ; Givoni B, 1980 , 1998; Equipe ARTOPOS, 1997 ; Groupe ABC, 1997; Escourrou G, 1983; Destobbeleire G. and Izard J-L, 1998; Akbari H, Dvis S, Dorsano S et al, 1992; Niachou et Coll, 2007).** of solar geometry and the different radiative and thermal fields that result from it leads us to consider the importance given to the most influential urban configurations.

2. Case study
2.1. Presentation of the case study
The study focuses on the city of Ouargla, located at 52° north latitude and 5.2° east longitude, characteristic of arid and semi-arid cities. Indeed, located between the latitudes of 15°C and 35°C and occupying the subtropical regions of Africa and Central and Western Asia, North-West and South Africa as well as Central and Western Australia **(Ferdheb ranch, 1960; Givoni, 1980; Konya, 1980; Baker, 1987)**, cities in arid and semi-arid environments are characterized by a climate characterized by two contradictory and contrasting aspects,namely, intense diurnal solar radiation and nocturnal cooling. **(Péguy.Ch-p,1970; Godard and Estienne,1970;Givoni.B,1978; Evans,1980; Drew.J-Betautres,1981; Gupta.V,1984 Sodha.M-S,1984; Baker , 1987; Fardeheb a , 1987).**
Such a choice is made for the above criteria:
- The existence of a weather station on the premises.
- The abundance courtyard configurations.
- The diversity and richness of the urban heritage of the city of Ouargla: Historic core (Kasbah), contemporary fabric, (Beni -Thor, Gara, Sid Boughofala, Mkhadma, Sidi amer...etc.), new town (khafgi).

2.2. Analytical approach
2.2.1. Choice of sites
Proceeding by the morphological approach **(Aymonino, 1974; Aldo Rossi, 1981; Sylvain Malfroy and Gianfranco Caniggia, 1986)**, samples were selected which belong to tissues at different levels of temporal formation and socio-cultural membership and which are:
> (historic core (kasbah) > The neighborhoods of sedentary nomads: the Beni Thor, the M'khadma, the Boughofala, Gara.….etc. > Recent interventions (new town).
Under the pretext that:
1. This situation may be the result of know-how operating with the climatic component (Case of the ksar).
2. Spontaneous consequence of an interaction between the physical and built environment.
3. Consequence of the transformations undergone by the form, insofar as the latter reflects the soul of its user according to his forecasts and desires **(Eleb-vidal, 1988; Levey and Segaud, 1983).**

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3. Micro climatic analysis

The investigation proceeds by field measurements. The analysis of the thermal performance of the courtyards proceeds by comparing the parameters measured (air temperature, relative humidity) with those under shelter measured at the meteorological station.

3.1. Measurement campaigns

The measurement campaigns took place for each station on a "typical day" in summer or winter successively at the following times:
- At sunrise, in the morning, the temperature being in phase of increase.
- At midday, when the sun is at its zenith.
- In the afternoon, at the time of the maximum temperature.
- At sunset and at 10 p.m. and 2 a.m.

The selected types were divided into groups of three to four according to their belonging to the same site and their proximity to each other. The various measurements followed a route chosen in such a way as to reduce as much as possible the time interval between two consecutive measurement points not to exceed 05 min. The measurement investigations were mounted at the centers of the courses. The measuring instrument consists on **an environment Meter 8820.**

3.2. Study parameters

To assess the impact of courtyard configurations on solar radiation and the resulting ambient quality, the parameters taken into account are:
- Orientation in relation to the sun.
- The impact of spatial form.
- The impact of the geometric configuration defined by the ratio.

