



TECHNIUM
SOCIAL SCIENCES JOURNAL

Vol. 37, 2022

**A new decade
for social changes**

www.techniumscience.com

ISSN 2668-7798



9 772668 779000

External envelope impact on thermal environment of heritage buildings from the colonial period in hot arid area

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Abstract. The present research aims to study the effectiveness of the envelope components of colonial dwellings in maintaining a comfortable indoor thermal environment. In hot and dry areas, extreme outdoor air temperatures compel designers to provide a better indoor thermal condition which remains a rather delicate task to achieve such as in the case of the city of Biskra. The heritage buildings were constructed in the colonial period in the Biskra region; the colonial district buildings are built with local materials such as mud bricks and stones that have a large thermal mass; these materials are the main component of the walls of the outer exterior skin. Onsite measurement campaigns were carried out to record air temperatures inside the inhabited area for 24 hours. Thereafter, the collected data were compared with the outdoor air temperatures to assess the effect of the envelope impact on the temperature variation. The important results remain in the envelope's crucial effect to achieve thermal comfort using local materials with a high thermal mass.

Keywords. Heritage Buildings; External envelope; Thermal comfort; Hot arid area.

1. Introduction

The concept of heritage is broad and includes many historical, cultural, social, and architectural aspects, etc., where we can divide it into two main parts, namely, tangible and intangible heritage. Heritage is mainly related to a place where historical buildings are considered to be tangible heritage, which we have to highlight and know the extent of their approval. Contemporary requirements (peripheral, climatic, functional...) and there are many heritage buildings at the global level that are not in line with contemporary international standards for building classification, both at the peripheral, energy level to achieve thermal comfort within the inhabited area, for example, but not limited to, Maison Hankar-Saint-Gilles, Ancien Moulin de L'abbaye de Grandpré-esves And Moulin Castral-Hollogne-Sur-Geer... etc (Olivier, 2014).

The thermal efficiency of the architectural envelope and its components determine the degree of thermal comfort within the field and the value of the energy consumed (Kemajou and Mba, 2011). Envelop is considered as the barrier through which heat exchanges take place between inside and outside, especially under hostile climate conditions such as hot and dry climates, which is a challenge for the designer to produce an architectural conception that contributes to reaching the limits of thermal comfort and energy saving.

In hot arid regions, the use of artificial ventilation and air conditioning and large energy consumption made it a challenge for designers in terms of achieving thermal comfort within the inhabited construction in the hot season. The energy consumption is reaching 70% of the general energy consumption in the summer period. The residential sector represents 46% of the final energy in Algeria and 28% of the primary energy which has an impact on the environment and the phenomenon of global warming (Fezzioui et al., 2008). Thermal comfort is an important requirement for indoor users of the house, to achieve this; many factors must play an effective role, the most important is the outer shell of the house which mainly consists of walls, ceiling, and openings.

2. Architectural envelope

As it is known that the architectural envelope separating the inside (the inhabited indoor space) from the outside, which is the barrier against the undesirable external climatic conditions, it behaves like such as the human skin, and the housing envelope basically consists of three important elements:

- The external walls, which represent the largest part of the building envelope
- The roof, which is the most exposed part of solar radiation and therefore has an important role in thermal environment control
- Openings, where the weakest part of the envelope components in terms of heat transfer

3. Methodology of the work

Our study is based on a quantitative method, which is an onsite measurement to evaluate the thermal environment of the colonial building. The indoor air temperature of the inhabited area is measured, and then compared to the outdoor temperature as well as for the internal humidity in order to identify the impact of the envelope components on the thermal comfort of the users.

4. Presentation of the case Study

A large part of Algeria includes the Sahara, which made 85% of the Algerian total area with a hot and dry climate as a result of the influence of the Sahara of the local climate (Mokhtari et al., 2008). The province of Biskra is our study, located in the south-east of the State of Algeria. The area is a commercial area, and this is due to its distinguished commercial location. The area lived under Roman rule until the advent of the conqueror Uqba bin Nafie, who liberated the area from Roman rule in the year 682 and thus entered the area under the banner of Islamic rule, and the area was subject to the rule of the Ottoman Turks and this in the period between 1430- 1451. As for the colonial period in the city, it began in 1838, but the actual entry was in 1844 (Terea, 2016).

