The impact of climate changes on the external environment of buildings and architectural design in Libya

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Abstract

Human understanding of nature and its environmental phenomena and geographical and climatic qualities made it able to evolve according to life needs that are in line with the changes that occur on those phenomena and qualities. From this point of view, people are trying to coexist with the development of the design of buildings so that they keep pace with the climatic changes in the world, as well as the development of materials used in construction such as reinforced concrete, glass spaces and others, as well as ventilation and heating methods, in addition to the insulators used to separate the inside and outside of the building. Due to seasonal changes during the year, the increase in temperatures in summer, the sharp decline in winter and the necessary need to use air conditioning systems in terms of heating and cooling in buildings to get a comfortable atmosphere. Hence the important role played by exterior walls and ceilings in the thermal insulation process, which in turn reduces the process of energy consumption as the development and restorations are made in the design of walls and ceilings that will be of high value for thermal insulation. The study aims to compare the architectural environment and the changes in the materials used in construction, designs and construction methods to the external environment of the building and the developments that took place to suit the climatic changes in the region.

Keywords: Environmental, Climatic, Development, Materials, Energy, Building**.**

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تأثير التغيرات المناخية على البيئة الخارجية للمباني والتصميم المعماري في ليبيا

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الملخص

تفهم الانسان للطبيعة وما فيها من ظواهر بيئية وصفات جغرافية ومناخية جعل منه قادر على التطور حسب الاحتياجات الحياتية والتي تتماشى مع التغيرات التي تحدث على تلك الظواهر والصفات. من هذا المنطلق يحاول الانسان التعايش مع تطوير تصميم المباني بحيث تواكب التغيرات المناخية في العالم كما استحدث المواد المستخدمة في البناء مثل الخرسانات المسلحة والمساحات الزجاجية وغيرها وكذلك طرق التهوية والتدفئة بالإضافة للعوازل المستخدمة للفصل بين داخل وخارج المبنى. نظراً للتغيرات الموسمية خلال السنة والزيادة في درجات الحرارة في الصيف والانخفاض الحاد في فصل الشتاء والحاجة الضرورية في استخدام منظومات تكييف للهواء من حيث التدفئة والتبريد في المباني للحصول على اجواء مريحة. من هنا جاء الدور الهام الذي تلعبه الجدران الخارجية والاسقف في عملية العزل الحراري والذي بدورها تقلل من عملية استهلاك الطاقة حيث يتم تطوير واستحداث في تصميم الحوائط والاسقف من شأنها ان تكون ذات قيمة عالية للعزل الحراري. وتهدف الدراسة إلى مقارنة البيئة المعمارية والتغيير الحاصل في المواد المستخدمة في البناء والتصميمات وطرق البناء للبيئة الخارجية للمبنى والتطورات التي حدثت لملائمة التغيرات المناخية في المنطقة.

الكلمات المفتاحية: البيئة، المناخ، التنمية، المواد، الطاقة، مبنى.

Introduction

Libya is located within the arid and semi-arid regions, where the Mediterranean climate is dominated by the Mediterranean, which tends to be temperate and has finally become inclined to the desert climate in terms of high temperatures and little rainfall in light of climatic changes. 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). In view of the continuous changes in the impact of climatic changes along the year, it has become necessary to expand horizons and know-how in the process of designing buildings and methods of protection from these changes, whether residential, commercial and industrial located in coastal or desert areas in Libya, which are classified as arid and semi-arid areas where the climate is hot and dry, which Affected by climatic changes such as high temperatures over long months of the year (the extension of the summer period), as well as the lack of rain and rainy months of the year, and this requires innovations and development in the general design of the buildings and the shape of the external environment of the building in line with the noticeable climatic changes that occurred to raise the level of performance. The design and future availability of a building prepared in terms of thermal suitability and achieving thermal comfort for its occupants.

