The effect of the patio on the indoor thermal performancein the colonial courtyard houses in the saharan climate. The case of Biskra in Algeria

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Abstract: A wide range of studies related to the evaluation of thermal comfort were undertaken on various types of buildings as an attempt to draw up that the interaction between the environment and the user is necessary to properly evaluate the indoor thermal comfort. The present research aims to explore the thermal quality within the French colonial houses in the town of Biskra where many passive techniques have been used for modifying the interior climate by promoting the passive cooling devices, inspired by the local traditional architecture. The courtyard, which is a one of the bioclimatic strategies to reduce the external climatic constraints, is also a key for passive cooling. Consequently, this work aims to characterize the impact of the patio in a saharan climate on the ambiance quality of the interior space of the houses. In this paper, an investigation is being conducted in five houses with patio, chosen as representative samples of colonial architecture in Biskra by an objective experimental method that contains in situ useful measurements for the calculation of Top and Tmr comfort indices according to the ISO 7730 standard for the evaluation of thermal comfort summer. In order to build more comfortable houses, many traditional techniques could be improved by using modern knowledge, rather than to be totally abandoned.

1. Introduction

Algeria has experienced several civilizations throughout its history, which have succeeded one another on the territory and affirm the Algerian identity that emerges from a country rich in culture, without neglecting the French colonial period which left us many architectural impressions and urban planning.

The work deals with atmospheres in patio houses dating from the French colonial era of the city of Biskra, based on the characteristics of colonial architecture that uses natural ventilation and cooling and their adaptation to the climate of the region. Many techniques, inspired by traditional local architecture, have been used (Deluz 1988). The interaction between the cultural factor and traditional methods was a prerequisite: "Housing for settlers must, of course, be adapted to the climate. This is the first condition. However, it is necessary to guard against copying what the natives have done, to imitate dispositions which have no raison d'être but their morals or their religion (Philomena 1992). In this study, we take the relationship between one of these architectural devices "Courtyard house" and the external climatic constraints.

From a thermal point of view, the patio (courtyard) functions as a surface to accumulate the cold air overnight by radiation (Bisam et al. 2010). In the afternoon, the temperature of the courtyard increases which allows convection and heat exchange with the interior fresh air in the night. For the ventilation, the courtyard functions like a chimney where the internal facades are pierced by small and rare openings to have a suitable freshness with the use of a fountain (Picard 1994; Arrouf 2004)

2. Literature review

Various theoretical researches and experimental attempts have been made on the effect of the courtyard "patio"; as a microclimatic modifier; on the thermal performance of buildings and cover a wide range of climates (Almhafdy et al. 2013, Canton et al. 2014). A mention of some previous works is made, that of Boulfani (2013) on the effect of the patio on summer thermal atmospheres, the experiment of which was carried out on seven colonial era houses in Jijel (Algeria) a city characterized by a moderate Mediterranean climate. The results showed that during the summer, the patio plays the role of a thermal regulator in a compact urban fabric. The depth of the patio has an important effect on the internal temperature (Tint). The north-east / south-west orientation is recommended but does not seem to have a significant effect on Tint.

Soflaei et al. (2015) studied the effect of the central courtyard on the sustainability of traditional houses in Iran, to improve the indoor thermal comfort in Iran's BS climate. The results of the field analysis of this quantitative study show that Iran's traditional central courtyards were designed on the bsis of

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Nomenclature

Hr	Relative humidity (%)
T	Temperature, °C
V	Air velocity, m/s

Greek symbols

α	Coefficient according to air velocity

Subscripts

a	Air
op	Operative
g	Globe
mr	Mean radiant
int	Interior
ext	Exterior

particular attention to the orientation and geometric properties of the physical and natural parameters that act as a passive cooling system.

Yasa and ok (2014) examined the energy efficiency of the courtyard as either a microclimatic controller in a warm climate or a climate controller at the urban scale, and to determine indoor comfort thermal states. In this study, using the CFD program seven houses in different climates in Turkey will be evaluated according to their thermal performance.

Hassan (2012) investigated the potential of a ventilated courtyard for passive cooling in a small building in a desert climate in New Aswan City, Egypt. The results of this study indicate that courtyard orientation and courtyard geometry are important factors in influencing the thermal performance of courtyard buildings model.

In fact, this work is founded on an experimental approach based on an objective evaluation of thermal comfort which focuses on the measurements of the three variables (Ta, H, Vair). In this respect, we chose five patio houses from the French period in Biskra (Algeria) with a difference in orientation and height, to verify the effect of the patio as a passive cooling strategy in arid climate.

