Roofing in the Oasis Desert: Causes and Factors of Disappearance, "The Tidikelt Region as a Model"

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Abstract:
Roofing in desert architecture is considered one of the most important stages in the adobe construction process, as it relied on raw materials provided by the natural environment. This study aims to highlight the importance of the roofing process and to shed light on the buildings located in the Tidikelt region.
The problem of this research revolves around the roofing technique in various buildings, and the reasons and factors behind its disappearance in this region.
The answer to this problem lies in the field examination of some surviving building models, through their description and analysis in order to determine the strength and fragility of roofing materials, while identifying the factors affecting the construction materials used for roofing these buildings.
This research paper concludes by highlighting the importance of roofing in preserving the safety of building coverings in the Tidikelt region, and how to preserve the roofing technique and ensure the continuity of this urban pattern in the oasis desert.
Keywords: desert architecture, building materials, Tidikelt, wooden roofing, factors of disappearance.

1-Introduction:

Mud architecture is considered part of the archaeological architectural heritage, as it holds great significance through planning, design, urban pattern, and construction materials.
Traditional architecture in the southern Algerian region is an integral part of the civilization of this ancient nation. The ksour and kasbahs in the Tidikelt region were considered among the most important achievements of the culture of this region, and therefore they must be protected and preserved from all factors affecting their archaeological condition.
Wood is considered one of the primary materials exploited in the construction of these buildings. Since the oasis desert contained this wood material, palm branches, and clay soil, man exploited them in the roofing process. There is no doubt that construction borrowed the roofing process from ancient buildings in human history. The local environment may have helped in that because of its availability and its inclusion of the raw material. However, this material may be exposed to some natural and human factors that subject it to damage and deterioration. All these manifestations cause severe damage to the roof. So what are the most

important manifestations and factors of roof damage in earthen architecture in the Tidikelt region?

From this problem stem the following partial points:

- To what extent can the construction materials used in the roofing process resist natural and human factors to ensure the safety of the roofs of oasis desert buildings?
- What are the most important preventive measures to protect this archaeological roof?

To answer the proposed problem, we relied on the descriptive study of the factors affecting roofing wood in the Tidikelt region, which is the spatial scope of the study, in addition to the analytical study that relied on analyzing the characteristics of each deterioration factor affecting the wood material used in the roofing process.

The Tidikelt region was chosen because of several advantages that made it a suitable place for settlement, and this is what made it a station for trade caravans coming from all directions. Therefore, all the available raw materials were exploited in order to establish one of the urban centers that possessed ksour and kasbahs built with these nearby materials and roofed with the wooden materials provided by the oases surrounding it on all sides. I chose two samples from the ksour and another from the kasbahs, in addition to shrines and one of the mosques of Tidikelt in which factors of the disappearance of the wooden roof were present, in order to attempt to cover all types of archaeological architecture in all the areas constituting the Tidikelt region over a time period exceeding approximately 150 years for the kasbahs, mosques, and shrines, while the houses exceeded 70 years in age.

Based on the above, in this research paper we attempted to shed light on the roofing process in desert architecture in general and in the Tidikelt region in particular, and the factors affecting its safety from natural and climatic changes, as well as human factors, in order to identify the main weaknesses and reach mechanisms of safety and sustainability.

This study was divided into two main sections. In the first section, we introduced the Tidikelt region and its geographical and astronomical location, then clarified its topography and prevailing climate, which is considered one of the most important reasons for choosing the site and planning the architecture of these heritage buildings. After that, we defined desert architecture and the building materials used in the construction and erection of ksour, kasbahs, houses, and shrines, as well as the most important raw materials used in the roofing process and their source, and how this process is carried out in order to roof buildings. In the second section, we presented the causes leading to the deterioration of roofing in the architecture of the Tidikelt region, such as natural and climatic causes, in addition to physical and chemical factors, as well as clarifying biological factors and their direct effect on roofing wood, concluding with the human factors that lead to the deterioration of the archaeological roof in the buildings of the Tidikelt region.

The conclusion of the research consists of some recommendations and solutions in order to preserve the safety and sustainability of the roofs of desert buildings.