Study Problem

Climate change has caused the need to create and develop the external environment and the general design of buildings, whether in the materials used in the construction or the design of walls and roofs, due to the inappropriateness of the old construction methods and their design, which is no longer in line with climate changes. Where it became necessary to use heat-insulating materials to help reduce the leakage and transfer of heat to and from the building, and the construction and design of modern residential buildings in most of them clearly to the positives that were achieved in the local traditional models, including integration and integration with the environment and human comfort inside the building, i.e., insurance Convenience and also affect energy saving.

Objectives of the study

1. Clarify the importance of designing the outer building envelope and its role in reducing the heat gain of the building.
2. Recognize the impact of climatic changes on the pattern of the external environment forms of buildings and their designs in the past and what they are now.
3. Identifying the characteristics and advantages of modern architecture in Libya and the changes occurring to it due to climatic changes.
4. Knowledge of building materials and methods of designing high-efficiency walls and ceilings used after climate changes in the region.

Research Methodology

This study depends on the inductive approach in collecting and analyzing data and information obtained from primary sources represented in the field survey, also based in some of its parts on previous studies and important scientific references such as books, scientific research and reports published on the relationship of climate change and architecture in arid and semi-arid regions. The study uses the descriptive analysis method to explore how climatic changes in the region affected the external environment of the building and the materials used in the construction, as well as the way the building was designed to cope with these changes.

Study area and climate

Libya is located in the northern of Africa (Figure 1). Most of the country is placed in the Sahara Desert, where most of the population is concentrated in the coastal zone commanding the Mediterranean Sea, and the largest part of the country is located in the Great Desert. Libya is bordered on the northern side by the Mediterranean Sea, and Egypt on the east, Sudan to the southeast, Niger and Chad to the south, and Tunisia and Algeria to the west. The country is dominated by a desert climate in the arid and semi-arid region, but along the coastal region dominating the Mediterranean Sea, it is temperate climate. The desert effect is strongest in the summer season, which lasts from October to

March, when the prevailing westerly winds bring cyclonic storms and rains throughout the northern region. The desert climate reaches the coast along the southern extremities of the Gulf of Sidra, where the desert region borders the sea in the Al-Hamraya (Sirte). The warmest months are July and August, when average temperatures in Benghazi and Tripoli, in the Mediterranean region, are in the low 70s and mid 80s F (low to high 20s C) and low 60s and mid 80s F (high 10) and low 30s c), respectively. The coldest months are January and February. Monthly winter temperatures in Benghazi range from the low 50s to the low 60s Fahrenheit (low to mid-10s Celsius), while those in Tripoli range from the upper 40s to the low 60s Fahrenheit (low to mid-10s Celsius). Annual precipitation is very low, with about 93 percent of the Earth's surface receiving less than 100 mm/year. The highest precipitation rates occur in the north of Tripoli (Nafusa Mountain Plain and Jefara) and in the northern Benghazi region (Al Jabal Al Akhdar), these two areas are the only ones where the annual precipitation rate exceeds the minimum (250-300 mm). It is essential for the sustainability of rain-fed agriculture. The average annual rainfall for the country as a whole is 56 mm. Temperatures range from over 40°C in the summer to below zero in the winter (UNDP. 2016).

Figure 1. Location of study area.

Source: https://www.world-grain.com/articles/10295-focus-on-libya

Climatic elements types and their impact on buildings

"We are one of the regions most affected by climate change", said Nasser Kamel, Secretary General of the Union for the Mediterranean. Also said scientists pointed out that the temperature rise in the Mediterranean basin has increased by 1.5 degrees Celsius, compared to the pre-industrial period, while the global average is 1.1 degrees Celsius. The new study predicted that the rise will reach 2.2 degrees Celsius by 2040, and it may reach 3.8 degrees in some regions of the Mediterranean basin, at the end of the current century. Heat waves are expected to become "more frequent and more intense".