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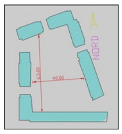
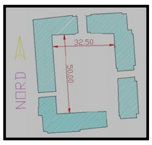
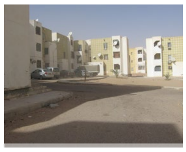
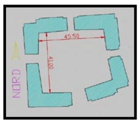
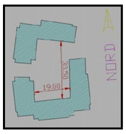
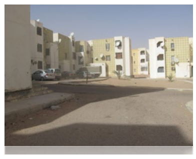
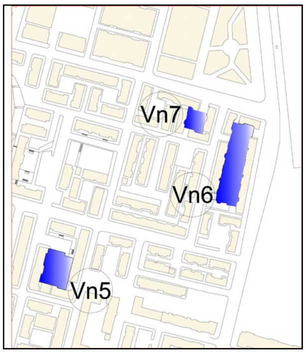
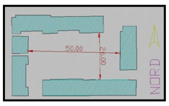
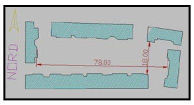
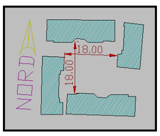
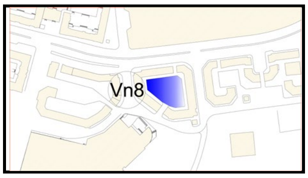
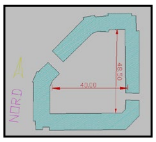
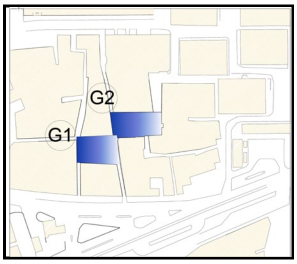
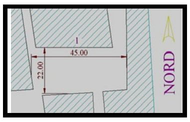
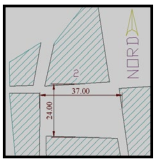
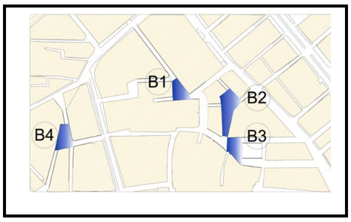
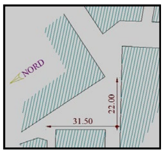
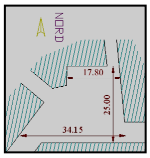
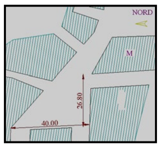
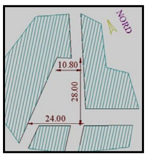
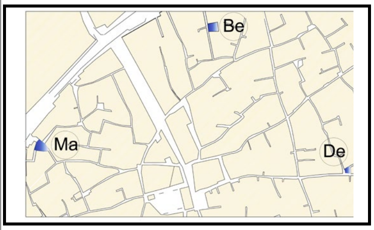
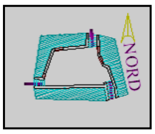
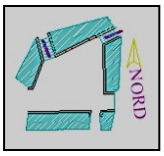
Table 1: Presentation of the different courtyards selected relating to the different districts. Source: The author, 2010.

Sites	Presentation of the different courtyards selected relating to the different districts **Source :** The author, 2010.	Selected units: Dimensions (m)	Selected units: orientations	Views of courtyard Analyzed
New city		**VN1** **Larg =47.00** **Long = 63.00** **Height = 10.00**	**North-South/width** **East-West / length** 	
		VN2 **Larg = 32.00** **Long = 44.00** **Height =10.00**	**North-South/width** **East-West / length** 	
		VN3 **Larg = 41.00** **Long = 45.00** **Height = 10.00**	**North-South/width** **East-West / length** 	
		VN4 **Larg = 19.00** **Long = 30.00** **Height = 10.00**	**North-South / width** **East-West / length** 	
New city		**VN5** **Larg = 26.00** **Long =50.00** **Height = 6.00**	**North-South / length** **East-West / width** 	
		VN6 **Larg = 18.00** **Long = 77.00** **Height = 6.00**	**North-South / length** **East-West / width** 	
		VN7 **Larg = 18.00** **Long = 18.00** **Height = 6.00**	**Square in shape.** **North-South / length** **East-West / width** 	

