

# TRANSFORMATION PROCESS AND INDUCED COMFORT IN THE OTTOMAN HOUSES

MARWA BENCHEKROUN, SAMIA CHERGUI, FRANCESCO RUGGIERO, SILVIA DI TURI

## Abstract

The old town of Algiers, known as the Casbah, is the product and the place of social relations, but also of cultural models impregnated with history and intrinsic immaterial qualities. It is the manifestation of a superposition of several strata in a complex and original system; it is the trace of successive occupations, the collective memory which preserves and transmits the adopted or rehabilitated cultures to its ways of life. In other words, it is a living whole that has withstood the wear and tear of time.

Algeria has a rich heritage, not only as a historical value and identity, but also for the different solutions used to meet the environmental requirements and more precisely the needs of comfort.

The Casbah of Algiers is an eminent example of a traditional human habitat, representative of the deeply Mediterranean culture, synthesis of numerous stratifications. It composed of the most interesting houses, which have retained their authenticity and integrity, such as the aesthetic characteristics, the materials used and the architectural elements, retaining their original aspects and expressing values that gave it a place in World Heritage in 1992.

They have an old architecture that remains impressive and represents aspects of traditional vernacular architecture, illustrated as an example of a perfect harmony in the built environment with the natural environment, allowing a quality of comfort, ensuring a healthy and comfortable indoor environment.

During the colonial and postcolonial periods, it is clear that the houses of the Casbah of Algiers had a process of transformation/modification that is still undergoing, due to the will of the inhabitants to rise to the standards of modernity. These same transformations have certainly manifested themselves according to the needs, but often at the expense of the environment. They are the result of the overlap and juxtaposition of architectural models (local and colonial ones): each way of life reflects a historical period and a population that is constantly changing.

This paper focuses mainly on the nature of transformations endured by the residential building of the old Ottoman Algiers until now and analyses their impact on thermo-hygrometric comfort and indoor microclimate. Our reflection is linked to concepts with multidisciplinary dimensions that flicker between history, architecture, town planning, geography, socio-cultural, hydraulics and environment. In fact, the environmental issue is becoming more and more dominant in the new orientations and concerns related to the improvement of comfort conditions.

Therefore, the applied methodology is based on two approaches: a historical one, aiming to identify the architectural changes into old Ottoman houses, transforming the space and the openings (*patio or chebâk* roofing "it is a house with a courtyard that is either covered with a fence called *chebâk*, or discovered called *patio*", close off openings, ventilation, new openings, kitchens and bathrooms renovation, heating plant system, etc.), and an environmental one in order to measure the effect of these transformations on the thermo-hygrometric comfort. These practices have generated sometimes small or even enormous disorders, which have brought changes also in the indoor comfort.

Archives consultation, field investigations, modeling and numerical simulations will be essential tools, which will allow us to achieve the expected results. A detailed corpus, considering the least transformed houses to the most transformed ones, will be presented, accompanied by an accurate evaluation of the parameters influencing the thermo-hygrometric comfort.

**Keywords:** Transformations, colonial/postcolonial Casbah houses, thermal comfort, modeling / simulation, Multidisciplinary approach.

## 1. Introduction

Algeria has a rich heritage, recognized not only for its historical value and identity, but also for the different solutions used in response to environmental requirements and more precisely to the needs of comfort. It harbors an invaluable variety of heritage, whether natural or cultural, tangible or intangible.

One of the most emblematic testimonies of this rich heritage remains the "*casbah of Algiers*" whose values of authenticity and integrity have made it a world heritage. It has always been a living place inhabited until today and has undergone various transformations over the centuries in both structural and spatial aspect as well as architectural one. Whether beneficial or detrimental, these transformations introduced during the colonial and post-colonial period had an impact on hygrothermal comfort.



*Figure 1. Aerial view of the Casbah of Algiers*

*Source: Algeria discovery, discover Algeria simply, Casbah of Algiers published on over blog, by MÉRIMÈCHE*

Given that the environmental issue is becoming increasingly dominant in relation to new orientations and concerns related to the improvement of comfort conditions, this work focuses on the impact that these different transformations appear to have on performance of hygrothermal comfort of the residential building in the old Ottoman Algiers.

The approach is based on two complementary investigations: a first historical approach aimed at identifying the transformations that have undergone the Ottoman residential building followed by another, generally focusing on the environmental approach, and more specifically on the effect that these transformations had on hygrothermal comfort.

The "Casbah of Algiers" is located on the Mediterranean coast. The studied urban site was inhabited at least as early as the 6th century BCE, as evidenced by the Phoenician counter that was installed there. The Casbah, which originally designated the culminating point of the medina of the Zirid era, now applies to the whole of the old city of El Djazair, within the limits marked by the ramparts of the " Ottoman era, built at the end of the 16th century.



*Figure 2. View of the Kasbah of Algiers*

*Source: site; Mémoires d'Alger, réalisé par Marc Morelle*

Thus, the residential heritage, faced with environmental challenges, is comparing with major deterioration which has produced irrevocable consequences in terms of discomfort; hygrothermal comfort being recognized as a target of the high-quality environmental approach, is part of the developmental efforts to improve the standard of living of man without compromising natural environment and his surrounding. The objective is somewhere to regain comfort by renewing the good gestures in terms of design and construction, to reconcile the building with the natural climatic factors.

In the context of our research we are led to identify a typical model of a house that has undergone the least transformation possible, while taking into account the parameters affecting this comfort, such as: moisture transfer within porous walls thermal or evaporation-condensation phenomenon), heat transfer, solar radiation, rain or mixed convection phenomena, ambient and wind air temperature or ventilation systems to evaluate its response to climatic stresses. This contribution of knowledge regarding comfort will help to correct the caused deterioration and to reconcile the building with its environment by responding to the new requirements of comfort.

## 2. Typologies and characteristics of the Casbah houses

### 2.1. Typologies of the houses of the Casbah

Studies on the domestic architecture of the Kasbah of Algiers are reduced and do not deep into the residential building analysis; nevertheless, among the existing literature, one of the most recent books is that of (Missoum, 2003)<sup>1</sup>; which consists of classification of original Ottoman houses typologies.

Also the work of the Atelier Casbah (ETAU-UNESCO/ PNUD, 1981)<sup>2</sup>; presents the general types of original houses accompanied by surface transformations and spatial-functional changes they have undergone.

These two documents dealing with the domestic architecture of the *medina* of Algiers, based on the use of Ottoman archival documents, also emphasize the specific terminology the domestic architecture which is designated in archival documents by three terms : *al-dâr* (house), *al-dwîra* (little house) et *al-ulwî* (upstairs House).

From the point of view of spatial organization, (Missoum, 2003)<sup>1</sup>; defines two main typologies: the house with *wast al-dâr* and the house without *wast al-dâr*, the Arabic word meaning the courtyard:

a) The house with *wast al-dâr* Includes two variants: with discovered *wast al-dâr* or with a *wast al-dâr* partially covered with *chebâk*, an Arabic term representing the cover of the roof of the courtyard by a screen, in the form of a well of light allowing to regulate the light and air to have a regular flow of ventilation.