Architects evaluate the design and redevelopment of buildings to increase their stability and adaptability to climate change. Modern designs and building materials have been introduced to adapt the external environment of the building to adapt to climate changes. While climate change is exacerbating warm summer temperatures, it may also make them cooler in winter. There are many climatic elements that must be considered and discussed by architects before designing a building, such as location, surroundings, sun path, wind, temperature, and others. 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).

As the temperature is considered one of the most important climatic elements that affect and reflect climate changes directly, and one of the most important factors affecting the external environment of buildings and its relationship to changing the design of modern buildings as well as the types of materials used in construction. Based on what the Secretary-General of the Union for the Mediterranean said, we note the change that occurred in Libya, which amounted to more than one degree Celsius during the last fifty years, and as shown in the climate data for four stations obtained from the National Center of Meteorology Tripoli. As shown in Figure (2), the location of the meteorological stations distributed over Libya, where Zawia station (1) and Shahat station (2) are located in the coastal region, where Hun station (3) and Al kufra station (4) are located in desert area. The analysis of the data of these stations, it became clear that there is an increase in temperatures of up to one degree Celsius, as shown in Figure (3).

This change affected the type of materials used in construction, as well as the change in the exterior designs of modern buildings in Libya.

Figure 2. the location of the meteorological stations distributed over Libya

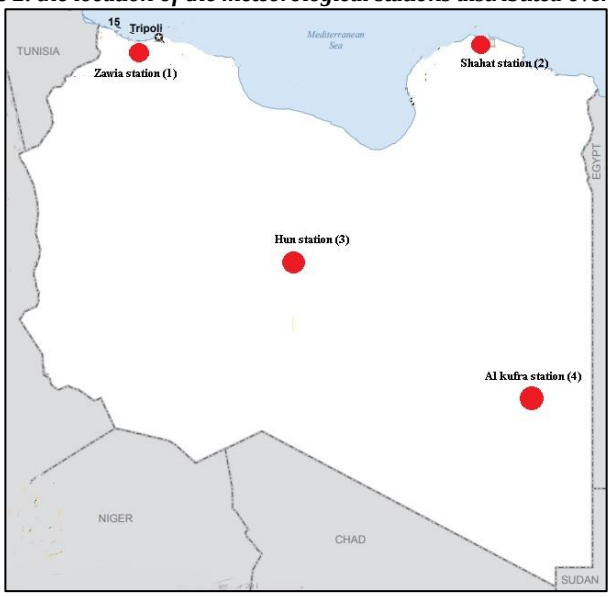
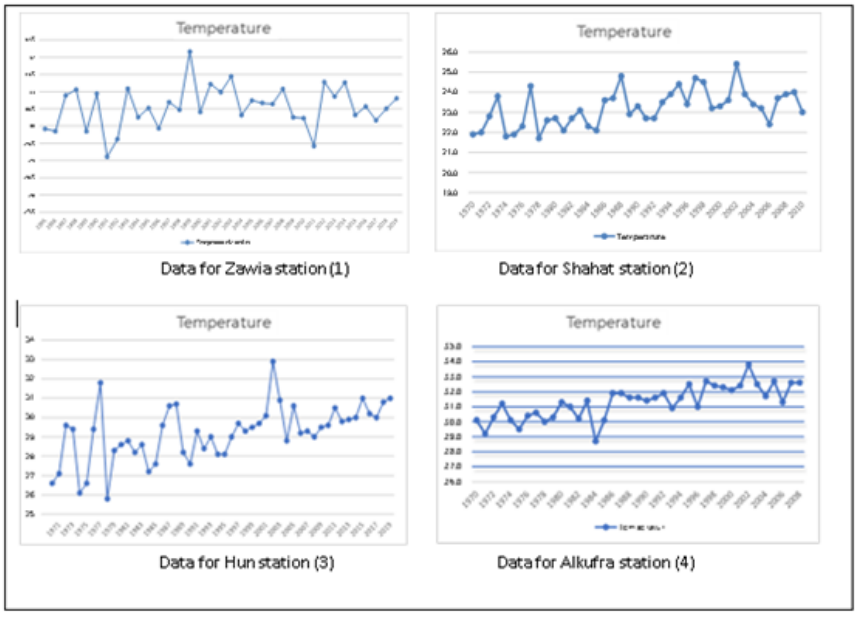


Figure 3. Temperature data for the four stations show the changes during last fifty years.



