



TECHNIUM
SOCIAL SCIENCES JOURNAL

Vol. 27, 2022

**A new decade
for social changes**

www.techniumscience.com

ISSN 2668-7798



9 772668 779000

When social practices produce space and create passive cooling systems in hot arid region

Ibtissam Benoudjafer¹, Imane Benoudjafer²

¹Department of architecture, Laboratory of Mechanical and Structures, University Tahri Mohammed of Bechar, Algeria

²Department of Civil Engineering, Laboratory of Mechanical and Structures, University Tahri Mohammed o Bechar, Algeria

benoudjaafar.ibtissem@univ-bechar.dz

Abstract. Practice social of people is the key to produce space and give a possibility to maintain thermal comfort and energy efficiency. The main objective of this research is to adapt the traditional strategies in the architecture actual, to achieved a thermal comfort and improve on reducing cooling load through the using of vernacular gait. Today, it is necessary to practice these systems in the current or conventional architecture of household. The study is especially for arid cities namely the region of Saoura, in the hot and dry climatic zone in Algeria, considered for this study. Two main factors is considered such as design and urban where taken into account in order to select the appropriate and specific passive cooling strategy. The results show that the passive cooling strategy of courtyard would be appropriate for arid regions, however a high thermal mass would be suitable for construction. In conclusion, this work made it possible to choose a suitable passive cooling strategy for all types of construction in hot and dry climates. Finally, this paper puts forward a set of recommendations to improve the passive design of future buildings in hot and arid climates.

Keywords. Passive cooling technique; traditional strategy, arid region, thermal comfort, performance effect, household

1. Introduction

In desert regions, poor adaptation of the building design and its indoor environment can result in a greater need for active cooling and thus, increased energy use. In a warm and dry climate, passive cooling strategies of a construction involve the adoption of three elements: typology of materials, shape and climate.

With the climate change challenges, the research of passive cooling solutions of buildings is crucial. After independence, the rate of urbanization was increased due to the strong demography and the demand for housing, as the case in Algeria – South. Today, the surge in energy consumption, excessive carbon emissions must be study new Passive cooling strategies, or innovated other strategies in vernacular architecture. In this situation urgency, the residential sector accounts for 60% of household energy use, we seriously in place to minimize electricity and gas consumption, to maintain thermal comfort inside buildings [1].

A passive cooling strategies in housing design can make a significant difference in energy consumption and to meet the thermal comfort needs of the inhabitants.

This study explores the characteristics of traditional housing, in arid region of Algeria, that contribute to making indoor spaces thermally comfortable. The investigation of sustainable strategies used in case studies in the hot and dry climate (south Saharan of Algeria), named Saoura region. These strategies have a significant impact on the microclimate of traditional houses and considerably reduce the need for electricity and mechanical power.

Vernacular passive cooling strategies, such as the courtyards, or ventilation of night, can be adapted to improve the energy performance of modern architecture. We will identified on some passive cooling strategies that were used in hot dry climate to reduce the use of energy for cooling, and enhancing an adapted architecture specific for these region. Furthermore, in this study, we will showing some examples of using the vernacular passive cooling strategies that are common in Saoura.

Many strategies will developed that the courtyards, multiple openings, stack-cooling, night ventilation, and using thermally massive materials, are among the most important strategies for ignored the heat in hot dry climatic houses.

Today in this situation, the research of the passive cooling strategies in vernacular would practices in modern construction; which is important reasons to reduce the irrational using in energy consumption, on electricity and gas.

The aim of this research is to present the main of various passive cooling strategies of vernacular architecture and applied for the current one in order to improve the thermal performances and reduce the energy consumption of residential buildings in arid regions, more particularly the southwest of Algeria; the city of Bechar.

1.2. The problem of construction and energy

The current problem of the construction sector in Algeria is the uncomfortable situation of buildings intended for housing, despite the enormous potential of electricity and gas consumption. Several factors have contributed to this situation, including the lack of enforcement of thermal regulations established in the country for a high exploitation of construction and high electricity consumption with a symbolic low price of electricity. Limited awareness of green building practices compared to most African countries. For this, the goal of this research is to develop renovated passive cooling strategies, and economical to improve thermal performance and reduce the energy consumption of residential buildings, in hot and arid climates, such as the Saoura region, located in South West of Algeria.