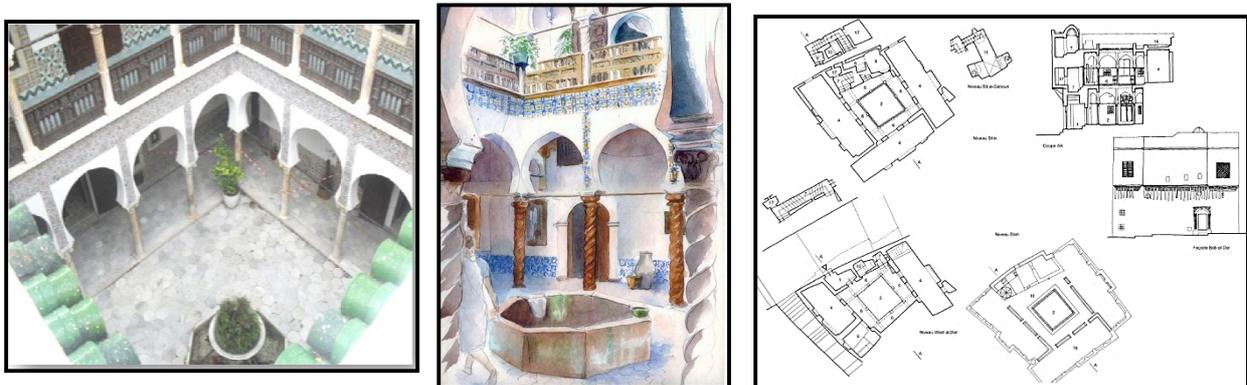


Figure 3. Houses of *wast al-dâr* typology

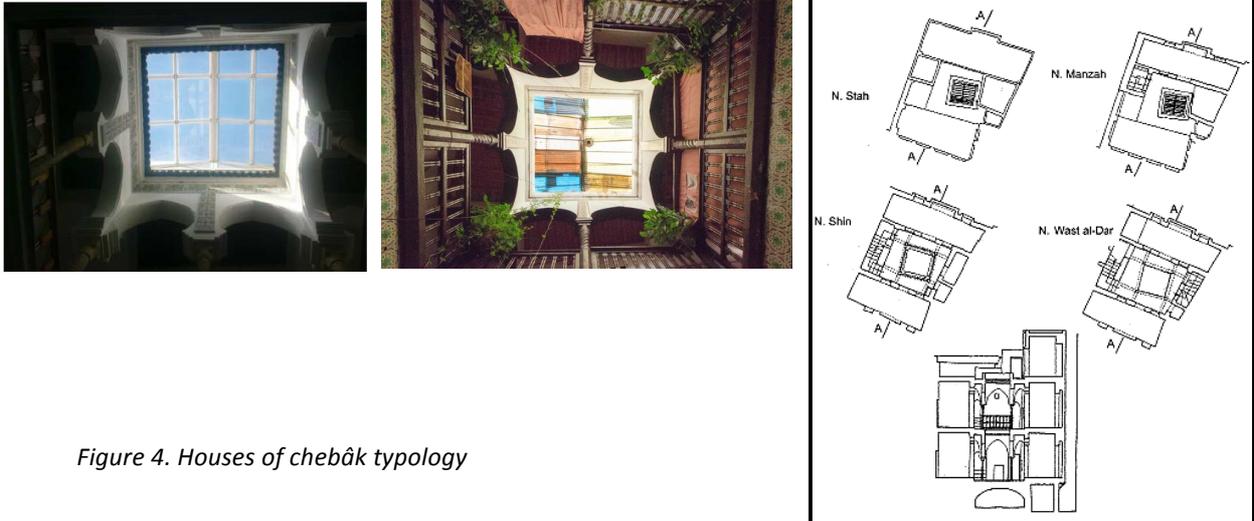


Figure 4. Houses of chebâk typology

b) The house without *wast al-dâr* called *al-ulwî*: which is a small house that is organized in height, which develops around a staircase illuminated by a skylight and whose rooms may be lit from the street unlike the other two types

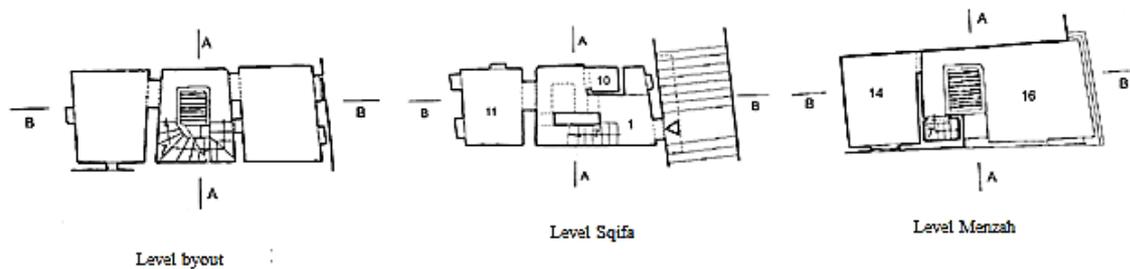


Figure 5. House of *al-ulwî* typology

In this article, the work will be on a single house typology (with *wast al-dâr*), in order to identify the nature and type of transformations that the house has undergone using archival documents and transformation report results / hygrothermal comfort will be presented while using the thermal dynamic simulation of the Design Builder Software.

## 2.2. Characteristics of the Houses of the Casbah

The old houses of the Casbah of Algiers border the narrow and winding alleys of this traditional medina and their traditional architecture testifies a rich past; seen from the outside, the dwellings look dark and devoid of all decor, but inside, the space is harmoniously arranged. The house is generally composed of a ground floor and a first floor, lined with galleries and arcades or open large rooms, in the center. The patio or the inner courtyard, often without any cover, is an element of thermal regulation and a passive cooling device with an influence on the internal comfort; all these traditional Mediterranean houses of the Casbah have in common, even in their diversity, to be adapted to the climatic constraints of the basin. Buildings often have thick walls constructed of limestone and clay brick (with small openings) that preserve them from heat during the day, then restore them at night, the materials used, the position of the house, the topography of the site and the old design of these buildings provide solutions that can still inspire in the construction of cities today.

However, the few houses in the Casbah of Algiers represent, in a way, this aspect of traditional vernacular architecture, which is illustrated as a good example of a built environment in perfect harmony with the natural

environment, allowing the same quality of comfort, while ensuring healthy and comfortable indoor environments.

Nevertheless, these houses have an ancient design which remains imposing not only for its heritage value but also for the environmental criteria that contribute to the new requirements and conditions of the current comfort, there are also some parameters that have allowed these houses to ensure the physical environment (topography, location of houses, configuration, position, orientation), climate and natural environment (temperature, humidity, solar radiation), social factors (type of occupancy, family number), architectural factors (stair position, opening, size of openings, orientation, materials [clay brick, earthenware, lime, stone, wood, ceramics] , type of cover, presence of wells and *djeb* that "is an Arabic name meaning a type of well for the recovery of rainwater", kitchen and bathroom numbers), these parameters at all times were used by man to design his shelter in order to ensure favorable living conditions and they influenced his comfort, they will be developed throughout this article.