National Center of Meteorology, Tripoli.

Climate influences on the external environment of buildings

The thermal performance of buildings is one of the most important criteria that must be taken into account in the building, which is the amount of energy that is reduced, gained and lost through its transmission to and from the surrounding environment. There are a number of factors in the building that determine the thermal performance of the amount of heat lost and gained. 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). Since the external facades of the building are the ones that reflect the nature of the building and are known as the architectural elements of the building, through the shape of the facades and the methods of their external packaging, the identity of the building is known, and it is responsible for protecting the building from the surrounding influences such as heat, wind, sunlight, humidity and others to provide an environment inside the building suitable for use (Lina 2016). The external facades of the building consist of:

Walls.

It is the main outer part of the building with the roofs that are exposed to the thermal radiation which come in to the building. Therefore, the material of its construction affects the amount of thermal permeability of the building. However, there is some difference between the side walls and the roofs, as the roofs are exposed to the sun more than the walls, as well as the difference in the angle of inclination of the sun on the roofs than on the side wall (Al-Issawi 2003)

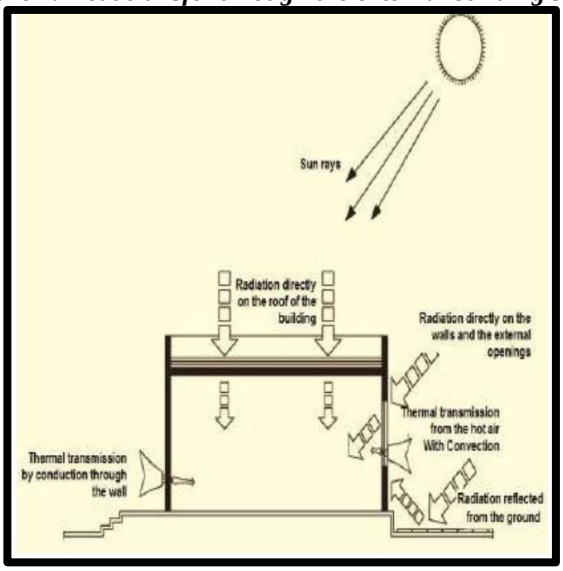
As agreed, that the quality of the materials used in the construction of the walls, their shape, composition and their color, have an effect on producing a comfortable environment inside the building. The light color and rough texture of the materials used in the exterior construction (external finishing) 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).

For the construction of the outer shell of the building, it is preferable to use materials that have the property of slow heat gain and loss, for their ability to retain heat during daylight hours. It is also required that the building be well ventilated to reduce the heat load resulting from the reduced heat during the day in order to be a source of natural cooling at night. Examples of these materials are concrete and brick buildings with large thicknesses (Al-Rubaie *et al.*, 2018).

In many studies, the walls are most affected by external heat due to their exposure to direct sunlight and heat transfer from hot air by convection, in addition to sunlight reflected from the ground and heat transfer by conduction as shown in Figure (4) (Sada 2014).

Figure 4. Heat transfer through the external building shell



Source:(Givoni, Baruch (1998). pp282).

The following table (1) shows the intensity of heat transfer from outside to inside, and we conclude from it that the walls the exterior of the building is the most element through which heat is transferred to the interior, as shown by the value of the interior through doors, windows, exposed external openings, as well as the ceilings (Sada 2014).