1.3. Research Methodology

The methodology will starts with understanding the different examples of passive cooling systems in the houses. This study should take into account the specificity of arid climate. Then, we will investigate how the design of these houses and their elements, such as orientation, openings could create passive cooling opportunities for residents through earth coupling, natural ventilation, evaporative cooling, dome ceiling, seasonal relocations, as well as the use of local and thermally massive materials. In the final of this method, we draws on the case studies and their features and brings together the findings from this study.

1.4. Findings

Findings suggests that the passive cooling strategies used in traditional houses in South west of Algeria, we have the potential to be applied to the modern and contemporary buildings, in arid region.

In this paper, we explores the characteristics of Ksour of south west of Algeria; witch is a traditional housing that contribute to making indoor spaces thermally comfortable. The examination of sustainable strategies used in many case studies in the hot and dry climate of Saharan Algeria indicates that such measures have a significant impact on the microclimate of traditional houses and considerably reduce the need for electricity and mechanical power.

1.5. Climate and Contextual Studies

To appreciate how passive cooling strategies has contributed in housing in hot and dry climatic conditions: this study has analysed many traditional buildings of Saharan areas of Algeria.

According to the Algerian National Center of Studies and Researches Integres of the Building (*CNERIB: Centre National d'Etudes ET de Recherches Intégrées du Bâtiment*) and the thermal regulation (DTR C3- 2), for residential buildings, Algeria has six distinguished climatic zones:

- Zone (A): in the north of Algeria, including the coastal zone;
- Zone (B): in the south of zone (A), including the plain behind the seashore;
- Zone (C): in the south of zone (B), including the highlands;
- Zone (D): in the south of Algeria, including the desert; and the climate zones (B') and (D'), representing subzones within the main zones (B) and (D), respectively. [18]

In these areas people had to evacuate most of the buildings from the city, because they had non-insulated construction, with conventional air conditioning systems and internal temperatures rose throughout the day and into the evening. Again, these residential buildings had not provided adequate shelter in these extreme conditions and specific for a very hot summer period, may have resulted in situations of discomfort of human life. For our study, we selected some ksour: Ksar Moughel and Ksar Bousemghoune, a famous vernacular constructions in the south of Algeria.

2. Passive cooling strategies in arid region

Designing a passive design is to make the most of the local climate, and responds to site conditions, to maximize the comfort and health of building users while minimizing energy consumption. The fundamental key to achieving passive construction is to choose a passive cooling system suited to the specific climatic conditions of each region. For this reason, it was necessary to seek reference to any technologies or characteristics of passive cooling strategies of a design adopted to reduce the high temperature of buildings, during the summer season, without the need for energy consumption in buildings.

The principle of passive cooling is to prevent heat from getting into a building during a warm day and bringing in cool air from outside when the temperature drops. The passive air cooling system provides cooling through the use of passive process without using customary mechanical units such as fan, compressor, etc. in regions where cooling is a dominant problem. Passive cooling strategy maximizes the efficiency of the building envelope by minimizing heat gain from the external sources and assisting heat loss to the natural sources of cooling such as air movement, cooling breezes, evaporation and earth coupling.[2]

The vernacular architecture of Saoura region, located in South west of Algeria, with its rich history and arid climatic region has a limited studies exploring traditional visions that can be the subject of several of researches, to optimization of modern buildings energy performance and maintain the thermal comfort.

In this field, several studies have been made. Izadpanahi P., studied the sustainable strategies used in the hot and dry climate of Iran indicates that such measures have a significant impact on the microclimate of traditional houses and considerably reduce the need for electricity and mechanical power. This study suggests that designing tall, north-facing walls, large and shallow pools in the courtyards, as well as seasonal relocation across the courtyard are among the most important strategies for mitigating the heat in Iranian houses.[3]

However, one more paper presents a parametric analytical study of roof solar chimney coupled with wind-cooled cavity using spreadsheet computer program. This system may be useful to be incorporated with a stand-alone building or with a cluster of buildings.[4]

The results were discussed in terms of passive cooling by natural ventilation and its impact on human comfort according to the ASHRAE adaptive model. While, as in the longer street canyons demarcated by building blocks on opposite sides, the wind speed has remained stable at low values with limited fluctuation until it rejoins the open water course.[5]

Other studies show that flat roofs can save energy and reduce air pollutants [6]. In arid regions, the use of terrace roofs as night space in summer makes it possible to reduce energy consumption and maintain comfort in summer. In hot, dry climates, it is estimated that nearly half of the urban peak load of energy consumption is used to meet summer cooling demands.