### 3. The Aspect of Comfort / Discomfort

Historically, man has tried to adapt to the external climate that may be hostile to him by building shelters. Then the evolutions of his expectations in terms of comfort allowed him to modify these shelters so that they are illuminated, heated, decorated and so on. However, at first, he rationalized the elements of his direct environment. The designers made shelters with local materials taking into account the free supplies and protecting themselves from unfavorable elements.

The search for comfort is recognized as one of the first engines that pushed man to achieve his first shelter. As a result, comfort is declared as an ecological relationship between the individual and his environment. It requires an interdisciplinary approach.

The concept of comfort evolved over time on the basis of architectural design. In antiquity and in the Middle Ages comfort appeared in space. Before the French revolution, it was an "ornament", but in the middle of the 20th century, comfort was associated with the addition of sanitary facilities and the rationalization of facilities to satisfy the requirements of the user. Currently, it is a part of an environmental approach.

Comfort contributes to the definition of well-being. "Comfort is related to feelings, perception, mood and situation. Its definition involves both a negative approach (absence of discomfort, which is characterized, for example, by the absence of pain, anxiety, etc.) and a positive approach (well-being and satisfaction). "(Moser, 2009)<sup>3</sup>. This definition of comfort puts us face to face with the complexity of measuring comfort since a high number of physical, psychological, physiological, cultural and personal parameters influences more or less the different comforts defined by (Moser, 2009)<sup>3</sup>; – Sensory comfort: refers to the quality of the environment (light, sight, air, tactile quality of materials ...) – Existential comfort: is related to the environmental quality of the living environment having psychic repercussions (in relation to its identity or its development) – Material comfort: corresponds to the satisfaction of primary and material needs – Aesthetic comfort: subjective, it depends on individual perceptions – Social comfort: balance between the need to be with others and the need for intimacy – Comfort of conformity: belonging to a social group The notion of comfort is then difficult to define. These aspects of comfort are approached in numerous research in various disciplines: physics, psychology, architecture, biology ... In our study, we will try to describe the conditions of comfort in the traditional houses of the old town of Algiers, some houses are very well maintained and preserved, which gives them a quality of life, comfort, well-being. Every construction should achieve these goals, and this is a teaching that has lasted for decades, (Roulet, 2008)<sup>4</sup>; explains the different transformations that these houses have undergone and what they have generated as an impact on comfort; more specifically on thermal or hygrothermal comfort he details the conditions for optimum comfort.

The study of the vernacular architecture shows that the designers of these buildings knew the climate and the solutions to protect themselves. Thus, at the Casbah of Algiers where the winds of the North can be violent and cold in winter, the windows of the north facades are small. On the contrary, in the South, they are large enough to capture free solar energy. In the same way, the walls are very thicker thick which allows, thanks to the thermal inertia, to maintain the freshness in the traditional houses in summer. Moreover, the occupants had an adapted behavior: they lived with their environment in order to protect themselves from the heat in summer or the cold in winter. The occupant is "active" within his residential building. Throughout the day, depending on the seasons and the climate, it acts on its solar protections, windows, etc. The occupant is an actor of his thermal environment and lives with his climate, he participates in improving his comfort and not action which allowed him to live in harmony with the surrounding environment while respecting the climate

and the surrounding nature, as stated (Heschong, 1981)<sup>5</sup>; « Since ancient times, the maintenance of heat or freshness is part of the everyday human activities and participates in an almost unconscious cultural plan ». However, during the colonial and post-colonial period, major economic and social changes led to an acceleration of development, which resulted in major changes in all its aspects, notably in the cultural, social, urban and, above all, architectural fields.

Moreover, the great economic and social changes of the last decades have led to an acceleration of development never equaled. The speed with which we are able to plan and realize new "turnkey" urbanizations and architectures have enabled major transformations of the city in all its aspects, in particular: cultural, social, urban and, above all, architectural.

This situation has led to the importation of architectural models that are not adapted to the local socio-cultural characteristics and human identities of the houses in the Algiers Casbah as well as the non-consideration of local architectural models better adapted to the climatic and topographical data specific to this Mediterranean city.

All these parameters mentioned above created a discomfort in these traditional houses in the Casbah because the new occupants thinking to do what is best to embellish his home and makes a gestures that does not give any consideration to the aspect of comfort and reduced these houses to simple residences that no longer enjoy any comfort so valued in his time.

#### **4. Phenomenon of Transformation / Modification**

The study analyses the transformations suffered in the Ottoman residential patrimony during two crucial periods favorable to our research, the colonial period (1830-1962) and post-colonial period (1962 until the current period).

(Benmeddour, 2016)<sup>6</sup>; explains in his book that the transformations that these residential buildings underwent during the colonial or post-colonial period were sometimes positive and sometimes harmful and had an impact on hygrothermal comfort.

During the colonial and post-colonial period, the houses of the Casbah of Algiers, as elsewhere, are seized by the process of transformation / modification, a will of the inhabitants to confuse with the actuality to satisfy their needs and their comfort. The transformations have generated disturbances that are sometimes small and sometimes enormous, which have led to changes in the hygrothermal comfort of space.

Concerns expressed by several researchers, such as (Lesbet, 2007)<sup>7</sup> and (Ichboudene, 2007)<sup>8</sup>; confirm the absence of a global vision at the Casbah of Algiers, which must take into account socio-cultural and environmental data of the traditional inhabited site.

We can divide these practices into two types: the first one regards the internal transformations such as the installation of washrooms, the new openings, and the obstruction of *djebbs* and wells which transforms them into sanitary voids, transformations that are made by the inhabitants of the Casbah who take the initiative to transform their spaces. Man brushes or adds a part to his façade, for example, piercing a window, or introducing bathrooms in an unthinking way, thinking that it improves the living conditions of the house he occupies, when in fact he destroys the originality of what remains this heritage. The second kind of actions consists of external transformations such as adding new windows, closing others due to alignments that there were in the period colonial.

(Lesbet, 2007)<sup>6</sup>; emphasizes that the majority of houses has undergone transformations or modifications over the centuries that have had major impacts on the hygrothermal comfort of this building. This is the basis of our reflection, which requires first of all to identify the theoretical nature of "hygrothermy" but also practical one.

Researchers such as (Croiset, 1968)<sup>9</sup>; define it in a measurable and quantifiable metrological sense (the sensorial comfort), through "a frequent measure in the building sector where the ideal comfort is sought for the safety of the inhabitants and the infrastructures", he also specifies that several parameters related to comfort and indoor microclimate are taken into consideration such as humidity, temperature, ambient air, ventilation).

All the researchers are agreeing on the transformations suffered by the Ottoman houses during the colonial and post-colonial periods and their impact on hygrothermal comfort. However, it is difficult to rely on such findings to assess the impact of these transformations on hygrothermal comfort. The latter remains difficult to define, due to the divergence of the opinions of the researchers, with respect to the nature of this hygrothermia, and the necessity or not to include the human factor (perception) in the evaluation of this comfort.

