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DIAGNOSIS OF DAMP AND STRUCTURAL PATHOLOGIES IN A SAMPLE OF MUD HOUSES USING 3D SCANNING. CASE STUDY: A HOUSE IN THE KHANGUET SIDI NADJI KSAR, BISKRA, ALGERIA

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ABSTRACT

Raw earth architecture is an important part of Algeria's cultural heritage, especially in arid and desert regions. These historic settlements, inhabited since the Middle Ages, have enabled people to survive in difficult conditions. However, these centres are now abandoned and neglected by their inhabitants, who prefer more modern lifestyles.

The Ksar of Khanguet Sidi Nadji in Biskra, a fortified urban settlement, is renowned for its rich historical heritage and exceptional architectural beauty. Classified as a natural heritage site in 1968, the ksar is facing gradual deterioration and increasing abandonment, mainly due to the intrinsic fragility of the mud buildings, structural problems and various pathologies. These deteriorations are exacerbated by the passage of time and human impacts, leading to premature ageing of the buildings, a lack of maintenance and the abandonment of certain structures that have become obsolete.

The aim of this article is to undertake an in-depth investigation of the pathologies affecting adobe architecture, using the 3D digital survey technique. The study will focus on a specific building (House 10) located in the ksar of Khanguet Sidi Nadji, selected from a representative sample. The in situ survey will be carried out in close collaboration with experts in the pathology of mud constructions, and will be supplemented by analyses carried out using specialist tools.

This scientific approach will enable us to establish a precise diagnosis, which is a prerequisite for the rehabilitation of this endangered architectural heritage. It will also ensure rigorous traceability, while promoting the use of raw earth as a sustainable building material.

KEYWORDS

Settlement, Abandonment, Pathologies, 3D Digital Survey Technique, Mud Constructions, Diagnosis

CITATION

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Introduction.

Carrying out a metrological survey is a fundamental and unavoidable preliminary stage in the initiation of any archaeological site preservation project, constituting the initial phase of all the studies relating to conservation. This crucial phase applies to all levels and spaces, and is of paramount importance when launching such an undertaking. The graphic representations resulting from this metrological survey form the essential documentary base, the corpus essential to any subsequent in-depth analysis. This initial metric survey is therefore an essential prerequisite and an intrinsic component of the process of studying and conserving archaeological heritage, conditioning the rigour and relevance of the entire scientific approach.

The purpose of this article is to present an example of a digital architectural survey carried out using a Leica - BLK 360 3D scanner on a sample of buildings in Khanguet Sidi Nadji. Khanguet Sidi Nadji is located in the Eastern Zab region, at the eastern end of the wilaya of Biskra, in the transition zone between the mountains and the Sahara. The main town is built on a steep mountain slope at an altitude of 254 metres, where the Oued El Arab emerges from the Aurès gorges. The oasis, with its 16,000 palm trees, is at the crossroads of the roads linking Biskra, 110 kilometres away, and Khenchela, 120 kilometres away. Administratively, Khanguet Sidi Nadji is attached to the daïra of Zeribet El Oued, from which it is 25 kilometres away. This case study will illustrate the potential of cutting-edge technologies in the field of architectural surveying and documentation of built heritage, using the specific example of the Khanguet Sidi Nadji site, which is rich in vernacular buildings emblematic of the earthen architecture of this region.

Fig. 1: view of khanguet sidi nadji
Source : Authors 2024.

Fig. 2: Location of the Khanguet Sidi Nadji commune.
Source: https://dz.freemeteo.com modified by the Author. 2024.

Methodology.

The in situ survey operations were carried out using the LEICA BLK 360 3D scanner, a compact, lightweight, fast and wireless instrument that is perfectly suited to the three-dimensional digitisation of complex environments. This 3D laser scanning tool is capable of scanning up to 60 metres with an accuracy of around 4 millimetres. Equipped with a panoramic imaging system, it can capture 360,000 points per second in a coloured 3D point cloud. The use of this cutting-edge technology for spatial digitisation represents a significant advance for architectural and archaeological field surveys. The high-precision technical performance of the LEICA BLK 360 scanner, combined with its manoeuvrability and speed of use, make it particularly well-suited to in-depth survey campaigns on heritage sites with complex configurations, such as the ksour and troglodyte dwellings in the region under study.

