Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 8, S. 142-150, 11, 2024

Araştırma Makalesi

IJANSER

https://as-proceeding.com/index.php/ijanser
ISSN:2980-0811

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 8, pp. 142-150, 11, 2024

Research Article

Climate Adaptation in Traditional Housing in the Algerian Sahara: A Manifestation of Ingenuity in Ksour and a Climate Challenge

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(Received: 02 December 2024, Accepted: 06 December 2024)

(3rd International Conference on Recent Academic Studies ICRAS 2024, December 03-04, 2024)

ATIF/REFERENCE: Sebti, M., Ghanemi, F. & Alkama, D. (2024). Climate Adaptation in Traditional Housing in the Algerian Sahara: A Manifestation of Ingenuity in Ksour and a Climate Challenge. *International Journal of Advanced Natural Sciences and Engineering Researches,* 8(11), 142-150.

Abstract – It is widely acknowledged that architecture and urban spaces can be designed in harmony with the climate. Traditional housings were the precursors of bioclimatic architecture, displaying human adaptation to the environment across the globe: troglodyte housings in China, Spain, and Egypt; bamboo huts in Southeast Asia; igloos in the Arctic; tipis among Native Americans; and Russian izbas. Primitive humans sought to adapt to the climate using very limited materials and techniques, facing the challenge of designing climate-responsive architecture. Traditional Housing in the Algerian Sahara, demonstrate this adaptation to the physical environment and protection against undesirable climatic factors. This study examines the climate adaptation strategies employed in traditional housing within the Algerian Sahara, particularly focusing on the ksour (fortified villages). These settlements exemplify ingenuity in responding to the region's harsh climatic conditions through various levels of adaptation have enabled these Saharan settlements to create spaces suited to harsh climatic conditions, including the compact urban forms, the street system, the parceling system, façades, efficient shading, natural ventilation, and locally sourced materials. These adaptations reflect an optimal expression of habitat, leveraging the climate through bioclimatic principles. By analyzing design principles and architectural practices, the research highlights how ksour architecture balances thermal comfort and energy efficiency while addressing environmental challenges. The findings underscore the relevance of these traditional solutions in guiding sustainable urban design in hot and arid regions today.

Keywords – Climate Adaptation, Traditional Housing, The Ksour, Algerian Sahara, Ingenuity.

I. INTRODUCTION

Climate concerns have occupied the thoughts of primitive humans, who for centuries tried to adapt to the climate with very limited materials and techniques. Empirical adaptation in Algerian Saharan housing reflected in the ksour (fortified villages). Saharan ksour respond to difficult climatic conditions by adapting to the physical environment and protecting against undesirable climatic factors. The term "Ksar" originates from the Arabic word "Qasr," which translates to castle or fortified village. The designs of these ksour demonstrated remarkable ingenuity [1]. Ksourian designs represent ingenious bioclimatic solutions, highlighting traditionnal expertise to the challenging climate of these regions, demonstrating their remarkable effectiveness [2].

Traditional housing reflects an environmental adaptation based on identifying challenges posed by the arid environment, such as temperature regulation, light management, solar protection, natural ventilation, and the choice of building materials. Within the scope of their knowledge, the Ksourians implemented solutions to achieve environmental balance in their dwellings [3].

II. MATERIALS AND METHOD

This study seeks to deepen the understanding of design principles and climate adaptation strategies in traditional Algerian housing, with a particular focus on Saharan ksour. These settlements demonstrate resilience to harsh climatic conditions by adapting to the physical environment and mitigating undesirable climatic factors. To achieve this, an analytical approach will be adopted, emphasizing the strategies employed by past communities to address the challenges of this unforgiving environment. Data collection involves reviewing literature on vernacular architecture and settlements, followed by selecting case studies for field surveys.

III. CLIMATE ADAPTATION STRATEGIES IN KSOUR

III.1. Compact Urban Form

The Saharan ksour, through their compact urban structures, have managed to protect their buildings from sunlight and cold nocturnal winds. Only the rooftops and a few façades are directly exposed to intense solar radiation [4]. The ksars of Ouargla, Touggourt, and Ghardaïa are examples that have responded to their hostile environment with a tightly packed urban structure (Figure 01).