Several research articles have concluded that one way to reduce energy production is to reduce the demand for air conditioning [3-5]. Instead of relying entirely on mechanical means dependent on electricity and generated primarily from fossil fuels, architects should invest time in researching passive strategies to achieve the best possible combination of low natural climate control for their buildings [3]. Mechanical and active systems can then become complementary aids.[7]

1. Overview of Traditional Saharan Houses in arid region

In hot and arid regions of Algeria, traditional builders adopted a series of Passive cooling strategies, can be adapted to actual building, and improve the energy performance in arid zone. We will present on some examples of using passive cooling strategies in traditional construction.

2.1. Vernacular Passive cooling strategy of design and construction

2.1.1. Courtyard

Courtyard is one of the most significant feature of houses in middle east and Kurdistan plain regions vernacular architecture, it is surrounding by continues or semi continues walls for other living spaces, which mediates the house, and the area is open to all the rooms surrounding it since it is the source of lighting and air as well (Fig. 1).

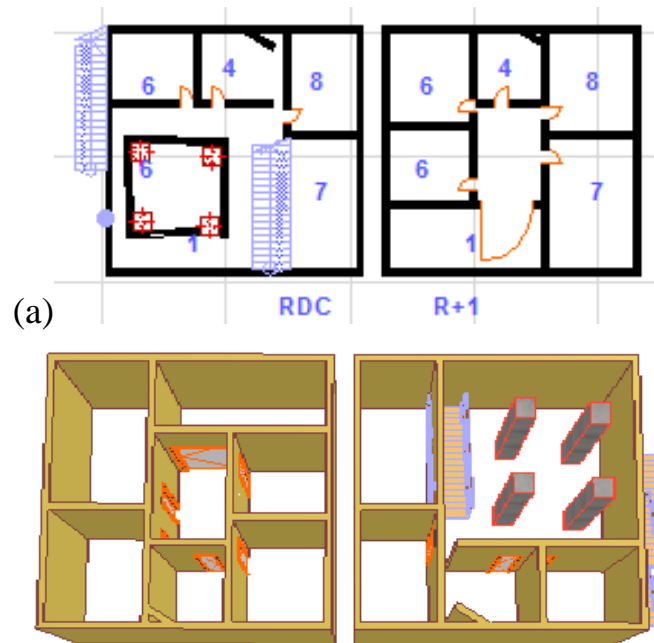


Fig. 1. traditional house with Courtyard type (a) plan and 3D Of Ksar Bousemghoun (Author, 2021)

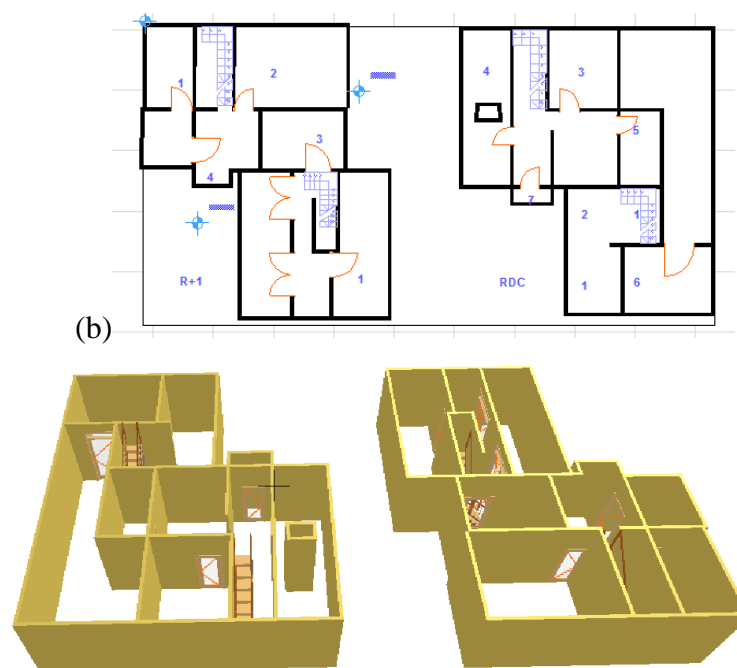


Fig. 2. Courtyard in traditional house type (b) plan and 3D of Ksar Bousemghoun (Author, 2021)

2.1.2. Compactness

The shape of a building is one of the keys to achieving the relationship between cost and performance. A building is an inhabitable volume delineated by an enveloping surface that

separates it from the exterior. The relationship between this surface and the volume contained is usually called the shape factor or the compactness index of a building. This coefficient is responsible for the characterization of the contact mode of the building with the exterior [1], [2], and it is considered only from the point of view of compactness.