The area of Biskra province is 21,509,85 km² and it is inhabited by about 722,274 people. It is characterized by a semi-arid to dry climate. The summer is characterized by heat and dryness, and the winter is characterized by cold as well as dryness. As for the winds, the Biskra region is characterized by hot southeast winds that may reach 80 km/h and cold northwest winds with a speed of 35 km/h. We also note that the city of Biskra is characterised with the valley of Sidi Zanzour, which descends from the Aures region and ends to Shatt Mlagh, south of the wilaya (Terea, 2016).

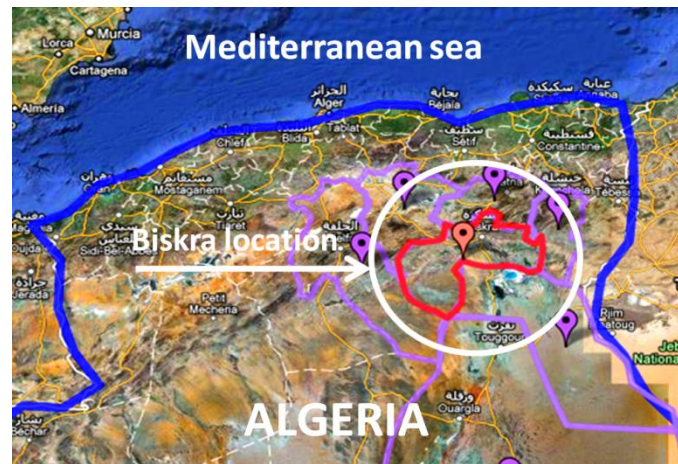


Figure 1. Biskra geographic location (Source: Google Earth).

5. Urban development of the city of Biskra

The province of Biskra has gone through many historical periods, which we can divide into three important stages:

5.1. Pre-colonial period

After the Ottoman Turkish control of the city of Biskra, the first nucleus of the city was formed, as the Turks divided the city into nine popular neighborhoods (Terea, 2016).

5.2. Pre-colonial period

In this era, after the French occupation of the city in 1844, the second nucleus of the city was formed, which is the colonial neighborhood (Terea, 2016), whose dwellings are characterized by local building materials represented in stones and mud, and this neighborhood has now become one of the city's heritage district (Agli, 1988).

5.3. Pre-colonial period

This stage witnessed a great demographic growth, which resulted in a rapid development and growth of the urban fabric of the city (Terea, 2016).

6. Urban genesis of the colonial district

Our study is the colonial district is the second nucleus of the city of Biskra, where it is currently considered a material heritage because of a large number of houses with history and heritage value based on many factors, including the local building materials used for construction, mostly made of natural stones and mud bricks. The buildings built in the

colonial period in the city of Biskra (Algeria), from the period (1883 to 1962) are considered heritage buildings, and this is due to many factors. It is characterized by a variety of construction materials between the old and the modern housing.

The colonial quarter is a group of allotments aligned in a chess plan parallel to the Fort Saint Germain wall and compatible with the existing buildings of the old village of Ras El-Ma. This type of assignment is found until (Militaire circle), after which the dimensions of the assignments change to become less (from 25 m to 30 m) and when we climb towards the north we find a third placement for the assignments of the colonial quarter, which is represented in five rows corresponding to the center of Fort Saint Germain, each assignment consisting of 4 to 5 dwellings positioned on the sides, each dwelling has an inner courtyard (some dwellings have 2 or 3 courtyards). The dwellings also have inner gardens (Sriti et al., 2002), the colonial city centre. The colonial neighborhood contains 688 dwellings, which is 2.7% of the residential neighborhood of Biskra, which represents the colonial center of the city (Abibsi, 2013).