### 5. Presentation of the case study (N ° 05 Impasse Bachara)

The traditional house, the object of our study is located in Algiers and more precisely in the upper Casbah, it is a building that has a single facade on the *impasse bachara*, typology *wast el-dar*, it covers an area of 120 m<sup>2</sup> and has a height of 10.33 m. It was built with ancient local materials (limestone and terracotta bricks and a mortar of lime), it is organized spatially by a court in the middle that is discovered (one and the rooms all around, it has a ground floor where one finds two large rooms, a kitchen and a room of water, on the first level the distribution is the same except for a room which is covered by a dome, on the terrace there is a part that is built representing the Menzah (a large space where women gather to discuss all kinds of activities) and the other part terrace for the machine.

Our choice was based on this house because it presents suitable criteria such as archival documents and field investigation have allowed us to identify a battery of transformations that it has undergone over the years. A few of them are listed here:

At the level of the ground floor; the development of a new kitchen with an opening on the courtyard, a functional change of the old laundry room in the kitchen, construction of two new rooms at the entrance of the house which was a courtyard, closing all openings, the addition of a toilet and two water points, the use of new materials such as concrete and paint, the increasing of families number living in the house (20 people live in this house currently).

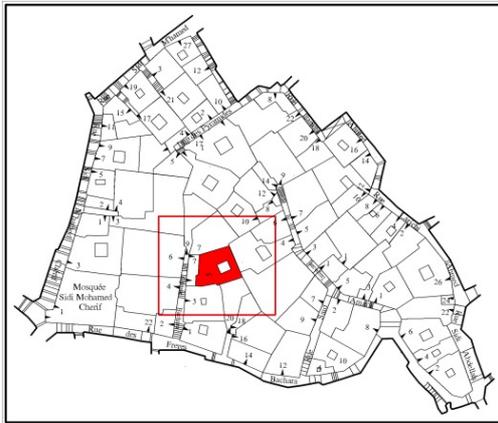


Figure 6. Situation of the house 5 impasse BACHARA, Source: Author

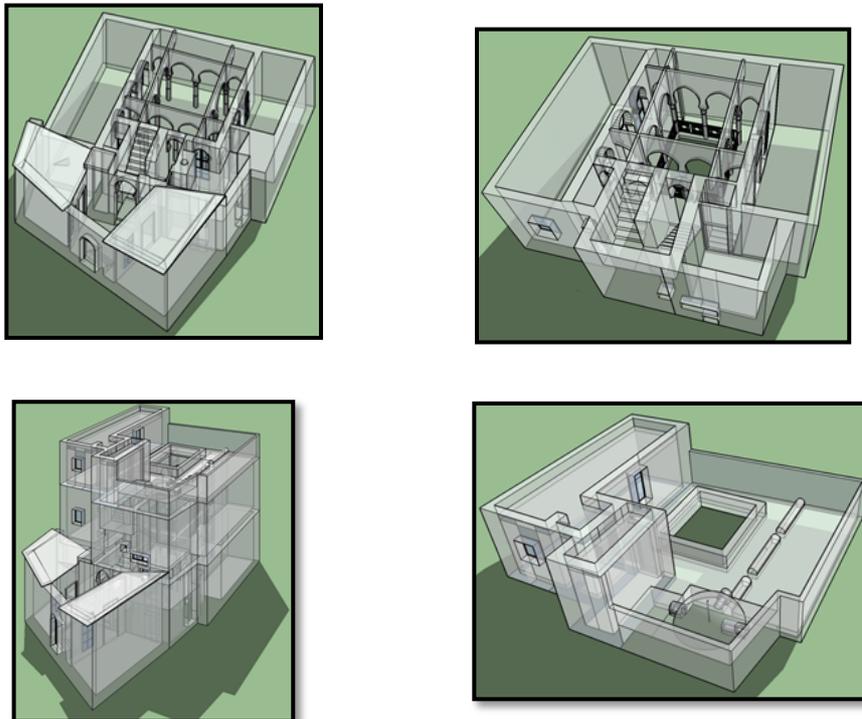


Figure7. Pictures of the modeling of the house by sketchup software



Figure 8. Roof top view, Source: Author



Figure 9. The new kitchen  
Source: Author



Figure 10. The House entry  
Source: Author

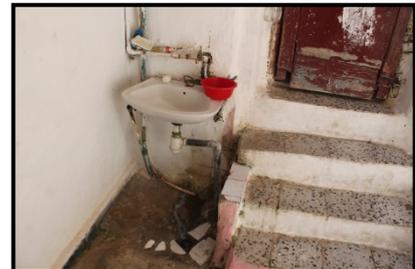


Figure 11. Water points  
Source: Author

## 6. Methodology

In order to identify the transformations and to study their impact on interior comfort, we have used as primary source the archive from OGEBC (Organisme de Gestion des Biens Culturels). It is a cultural property management agency located in Bab El Djdid in Algiers, it is the graphic archive of the ottoman house plans, the documents useful to determine the nature of the transformation that the house has undergone. This tool enabled us to establish the old state of the house studied. Once the building was identified, we went on to field investigation, which enabled us to locate the house on the ground, update the survey and identify the transformations it underwent, and then we carried out the modeling and numerical simulation through the use of Design Builder software.

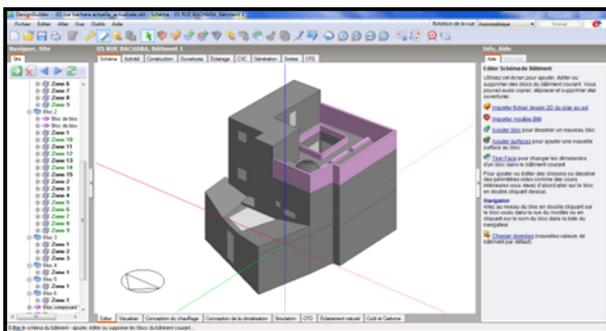


Figure 12. Software Builder Overview, Source: Author

## 7. Design Builder Software

### 7.1 Software Overview

The Design Builder software is based on the Energy Plus engine, developed by the US Department of Energy, to carry out dynamic energy simulations of the energy behavior of the building. DesignBuilder/EnergyPlus is used first to evaluate a building's energy consumption or demand, but also to assess the comfort of users in the building.

DesignBuilder/EnergyPlus is one of the most advanced software packages that can be used to integrate heating or cooling systems in addition to the need calculation. It also calculates different parameters allowing evaluating the thermal comfort through algorithms allowing to treat this data. Thus, we can list the calculated parameters and those that are not calculated among those that are commonly used to evaluate comfort.

Parameter	
air temperature	calculated
radiant temperature	calculated
operating temperature	calculated
air humidity	can be calculated, but most often fixed
CLO	input data that can be changed over the year
air flow rate	imposed equal to 0,137m / according to ASHRAE
metabolism	defined by the user
PMV	3 types of index

*Table 1. Table showing the parameters of Design Builder*

it should be noted that the algorithms for calculating the PMV are proposed making the tool particularly interesting for the analysis of comfort. However, since several of the variables taking into account in the algorithm are either fixed or input data fixed by the user, the interest is then more relative. The remaining calculated variables are air temperatures and radiant temperatures. The operative temperature translating the two is then a relevant indicator of the comfort of the user.