		**VN8** **Base = 44.00** **haut = 49.00** **Height = 18.00**	**North-South / Base** **East-West / height** 	
Gara District		**G1** **Larg = 23.00** **Long = 36.00** **Height = 6.00**	**North-South / length** **East-West / Width** 	
		G2 **Larg = 22.00** **Long = 46.00** **Height = 6.00**	**North-South / length** **East-West / Width** 	
Boughofala District		**B1** **Base = 32.00** **width = 22.00** **Height = 6.00**	**North-east / south-west orientation** 	
		B2 **Base = 34.00** **width = 25.00** **Height = 6.00**	**North-South orientation** 	
		B3 **Base = 40.00** **width = 40.00** **Height = 5.00**	**East/West orientation** 	
		B4 **Base = 24.00** **width = 28.00** **Height = 6.00**	**Orientation: northwest/southeast** 	

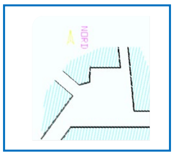
historic core		**Ma** **Base = 15.00** **width = 8.00** **Height = 5.00**	**Nord-Sud / hauteur** **Est-Ouest / Base** 	
		Be **Base = 10.00** **width = 6.00** **Height = 8.00**	**Nord-Sud / Base** **Est-Ouest / hauteur** 	
		De **Base = 10.00** **width = 8.00** **Height = 6.00**	**Nord-Sud / Base** **Est-Ouest / hauteur** 	

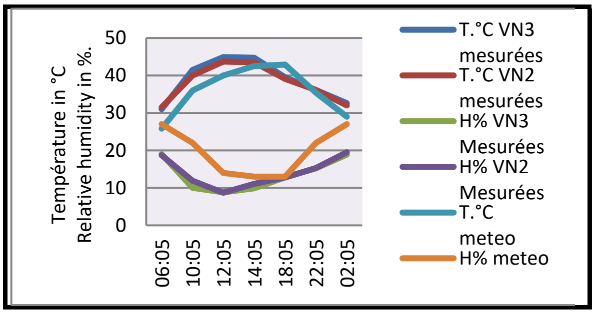
4-Evaluation of the impact of courtyard configurations on solar impact:

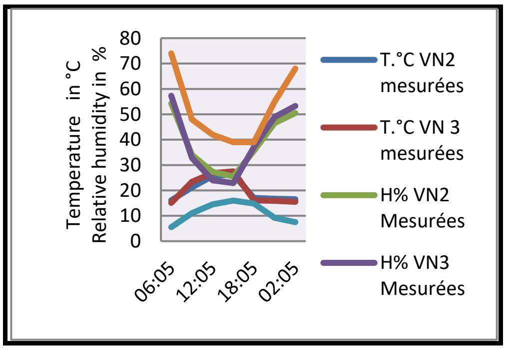
4-1- Influence of orientation with respect to the sun:

The evaluation of the influence of orientation with respect to the sun was made by comparing respectively the following courses of the same geometric configurations and different orientations and which are (B1-B2-B3) and (VN2-VN3).

Table /01: Course presentation: B1-B2-B3.

Courtyard B1 : the extension of the North-South direction.	**Courtyard B2**: Northwest/South-East perpendicular to the Base	**Courtyard B3**: in the extension of the east-west direction
		





Graphs /01: Comparison of temperatures and relative humidity of the daily air of courses B1-B2-B3.
Left: Summer period **Right Winter period**

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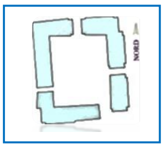
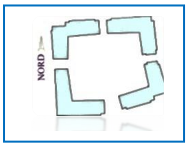
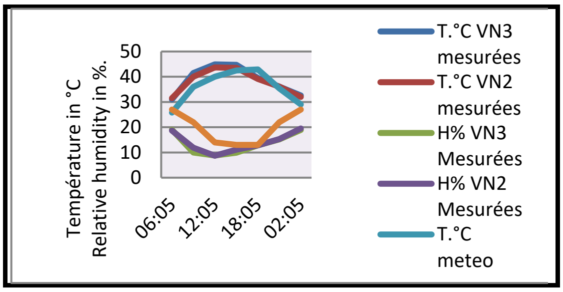
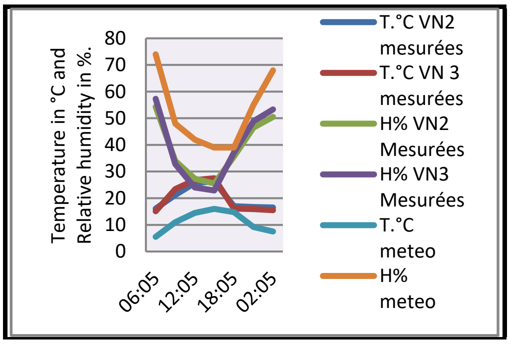
Table /02: Course presentation: VN2-VN3