Table 1. Maximum heat transfer value U for the exposed element

ON	Construction elements of the external shell of the building	maximum heat transfer value U (W/m2.°K)
1	Exterior wall	0.5
2	Exposed horizontal roof	0.39
3	Exposed and inclined roof	0.39
4	Ground connected solid floors	0.46
5	Exposed floors	0.46
6	External windows	2.46
7	Exposed external doors	6

Source:(Givoni, Baruch (1998). pp282).

Types of walls, roofs and materials used in construction after climate change

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).). As well as the possibility of dealing with ceilings due to their influence and exposure to solar radiation, and the use of double ceilings and double walls with the addition of insulators (Muhammad Abdullah 2016). The architectural vocabulary of the elements of the outer shell of the building that achieve environmental suitability such as in the ceilings and walls, and the use of different geometric shapes in the double ceilings and double walls and the use of insulators and other treatments (Abdurahman, *et al.*, 2018)

The focus in this study is on the walls and roofs as the most important element in the building in affecting the thermal

performance calculations (Nahla 2007). The rapid development in the world of building materials and the increase in demand for them in the local construction market, which led to the emergence of new types of materials used in construction, such as hollow red and cement bricks, including those filled with cork, as well as solid limestone bricks.

Samples of material

1. Solid stone bricks Figure (5) are among the building materials that play an important role in thermal insulation from the surrounding environment of the building, as isolating the heat shed on the external walls throughout the day provides a comfortable environment internally at a suitable temperature, in addition to reducing the amount of heat shed on it. When the outside weather cools down during the night, the process is reversed, as the bricks emit reduced heat, which causes a slight increase in the internal temperature of the building (Al-Rubaie et al. 2018).

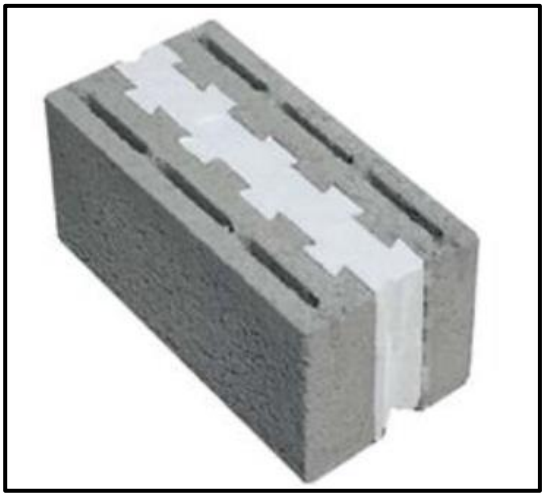
Figure 5. Solid limestone bricks

2. The hollow cement block Figure (6) is used in the construction of walls as well as ceilings, where the "brick" block is made of cement, sand and sesame aggregate, and its weight is somewhat heavy if ordinary aggregate is used in it, and its weight is reduced by half if light aggregate is used that produces pumice stone, and its weight is very light in relation to its compaction and mixing. This is attributed to the type of aggregate used, as it contains a high void ratio. The thermal insulation value of the hollow cement block clearly affects the internal environment of the building throughout the day, due to the existing hollow gaps.

Figure 6. Hollow cement block

3.Insulating block Figure (7) this type of block is characterized by its light weight, as it weighs one-third of the weight of a cement block. It is easy to carry and install, and is also characterized by high strength relative to its weight, heat and sound insulation, economical and quick installation, easy installations inside, fire resistance and low moisture absorption.

Figure 7. Cement bricks coated with cork



4.Red brick is a building material Figure (8,9) used in the construction of walls, ceilings and sidewalks from building components, and it is produced in different shapes, types, materials and sizes according to the region and time period.