Parameters influencing comfort are numerous and are composed of two types: physical parameters and human variables which can be measured by the following climatic variables: such as Air temperature,  $T_a$  (or ambient temperature),  $T_r$  (mean temperature of radiation),  $V_a$  (air speed),  $w$  (air humidity), and physiological variables, such as Metabolic heat production,  $M$  (AFNOR standard X35205), factors related to the isolation of clothing,  $F_{cl}$  (ISO 9920 standard), thermal insulation, resistance to evaporation, skin temperature and internal temperature and the rate of moisture production (sweating).

For this work, the parameters studied are the different temperatures, humidity and ventilation for the case of traditional and current house.

### 7.2. Simulation methodology

In this work that we propose, dynamic thermal simulation aims to provide a method that allows the improvement of the behavior of the building in terms of energy consumption and comfort of the user.

Thus, it is primarily used for comparative studies: two different architectural solutions or two different systems are studied in terms of the impact on energy consumption and user comfort. Our work consists in establishing virtual simulations in the summer period for the case of the house in the old state as well as the current state in order to identify that there are bad transformations that were made to meet the requirements of comfort but have had a negative impact on the hygrothermal comfort of this house.

The idea here is to compare the difference between what was comfort in ancient times and what it has now become, the house in his original state and the different transformations it has undergone during years and to see if there has been an impact on the interior comfort, to carry out comparative simulations, based on the archives documents of the house (5 impasse Bachara) as well as his current statement.

## 8. Mathematical Equations

### Operating temperature

It is the temperature of a fictitious room, assimilated to a black body at uniform temperature, in which an occupant would exchange the same total amount of energy (radiative and convective) as in the real room. It is given by the expression

$$T_0 = h \cdot T_{\text{air}} + (1-h) \cdot T_r$$

- $T_{\text{air}}$ , the air temperature
- $T_r$ , the average radiant temperature
- $h$ , coefficient of weighting between convective and radiative exchanges

For the mean radiant temperature, we consider a person located in the middle of the room, and it is then the mean surface temperatures weighted by their surfaces.

$$T_r = \frac{\sum_i T_i \cdot S_i}{\sum_i S_i}$$

Most often the weighting coefficient  $h$  is taken to be equal to 0.5. The operative temperature is then the mean of the air and radiant temperatures.

DesignBuilder and EnergyPlus simulations can generate in-depth data on the environmental conditions in the building and the resulting levels of occupant comfort. In our case the chosen indicator of comfort is the temperature; operating temperature, radiant temperature, air temperature and outdoor dry temperature, as well as another parameter which is the sum of the mechanical ventilation + the external ventilation + the infiltration:

Indoor air temperature: calculation of the mean air temperature.

Indoor radiant temperature: mean radiant temperature (MRT) of the area, calculated assuming that the person is placed in the center of the zone, without weighting a particular surface.

Indoor operating temperature: average of indoor air temperatures and radiant temperatures.

External dry temperature: data from the site.

Relative humidity: calculation of the relative relative humidity of the air.

Wind Meca + Vent Nat Ext + Infiltration: sum of the outside air (in Vol / h) entering the zone:

HVAC system + natural ventilation + infiltration, Mechanical ventilation + external natural ventilation + Infiltration data, represent the sum of the fresh air supplied by the HVAC system, infiltrations and external natural ventilation at renewal rate  $d$  air per hour (Vol / h). These data used with other environmental results can be very useful to check the discomfort of the occupants.

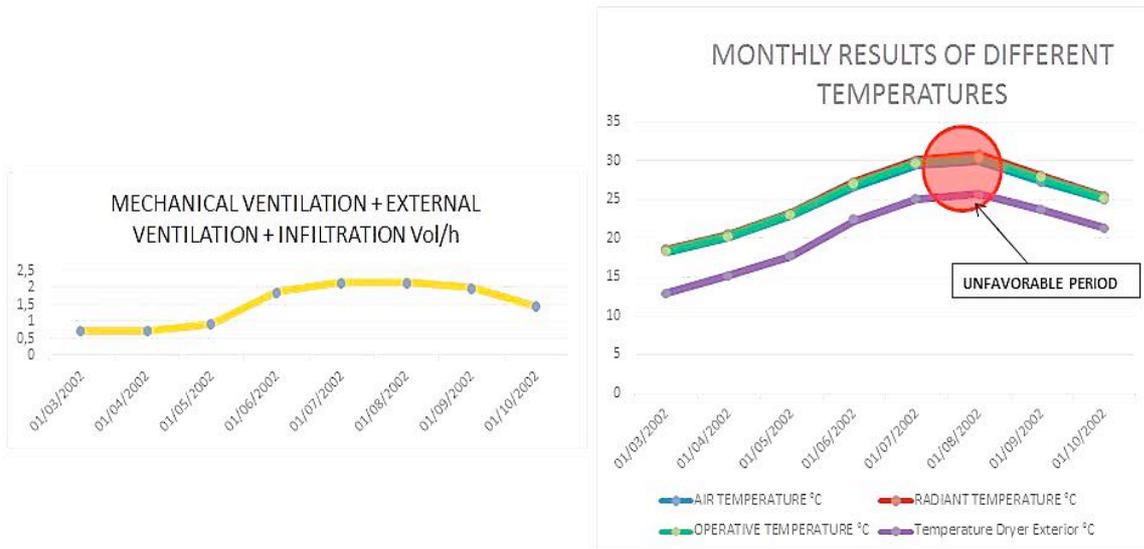
Minimum temperature: it represents the internal temperature below which the ventilation will be stopped

Maximum temperature: it represents the internal temperature above which the ventilation will be stopped.