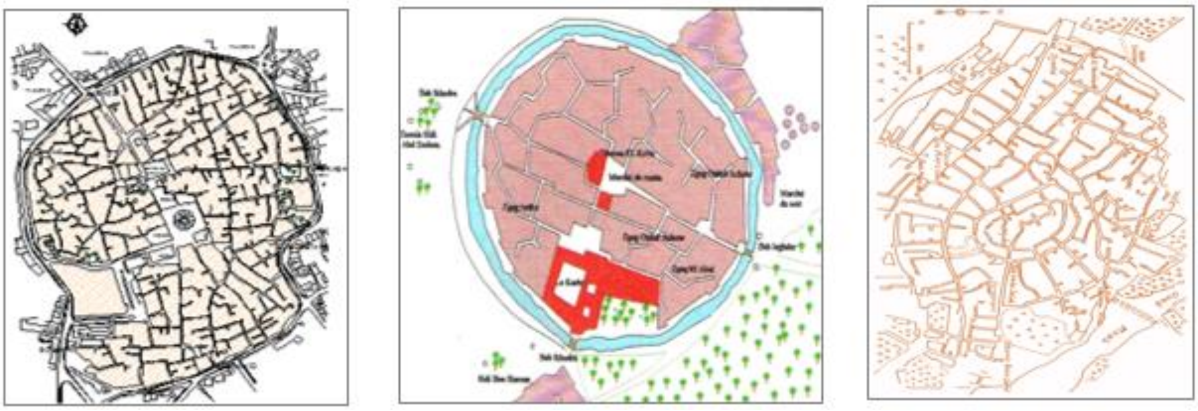

Fig. 01: Compact fabric of various ksour in southern Algeria (from left to right: Ouargla, Touggourt, and Ghardaïa). Source: Author, 2023.

Built on the principle of vertical or horizontal compactness, ksour characterized by urban structures that minimize exposure to summer sunlight and winter winds. Houses grouped together, with adjacent walls delimiting the sunlit areas (Figure 02). High density and shared boundaries enhance wind protection and reduce heat loss [5].

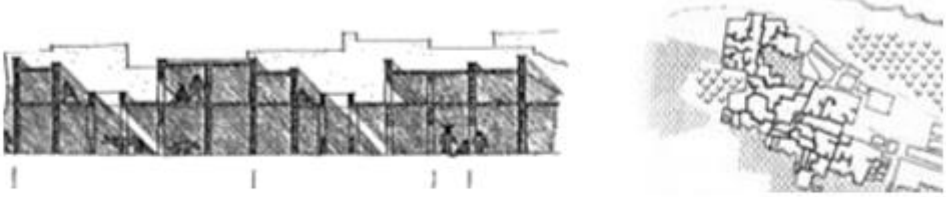

Fig. 02: Horizontal and vertical compact urban textures. Source: Author, 2023.

The dense urban configuration maintains relatively warm conditions throughout the day by offering protection from cold winds and sandstorms as a primary parameter (Figure 03).

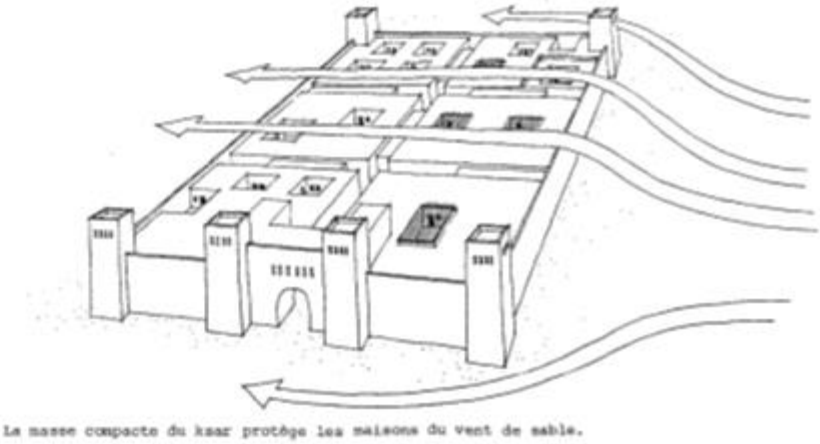

Fig. 03: Protection of homes from sand-laden winds.
Source: Alain M. Viaro and Arlette Ziegler, 1983.