Figure8. Hollow red bricks of different sizes are used in building walls

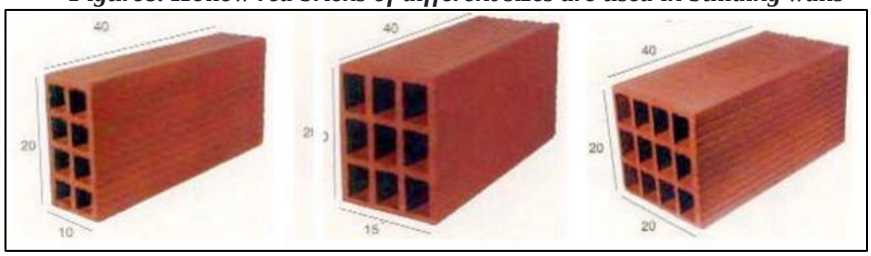
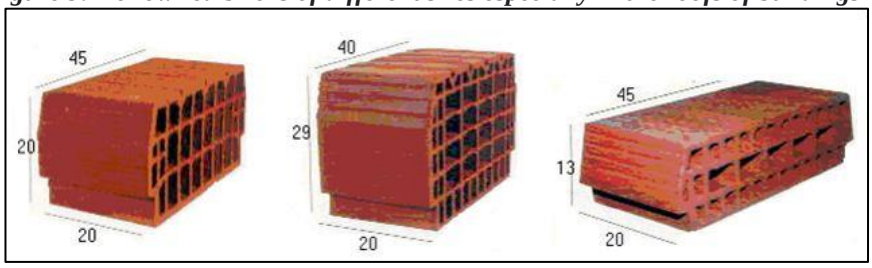


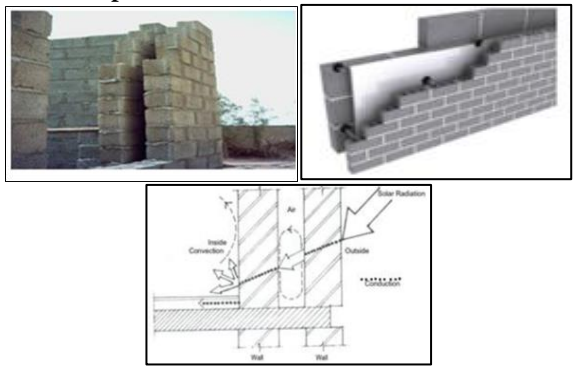
Figure 9. Hollow red bricks of different sizes especially in the roofs of buildings



Examples of some modern construction methods:

1. Two parallel walls, with thermal insulation between them Figure (10). It is the traditional system, and it is considered the best solution in wall insulation, and in this system two parallel walls are built so that types of thermal insulation are installed between the voids of the two walls, as these panels completely separate the outer wall and the inner wall of the building, and the cost and maintenance factor is taken into account, as well as The thermal bridges in the beams, columns, and floor posts are not covered by a heat insulating material in the external walls.

Figure 10. Two parallel walls, with thermal insulation between them

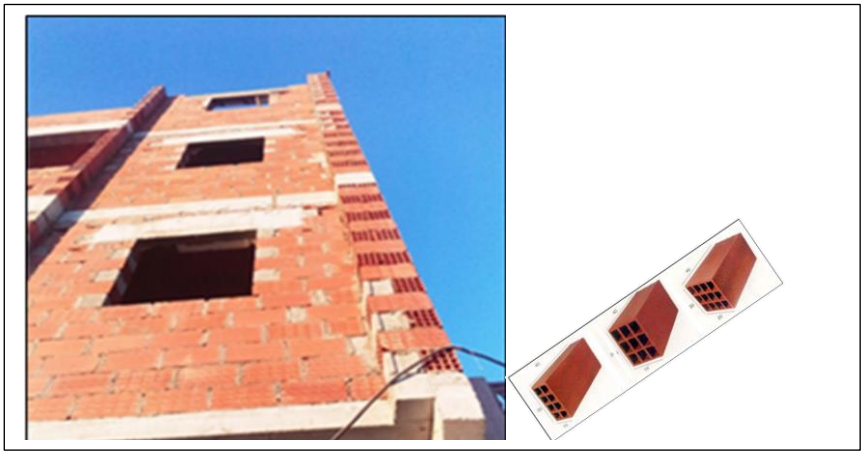


2. One wall of insulated cement bricks.
   The single wall system is made of cement bricks insulated with one slice Figure (11), of extruded or expanded polystyrene, and in this system, there are thermal bridges resulting from the use of cement mortar between the blocks during installation. Better than the first system.