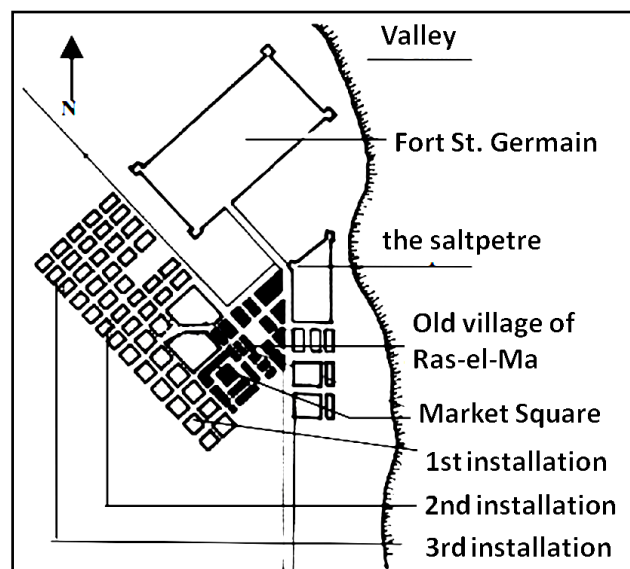


Figure 2. Colonial district genesis (Sriti et al., 2002).

7. Housing conditions

7.1. *Building conditions of the colonial district*

The building materials used in the construction of the housing in the colonial neighborhood are mostly local building materials. We find that the external and internal walls, same for the structural system, are either made with stones or mud bricks, in addition to artificial materials such as gypsum, bricks, glass, iron, bronze. Those constructive systems are primitive compared to the size of the dwellings and compared to the walls (external and internal) and tiles. A dwelling built with stones was chosen as a building sample for the research, considering that the clay brick, which have better thermal efficiency compared to stone, and thus knowing the efficacy of the stone as a building material for external walls in hot and dry areas.

The table 1 presents a classification of the colonial neighborhood housing in terms of construction status (good, medium and poor condition), where the number of housing units in this neighborhood is estimated at: 688 housing.

Table 1. Colonial district's buildings conditions (Abibsi, 2013).

Housing condition	good	medium	inferior	the total
Number of residences	190	347	151	688
Percentage (%)	27,61	50,44	21,95	100

7.2. *Building storey number of the colonial district*

The table 2 presents the storey's number of the colonial housing, as we find that the majority of housing has a ground floor and a first floor, which includes the house on which our study was completed.

Table 2. Colonial district's buildings storey number (Abibsi, 2013).