3. Study case

The survey was conducted in Biskra, a town in southern Algeria, with a latitude of 34° 48 'North and longitude of 5° 44' East. It is characterized by a Saharan climate (hot and dry). The choice of Biskra makes it possible to measure the perception of the thermal comfort inside the colonial houses during the hottest period in 2016 (28 and 29 July).

The study area is limited to Biskra town center, which is a colonial heritage (Fig. 1.a), with a more or less homogeneous built frame in a uniform pattern, it is presented as a chessboard with straight streets of a width of 5 metres in a north-west / south-east orientation.

The investigation focused on the colonial houses that contain space and architectural devices to ensure comfort inside their homes (Fig.1.b) (Deluz 1988, Picard 1994).

3.1. Description of the Colonial House

According to the descriptions of military engineers and French architects, the design of the colonial house is inspired by traditional local architecture by the use of local materials with a mass of 60 to 80 cm, Earth brick, which have a great capacity to store heat where the thermal inertia allows to keep the cool temperatures of the night throughout the day (Philomena 1992; Picard 1994, Malverti 1990).

The traditional architectural features used in the house, such as the patio (fig. 2), are the determining elements of the bioclimatic architecture for a better evaluation of the thermal comfort. (Bisam et al. 2010).

The present research has examined the role and real impact of this architecture (patio house) on indoor comfort in the hot and dry climate of Biskra (Table 1). Five patio houses representative of the colonial architecture were chosen with two different orientations compared to the main entrance (North-West / South-East, North-East / South-West) and a difference in height (R and R+1).

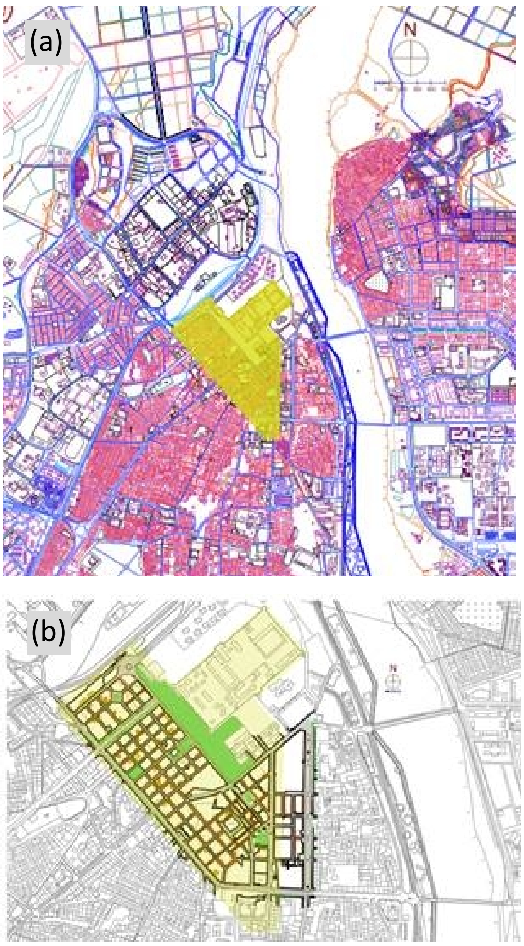
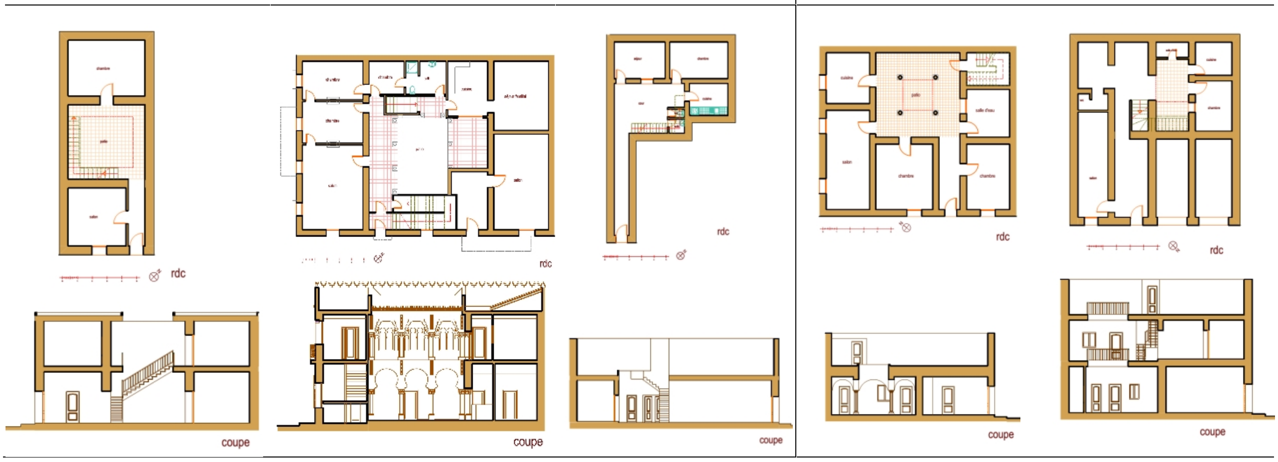


Fig. 1. Representative map of the study case (a) Situation map of the Colonial Checkerboard of Biskra and (b) Mass plan of the Colonial Damier of Biskra.