02- Desert Architecture:

It is that architectural art born from harsh climatic challenges. This architecture is also considered as buildings adapted to summer heat and winter cold, thanks to the exploitation of

the raw materials created by nature and brought close to man, which he adapted and turned into a dwelling that protects him from the heat of the sun in summer and the cold of winter.
These buildings are distinguished by their planning and form, as they are based on a set of materials provided by the environment. Thus, Hajira Tamaklisht defined them as desert dwellings characterized by several distinctive features in their form imposed by nature and climate.[1]

03- Building Materials in Desert Architecture:

1- Building Materials: The inhabitants of Tidikelt relied in building their dwellings on the raw materials available in nature and nearby. Perhaps these materials had the advantage of being suitable for construction, in addition to being easy to obtain. Among the most important of them are:

A - Stones:

Stones are considered among the most important materials used in the construction process since ancient times, and they were the basic material in building ksour, kasbahs, and houses. Stones were used in building the foundations of the Prophet's Mosque, and the Companions, may Allah be pleased with them, adopted building with them. Thus, Muslims continued to use them throughout the Arab East until they reached the Islamic Maghreb, where they were used in all types of desert architecture, such as the Great Mosque of Kairouan in the late eighth century AD. They are quarried from quarries for use in the construction process because they are distinguished by solidity, in addition to their abundance, which reduces their cost when compared with similar materials.

B - Clay:

I begin with the words of Allah the Almighty: "and He began the creation of man from clay."[2]Clay is considered one of the oldest and most widely used materials in construction for thousands of years. "It consists of minerals formed by climatic changes affecting different types of rocks."[3]Its use spread across ancient civilizations such as the Pharaonic, Roman, and Islamic civilizations, as well as many others. They built and constructed with techniques and styles, some of which still remain.

C - Brick or Adobe:

Abu al-Arab was the first to refer to the method and technique of its manufacture in the context of his account of Abu al-Walid Marwan ibn Abi Shahma al-Masili: "Abd al-Rahman and his son told me that he used to make bricks with his own hands, then give one-third of what he earned from it in charity, spend one-third on his family, and put back one-third into straw and whatever was needed to improve the brick-making process."[4]It facilitated the process of building and erecting structures at the lowest cost; therefore, people widely embraced it. Brick was used in different parts of buildings and houses, such as the construction of rooms and other internal facilities.

D - Wood:

It is the structural tissue of green plants and consists of cellulose fibers, hemicellulose, and lignin. Wood also refers to other plant materials that possess similar characteristics.[5]

It is a material produced from plants and is the most complex in the world of organic materials, on the one hand, in terms of its unique structure and components, in addition to its organization within the cellular tissue structure.[6]

Wood is an essential material in the roofing process of residential facilities in the Tidikelt region, since palm wood is abundantly available. All the elements of its upper part are exploited and prepared for the roofing process of residential structures in the Tidikelt region; see Figures 01 and 02.

Figure No. 01: Palm Groves in the Tidikelt Region
Figure No. 02: Selecting the Palm Tree for Use in Roofing

3- Wood Cutting Sections:

1- Tangential section: It is the section resulting from cutting the wood vertically to the radius. This is how palm trunks are cut for the roofing process.

2- Radial longitudinal section: It is the longitudinal part that is parallel and centrally perpendicular to the radius, "the palm trunk."

3- Cross section: It is the horizontal section located on the trunk of the tree or palm in order to show the annual growth rings.[7]

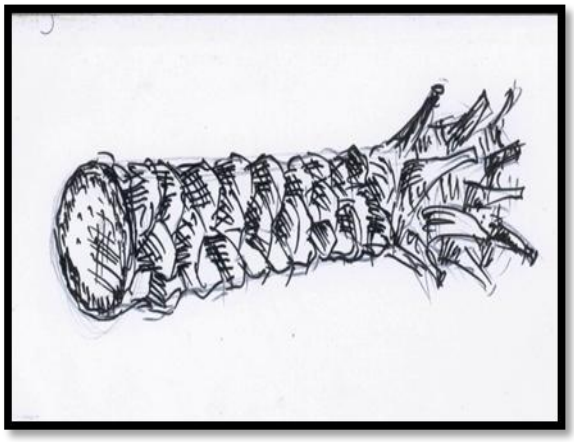
4- Preparing Palm Branches and Trunks for the Roofing Process:

A- Cleaning process: The palm trunk is cleaned of the palm fronds and karanif attached to it, in addition to removing the fibers surrounding the trunk until the trunk becomes free of karanif, fronds, and even fibers. Thus, all the units are arranged separately: the trunks, then the karanif, then the fronds, and finally the fiber. All these operations are carried out while the palm tree is still standing and planted in the ground, because the fronds must be removed while green so that they can be straightened and dried, becoming dry, straight, strong, and solid. The same applies to the karanif and all the fibers, in order to benefit from their components, that is,

because they contain the water element. The dead palm tree is not suitable for the roofing process because it is fragile and lacks the essential elements composing it, most importantly water. See Figure No. 01.

Figure No. 01: The Process of Cutting the Palm Tree

B- Palm Tree Cutting Process: In the construction and roofing process, the living palm tree that is no longer able to produce dates is used, in addition to the very tall palm tree that is difficult to climb or ascend, or that poses a danger to humans, animals, and the other palm trees because of its height and fragility. See Figures 02 and 03.



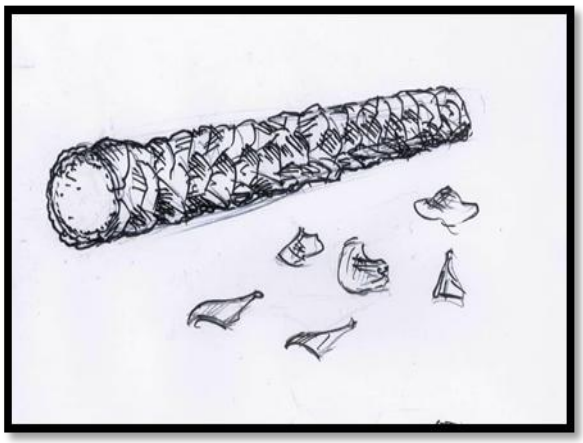


Figure No. 02: The Process of Cleaning the Palm Trunk
Figure No. 03: The Process of Removing the Palm Frond Bases and Fibers

Palm trees of similar length are cut in order to use them in the roofing process. They are cleaned of the frond bases and left in the sun in preparation for cutting afterward. There is another case in which the palm tree is already dry and withered, especially if it has been uprooted by the wind.

C- Trunk Cutting Process:

At this stage, the palm trunks are divided either into two halves or into four sections depending on the diameter of the palm trunk. If the diameter is large, it is divided into four sections, and if it is small, it is divided into only two sections. See Figure No. 04.

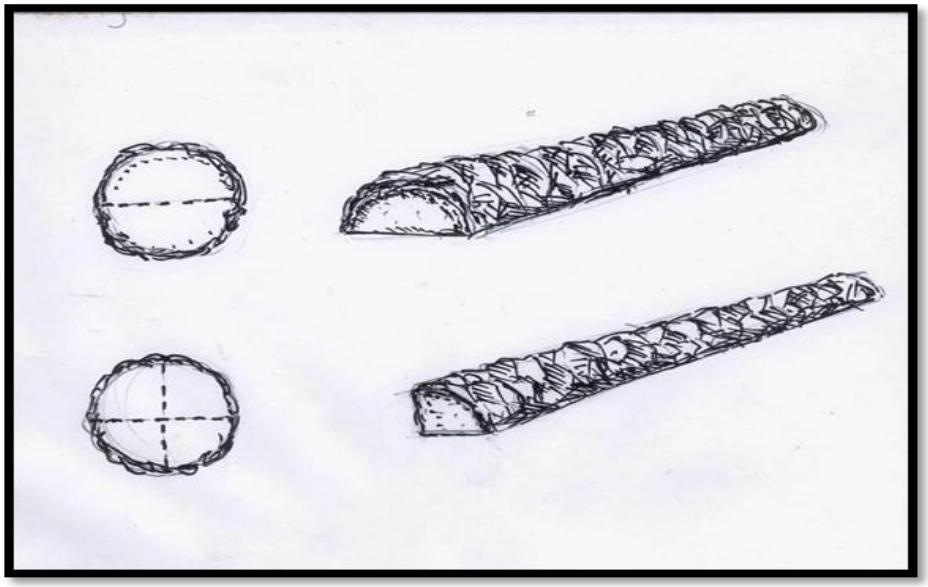


Figure No. 04: The Process of Cutting the Palm Trunk

Figure No. 03: The Process of Roofing Using Wood and Palm Frond Bases

5- Roofing Technique in the Oasis Desert of the Tidikelt Region:

The roofing stage is considered one of the most important construction stages for covering houses, ksour, kasbahs, and some passageways in the Tidikelt region. Flat roofing was the most commonly used and widespread type in these desert areas. It was used because it was the most suitable and appropriate for the desert environment on the one hand, and because it was exploited for other benefits on the other hand. In summer, the rooftops are used for sleeping, drying clothes, and drying dates. The length of the palm wood branch controls the process ofthe

roofing of the walls of the rooms or passageways intended to be roofed or flattened. As Abd al-Rahman Ibn Khaldun pointed out[8], a distance of about 20 cm is left between one trunk and another, so that the karanif are placed in an alternating manner over these trunks to cover the entire gap. This process continues until the whole room is completed, then fronds, fiber, and straw are placed as a lining for the karanif and to level the surface. Finally, clay mortar is poured over them in order to give solidity to the surface. See Figure No. 03.

There is also another roofing method, namely roofing with palm fans, where wooden trunks are placed at a distance of 20 cm or 25 cm apart. Then, the frond stalks stripped of their leaflets are placed vertically over the wooden trunks. After that, the fronds are placed on these woods until the room is fully covered. Next, a quantity of fibers is placed over these fronds to reinforce their lining. Finally, clay mortar is poured to support and strengthen the roof.

6- Causes and Factors of Roof Disappearance in the Tidikelt Region:

A- Natural Factors:

- Heat: Heat is considered one of the factors causing roof deterioration in adobe buildings in the Tidikelt region, and it plays an important role in the deterioration of wood. It is directly related to humidity, since when the temperature risesWhen the temperature rises, humidity decreases, and whenever the temperature decreases, humidity in the wood increases. Heat affects the moisture content of the wood, causing the cells to dry out and shrink, which leads to cracks, twisting, and deformations. All of this occurs as a result of rising temperature and the passage of time. Thus, the cellulose nitrates deteriorate, the strength of the palm weakens, it becomes subject to thermal decomposition, and it loses its strength and rigidity. See Figure No. 04.

Figure No. 04: Representing the Drying and Breaking of Wood

-**Humidity:** Humidity has a significant effect on wood, as it causes its deterioration, especially the wood used in the roofing of adobe and archaeological buildings. The wood intended for roofing absorbs or loses moisture according to changes in its percentage in the surrounding environment. Thus, the piece of wood shrinks or swells through absorbing moisture from walls saturated with groundwater. Shrinkage reaches 6% in the tangential direction and 5% in the

radial direction[9]. Cellulose and hemicellulose decompose in the presence of moisture, and this decomposition contributes to their fragility. Moisture in wood is formed either through rain or groundwater. When the wooden material becomes saturated with moisture, it acquires a kind of softness, making the roof loose and not solid. These woods then bend when walking on the roof, making them easy to break, and consequently the entire roof collapses due to this moisture resulting from the previously mentioned factors.[10]

-Dryness: Dryness affects the wooden material used in the roofing process as an inevitable result of the expansion and contraction process caused by dryness in response to variations in humidity and temperature in the atmosphere. High humidity exposes the wood to dryness as a response to variations in its percentage in the environment. If the humidity level decreases, the wood dries out, recedes, and becomes subject to shrinkage. As a result, the roofing loses its strength and rigidity, and part or all of it collapses.

B- Physical and Chemical Factors:

-Light: Light affects the wood used in the roofing process, as light, through the ultraviolet rays coming from the sun, causes the fibers to undergo photodegradation, and thus the cellulose particles disintegrate and break[11],The shades forming the courtyards of houses are more exposed to sunlight, as the sun's rays reach the entire courtyard despite the variation in temperature between forenoon, noon, and afternoon. Wood may also be exposed to the effect of light during the process of drying and cutting, as it remains under sunlight for a long period before being used in the roofing process.[12]

-Rain: The roof of earthen architecture is affected by rain, as heavy rainfall saturates the pores of the clay, giving it extra weight at the level of the building surface. The excess water drains through the gutter, yet some of it remains, forming small pools on the surface. This weight, resulting from the saturation of the clay pores on the one hand and the weight of the accumulated water on the other hand, causes great pressure on the roof. The wood and palm frond bases become unable to bear that weight, so one or two pieces of wood break. In this way, the roofing weakens, collapses, and falls. See Figure No. 05.