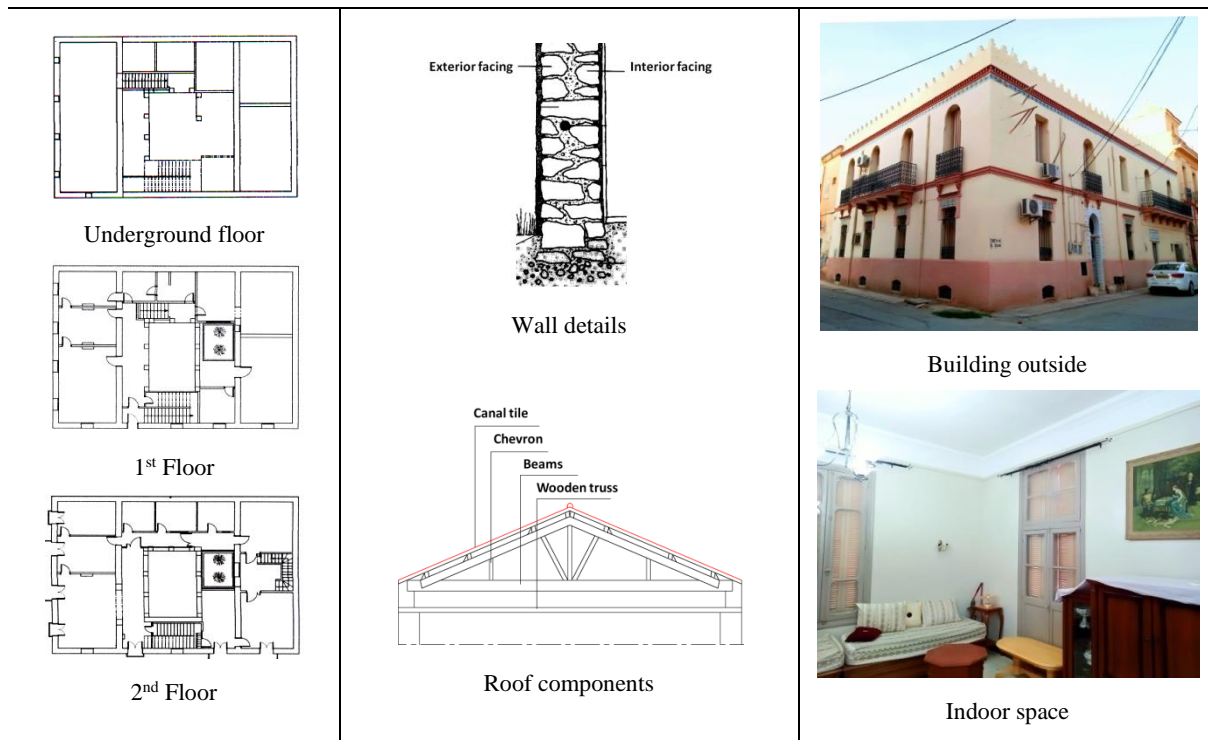
Number of Storey	Ground floor	1st Floor	2nd Floor	3rd Floor	4th Floor
Number of residences	87	505	68	24	04

7.3. *Building sample conditions*

The building sample is a house located in the colonial district, which is currently known as Khalifa House. In the late sixties, the state dispossessed part of the house, estimated at 50 m², latter it becomes the National Center for Algerian Women.

Table 3. Building sample conditions.

Building sample conditions		
Building Plans	Construction components details	Building Indoor and outdoor



Despite the modifications that have taken place, it still maintains its clear heritage and historical value at the level of the facade and the interior areas. It falls under the architectural style known as the "Arabesque style". It is an architectural style that combines colonial architecture and Islamic architecture. Some have called it local rationality and its beginnings were through an architectural trend that appeared in the mid-nineteenth century, it began in Egypt, and we find this style widely spread in several Algerian cities, including the capital (Khaladi, 2014).

8. Onsite measurement campaigns

8.1. Measurement protocol

In the experimental part, we have previously relied on the quantitative method, which is taking measurements on the ground level of air temperature ($^{\circ}\text{C}$) and relative humidity (%). The "data logger testo 174" was used in order to measure the indoor air temperatures inside the inhabited spaces and compare it with the outdoor air temperatures and thus evaluate the outer housing envelope and its effectiveness in reaching the limits of thermal comfort. This last is a state of general and stable comfort for the body; it is relative and varies from person to another according to many factors such as: dress, gender, age, activity in force. According to Vitruve, all buildings must be comfortable and healthy, and therefore the role of the envelope of the dwelling as an important part in achieving thermal comfort, especially in hot and dry areas such as the city of Biskra.

8.2. Results analysis

Thermal measurements were taken using the testo174 device every hour for 24 hours in October 19, 2022 in order to avoid the use of cooling devices or heating devices and to obtain more accurate and realistic results and to reach the effect of the envelope of the heritage

dwelling on air temperature changes between inside and outside a room on the 1st floor with a south-western facade.