The cutting-edge technical features of this terrestrial laser scanner enabled high-resolution digital acquisition, providing a faithful representation of the complex geometry of the buildings studied, as well as a precise reproduction of the textures and damage present on the scanned surfaces. The mobility and speed of implementation offered by this 3D scanning system greatly facilitated the field survey operations, enabling a methodical and exhaustive exploration of the site using a systematic grid. The implementation of this cutting-edge technology in heritage survey campaigns represents a significant contribution, making it possible to overcome the limitations of traditional methods by acquiring dense, information-rich spatial data, essential for the precise digital documentation of buildings with complex architectural configurations. The use of these terrestrial laser scanning tools represents a significant advance in the methodology for surveying and documenting vernacular built heritage and mud buildings, whose irregular geometry lends itself particularly well to this high-definition three-dimensional acquisition technology.

Fig. 3: Leica Blk 360 3D scanner. Source: Authors. 2024.

The 3D laser scanning method uses laser ranging, where a coherent beam of light is projected onto a scene and the distance is determined by measuring the travel time of the reflected beam. This technique samples millions of points sequentially and records their position in a three-dimensional point cloud, providing an accurate digital representation of the geometry of objects. This innovative technology guarantees high-resolution, reliable geometric acquisition, which is essential for accurately modelling buildings with irregular shapes and complex geometry. The implementation of this method represents a major contribution to the digital documentation of vernacular built heritage, overcoming the limitations of traditional survey techniques by capturing exhaustive spatial data in situ.

Photo 1: 3D survey from different stations of the Khanguet Sidi Nadji sample. Source: Authors .2024.

The selected sample.

In this article, we will present house 10, one of the constructions selected from the study sample of the ksar of Khanguet Sidi Nadi.

House 10, a structure built against the retaining wall of the Ksar of Khanguet Sidi Nadji: Diagnosis of pathologies.

House 10 is located between Harat Moussa and Krazda, set against the retaining wall of the ksar; we have no information about the owner. The choice was obviously made in relation to the choice of sample justified in the previous chapter, but also to distinguish the pathologies of a building leaning against the retaining wall of the ksar from the others.

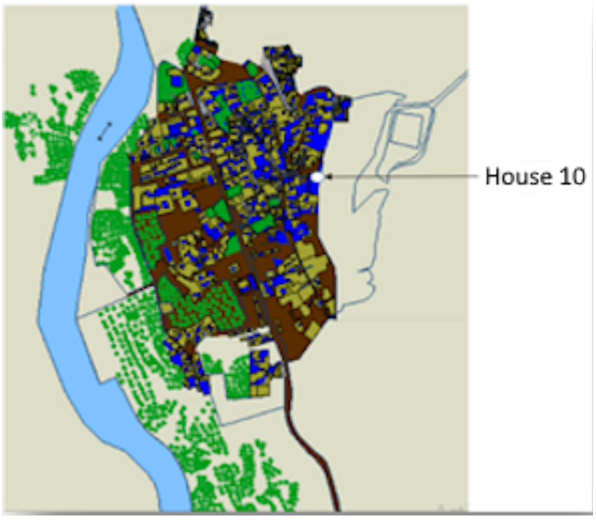

Fig. 5: Location of house 10 in the Khanguet Sidi Nadji ksar. Source : Authors.2024.

House 10 has a central patio, with a juniper wood walkway. A half-level under the ground floor contains commercial premises. The ground floor is built entirely of stone, which explains why the owner of the house is financially well-off. The ground floor is in a good state of conservation, unlike the first floor, built of adobe, which has many structural defects.

Fig. 7: Plan view of house 10 surveyed with Jet Stream Viewer (location of survey stations and diagnosis). Source : Authors.2024.

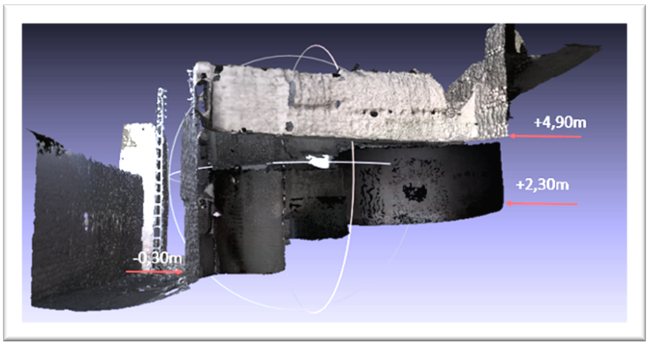

Fig. 6: Textured 3D cross-section of house 10 treated by Mesh Lab (showing the different levels of the house). Source : Authors.2024.