Compactness is one of the most important factors, which reduces heating and cooling requirements. These parameters result from geometrical concepts, used to maximize the internal volume of the structure according to its shape.[9]



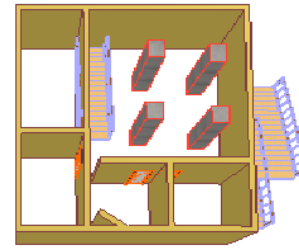
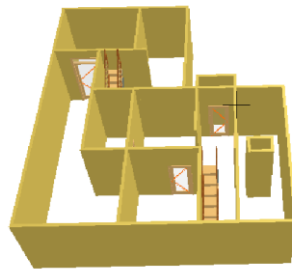
Fig. 3. Compactness of traditional builders (Google Earth)

Figures 3 proves that the compactness is better when the compactness index is lower. For this reason, we must privilege some urban typologies such as the rows of terraced houses, collective buildings and high-dimensional buildings.

Table 1. Examples of traditional houses and factor of compactness

Sample (city)	Plan	House b
House a		

3D of houses



Courtyard dimensions	2.5mx5mx2.8	7.5m, 7.5m,2.8m
Area m2	12.5	56.25
Factor of compactness M²/M³	0.54	0.35

The analysis of table 1 shown that the three houses indicates a factor of compactness, between 0.20 and 0.54 and the area of the courtyards of all the houses were covered 50 % of area of house. The proportion of the courtyard area decreased to between 10% and 15% of all the houses.

Table 2. The spaces and practices of housing

	Space		Practices
private	Living room <i>Massria</i>	For the guests	welcome guests and foreigners
	Entrée <i>Skifa</i>		Enter
Private spaces			
Familial	Courtyard <i>wast edar</i>	For the family	Divers
	Kitchen	For women	Cooking
Individual Spaces	Room <i>bit</i>	For women and men	Sleep
Private	Bathroom +toilet	-	For family

The house is organised with hierarchical space (going from the public to the private) and introverted, versatile, designed around the *wast eddar* (courtyard) which opens onto the kitchen (space reserved for wife). She obeys rules and social standards: discretion, reception, housework.

In addition, it is articulated in the semi-public space (the alley) by a chicane entrance (*skifa*), the role of which is to preserve the privacy of the central patio from strangers. This is the place for family reunions.

2.1.3. Accessible terrasse and roof using

The use of the roof and accessibility of terrasse of houses was always feasible for natural cross ventilation in the summer. This strategy is to answer the problem heat temperature at night. The courtyard helps the air to circulate through the house, which was seen in all the

buildings in this study. The use multiple wide windows on the same wall instead of providing a single opening on the wall.

2.1.4. Night ventilation

Night nocturne ventilation is a passive cooling technique that uses the air movement to cool the building fabric at nighttime [10]. The building openings remain closed during the daytime so that the cool air from the night flushing can keep the building fabric cool during the day. Climate conditions have been shown to affect night purge ventilation. Higher differences between the outside temperature and the building fabric during the night can cause the mass cooling of the building [10].

This strategy was seen in courtyard witch usually surrounded by two stories at a height that allows sunlight to reach parts of the courtyard floor for a period of time, determined by the shape of the courtyard and the proportion of the wall height to the width of the courtyard [4].

2.1.5. High thermal mass with night ventilation

Night ventilation is passive ventilation using cold night air to cool the structure so that it can absorb heat gains during the day, reducing daytime temperature rise.

To optimize the daytime cooling capacity of the thermal mass, the mass should be ventilated at night to allow the relatively cool night air to carry away the heat absorbed into the mass during the day, as shown in Figure 4.

The thermal properties of pavement materials play an important role in passive cooling. The air trapped inside internal courtyards has a low thermal capacity, following the temperatures of the surrounding surfaces during the night and cooling the courtyard walls and floor mass via outgoing longwave radiation [6]. The specific properties for the adobe bricks mentioned above make them a good choice for the courtyard pavements as well.

