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## THE ROLE OF CLIMATE CHANGE IN CHOOSING THE TYPE OF URBAN CONSTRUCT IN THE WESTERN REGION OF LIBYA

**Abstract:** Libya, country with a desert climate and sun protection inside and outside the building is desirable all year round. This called for the attention of architects and construction workers by applying the process of designing buildings in a way consistent with the climate prevailing in the Ghadames region, while minimizing the effects of construction and its use on the environment and maximizing harmony with nature. The phenomenon of climate change is a global phenomenon that does not stop at the borders of a specific region or country. Rather, it is a phenomenon that faces all developed and developing countries of the world alike, even if its effects vary due to the development of technology. The importance of the phenomenon of climate change lies in its various direct and indirect effects on human life. Given the seriousness of its effects on the environment and human health, this phenomenon has received the attention of the international community and the scientific and political circles because it will expose many countries of the world to risks, including severe drought that leads to a decrease in agricultural and livestock production. It has also become a new reason or factor for potential conflicts.

**Keywords:** Libya, climate change, urban construct, Ghadames

### Introduction

Global temperature change is one of the most significant types of climate change of concern to the World Meteorological Organization in general, and the Intergovernmental Panel on Climate Change in particular, because any change in temperature will lead to changes in all other climate components. According to the mean global temperature of the world has increased by 0.74 °C in the last 100 years (Solomon et al., 2007). This increase in the global

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temperature is not homogeneously distributed over the Earth's surface, varying among regions and locations (Gavrilov et al., 2015).

Libya is particularly vulnerable to the effects of climate change due to its geographical location, the less diversified nature of its economy, which relies primarily on oil, limited freshwater resources and arable land, and its political situation resulting from conflicts and migration challenges. The materials used in construction have a direct relationship with the impact of climatic changes on the external environment of the building (Elaswed, 2023).

The effects of the phenomenon of climate change have become clear and in dangerous forms, which have become embodying a grave threat to the manifestations of sustainability in the environmental, economic and social fields in the entire world (UN report 2011).

Therefore, given the cyclical climate change throughout the year, it was essential for planners to select and adopt methods to protect against external climate fluctuations in building design, especially in areas with hot and dry climates.

This necessitated the adoption of environmental thermal design treatments used during the building design process to improve the level of thermal design performance and enhance the building's future thermal performance and thermal comfort for its occupants. The research problem emerged from the lack of knowledge of the planning standards necessary for selecting building types and the impact of climatic factors on the architectural design of buildings, as well as the failure of most designers to resort to this type of building.

Traditional architecture in hot, dry regions has a distinctive character, differing from one region to another within a single country, and from one country to another according to building materials, customs, and traditions (Al-Saqqaf, 2009).

The design of the building and the building materials used play an important role in determining the thermal performance so that the building is affected by the heat loads resulting from the sun's rays that are transmitted through building elements such as walls and ceilings, in addition to doors and windows. In contrast, this thermal response determines the amount of energy required for heating and cooling to maintain optimal thermal comfort conditions for the occupants (Al-Rabaie et al., 2018).

The method of applying thermal control to buildings varies according to regions and climatic environments. Hot, dry environments stand out as areas with special thermal control strategies that require specific environmental design treatments to achieve them. These treatments are implicitly integrated into the overall building design, taking on a formal or detailed dimension. These treatments often vary depending on the building's function and the surrounding regions and environment. This has generated a large number of environmental treatments that can be employed during the various design stages (Younis Mahmoud, 2016). It has become a given that architecture is the product of the interaction between environmental variables and humans. Architecture is an entity that represents the translation of the interrelationships between these two aspects. Therefore, we find that buildings acquire their different characteristics depending on the region and climate to which they belong, making them environmentally responsive buildings. It has been concluded that environmental treatments in traditional architecture can be successfully used in high-rise buildings to achieve thermal comfort for users. The weather in this region tended to be very cold in the winter, while the summer was very hot. As a guide, these

houses were designed to provide protection and thermal insulation throughout the year. (Abdulkarem, 2021).

## **Materials and Methods**

The main objective of the research is to identify the traditional architecture and determine the environmental design treatments in it, in one of the desert cities in Libya (Ghadames Oasis). These treatments achieved the required thermal comfort for its users without resorting to the use of mechanical means:

1. Knowing and studying the characteristics of local desert buildings (Ghadames as an example) and the extent of their benefit in designing modern residential buildings in the future in hot and dry climate areas.
2. Identify the types of thermal insulation materials used in old buildings in the southwestern region of Libya.
3. Identify the most important types and materials of thermal insulation used locally in the region.
4. Benefit from thermal insulation materials to face different climatic conditions.
5. Identifying the appropriate block shape and the best distribution of spaces in modern residential buildings in the city, in addition to knowing the best orientation of buildings in the southern region to reduce heat gain.