Figure No. 05: Showing the Collapse of the Wooden Beams of a Passageway Due to Rainfall

Stagnant rainwater runoff contributed to shifting and weakening the foundations of some earthen buildings by dissolving and removing the mortar binding the stones used in the construction of these foundations. It also directly affects the building components and architectural elements, such as the external walls directly exposed to rain. This is followed by the effect of heat, resulting in cracks and fissures in the wall. The latter may extend to the top of the wall, affecting the roof and consequently causing either the collapse of part of the roof or a weakening of its strength, making it difficult to walk on the roof surface afterward.

-Water: Water constitutes a fundamental factor in the disappearance of roofing in the oases of Tidikelt. As is well known, this region is rich in underground groundwater, which makes the water table always high and close to the ground surface. This water affects roofing by generating a high degree of humidity, which in turn has a direct effect on the wood used in the roofing process, and the humidity activates the action of bacteria that become active under the effect of humidity and heat. The rise in the water table leads to the saturation of the foundations with water, and this water then rises through the pores of the adobe until it reaches half of the wall. This part then becomes fragile, after which a crack may occur that can reach the roof, causing the roofing to become unstable and weak, and sometimes part of it collapses and falls, because this wall is not reinforced with supports linking its parts together, as we observe in current architecture, where walls are provided with columns that connect the parts of the wall and prevent them from cracking and collapsing. See Figure No. 05.

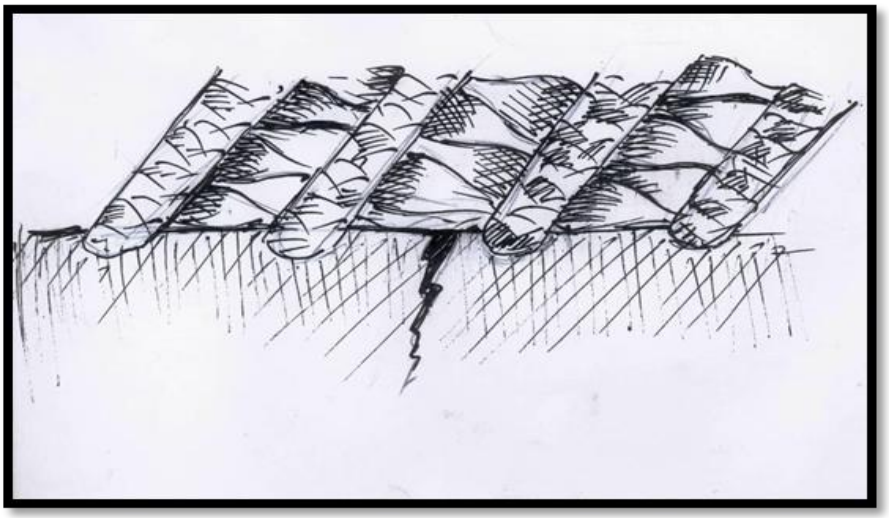


Figure No. 05: Represents the roof being affected by the cracking of the walls.

C- Geological Factors: Geological factors played an important role in the deterioration of the roofing structure in the Tidikelt region, including:

- Vibrations resulting from movement: The vibrations resulting from the movement of people and vehicles have a direct effect on earthen architecture in general and on roofing in particular. The process of moving on the roof, back and forth, generates several vibrations that are felt by the wooden roof underfoot, especially during the drying of crops, which requires continuous turning under the sun’s rays. This increases movement on the roof, and

consequently increases the vibrations resulting from this movement, exposing the wooden roof to weakness and collapse.

As for the movement of vehicles, due to the narrowness of the alleys and streets, because their planning was originally not designed for this type of means of transport, since animals were the available means at that time, the streets of earthen architecture in the Tidikelt region were laid out as narrow and not wide. With progress and urban development, vehicles of various types and sizes appeared, taking these streets and alleys as roads to travel through, leaving behind strong vibrations that affected the earthen architecture and the wooden roofs. These vibrations are transmitted through the walls, causing cracks and fissures in them, along with weakening the strength of the roof, which became saturated with these vibrations, thus disturbing its cohesion and balance. All these vibrations contribute to its collapse and fall.