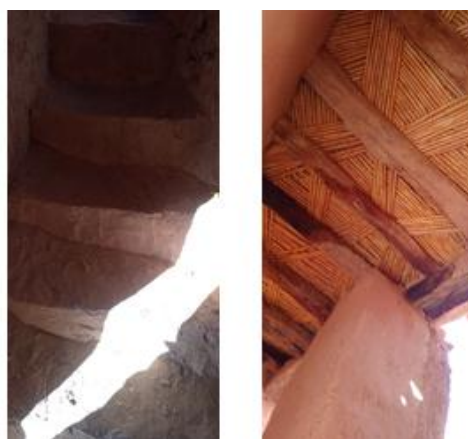


Fig.4 The thermal properties of materials wall of Ksar Moughel (Author, 2021)

- The figure 5 shows the use of **Adobe bricks**, which have a high **thermal mass performance**, with a high heat **capacity** can help to reduce the speed of heat transfer from outside to inside the building through absorbing and retaining sun's radiation throughout the day, and preventing the heat from reaching interior spaces. (figure5)

- In addition, the use of natural material can offer steadier thermal conditions for indoor areas. At night, with the high capacity of walls can gradually warm up the interior spaces, making them cooler and ready for the next day. [11,12]



Fig.5 composition of exterior wall and natural material of Ksar Moughel (Autheur, 2021)

- From this study, the choice of natural materials creates a “*Flywheel effect*” that mitigates the outside warmth and moderates the temperature within adobe buildings as a result of its high heat capacity [13].

2.1.5. *Skifa*

It is a small hall in direct contact with the entrance to the house covered with three walls (between the entrance and the rooms) and the fourth side is completely open to the fresh air and overlooking the interior courtyard. . It has a higher roof than the other rooms. Sometimes the level of it is the ground and the other adjoining rooms are higher than the courtyard floor.

2.2. *Passive cooling strategy in urban environment*

2.2.1. *Morphology of the ksar*

The morphology of the ksar is composed of an inhabited space (dwelling).

The constructions were a compact architecture, with houses distributed with a ground floor and rarely a floor around an interior courtyard. [14]

For an urban scale: earth-colored dwellings surrounded by a public square called **rahba** and main and secondary streets called **Zgag**. This structure is hierarchical

Traditional cities are often cited as a model of climate adaptation, particularly in hot and dry climates. Recently, scientific studies have been undertaken to establish the veracity of this belief. Most authors have emphasized the importance of the compactness of development, often expressed in terms of the aspect ratio of streets, as a key factor in the protective effect of the urban fabric. [15]

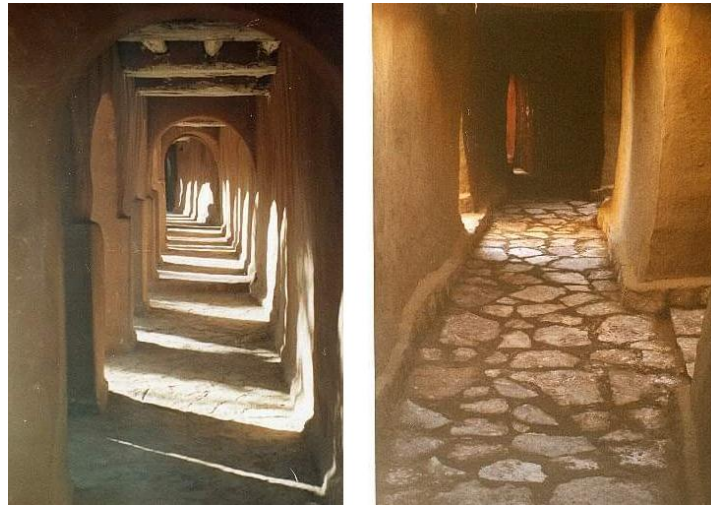


Fig. 6. The urban passage of ksar of Moughel(Autheur, 2021)

The relation between a compactness of buildings and urban approach, improve the thermal comfort and reduce the energy consumption of heating and cooling of buildings in these areas. It is improve the quality of the built environment by developing a new or updated conceptual model, firstly by enhancing local natural resources, and secondly by processing information through scientific tools [16].

2.2.4. Micro climate of vegetation

Microclimates of the ksar Moughel (average air temperature). In winter, the mean air temperatures measured in the traditional ksar Moughel were significantly higher during the night (12.5°C to 13°C) when compared to the exposed site of the airport on the plateau (10°C).