The importance of the research lies in its addressing the issue of how to achieve thermal comfort in buildings, given the numerous challenges they face. Thermal comfort is a necessary requirement for building users, given its impact on health, psychological well-being, productivity, and economics, as an environmentally friendly solution for self-adaptation to the environment.

The desert areas with extreme climates are among the most difficult climatic environments that reflect negatively on humans and affect their daily activities, which negatively affects their performance and production. To make these environments more suitable for living, it was necessary to resort to innovating and developing architectural solutions that replace the use of electrical or mechanical means to provide thermal comfort inside buildings. The idea of shelter was based in ancient times on the basis of protection from natural and human influences such as animals, in addition to harsh climatic factors that humans cannot coexist with. After shelter in ancient times was a cave in a mountain, today it has become buildings made of modern construction materials and finishes that were discovered and developed over time.

This development went through many stages and many eras, in which many designers and architects participated, some of whom added development to architecture with the emergence of new styles, and some of whom contributed to the discovery and development of modern materials, whether construction or architectural materials. Some of them also participated in their architectural works until they became part of the heritage and civilizations of nations, like many buildings that became a cultural symbol for nations to be proud of and their civilization.

The possibility of controlling external environmental influences in desert cities in general is broad. Methods for avoiding the harsh conditions of the external environment have varied and take many forms, such as determining the seasonal winds, choosing the most

appropriate orientation for the building mass, and employing adjacent areas and planted trees for shading, as is evident in the city of Ghadames. It is also possible to benefit from any water source on the site to improve the microclimate area surrounding the building, as the city contained an amazing water drainage system by exploiting the water of Ain al-Faras and distributing it to the orchards surrounding the city through waterways all located under the city, in addition to controlling the external building materials of the site that affect in one way or another, it affects the thermal performance of the building.

In the recent past, architecture was characterized by the use of local building materials, which used simple techniques that were compatible with the surrounding nature. It was called popular or rural architecture, as it relied on historical patterns and shapes as a basis for design. The people has dealt with natural materials since ancient times, and the beginning was by using clay, as it was one of the materials available locally. The construction method was mixing clay with hay and the remains of tree branches and building walls exceeding 45 cm in thickness.

As agreed, that the quality of the materials used in the construction of the walls, their shape, composition and their color, have an effect on producing a comfortable environment inside the building. The light color and rough texture of the materials used in the exterior construction (external finishing) are preferred in order to reduce the effect of the sun's rays falling on the building during the period of maximum brightness (Huda 2012)

The ceilings were made of wooden beams next to each other, separated by distances not exceeding 30 cm. Clay not mixed with hay and tree waste is used in mortar, plaster and roof covering.



*Fig. 1. Stone masonry model (Jarad, 2024)*

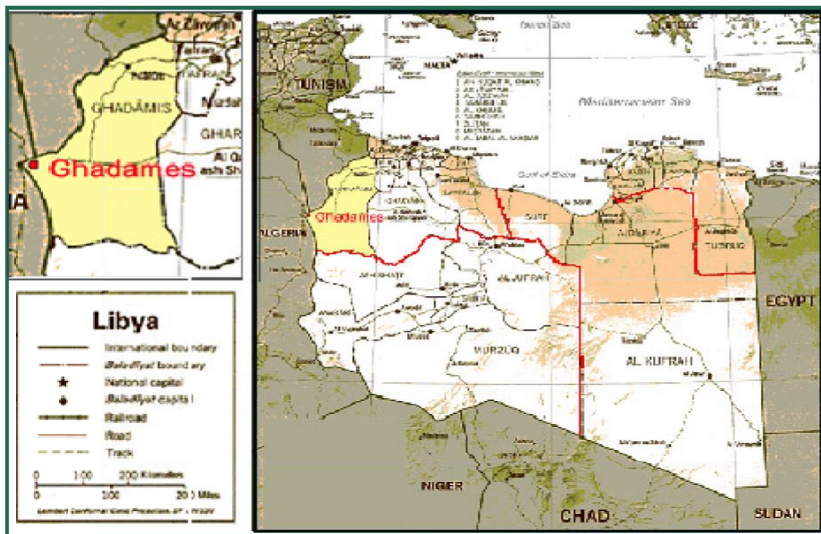
The stones were collected room by room and transported to the construction site, then placed on top of each other to build the foundations and walls as figure 2. This type of construction is characterized by maintaining the temperature inside the building, as it absorbs heat during the day and retains it inside the building. It limits the cold at night from entering the building as a result of it retaining heat during the day, and so on.