The VN2 courtyard North-South direction compared to its extension 	**The VN3 Courtyard** East-West direction compared to its extension 





Graphs /01: Comparison of temperatures and relative humidity of the daily air of courses VN2-VN3
Left: Summer period **Right Winter period**

4-2- Influence of the geometric configuration defined by its (H/L ratio):

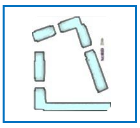
The evaluation was made by comparing courses of different ratios and of the same orientations and relative to courses of triangular spatial shapes and opted for a comparative analysis relating to two variants

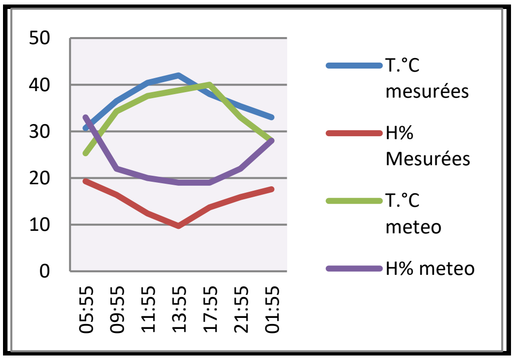
* Variant 1: and includes the following courses: (B1 and VN1)

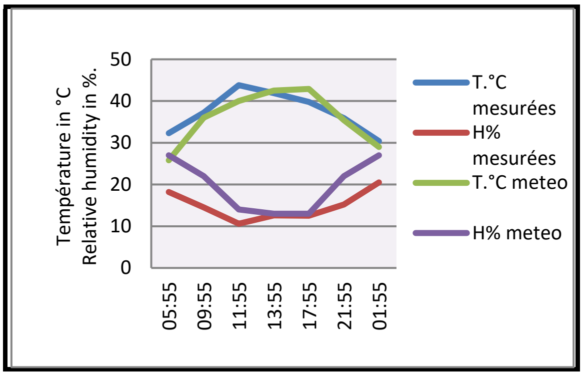
* Variant 2: and includes the following small courses: (Belguelane-Dekis)

- The courses of rectangular spatial shapes and opts for a comparative analysis relating to the medium-sized courses: (- G2- VN5-).

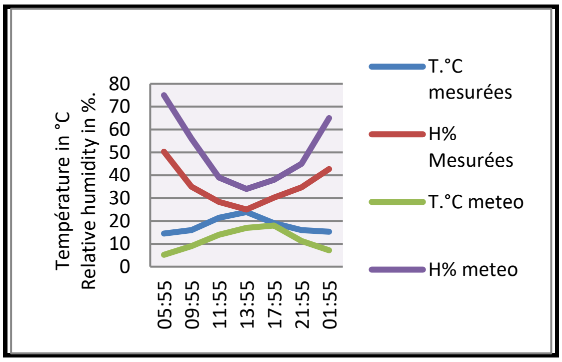
Table /03: Course presentation: B1 et VN1

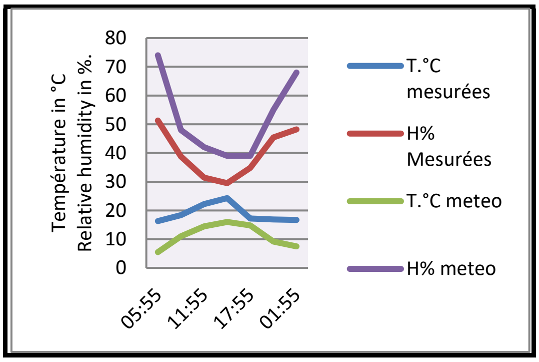
Courtyard of Variant 1/ Orientation In the North-South extension	
courtyard B1 ratio 6/22=0,27 	**courtyard VN1** ratio10/40=0,22 