Figure 11. single wall system is made of cement bricks insulated with one slice

3. Red building bricks Figure (12), are among the best types of bricks for construction, both ancient and modern, as they consist of a mixture of clay, sand and lime, in addition to iron and magnesium oxides, where natural soil is used to produce bricks. The use of hollow red bricks (Al Yajur) has finally become common in Libya, except in the construction of walls or ceilings, as it has many advantages that are suitable with climate changes, which prompt many individuals and companies to adopt it in construction, as it saves red bricks the energy of homes during the winter season and keeps it cool during the summer; As it absorbs heat from the sun's rays during the day, and transmits it with the arrival of the evening.

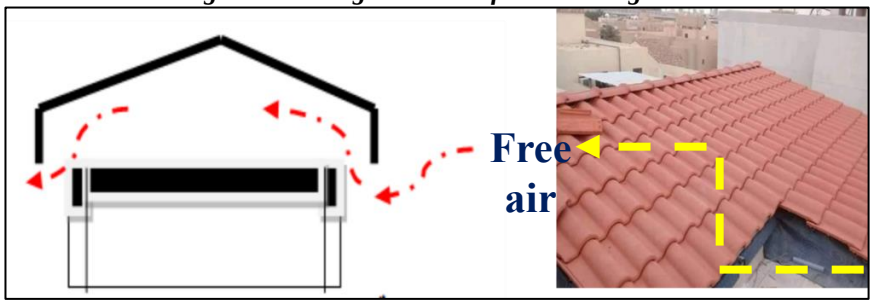
Figure 12. Using red bricks that reduce the temperature in hot periods Heating in cold periods



Roofs

The roofs are made of two tiles completely separated from each other Figure (13), to leave a void for completely free air movement, and here the upper slab plays the role of an umbrella that protects/ The main roof or the lower slab from the sun's rays with the formation of the air layer sandwiched between them.

Figure 13. Using double roof with moving air.



(Al-Sharif, *et al*., 2021)

Findings and recommendations

- There is a clear change in temperatures except in the coastal areas of Libya or the desert areas during the last fifty years, and sometimes it reaches one degree Celsius.

- The materials used in construction have a direct relationship with the impact of climatic changes on the external environment of the building.
- Walls and ceilings are among the most affected parts of the building by the surrounding climatic factors, especially by the sun's rays falling on the building.
- The method of designing and building walls and ceilings can reduce the impact of climatic factors on the external environment of the building and provide a comfortable environment inside the building.
- The use of traditional building materials without the use of thermal insulation materials to a rise in the temperature inside the building.
- Double hollow roofs and shaded roofs have the ability to resist the intensity of sunlight, air conditioning the building, and provide comfort for the residents of the building.
- There is a development in the architectural design of buildings and the type of materials used in construction to adapt to climate changes in the region

Conclusion

1. Climate changes play a major role in changing the construction method and the design of modern buildings, as well as the materials used in construction.
2. Walls are most affected by external heat due to their exposure to direct sunlight and heat transfer from hot air.
3. The quality of the materials used in the construction of the walls, their shape and composition, as well as their color, affect the production of a comfortable environment inside the building.
4. To build the outer shell of the building, it is preferable to use high-quality and efficient building materials that have the property of slow heat gain and loss, for their ability to retain heat during daylight hours.
5. Making the walls double with the same idea that double roofs have the ability to resist the intensity of sunlight. Also, double hollow roofs and shaded roofs have the ability to resist the intensity of sunlight.

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