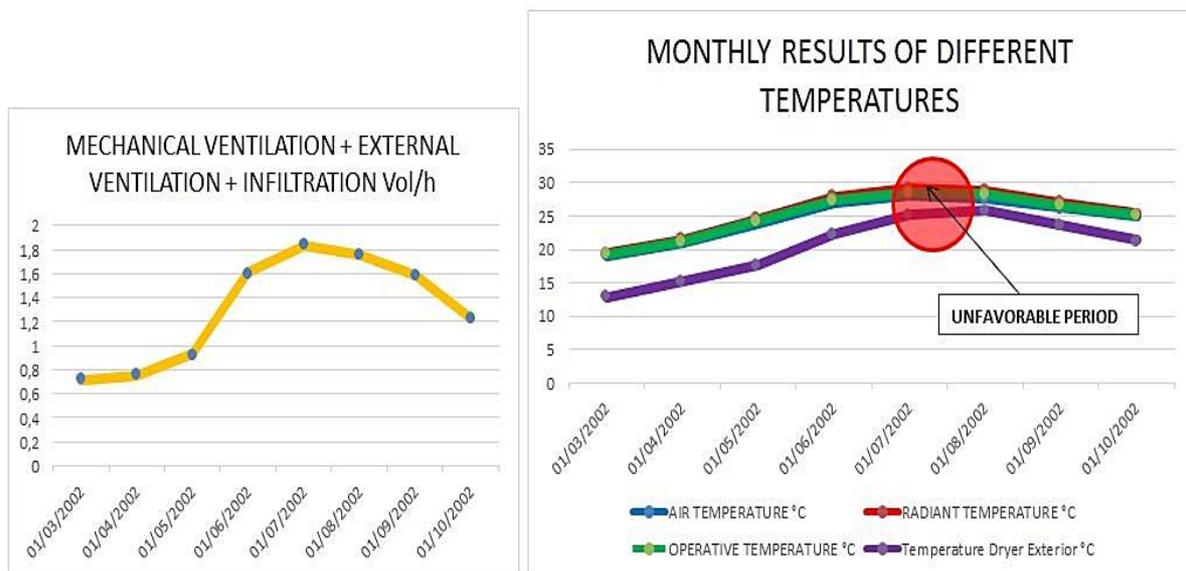
## 9. Simulation and results

The graphs represent the results obtained by virtual simulation of the house No. 05 Impasse Bachara in its old and current state. The parameters studied are the different temperatures as well as the ventilation. In the case of the old house there is a natural ventilation without any cooling system, we note that the difference in temperature is constant between the inside and outside, as for the ventilation it is also constant with respect to the temperature, as soon as the external ventilation and the infiltration increases the temperature decreases and viceversa.

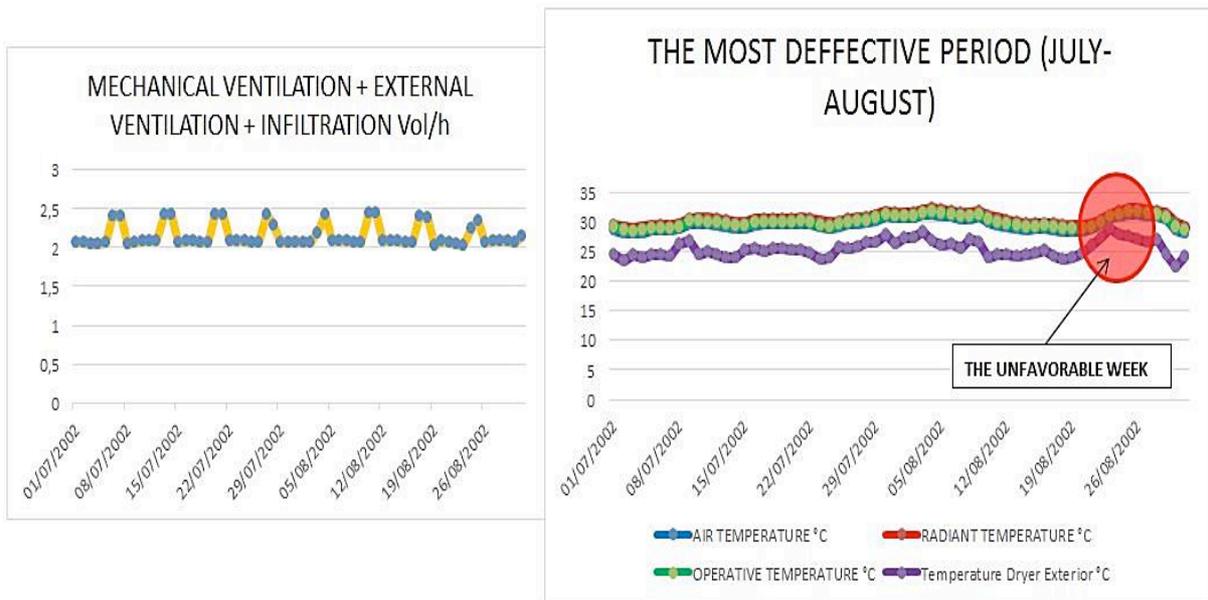
In the current house, in its transformed state, the transfer of temperature between the interior and the outside is destabilized.



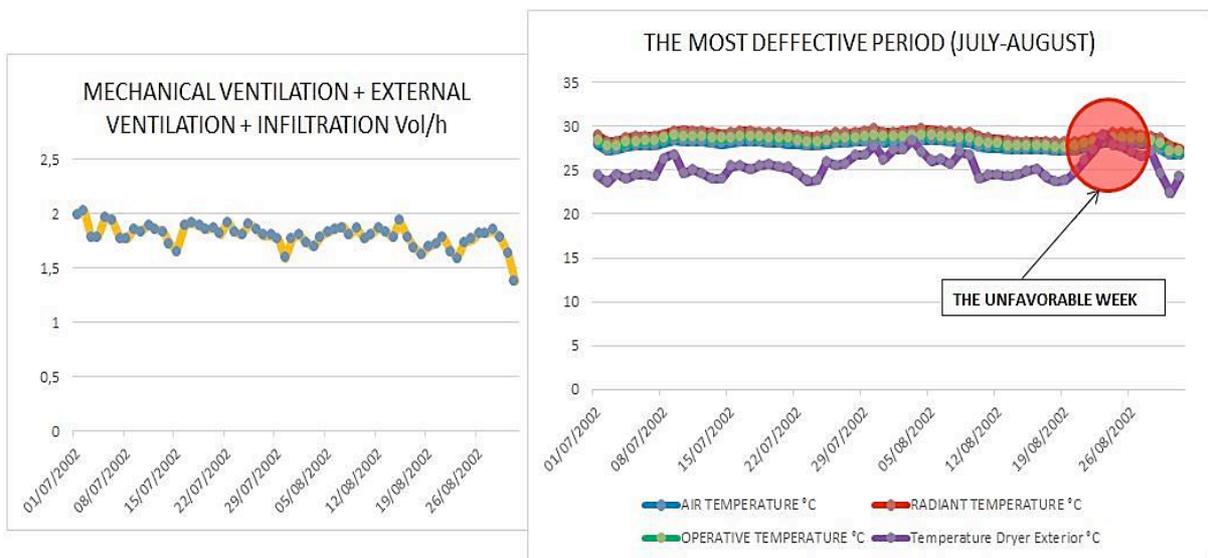
Graph 01 and 02. Ventilation and different temperatures for the old state during the summer period