Fig. 2. Patios of the studied five houses in the Colonial Damier of Biskra.

Table 1. Architectural survey of the five houses in the Colonial Damier of Biskra.

North-West/South-East orientation			North-East/South-West orientation	
House 1	**House 2**	**House 3**	**House 4**	**House 5**



4. Methodology

In order to evaluate the thermal comfort inside the colonial houses, the work is based on an analysis model based on an experimental approach.

4.1. Experimental Approach

It is based on the measurement of the climatic conditions inside the houses and at the level of the patio. The measurements were taken by the KIMO instrument, which enabled us to measure air temperature (Ta), air velocity (Va), relative humidity (Hr) and globe temperature (Tg). The measurements were taken during the hottest period of the city of Biskra in 2016 (28 and 29 July), at the centre of the space with a height of 1.1 m (Benharket and Rouag 2016). As for the measurement campaign, it took place during the hottest period of the city of Biskra in 2016 (28 and 29 July). The calculation of the mean radiant temperature is made by the following formula:

$$T_{mr} = [(T_g+273)^4 + 2.5 \times 10^8 \times V_a^{0.6} \times (T_g-T_a)]^{(1/4)} - 273 \quad (1)$$

According to the adaptive approach, the Top index (operating temperature) was calculated according to the following formula:

$$T_{op} = \alpha T_{air} + (1- \alpha) T_{mr} \quad (2)$$

With: $Va<0.2 \rightarrow \alpha=0.5$; $0.2 \leq Va<0.6 \rightarrow \alpha=0.6$; $0.6 \leq Va \rightarrow \alpha= 0.7$.

5. Results and interpretation

5.1. Indoor thermal environment

A statistical summary of the internal environmental parameters observed in the five houses during the investigation days is presented in table 2. Reading the histogram (Fig. 3) shows that the average indoor temperatures in all homes are lower than the measured outside temperature. This is due to the effect of the thermal inertia of the stone and the ground brick (Bisam et al. 2010, Soflaei et al. 2015). We also notice a difference between the outside temperature and that of the weather.

Table2. Summary of measured climatic data in the patio of the five colonial houses, Biskra

Houses	House 1	House 2	House 3	House 4	House 5
Tint	38.4	32.4	37.1	35.2	33.3
Text	40.8	38.5	38.3	40	40.9
Tweather	40	37	39	39	39
Hint	21.9	36.3	35.8	30.1	43.3
Hext	18.7	23.8	28	28.5	15.9
Hweather	10	25	21	18	18
Vint	0.25	0.06	0.09	0.00	0.00
Vext	1.2	1.9	1.76	0.55	0.6
Vweather	3.1	4.1	3.1	5.1	5.1

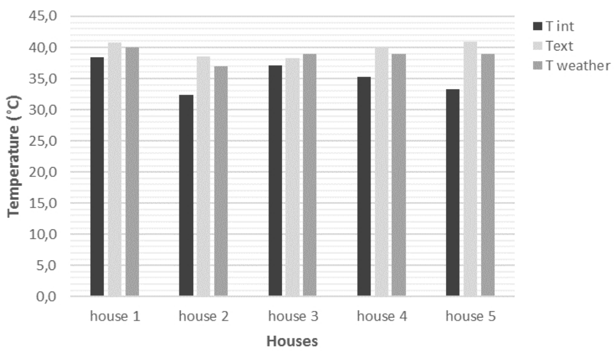


Fig. 3. Differences of temperature (int / ext / weather) in the patio during the period of measurement

The figure 4 shows that the average relative humidity varies between 22.9%, 43.3% inside, it is higher than the outside. The average air velocity (Fig. 5) is three times lower inside than outside, because the doors and windows are closed, which reduces heat exchange by evaporation, and for this reason humidity is maximal indoors (Boulfani 2010).

5.2. Comparison of operating temperature, mean radiant temperature and indoor temperature

We observe, by comparing the mean operating temperatures in the five houses, that the curves follow almost the same paces as those of the air temperatures (fig. 6) because the air velocity is less than 0.3m / S. The obtained operating temperature of house 1 and house 2 is the same as the air temperature. For the house 3, the value of Top has an interesting difference of 1.4°C as we found for the MRT which is 39.9°C (table.3) which can be explained by an effect of exposure to Solar rays because of the orientation of the North-West / South-East house which is the most unfavourable (Boulfani 2010) and also its low height.