In summer, the overheating effect in urban canyons is mainly felt at night. During daytime thermal stress, compact urban spaces can create a "cooling island" effect, as pedestrians in canyon-like streets absorb less thermal energy than in open environments. This effect depends primarily on the human body's thermal conditions rather than the surrounding air [6]. It is attributed to several factors, such as the shade provided by urban canyons throughout most of the day, reduced pedestrian exposure to high-wavelength radiation, and the high thermal inertia of the streets (Figure 04).

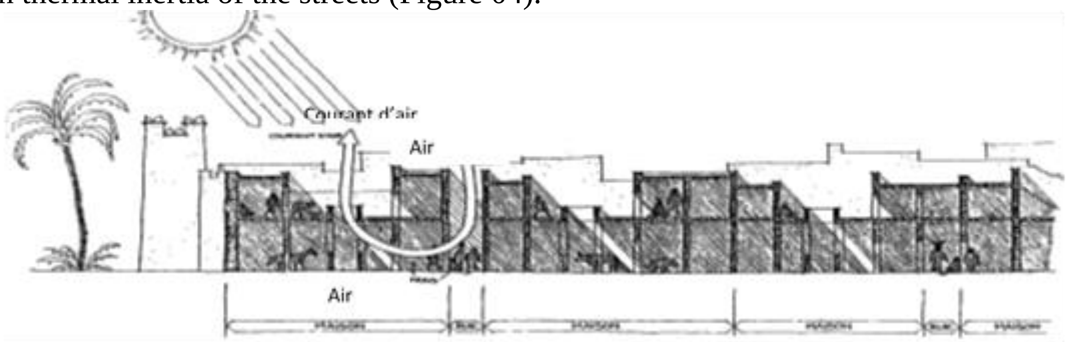

Fig. 04: The shading effect and solar radiation control.
Source: Alain M. Viaro and Arlette Ziegler, 1983.

During the day, the cooling effect of ventilation under outdoor conditions is limited by high air temperatures and low wind speeds. However, ventilation plays a crucial role early in the morning and late in the day when the winds are cooler and stronger. At these times, the orientation of streets becomes important. A combination of shading and ventilation can significantly improve outdoor conditions [7].

III.2. Reduction of Building Envelope Surface

The ksour characterized by their compact morphology, earthy colors, and locations within green spaces. Houses designed to limit wall exposure to sunlight (Figure 05).