Fig. 6: Es-sûr (remparts) of ksar Moughel (Author, 2021)

The most prominent factor in hot climate is the temperature, especially during the hot summer. Therefore, using the system of vegetation on company of water were used since

ancient times tried to address climatic conditions of surroundings, as well as the blazing sun so the treatment came via isolating within the home on the outer perimeter.

Creating an open environment inside the building allow the free movement of airways and the continuation of the air even in case of in poor air movement in the outer space of house. By common method upward movement of hot air that the creation of a difference between the temperatures of the airways layers, [14]

Moreover, it should be implanted to react favourably with wind orientation at different seasons of the year. In the summer, the position of the courtyard should receive enough light, but also have enough shade to keep a cooler temperature. [8]

3. Results and discussion

This article studies the sustainable passive cooling techniques employed by traditional houses in Algeria, presented by Ksar Bousemghoun and Ksar Moughel- in hot and dry climates. The results suggest several techniques for cooling buildings in summer, including shading outdoor spaces, coupling with the earth, natural ventilation, and night ventilation at night, materials with high heat capacity as well as the usefulness of terraces in summer.

- The courtyard is a passive cooling strategy that contributes to the thermal comfort of residents. This strategy is one of the most practical passive solutions that can be using into contemporary housing design. It is should be taken into account in building codes and regulations given the geography and context of the site.
- The use of hight compacity of material has been identified as another sustainable solution to create thermally comfortable underground spaces.
- Another strategy is compactness, which is a very effective passive cooling strategy, it is not applicable in all settings in hot and dry climates, such as desert regions.
- Additionally, natural ventilation has been used as a passive method of circulating air around the house to reduce energy consumption for cooling.
- on an urban scale, the compact urban morphology of the buildings facilitates the convection of heat in the space and encourages fresh air to enter by minimizing the openings on the exterior walls.
- The vegetative strategy used in Ksourien homes can create a sustainable microclimate in residential environments. The fundamental principles uncovered by this research can be adopted in many modern and contemporary homes with similar climatic conditions to reduce energy consumption and create a thermally more comfortable environment without the use of expensive mechanical services for both. However, it is important to note that not all the strategies discussed are applicable in arid regions, because of the scarcity of water sources

4. Conclusion

This paper presents the vernacular passive cooling strategies in Saharan of Algeria. These strategies are very important for the architectural design of contemporary sustainable urban. The main objective is to promote thermal comfort and reduce energy consumption. The building envelope plays a role of blocking or rejecting solar heat gain and tries to keep the building cool from the summer heat. The passive design depends on the climatic conditions of the area and should be designed accordingly. Passive construction is often the fundamental element of a thrifty and profitable building. In a hot and arid climate, most of the energy load

comes from mechanical systems, so this load could be reduced by applying passive cooling techniques to the building, such as compactness, which can significantly reduce energy consumption. This article shows that passive cooling strategies applied in vernacular houses can block solar heat and could provide adequate comfort. Compactness is a suitable technique in the building means few openings, can be fresh air and distributed throughout by the central courtyard.

The recommendations selected of some technical of vernacular passive cooling can be applied for the actual building in desert region of Algeria:

- The courtyard in traditional houses, which facilitates evaporative cooling, plays a role of thermal regulator in summer and winter. Regardless of whether contemporary dwellings have a courtyard or not, the natural ventilation strategy is still applicable.
- The correct positioning of openings in the walls mainly drives natural ventilation, which is easily tackled from the design phase of buildings.
- This study also examined adobe brick as a local and dominant material used in Ksourian houses. Previous studies have shown that the use of hollow stone or brick are more durable and thermally massive materials with the lowest amount of grey energy.
- Nocturne Ventilation, its effectiveness increases and considered to be the best reliable mean to overcome the inadequacy of natural ventilation alone to successfully ventilate the building.

The analysis of passive vernacular cooling of buildings can be sustainable systems, inspired by vernacular architecture can be adapted to contemporary architecture in Algeria and the redesign of these systems with sustainable principles and the use of new technologies are effective solutions for strategies that can fight against the harsh climate of hot and arid regions

Acknowledgments

The authors would like to express their gratitude to the TAHRI Mohamde Bechar University, as well as to the ENERGARID and LMS laboratory, Ministry of Science and Research Algeria, for their support.