D- Biological Factors: These factors have a direct effect on roofing in earthen architecture in the Tidikelt region. These factors differ from the other factors mentioned above, among which we find:

- Decay: The decay of the wood designated for roofing occurs due to woodworm, scientifically known as Anobium, which is a genus of beetles belonging to the family Anobiidae, and it has about seven species, of which 05 are extinct.[13]

This insect bores into the wood, creating holes and internal cavities within the timber, forming an empty cell inside it. This weakens the strength of the timber or the karnafa, and consequently reduces its resistance, causing the roofing to collapse at the weak point. As a result, one or two pieces of timber may break, along with the corroded karnafas between them. See Figure No 06

Figure No. 06: Represents an image of termites.

-Termites: These are cellulose-eating[14] insects characterized by chewing mouthparts, moniliform antennae, and compound eyes. The number of their species has reached more than 1,700 types of termites that attack building timber.[15]

Termites attack the timbers and karanifs of roofing, causing clear brittleness in them. As a result, the timber can no longer withstand and bear the weight of the mortar, so it breaks and the decayed roof collapses. See Figures No. 07 and 08.

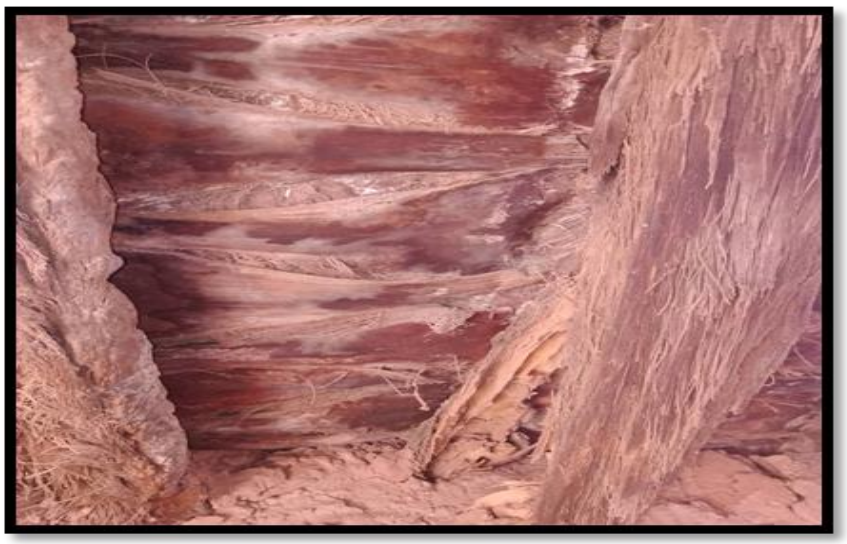


Figure No. 07: Represents termites.Figure No. 08: Represents wood damaged by termites.

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Drywood termites: This is one of the types of termite insects. This insect spreads rapidly in buildings and causes highly serious damage to wood and structures[16]This insect attacks dry wood and bores tunnels and nests in the form of passages in all directions, in which it lays its eggs and waste. The reason why wood is attacked by this type of insect is heat and dryness, as it attacks wood found in hot and dry regions, as is the case with the wood of the Tidikelt region, which consists of date palm wood. This region is characterized by high temperatures, especially in summer; therefore, it found a suitable climate there, becoming one of the manifestations of the deterioration of the wooden roofing process in earthen mud architecture.

E- Human Factors: The human factor may cause certain phenomena that lead to the deterioration of buildings and archaeological sites, among which we find:

- Fires: Wood was the first, if not the only, means used for cooking and heating in traditional earthen heritage buildings in both eastern and western Tidikelt. Flame sparks may lead to the release of carbon dioxide gas, giving the roof a kind of blackening due to the smoke resulting from cooking in stoves and kitchens, and even in rooms and shelters because of fire used for heating. When the roofing wood becomes saturated with the gases emitted by fire, it loses all

vital elements, such as the water in the wood found in the cellulose material, making the wood unable to bear the weight of the roofing, which leads to the collapse of the wooden roof.