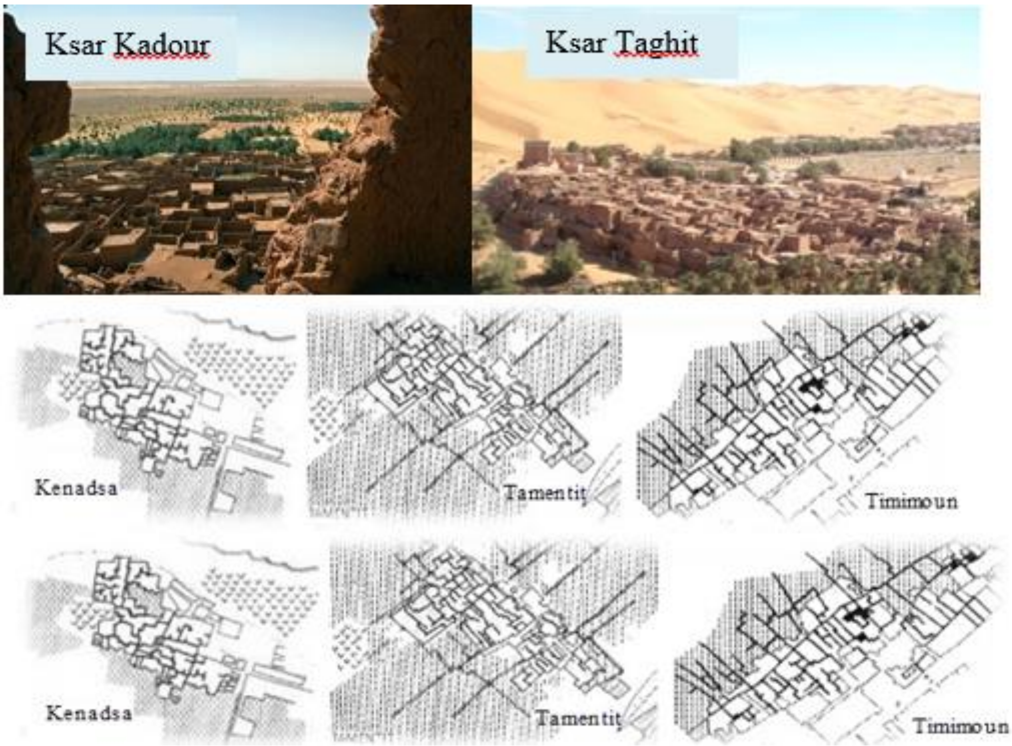

Fig. 05: Ksour in the Western Sahara.
Source: Author, 2023.

III.3. Building Shape and Orientation

The parcel division system in ksour involves a complex arrangement of plots that are highly interconnected. This connectivity is complemented by other concepts such as centrality, linearity, spatial hierarchy, internal distribution, the interiorization of outdoor spaces, and the façade as an urban entity. The optimal orientation for urban blocks, which are the fundamental units of the urban fabric, is 45 degrees relative to the prevailing winds (Figure 06).

Fig. 06: The ksar of Tamacine: Orientation of blocks relative to prevailing winds.
Source: Author, 2023.

The irregular alignment of plots creates continuous windbreaks [8]. The strong adjacency and clustering of plots minimize surfaces exposed to solar radiation, reducing heat storage and lowering radiant temperatures (Figure 07).

Fig. 07: Adjacent and irregularly aligned plots in the ksar of Lichana in Biskra.
Source: Marc Cote, 1988.

III.4. Street Design and Orientation

The street network in ksour is composed of organic, winding, and irregular pathways that are narrow and lack sidewalks. These pathways punctuated by intersections and interrupted by perpendicular streets. The width of streets decreases near house entrances, creating a spatial hierarchy transitioning from public to private spaces (Figure 08).

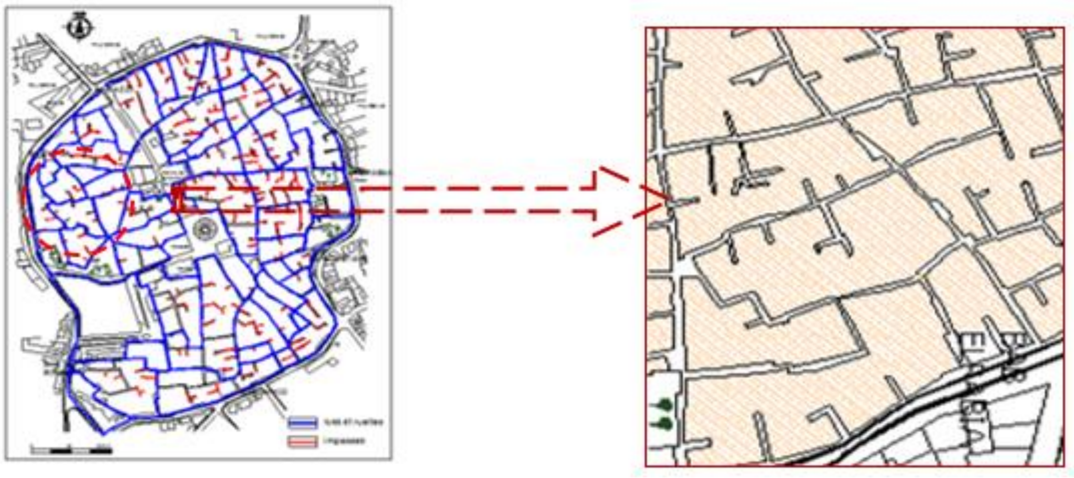

Fig. 08: Hierarchical structure of the street network in the ksar of Ouargla.
Source: Author, 2023.