### ***Ghadames city as a case study***

The phenomenon of urbanization in Libya is very old since Phoenician and Roman times, but the contemporary urbanization due to the late sixties of the twentieth century (Jarad, 2017).

Ghadames is a Libyan city located near the border intersection of Libya, Tunisia and Algeria in the western part of the country at a latitude of 08.30 north and a longitude of 03.9 east, and rises above sea level 357 m and is about 543 km southwest of the capital Tripoli. (El-Agouri, 2004). It is notable that the southern Libyan cities have gained importance through the rise of different kingdoms and empires through their history, which continued to be centres of political dominance over surrounding counties. (Jarad, et al. 2022).

Ghadames is a palm oasis, with a population of 52,000 people, the main reason for its origin and development is that it was a station where commercial caravans coming from south to north and vice versa rest, and it is one of the most famous cities on the trade line between North and South Sahara and has a prosperous historical relationship in trade with several other commercial centers in Central and West Africa, such as the city of Timbuktu in Mali.



*Fig. 2. Geographical location of Ghadames city (Libyan Atlas, 1970)*

The city of Ghadames is 600 km from the capital Tripoli. The United Nations Educational, Scientific and Cultural Organization (UNESCO) classified ancient Ghadames as a historical city and protected by the organization, Islam entered Ghadames in the year 44 AH by the companion conqueror Uqba bin Nafi Al-Fihri. The Christian and Jewish religions were predominant before Islam and there are many indications for the existence of these Abrahamic religions, including the existence of an ancient tribe descended from Bani Walid bearing the name Joshua, a sacred name mentioned in the book of Joshua in the Old Testament, says Procopius Caesarea: "There is also here a city called Ghadames, where live the Moors who were peaceful with the Romans since ancient times and the emperor Justinian gained all of these and embraced the Christian faith voluntarily and these are called (Pacati)", because between them and the Romans a treaty Moore is one of the names by which he described indigenous Libyans.

The city was subject to the control of the Greeks and then the Romans, until the Muslims entered it, and reached the peak of its glory in the eighteenth century when it was subject to the Ottoman rule at the time in Libya, and it became an important center for caravans and a point for trade between the cities of the African continent, and the Italians occupied it in 1924 AD, and subjected it to their authority until their defeat and the entry of French forces to it in 1940 AD and the French remained in Ghadames until 1955. The city is divided into three sections: the old city with the wall and the mosque, the palm forest, and the modern city with the new buildings. And in the center of the city Ain al-Faras.

The urban fabric of the old city of Ghadames and the factors affecting its formation: Through the analysis of the previous arts and the general plan of the old city in the oasis of Ghadames, it is clear that the city was formed throughout history gradually in the form of a combined fabric and was built on the organic structure that depends on the natural growth of the urban fabric. The design of the city was particularly based on protection from climatic conditions (hot, dry desert climate). The residents of the city of Ghadames benefited from the nature surrounding them, as we find that the Ghadames Oasis is surrounded by palm trees on all sides, which made it surrounded by shadows. It is also irrigated from underground springs and wells, such as (Ain al-Faras), which still has water till this day.

In addition, the winds pass through the shade and water, and these cold air currents enter the city through the ventilation holes in the streets of the city and expel hot air currents through natural convection currents, as we note that the covered corridors to protect from sunlight and the openings in them work to attract cold air from the outside and move it inside these corridors, in addition to the design of the city in a compact manner, and there are windows in some of the roofs of its dwellings, which provide the lower spaces in sufficient quantity of light.

Due to the harsh external atmosphere of the Ghadames area, the design focused mainly on how to reduce the impact of the negatives of these harsh conditions on the building mass, and for that, the area of the external buildings has been reduced using compact shapes that have a small surface area to size ratio, which was often directed towards the interior with the use of the internal courtyard with the possibility of shading the ventilation openings and external spaces from the sun in the summer with some tree trunks. Through the daily variation in day-night temperatures that characterize the region, the walls and ceilings have had great thermal performance. This can be achieved by using materials with certain structural properties such as materials with high heat capacity and materials with low heat conductivity and the use of awaz for, and it is recommended to shade the walls and ceilings from solar radiation to reduce the percentage of rays that you can receive daily.