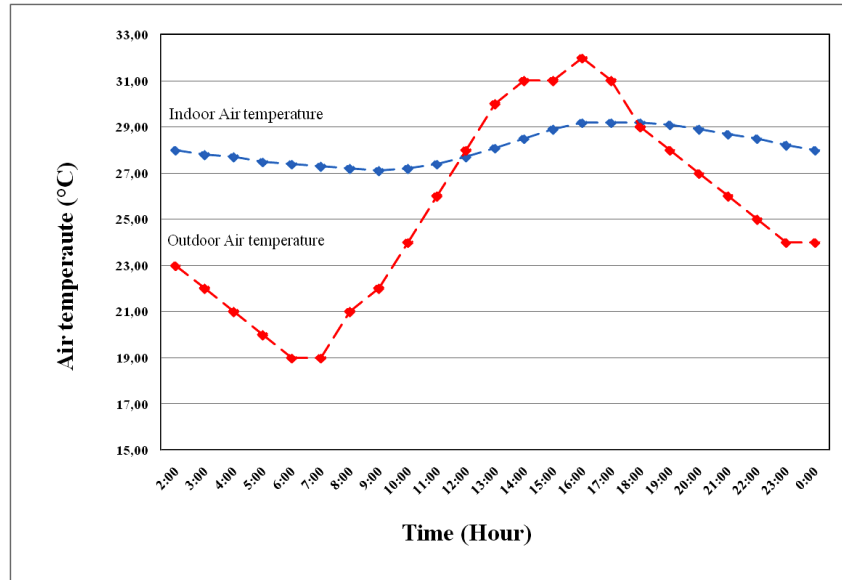


Figure 3. Air temperature variations between the indoor and outdoor spaces.

Through the air temperature variation graph in the figure 3 above, we note that the indoor air temperature is more stable compared to the external air temperature, as it ranges between 27.1 °C and 29.2 °C with a difference of 2.1 degrees, and the external temperature ranges between 19 °C and 32 °C with a difference of 13 degrees record at 9 o'clock in the morning. We have also recorded 27.1 °C within the inhabited area; it begins to gradually rise with the rising of the sun where the intensity of the rays on envelopes of the dwelling until its peak 29.2 at 6 o'clock in the evening.

9. Results interpretation

After the results analysis of the data shown in the previous graph (Fig. 3), we notice in close proximity to the stability of the indoor air temperature compared to the external air temperature, as it ranges between 27.1 °C and 29.2 °C, with a small difference estimated at 1.9 °C, while the external temperature ranges between 19 and 32 °C. This is mainly due to the high thermal mass of the external walls in addition to the air space in the ceiling layers. However, the indoor air temperature remains outside the thermal comfort limits, which range between 21 and 25 °C, and this is particular to the hot arid areas such as the city of Biskra. In order to reach the limits of thermal comfort within the inhabited space, many elements must be involved, among which, the most important the users post-occupancy comfort of the inhabited space (Mansouri et al., 2022), as the indoor space is ventilated in relatively cold times at night, as well as reducing the internal thermal loads such as active electrical devices.

10. Conclusion

The dwellings still fulfill their primary role, which is to create a comfortable space for users, as it is known that a dwelling is a place for rest in all its aspects, among them are the thermal comfort aspect. In this article, we tried to find out the effectiveness of the envelope of the heritage dwellings of the colonial period in order to provide a comfortable indoor thermal environment for users. Despite the old buildings in the colonial neighborhood, which is one of

the heritage districts in the city of Biskra, a large part of them (the buildings) are still well functioning while preserving the original architectural image, such as the Khalifa house, which is the our study case.

According to the onsite measurement campaigns conducted to record the indoor and outdoor air temperatures, we found a difference of 2.8 °C between them; this is due to the large thermal mass of the external walls, which are made of stones. The greater the thermal mass of the external walls, the more comfortable is the inhabited area. We have to mention that required for the thermal comfort limits are outside the comfort zone; this is mainly due to other elements that compose the envelope, such as the ceiling and opening surfaces.

In order to achieve thermal comfort inside this type of building, many elements must be taken into consideration despite the fact that preserving the appearance and value of the colonial heritage of these buildings. Among these thermal condition improvements are: the use of thermal insulators at the walls and ceiling level, the appropriate glass type, and increasing naturally ventilating all these building elements contribute to enhancing and reaching thermal comfort in buildings under hot arid climate conditions.

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