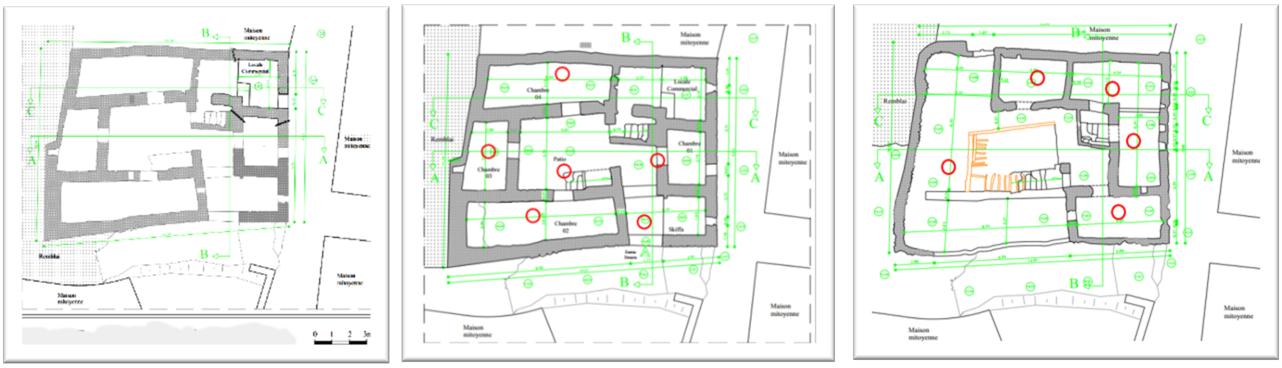

Fig. 8: Location of disorders (damp and structural) on the different levels of house 10. Plans based on the survey. Source: Authors.2024.

Results and discussion of the diagnosis after the survey:

Dampness: (House 10)

Capillary rise.

The damp conditions in this house can be observed at the -0.30m level of the ground floor. This level is in direct contact with the ground. The disorders observed in this case concern the stone material. Starting with capillary rise, which has caused erosion at the foot of the wall, in some cases leading to hollowing. We observed efflorescence caused by water from rising capillaries which, carrying mineral salts, rises to the surface of the walls and evaporates, leaving behind white crystals.

On the first floor, the majority of rooms show head erosion despite the presence of the floor. This phenomenon developed following rainwater infiltration through the roof. This disorder caused a number of wet patches, run-off, disintegration and hollowing out of the mud bricks, as well as erosion of the bottom of the wall.

Photo 2 n°: Damage to the bottom of the wall caused by efflorescence, with detachment of the coating plaster. Source : Authors.2024.

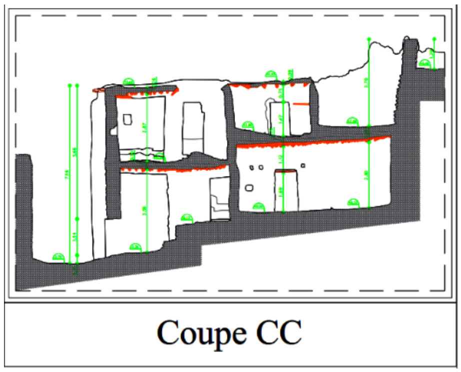

Fig. 9: Location of the disorder in section CC. Source: Authors.2024.

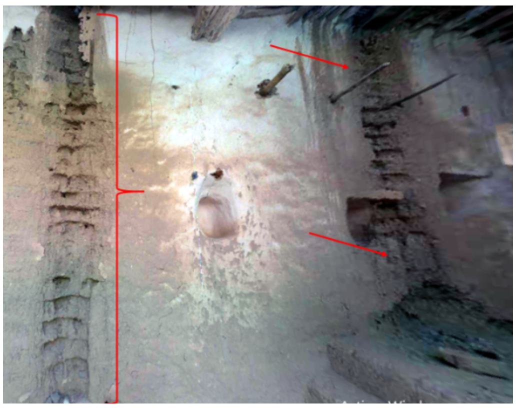

Photo 3: Head erosion, hollowing of the mud brick and deterioration of the bottom of the wall caused by rainwater infiltration. Source : Authors .2024.

Dampness in the interior floor: (House 10)

The floor of house 10 is made of palm and juniper wood. However, this floor has been the victim of a fairly serious disorder. The phenomenon is very noticeable in the commercial premises at -0.30m from the ground floor level and even in the ground floor bedrooms. Photo 128 shows the floor covering the ground floor. Part of this floor has been the target of rot due to the excessive humidity and lack of ventilation in this area. The rotting juniper wood has weakened the structure of the floor and made it unstable. This phenomenon is less visible on the side where the opening is located because of the good ventilation. In addition, termites and weevils are insects that feed on juniper wood. If infestations are not treated quickly, they can cause major damage.