Previous generations invented methods and treatments in construction and planning to reduce the impact of the extreme desert climate and succeeded to a large extent in adapting to the hot-dry climate, and there are still cities that exist to this day witness to the success of man in resisting the desert climate, and these cities include the city of Ghadames in Libya and Ghardaia in Algeria.

The residents of the old city of Ghadames provided valuable lessons in sustainability in desert areas through the innovation and development of architectural solutions and treatments that helped reduce heat gain, which was reflected in the thermal comfort inside buildings (whether in summer or winter), which made the city an urban center for centuries in a row. This paper sheds light on the depths of the old city of Ghadames and concludes

the most important treatments and architectural solutions used in this city and benefit from them in the development of building engineering based on the principle of sustainability, which has become a major requirement in modern architecture.

## Results and Discussion

The study aims to analyze the methods that have been followed in one of the desert cities in Libya (Ghadames city) to protect against the impact of the desert climate and reduce heat gain and provide thermal comfort in buildings without resorting to the use of electrical and mechanical tools, which consume a large amount of fuel and energy, which helps to increase emissions and raise the level of pollution in the environment, which negatively affects the climate, as what we are witnessing from violent climatic fluctuations and melting of polar ice is a result of Mainly from the increase in pollution rates. Desert cities are located in the most extreme climates in the world, in which humans can only live by innovating solutions and treatments that reduce the impact of climate and make desert areas places to live in. Most of the studies that dealt with the analysis of the urban fabric of the city pointed to the uniqueness of the old city with its architectural style, which arose under the influence of several factors.

### *The geographical factor*

This factor was represented in the presence of the spring of water called (Ain al-Faras) in the middle of the oasis of Ghadames and surrounded by large areas of palm trees made it an ideal place for the establishment and development of the city, as the spring of water was the main source of water and the palm light is one of the sources of lunch, which contributed to the growth of the city within this oasis and its resilience in the face of difficult climatic factors to this day.

The rocks of the Cretaceous period constitute the most important geological formations spread in Ghadames and Hamada red and the geological structure of the study area consists of different stones that include stones (dolomite, clay, black and white stones in addition to limestones that form the horizontal layers, which date back to the upper Cretaceous period and cover these layers with sloping stones or dirt with sand sediments formed by wind and water. These natural geological components constituted the main source of building materials on which most of the buildings of the old city were built, in addition to the presence of palm trees that were used as bridges to load roofs on them.

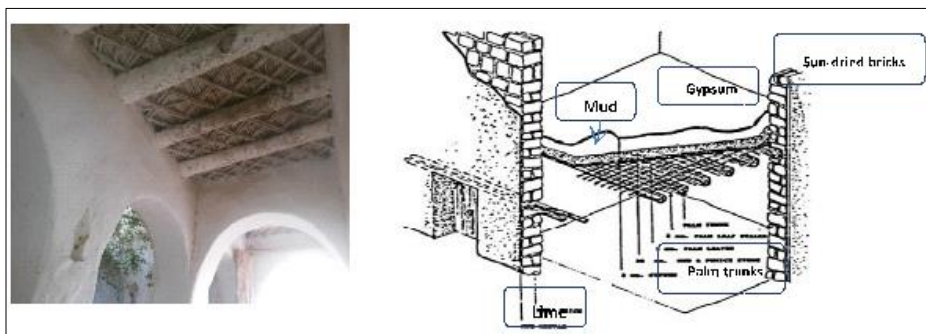


Fig. 3. Basic building materials in old buildings in Ghadames (Shawesh, 1993)

### ***Social factor***

It has a major role in shaping the urban fabric of the city, which consisted of different residential neighbourhoods. Each residential neighbourhood is inhabited by a specific tribe and the residents of the same neighbourhood are not confused except in rare cases, and each neighbourhood has its own entrances, a main mosque and the central market square, and as shown in the following diagram, we find that the city consisted of the following residential neighbourhoods:

#### ***Reducing the wind speed entering the architectural fabric of the city***

The city was built in the form of a compact urban fabric that grows organically and this type is characterized by the compaction and adhesion of its buildings to each other, and this is what helps to reduce the area exposed to external factors (unlike the open system) and thus reduce heat gain and increase the level of thermal comfort inside the building, and the use of a network of streets that are not straight and narrow covered and whose width ranges between 5.1 to 3 meters works to break the wind speed (especially hot winds in summer or cold in winter loaded with dust) and according to what was mentioned above, the lower the speed of air currents, the less heat entering, through field measurements, the speed of air currents in the internal alleys ranges from 3-51 km per hour. Diversifying the sizes of streets and reducing the air speed inside them. By taking into account these elements, it is possible to provide the best designs suitable for practical life with climate changes (Saryh et al., 2014).