References

- [1] S.M.A. Bekkouche et al. Introduction to control of solar gain and internal temperatures by thermal insulation, proper orientation and eaves Energy Build (2011)
- [2] M.R. Yaiche et al., Revised solar maps of Algeria based on sunshine duration Energy Convers. Manag, (2014)
- [3] P. Izadpanahi, L. Mahmoudi Farahani, R. Nikpey Lessons from Sustainable and Vernacular Passive Cooling Strategies Used in Traditional Iranian Houses. J Sustain Res. 2021;. <https://doi.org/10.20900/jsr20210014>
- [4] M. Aboulnaga, For natural ventilation in buildings in hot arid climates: An energy conservation approach in Al-Ain city, Renewable Energy, 14, 1– 4, 1998, pp 357-363 [https://doi.org/10.1016/S0960-1481\(98\)00090-1](https://doi.org/10.1016/S0960-1481(98)00090-1)
- [5] A. Khaled, L. Al-Sallal, Analyse du flux d'air extérieur et potentiel de refroidissement passif dans le contexte urbain moderne de Dubaï, Énergie renouvelable 38, 1 , 2012 , pp 40-49, <https://doi.org/10.1016/j.rerene.2011.06.046>

- [6] C.E. Rogge, B.A. Eppley, Behind the Bocour label: Identification of pigments and binders in historic Bocour oil and acrylic paints, *Journal of the American Institute of Conservation*, 56, 2017, pp. 15-42.
- [7] M. Dabaieha, O. Wanas, Mohamed Amer Hegazyc, E. Johanssona, Reducing cooling demands in a hot dry climate: A simulation study for non-insulated passive cool roof thermal performance in residential buildings *Energy and Buildings* Volume 89, 15 2015, pp 142-152, <https://doi.org/10.1016/j.enbuild.2014.12.034A>.
- [8] B. Yaseen Raof, Developing Vernacular Passive Cooling Strategies In (Kurdistan-Iraq) *International Journal of Scientific & Technology Research* 2018 ,7, ISSUE 3 , 2018,
- [9] panel S.M.A. Bekkouchea T. Benouazb M. Hamdania M.K. Cheriera M.R. Yaichec N. Benamrane a N Judicious choice of the building compactness to improve thermo-aeraulic comfort in hot climate. *Journal of Building Engineering* Volume 1, March 2015, pp 42-52 Khandekar,
- [10] Artmann N, Manz H, Heiselberg P. Climatic potential for passive cooling of buildings by night-time ventilation in Europe. *Appl Energy*, 2007;84(2): pp187-201. <https://doi.org/10.1016/j.apenergy.2006.05.004>
- [11] Behbood KT, Taleghani M, Heidari S. Energy Efficient Architectural Design Strategies in Hot-Dry Area of Iran: Kashan. *Emirates J Eng Res.* 2010; 15(2) pp85-91.
- [12] Benghida D. Adobe Bricks: The Best Eco-Friendly Building Material. *Adv Mat Res.* 2015;1105: pp386-90. <https://doi:10.4028/www.scientific.net/AMR.1105.386>
- [13] Yilmaz Z. The effect of thermal mass on energy efficient design. In: VI. International HVAC+ R technology symposium; 2004 May 3-5; Istanbul, Turkey.
- [14] I. Benoudjafer, Amélioration de la performance énergétique d'un bâtiment résidentiel (cas de la ville de Bechar), *International Journal of Scientific Research & Engineering Technology (IJSET)* Vol.11, 2019, pp.25-31
- [15] S. Kitous; M. Djenane, N. Daoudi, A. Boussoualim, R. Bensalem(1), L. Adolphe(2) Thermal behaviour of compact urban fabric in hot and dry climate: case study of M'zab Valley. *Experimental results. Plea2004 - The 21th Conference on Passive and Low Energy Architecture.* Eindhoven, The Netherlands, 2004, pp 1 of 6
- [16] N. Fezzioui, M. Benyamine, ; B. Draoui, . ; C.A. Roulet, The traditional house with horizontal opening: a trend towards zeroenergy house in the hot, dry climates, *Energy Procedia*, Volume96, pp 934-944
- [17] S. Semahia, N. Zemmouri , M. K. Singhc , S. Attia, Comparative bioclimatic approach for comfort and passive heating and cooling strategies in Algeria, *Building and Environment*, 2019