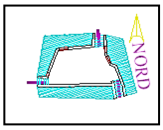
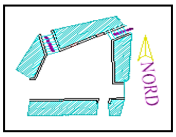
Graphs /03: Comparison of temperatures and relative humidity of the air daily courses B1-VN1 (Summer period).
Left: B1 **Right VN1**

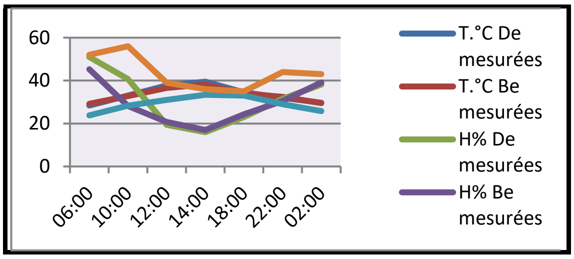


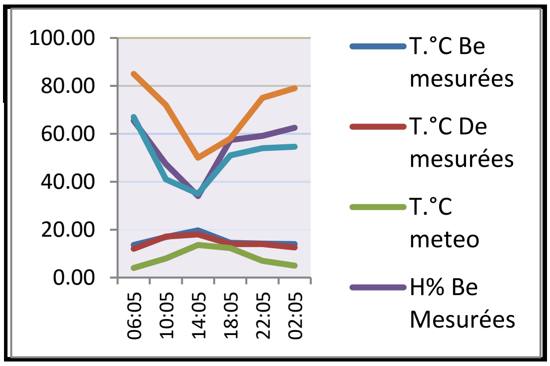


Graphs /03: Comparison of temperatures and relative humidity of the air daily courses B1-VN1 (Winter period).
Left: B1 **Right VN1**

Table /04: Course presentation: Belguelane et Dekis

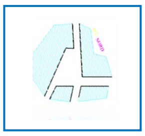
Courtyard of Variant 2/ North-South Orientation			
The Belguelane courtyard ratio=8/6 = 1.33		The Dekis courtyard de ratio=8/10 = 0,8	

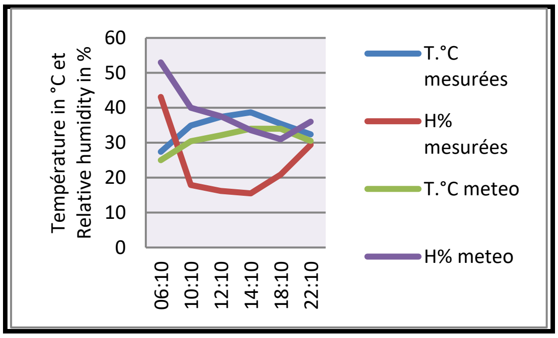


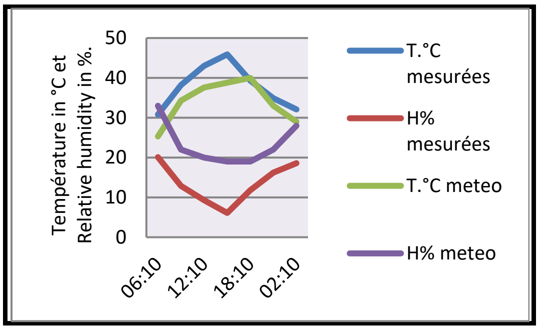


Graphs /04: Comparison of temperatures and relative humidity of the daily air of courses Belguelane and Dekis
Left: Summer period **Right Winter period**