The roof may be completely or partially burned due to human error or negligence, such as in the kitchen, which often contains cooking wood; a stray spark is capable of setting a kitchen or an entire house on fire.

Storerooms, or what is locally called al-mishar, are also exposed to the factor of fires in the Tidikelt region because they contain highly flammable grasses, such as the remains of wheat branches used to cover crops like onions and garlic. When fire ignites or a spark falls from a palm frond used for night lighting, it is enough to set the entire crop on fire, especially with the presence of those fragile branches that facilitate the ignition and rapid spread of fire. When the kitchen or storeroom burns, the roofing wood burns and becomes charred, and consequently the roof collapses.

-Negligence: The restoration process is an artistic process that enhances the durability of earthen landmarks. Human neglect of periodic restoration operations, represented in replacing worn, broken, and eroded wood and karanifs, reinforces the renewal and durability of roofing. In addition, providing cracked and fissured walls with external support gives them a kind of additional strength that prevents their collapse and increases the cohesion of the roofing process that has weakened because of this visible crack in the wall.

-Wars: Conflicts and wars do not only threaten human life, but also threaten property and archaeological and cultural acquisitions. Heritage is exposed to the danger of theft and looting, the worst of which is the total or partial destruction of these landmarks, and the best example of this is the Kasbah of al-Arab located in the Sebkha district in the area of in Ghar, belonging to the eastern Tidikelt region, which was subjected to artillery shelling during French colonialism in the Battle of in Ghar on March 19, 1900. The kasbahs and houses were completely destroyed over the heads of the male and female mujahideen, who remain to this day beneath the rubble of this shelled kasbah. See Figure No. 09.

See Figure No. 09: The collapse of the Kasbah of al-Arab due to artillery shelling.

Conclusion:

Roofing earthen architecture in the Tidikelt region with wooden materials is the most suitable and best choice in terms of the availability of the raw material and its proximity to people. In addition, its compatibility with simple adobe materials gave it a kind of proportion, harmony, and simplicity in construction and roofing that suits the climatic nature of this region. Palm wood is a basic material in roof construction due to its availability and its resistance to heat and weight; therefore, it was used in the roofing process, as the length of the wood designated for roofing controls the area of the rooms and shelters. However, this organic material may be exposed to a set of factors and risks that affect and damage it. These factors differ in the manner and degree of causing harm and damage to the wood material, such as heat, humidity, and light. Whether individually or combined over a period of time, these factors lead to the inability of this timber to resist them; consequently, it yields to these effects and becomes subject to breakage and brittleness, and finally the roof can no longer bear the load and falls and collapses either totally or partially. Water also acts in this way: when the groundwater level rises or the clayey and earthen pores become saturated with rainwater falling on the surface, in addition to the weight resulting from this saturation with rainwater, a burden is created that the timbers cannot bear; consequently, the roofing falls under this heavy load.

The wooden elements constituting the roof in the Tidikelt region are considered an important element of mechanical resistance, yet the many vibrations that were not included in the planning of this heritage threatened its strength and became one of the factors weakening this simple roofing, which would have remained strong were it not for the intensity of the vibrations resulting from the movement of vehicles in the narrow streets close or adjacent to the buildings. If these streets had been wide, these vibrations would not have been so strong. Rather, man would have sufficed in overcoming the vibrations resulting from his movement and the weight of crops on the surface by replacing one or two pieces of timber that were clearly affected by the vibrations.

Heat and humidity are two essential factors in activating microbiological deterioration, such as the growth of certain microorganisms, together with the suitability of the environment for certain insects that damage wooden material.

As for the human element, all the authorities entrusted with archaeological awareness must be supported regarding the importance of heritage and antiquities in order to ensure vigilance and caution against all these risks, whether deliberate or unintended, and to activate the international, national, and local bodies to deter acts of destruction to which antiquities and monuments are exposed during wars and conflicts.

It is therefore necessary to cast serious attention on the condition of archaeological monuments, especially roofing, because it is the pillar of all architecture; without the roof, monuments become mere ruins. It is imperative to restore roofs damaged by surrounding factors, and a preventive approach against deterioration must be established as an objective for protecting archaeological sites in order to reduce the risk of demolition and urban expansion.

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