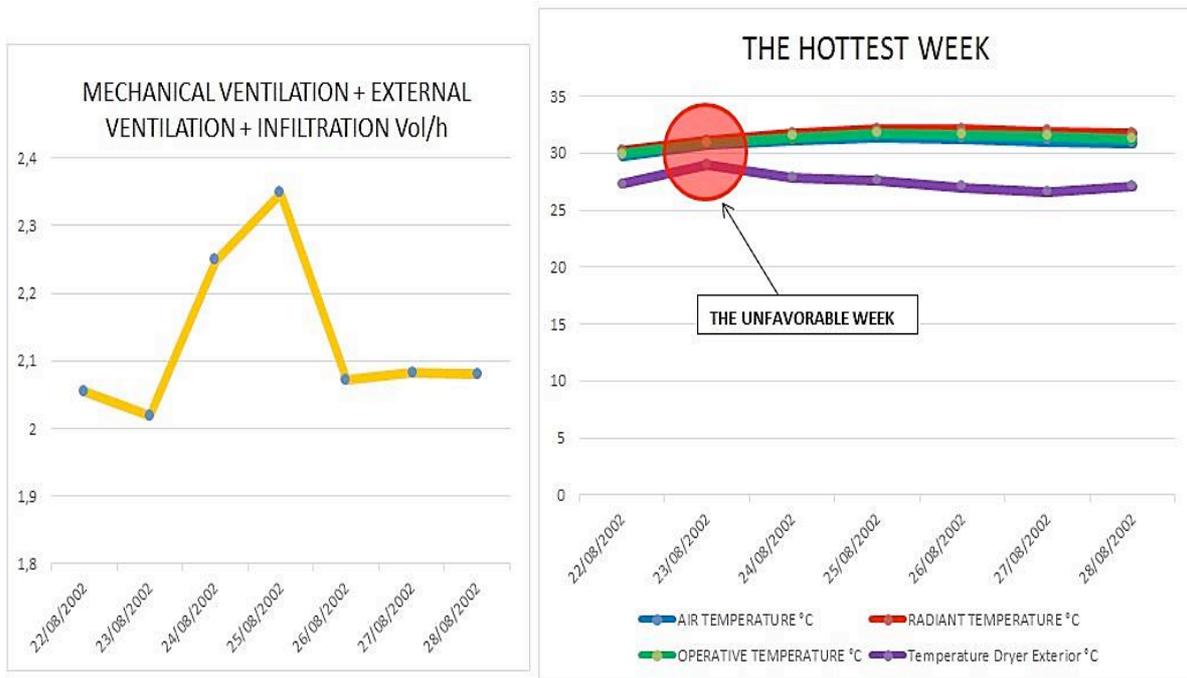
Graph 03 and 04. Ventilation and different temperatures for the current state during the summer period



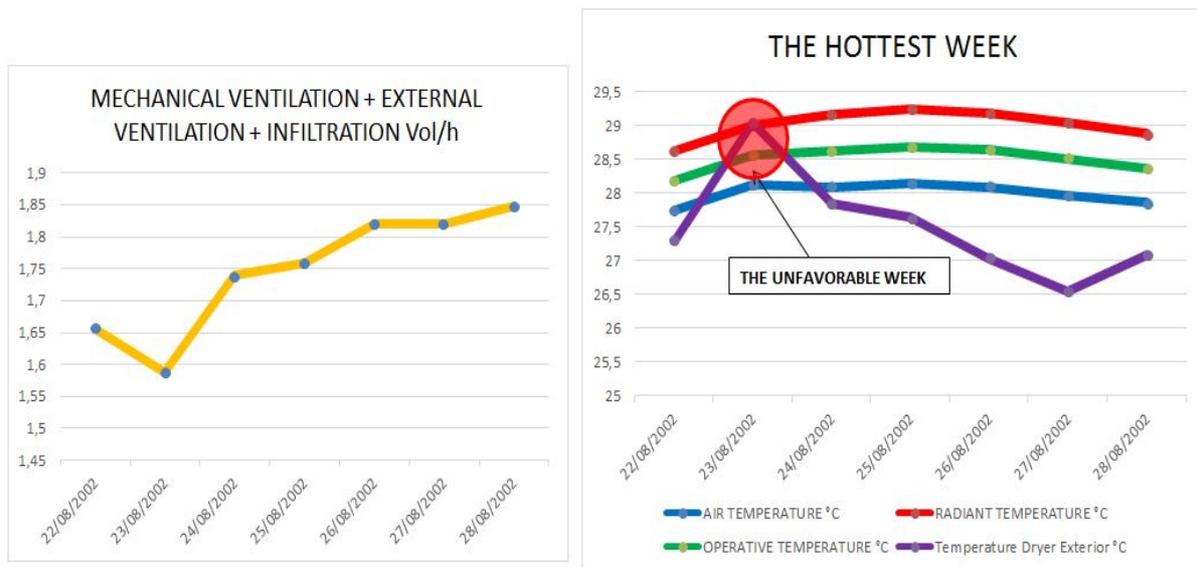
Graph 05 and 06. Ventilation and different temperatures for the old state during the two months (July-August)



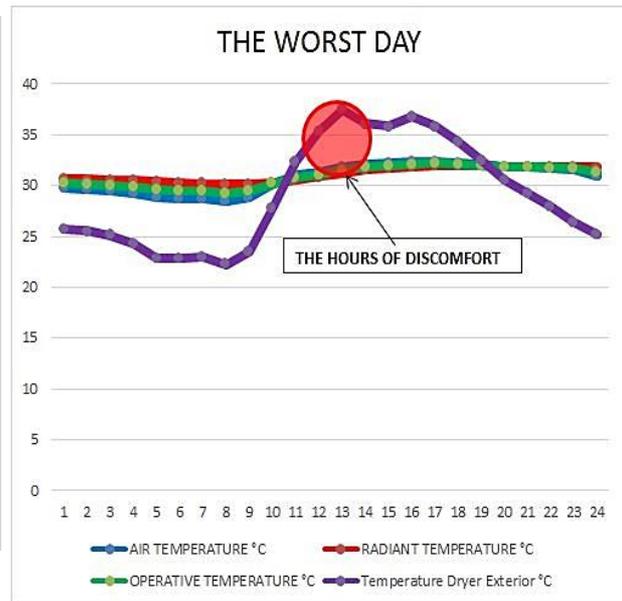
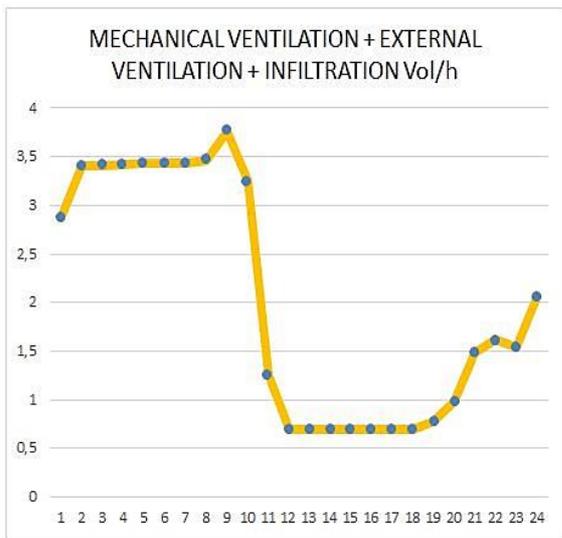
Graph 07 and 08. Ventilation and different temperatures for the current state during the two months (July-August)