Table /05: Course presentation: VN8 et B4

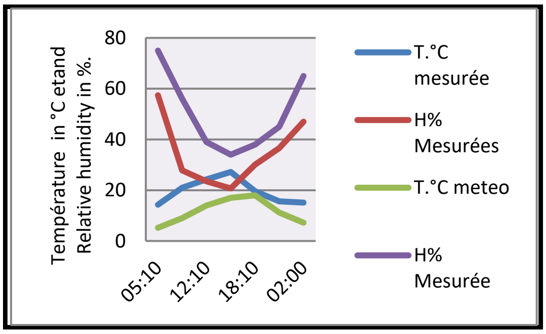
Courtyard of Variant 2/ Orientation In the North-South extension			
courtyard VN8 ratio 18 /40= 0,45		courtyard B4 ratio 5/24 = 0,20	

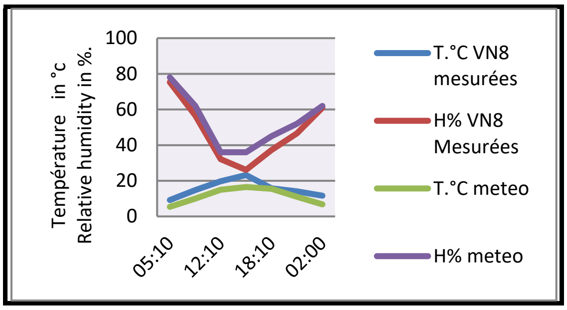




Graphs /05: Comparison of daily air temperatures and relative humidity courses B1-VN1 (Summer period).

Left: VN8 **Right B4**

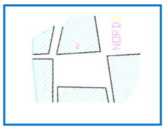
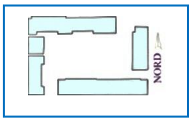


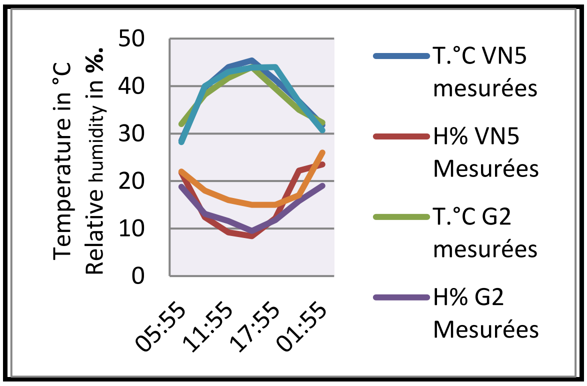


Graphs /05: Comparison of temperatures and relative air humidity daily courses B1-VN1 (Winter period).

Left: VN8 **Right B4**

Table /05: Course presentation: G2 et VN5 :

Courtyard of Variant 1/ Orientation In the East-oust extension	
courtyard G2 ratio 6/22 = 0.30 	courtyard VN5 ratio6/26=0,24 



Graph 06: Influence of the elongation of the dimension in length on the air temperature (case of VN5 and G2).

5- Results and discussion:
Some data were not taken on the same day, the comparative analysis was made relative to the differences recorded between the temperatures measured in the field and those raised at the level of the meteorological station.

These investigations carried out on the thermal behavior of current configurations have made it possible to record the following results:

- The high air temperature values recorded at the courtyard level during the summer and the low values recorded during the winter, which reflect the low solar radiation in winter and its intensity in summer.

- Although the air temperatures recorded at the level of the courtyards during the winter season mark increases compared to those recorded, under shelter, at the level of the weather station, these do not manage to reach the performance thresholds:

* The maximum temperatures reached for the month of January reach the following values: (recorded at courtyard G1): 14.3°C at 6 a.m., 16.9°C at 10 a.m., 26.4 °C at 2 p.m., 17.8° C at 6 p.m., 15°C at 10 p.m., 14.6 °C at 2 a.m.

* The relative humidity is: 73.7% at 6 a.m., 37.2% at 10 a.m., 23.00% at 2 p.m., 48.00% at 6 p.m., 63% at 10 p.m., 68.5% at 2 a.m.

* Those recorded at the weather station as follows: 5°C at 6 a.m., 7.4°C at 10 a.m., 14.8°C at 2 p.m., 14.6°C at 6 p.m., 8.8°C at 10 p.m., 6.7 °C at 2 a.m. relative to temperatures and, 88.00% at 6 a.m., 80.00% at 10 a.m., 58.00% at 2 p.m., 60.00% at 6 p.m., 76% at 10 p.m., 86.00% at 2 a.m.