*Fig. 4. Reduce heat gain and increase the level of thermal comfort inside the building (Jarad, 2024)*

#### ***The use of the multi-storey vertical system (Multi Floor)***

This system helped to resist and reduce heat gain, because each roof layer and each air layer between the ceilings or floors works as a multi-layer heat insulator as shown in the attached figure, in addition to converting the building block from one floor.

Extending horizontally to a multi-storey block that works to reduce the area exposed to direct solar radiation or wind, whether cold or hot, as the heat area is directly proportional to the amount of heat gained.



*Fig. 5. Multi-storey vertical system (Multi Floor) (Jarad, 2024)*

*The use of building materials with high thermal resistance*

This makes the building envelope act as a protective shield that protects the internal parts of the building and provides good levels of thermal comfort. For example, we find that the components of the outer shell of the building are: Mud or clay in addition to the use of some types of stones in the construction of walls (Limestone) where the small ones are used to make clay concrete that is used in ceilings. Palm tree trunks and leaves are used in roofs (Palm trunks). Lime, which is used to cover the outer walls, is also an auxiliary factor in reducing the impact of solar radiation, as its white color works to reflect between 10-30% depending on the orientation of the building and the angle of incidence of solar radiation. One of the most important factors taken into account when designing a building is the treatments that reduce heat gain in the summer and heat loss in the winter across the mass of the building, and this is done by choosing building materials with high heat capacity and using insulators (Al-Sharif et al., 2021).



*Fig. 6. Building materials with high thermal resistance (Jarad, 2024)*

### *The use of natural ventilation systems*

Spread on the internal courtyards (Courts) between the residential units and the upper ventilation openings (in the ceilings) (Air Shifts), which work to withdraw hot and consumed air from inside the buildings to the outside in the daytime periods, and these openings also work to introduce cold air relatively humid at night, as it depends on the physical principle that the cold air is heavier and therefore descends to the lower layers, while the hot air is the lightest and moves up. Upper roof openings and interior courtyards as key elements to move air naturally (Kamel Saeed, 2023).

### *Reducing the size of external openings*

The term external openings in buildings is called windows and doors, and their classification comes as weaknesses in the thermal performance of buildings, as their composition has a greater thermal conductivity coefficient and therefore the amounts of heat that the window through these elements are considered the largest, especially in the external parts of the building (facades) and the builders of the old Ghadames housing have alerted to that, so they reduced the areas of the windows and kept them away from direct solar radiation so that most of them open in the internal courtyards. Where the areas of these windows range (40 x 40) cm and sometimes up to (80 x 80).

Architecture has been the primary means humans have devised to protect themselves from harsh external environmental conditions by exploiting natural energy sources such as the sun, wind, and the potential of the soil. Through this model, the researcher reached a firm conviction that there is an important architectural heritage that can serve as a launching pad for a better future. This heritage has a clear identity, namely the Libyan identity, and a distinct character, namely the desert identity.

## **Conclusion**

During successive centuries, the inhabitants of the old city of Ghadames built housing to protect them from the conditions of the desert climate in summer and winter and provide them with good levels of thermal comfort without resorting to the use of electrical and mechanical means for that, but on the contrary they used architectural treatments and developed their architectural style in terms of design, building materials, natural ventilation and others to provide thermal comfort. The architecture of the city of Ghadames has provided a great lesson in sustainability that must be used in the future, so in future projects, the governments must make every effort to find design standards that serve and promote the concept of sustainability in our local Libyan architecture and rely on clean alternative energy as a main source of energy. Based on the results drawn, the author recommends the following: Adopting the Compact Texture system when planning modern urban agglomerations in desert areas. The use of the vertical construction system (Multi-Floor) as a structural system for buildings in areas with extreme climates due to the protection and thermal comfort it provides to users; Paying attention to building materials and setting design standards for modern building materials in the climate in hot dry regions.

Conflicts of Interest: The authors declare no conflict of interest.

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