The main streets of the ksar are oriented from northeast to southwest to benefit from humid winds and to alternate between shade and sunlight within the streets. The façades, generally large, are typically oriented north and south. Northern façades remain shaded, while southern façades can also benefit from shading [9]. This orientation reduces direct solar absorption. In very narrow streets, sunlight may not penetrate, resulting in low heat absorption. The geometry and light color of streets also contribute to reducing solar radiation exposure (Figure 09).

Fig. 09: Effect of street orientation in blocking sunlight penetration.
Source: Author, 2023.

Additionally, the narrowing of streets creates a Venturi effect, where wind pressure decreases and speed increases as it flows deeper into the built environment. This natural ventilation enhances airflow and cooling (Figure 10).

Fig. 10: Street narrowing and the Venturi effect.
Source: Author, 2023.

III.5. SHADING

Narrow and winding streets reduce the duration of sunlight exposure on façades and limit the wind's ability to disperse the cool air accumulated overnight. Depending on their orientation, these streets can provide shade for varying durations throughout the day (Figure 11).

Fig.11: Shading effect created by east-west oriented streets in the village of Melika, Mzab Valley. Source: Bennadji Amar, 1999.

In cases where shade is insufficient, covered passageways serve as resting spots for pedestrians, allowing them to cool off before continuing their journey under the blazing sun [10]. The half-covered street system, formed by upper floors connecting adjacent houses, creates shaded, furnished urban spaces at ground level. This design generates artificial breezes by utilizing air pressure differences between shaded and sunny areas, enhancing ventilation and cooling in urban spaces during summer [11].

Fig. 12: Covered passageways and shaded cul-de-sacs.
Source: Author, 2023.

Upper-floor rooms often extend into the streets, sometimes providing shade (Figure 13). These projections, or overhangs, allow for adjustments in the interior layout or for expanding living spaces, while also contributing to shading the streets below [12].

Fig. 13 Shading effect from overhangs.
Source: Author, 2023.

III.6. Material Selection

Traditional constructions in ksour distinguished by their significant thermal inertia and their ability to regulate radiation. This thermal inertia is achieved using massive construction materials sourced locally. [13]. The materials used vary across regions in the Algerian Sahara and include the following:

A. Earth

Earth is perhaps the oldest construction material known to humanity, with specific techniques developed for its use:

1. **Rammed Earth (Pisé):** Sandy soil with gravel and pebbles, containing 10-20% clay, is aerated after extraction and compacted in its natural moisture content within a mold. This forms a lean concrete that hardens as it dries.
2. **Adobe (Unfired Brick):** Made from a mix of clay soil (up to 30%) and sand, combined with water to achieve a semi-firm consistency (15-30% water). The mixture is molded into blocks similar in size to standard bricks and left to dry under the sun. Clay-rich soils (locally known as "toub") are typically used, where the soil is moistened, kneaded, and allowed to dry in the sun.

B. Stone

Stone is a preferred construction material due to its high compressive strength. However, it is relatively vulnerable to weathering, particularly humidity and frost. Typically, uncut stones of varying sizes leveled and laid on a bed of earthen mortar. The stones, often calcareous or rounded types, sourced from riverbeds (wadis).

Fig. 14 & 15: Traditional use of rammed earth (Pisé) and sun-drying of Adobe bricks.
Source: Dethier J., 1986.

IV. CONCLUSION

The traditional ksour of the Algerian Sahara demonstrate impressive climate adaptation strategies, employing a combination of urban design, material selection, and spatial organization to mitigate the harsh environmental conditions of the region. The integration of compact urban fabrics, effective shading techniques, natural ventilation, and the use of locally sourced materials significantly contributes to thermal comfort and energy efficiency within these communities.

These ancient urban strategies highlight the ingenuity of traditional architectural practices in adapting to extreme climates. The sustainability of ksour as a model for climate resilience is clear, offering valuable lessons for contemporary urban design in hot and arid regions. By integrating modern technologies with these traditional approaches, it is possible to create comfortable, energy-efficient, and climate-resilient environments that reflect the wisdom of past generations while addressing current and future challenges. The use of ancient architecture technology offers real opportunity today to provide thermal comfort and to reduce the energy loads of the summer season [14].

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