- The best situations are recorded at the end of the winter season, for the month of February from 10 a.m. to 2 p.m. and which extend until 6 p.m., in the case of courses (VN1-VN2-VN3-VN4 and B1- B2-B3-B4, as follows:

18.4°C at 10 a.m.; 22.2°C at noon; 24.3°C at 2 p.m.; 17.2°C at 6 p.m. for the case of courtyard VN1.

21.2°C at 10 a.m.; 25.7°C at noon; 26.3°C at 2 p.m.; 17.0°C at 6 p.m. for the case of courtyard VN2.

23.4°C at 10 a.m.; 26.8°C at noon; 27.3°C at 2 p.m.; 14.1°C at 6 p.m. for the case of courtyard VN3.

23.0°C at 10 a.m.; 25.8°C at noon; 26.4°C at 2 p.m.; 16.5°C at 6 p.m. for the case of courtyard VN4.

21.0°C at 10 a.m.; 24.3°C at noon; 27.2°C at 2 p.m.; 19.6°C at 6 p.m. for the case of courtyard VN4.

- Relative to the summer season, the temperatures recorded are high and show higher differences compared to those recorded under shelter at the weather station.

- All the courtyards have a parabolic shape expressing continuous exposure over time from sunrise to sunset. The heat peak is recorded at noon and 2 p.m.

The temperature differences recorded compared to those recorded at the meteorological station oscillate between:

minimum values of:

0.3°C to 2.2°C at 6 a.m. at VN5 and VN8; -0.2°C to 2.2°C at 10 a.m. at VN6 and VN8.

0.9°C to 2.7°C at noon at VN6 and VN8; 1.2°C to 1.8°C at 2 p.m. at the level of VN5 and VN6.

-3.2°C to -1.00°C at 6 p.m. at VN8 and VN6; -0.2°C to 1.7°C at 10 p.m. at VN8 and VN2.

and maximum of:

5.4°C to 6.2°C at 6 a.m. at Belguelane and B3; 4.7°C to 6.4°C at 10 a.m. at Dekis and Mansora.

6.7°C to 7.7°C at noon t at Dekis and Mansora; 5.8°C to 6.2°C at 2 p.m. at Mansora and B3.

-0.2°C to 1.5°C at 6 p.m. at B3 and Mansora. ; 1.8°C to 3.4°C at 10 p.m. at B3 and Belguelane

- The temperature differences drop at sunset and rise in the evening from 22 following the release of heat stored in the mass of materials during the day under the effect of night cooling.

- Although the temperature differences recorded are greater than those recorded at the weather station, reductions are examined in relation to a few cases, The first is that relating to the orientation with respect to the sun, the second is that of the impact of the fraction of the dimensional ratio of the height of the courtyard to its width expressed by the ratio.

a) Influence of orientation relative to the sun :

The most favorable orientations are:

- A courtyard that extends in the north-south direction. (case of VN1 and B1)
- A north-west/south-east courtyard (case of courtyard B2).
- A yard that extends in the east-west direction is the most unfavorable.

The difference reaches 3°C for the case of a courtyard that extends in the north-south direction.

b) Influence of the geometric configuration defined by its ratio :

- The various comparative analyzes have shown that all the courtyards presented constitute low courtyards (height <2.5 width) and small ratios, which favored their permanent exposure to solar radiation.

(Piras E1998 http://lesowww.epfl.ch/master.html (Consulted on 02/22/2004).

This also justifies the protection of facades, in arid and semi-arid environments and in most cases by overhangs, balconies and generally arcades.

The examination of the relation of dependence of the elements of the courtyard on the solar incidence revealed the importance of the relationship maintained between the width of the courtyard to its spatial extent where a narrowing in width accompanied by an extension in length brings the the greatest temperature reductions. We cite the cases of the comparative analyzes of the courses: Belguelane and Dekis and of the courses: G 2 and VN5.