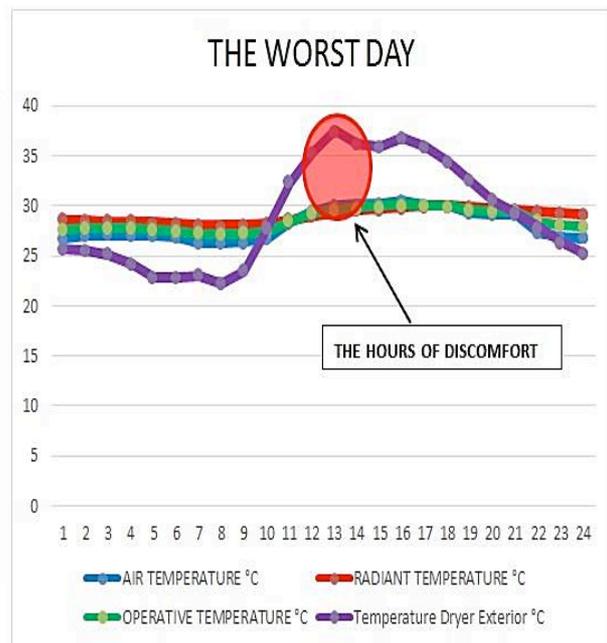
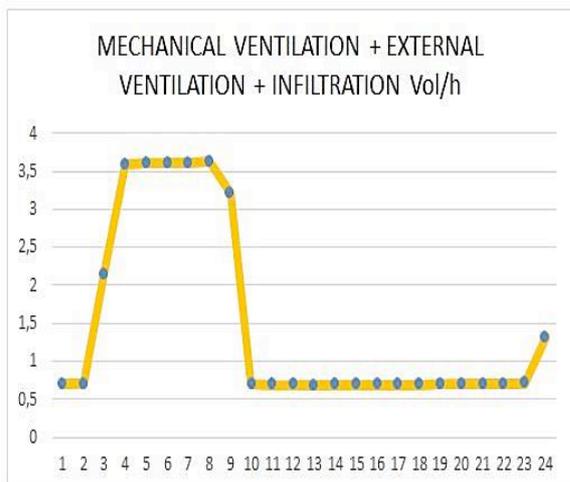
Graph 09 and 10. Ventilation and different temperatures for the old state during the hottest week



Graph 11 and 12. Ventilation and different temperatures for the current state during the hottest week



Graph 13 and 14. Ventilation and different temperatures for the old state during the worst day



Graph 15 and 16. Ventilation and different temperatures for the current state during the worst day

From the monthly study of our study case in both periods, we were able to determine the worst period, the warmer months (July-August).

We observe in the former case that the difference between the external dry, radiant, air and operative temperature is constant, confirming that there is a balanced temperature transmission compared to the current state of the house. We see that this difference in temperature outside and inside is almost non-existent, which explains why the temperature transmission is insufficient due to the architectural modifications carried out on the house.

As for the ventilation graph during the monthly period, we notice that the air flow increases as soon as the worst period for both (old and current) is reached.

For the worst period (July and August), on the former case mechanical ventilation is non-existent since it is a natural ventilation, we notice on the graph of spikes of 2.5 vol / h, explained by phenomena such as thermal inertia, humidity, air inlet and outlet. For the present case, there is the presence of mechanical ventilation (air conditioning) which influences the temperature so that it can increase or decrease the temperature.

From graphs 5 and 6, 7 and 8, we were able to define the warmest week from 22 to 28 August in order to be able to interpret and explain the results more precisely.

During this week, we note that for the old case of the house, the transmission of temperature between the inside and the outside is balanced, even if the outside temperature is lower, as for the present case; we note that the difference is unbalanced and we can observe it more precisely during the worst day (August 23).

According to the obtained results, it can be said that the house N ° 05 impasse Bachara in its two cases (old and present) presents an overheating, since the internal temperature is higher than the outside temperature; however, in the former case, the temperature difference between the interior and exterior is constant, as in the present case, has undergone various transformations over the years, such as the introduction of the toilet, the new opening, use of new materials (Concrete, tarnishing, etc.), as well as the modification of the floor and roof covering, resulted in a remarkable temperature difference and therefore destabilization.

## 10. Conclusion

The study focuses on the transformations that the house underwent during the colonial and post-colonial period and its impact on hygrothermal comfort. This work allowed us to study this house from a new angle, combining a multidisciplinary and more precisely between the knowledge of physics (hygrothermal comfort) and the heritage as well as the architecture of this building (the different stratifications that have undergone this house for centuries).

From the obtained results, it can be concluded that the various transformations that have undergone the traditional house N ° 05 Impasse Bachara such as [the closure of openings reserved for aeration, the arrangement of new kitchens, the use of concrete to reinforce certain parts or the introduction of electronic devices (refrigerator, microwave, air conditioner, washing machine, etc.) have led to modifications of the microclimate inside the house, making the living conditions worse.

This work allowed us to examine two parameters (temperature and ventilation) and their influence on the heat transfer inside and outside the house.

Through these results, we can confirm one of the hypotheses that some houses (like the one studied in this article) of the Casbah have undergone negative transformations and that have modified the hygrothermal comfort negatively.

In the prospects; it would be interesting to enrich this work with:

- A study on other parameters of comfort: humidity, orientation of the house, energy consumptions.
- A thermal dynamic simulation study extends to the annual period.
- Conduct an in situ measurement campaign to verify the results obtained by thermal dynamic simulation.

## References

- ATELIER CASBAH., 1981. *Projet de revalorisation de la casbah d'Alger, Plan d'aménagement préliminaire : ETAU ETAU-UNESCO/ PNUD*. Alger.
- BENMEDDOUR Mohamed., 2016. *CASBAH d'Alger patrimoine en danger*. Editions Houma Alger. 158p.Alger.
- CROISSET Maurice., 1968. *L'Hygrothermique dans le bâtiment, confort thermique d'hiver et d'été, condensations*, Eyrolles. National School of Architecture, online catalog, Rabat  
<[http://cdena.archi.ac.ma/opac\\_css/////index.php?lvl=author\\_see&id=5469](http://cdena.archi.ac.ma/opac_css/////index.php?lvl=author_see&id=5469)> [Accessed January 2016].

- FRONTCZAK, Monika, Pawel WARGOCKI., 2011. *Literature survey on how different factors influence human comfort in indoor environments. Building and Environment*, 46(4) pp. 922-937.
- GUION, P., (1940). *Images du vieil Alger*. Alger.
- HESCHONG, Lisa., 1981. *Architecture et volupté thermique. Parentheses*. 93p. (Habitat/Ressources). *Marseille*.
- ICHEBOUDENE Larbi et NACIB Youcef., 2003. *La Casbah d'Alger et l'Architecte Paul GUION*, Publisud, Paris.
- LESBET Djaffar., 1985. *La casbah d'Alger: gestion urbaine et vide social*, Office des publications universitaires. 235p. Alger.
- MISSOUM, S., 2003. *Alger à l'époque ottomane, la médina et la maison traditionnelle*, INAS, Alger.
- MOSER, Gabriel. 2009. *Psychologie environnementale, les relations homme-environnement*. Bruxelles : de Boeck, 298 p. ISBN : 978-2-8041-1753-5.
- NICOL, J.F, M.A, HUMPHREYS., 2002. *Adaptive thermal comfort and sustainable thermal standards for buildings. Energy and Buildings*.34(6). pp. 563-572.
- RAVÉREAU André., 1989. *La Casbah d'Alger, et le site créa la ville*, Sindbad, Paris.
- ROULET, Claude-Alain., 2008. *Conditions de confort et de logement sain*. EPFL, 70 p. available at < [www.enrdd.com/documents/documents/ConstructionEcoconstruction/Architectureresponsableetdeveloppementdurable/roulet2008.pdf](http://www.enrdd.com/documents/documents/ConstructionEcoconstruction/Architectureresponsableetdeveloppementdurable/roulet2008.pdf) >.