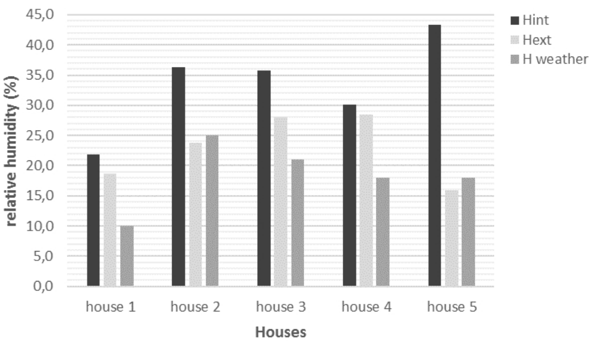


Fig. 4. Differences of relative humidity (int / ext / weather) in the patio during the period of measurement.

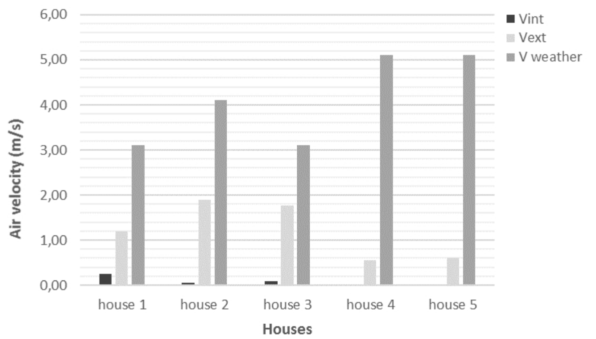


Fig. 5. Differences of Air velocity (int / ext / weather) in the patio during the period of measurement.

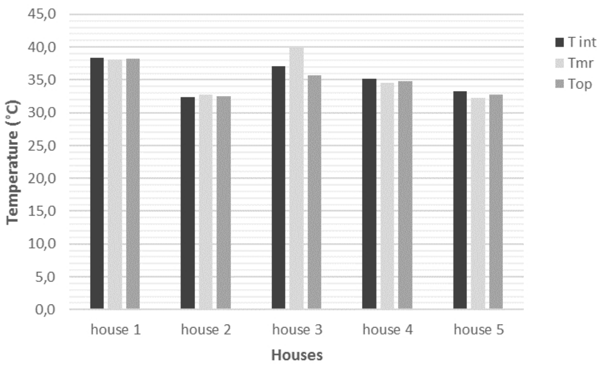


Fig. 6. Comparison between Top, Tmr and Tint of the five colonial houses.

Table 3. statistical summary of objective indices in the patio of the five colonial houses, Bisktra

Houses	House 1	House 2	House 3	House 4	House 5
Tint	38.4	32.5	37.1	35.2	33.3
Top	38.2	32.5	38.5	34.1	32.8
Tmr	38.1	32.7	39.9	34.5	32.3

According to the graph of Top and MRT (Fig.6), the curves are above the comfort zone which is for the Top is 22.5°C<top<28.0°C according to ISO 7730, with remarkable differences between the studied houses. Thereby house 4 and house5 respond better than the rest of the houses due to their North-East / South-West orientation, and the house 5 house is also the most comfortable with a Top 32.8°C (close to the comfort zone between 30.8 and 32.5°C) (Ealiwa et al, 2001) because of its height R + 2 (the depth of the patio).

6. Conclusion

This analysis showed the role of the patio of the colonial house on the interior thermal comfort in a desert climate. An objective investigation was made on five patio houses representative of colonial architecture in Biskra during the hottest period (end of July 2016). This confirms that the patio is a key element of climate adaptation that is characterized by a multifunctional role (vision, ventilation, lighting, use, distribution). It is a bioclimatic device par excellence associated with precise design conditions such as height, the more the height is R + 1 or more, the more the house behaves in a positive way, provided that the latter is oriented according to the most favourable axis, is north-east / south-west.

Finally, this article allows us to deduce that the rich architectural heritage of the region should be carefully analyzed and understood in its own historical and physical context. This legacy is a true laboratory in terms of comfort of great importance. Its construction techniques that have been used contribute to meet the needs of the human person from the thermal point of view to ensure its comfort inside the houses throughout the day.

There are many traditional devices that can be spread out into urban and architectural devices to help solve climate problems. The reintroduction and strengthening of these traditional techniques can contribute to the sustainability of the environment and contemporary culture.

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