Examination of the ratio shows that raising the height to the width which implies a reduced angular opening brings reductions in air temperatures.

A ratio of 0.45 records a reduction in temperature for the period from noon to 2 p.m. of 2.4°C compared to a ratio of 0.20 (case of courses B4 and VN8).

(The same result recorded for the case of the comparative analysis of the two courses Belguelane and Dekis).

A ratio of 0.8 records a temperature reduction from noon to 2 p.m. of 1.3°C compared to a ratio of 0.6.

On the other hand, nocturnal cooling conditions are favorable compared to those with a large angular aperture, this implies a larger view surface to the sky.

- The differences recorded at the level of high ratio prices are less significant than those recorded at the level of average ratio prices, especially during the period from noon to 2 p.m.

What lets consider a new report is that of the influence of the reduced ratios on the inter flexions of the surfaces and their resulting consequence on the temperature of the air on the one hand, on the other hand, the effect brought by the exchanges of air produced between sunny and shaded surfaces for average ratios.

6. Similar works:

Several researchers have studied the relationship of dependence between urban configurations and solar and energy constraints for considerations of microclimatic improvement and the quality of the atmosphere in outdoor spaces.

Including: **(Knowles, 1981; Oke, 1988; Amfield, 1990; Djenane.M, 1998; Ali Toudert.F, 2000.)**

The elaborate research has led to the result that the profile of the built form is decisive because it defines the concept of opening to the sky responsible for the conditions of solar access.

And that an opening to the sky of the reduced urban form prevents solar access, while a large opening to the sky is beneficial for good night cooling because it promotes rapid dissipation of the heat stored in the mass of materials.

Comparative microclimatic studies relating to urban configurations of different ratios.

And count the analysis two urban canyons two ratios representing extreme differences in the city of Fez (34° North). One reduced in a modern residential area (the Adarissa district) and the other elevated in a dense traditional residential area (The Seffarine District in the medina). performed by: Erik Johansson, Karin Grundstrom, Hans Rosenlund **(Erik Johansson, Karin Grundstrom, Hans Rosenlund,2001)**

The other carried out by Angeliki Chatzidimitriou and Simos Yannas **(Angeliki Chatzidimitriou and Simos Yannas ,1990)** relative to obvert spaces of urban courtyards in northern Greece.

Investigations include measurements of air temperature and relative humidity in urban canyons, street surface temperatures, and horizontal and vertical wind speeds.

And came up with the following results:

That the high ratio configurations present a stable climate and plunge into the comfort zone during the hottest period of the day and in summer and that a temperature difference of about

10° is recorded at the level of the canyon in the traditional district compared to the modern district, due to several factors, all related mainly to the urban geometry, and which are explained by the fact that high ratios hinder solar access.
The contribution of traditional building materials (dense bricks) also have more heat storage capacity than modern building materials (hollow blocks), so a greater part of the air temperature rise at the during the day will be absorbed by the canyon surfaces and released during the night. comfort. With the exception of the winter period which is in the comfort zone or some stations in the presence of greenery.

7. Conclusion:

The present study on the thermal behavior of urban courtyards defined only by their spatial geometric configurations and different ratios, related to different orientations, has made it possible to understand that the latter do not manage to reach the performance thresholds, especially in the summer period. . This is justified by the fact that all the courses presented constitute low courses (height < 2.5 width) and small ratios (**Piras E1998 http://lesowww.epfl.ch/master.html (Consulted on 22/02/ 2004)** which favored their permanent exposure to solar radiation, associated with a negligible relative humidity level opens the way to consider the effect brought by the corrective elements.
This is the consideration of the different possibilities of development of the plants as well as their natures (we count the effect of shading and evapotranspiration) for the case of the average ratios as much as the latter favor sufficient surfaces for the planting of plants known by their role of regulator of microclimate, let us add to this, the effect provided by the various humidifying elements (jet of water, basins, fountains, etc.) A second attention is paid to the effect provided by the various alternatives for promoting ventilation (air outlets) and their effectiveness, especially in courses with high ratios (height > 2.5 width).

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