Photo n°4: Development of mould on juniper wood caused by condensation, infiltration and poor ventilation. Source : Authors.2024.

Dampness in the facade walls: (House 10)

The erosion at the head of the wall in house 10 is very noticeable in both the mud and stone sections. The unprotected walls have been altered, distorting the appearance of the wall, particularly on the north facade. The lower part of the building is in a good state of conservation, and erosion of the lower part of the wall is limited to rainwater run-off favoured by the slope of the land. There is little evidence of splashing.

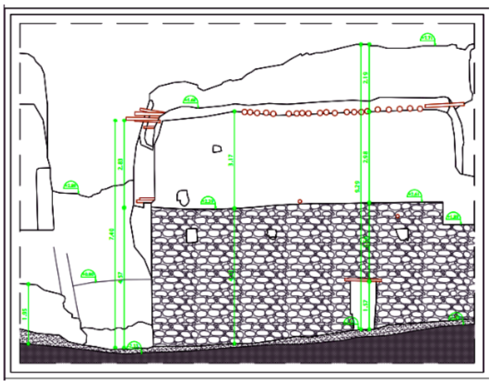

Fig. 10: House 10, south facade based on the survey. Source: Authors.2024.

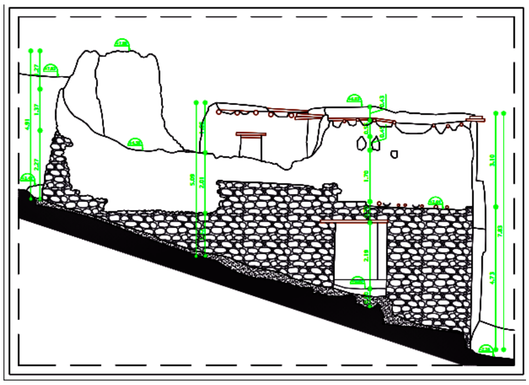

Fig. 11: House 10, north facade based on the survey. Source: Authors.2024.

There is also rainwater infiltration due to poor joints between the wood flooring and the walls. The water follows the cracks between the joints, which are not properly sealed, and in the absence of maintenance, this has led to the deterioration of the walls, ceilings and floors.

Disorder caused by the dual action of damp and wind: House 10

The infiltration of rainwater into the interior of house 10 has caused considerable damage. The floor has been destroyed and the rest of the juniper beams have disappeared. This disappearance can be explained by acts of looting that affected the entire Ksar. The black stains on the wall, caused by run-off water, are the colour of mould that has developed on the wood due to a lack of ventilation, as this space has no openings.

The winds also caused a great deal of damage. Loaded with sand, they have contributed to accelerating the effects of erosion.

Photo 5: Damage caused by run-off, infiltration, internal condensation and wind. Source : Authors.2024.

Disorder caused by damp on the roof: (House 10)

The disintegration of the elements making up the floor as a result of water and wind caused part of the covering of the first-floor passageway to be lost, which in turn deteriorated, revealing the protruding wooden bars. Photo 130 shows the appearance of the floor stones due to head erosion and the disappearance of the layer of earth covering the roof.

Photo no. 6: Disintegration of roof components due to head erosion. Source : Authors.2024.

Structural damage: (House 10)

Structural damage to the staircase

In photo. No. 7, we can see crumbling and erosion of the unbaked earth that joins the steps of the stone staircase due to direct exposure to humidity. A loss of material and structural strength, with bending of the palm wood beam that forms the framework of the staircase due to overloading caused by the destruction of the upstairs passageway.

In addition to this disorder, the staircase has been subjected to heavy loads and ground movement, causing subsidence and settlement. The steps have warped and cracked. The disintegration of the raw earth making up the staircase as a result of the impact of the collapses has caused the staircase to lose its cohesion, cracking and breaking.

Photo 7: Disorders diagnosed at staircase level in house 10. Source : Authors.2024.

Structural specificity of house 10

House 10 has a specific construction on the ground floor. One of the bedrooms is built on the retaining wall of the ksar (Photo 8). We did not diagnose any structural pathologies; on the contrary, the space is very well preserved, apart from patches of mould (condensation) caused by the infiltration of moisture through the floor. To remedy this problem, the occupants had used cardboard to protect themselves.

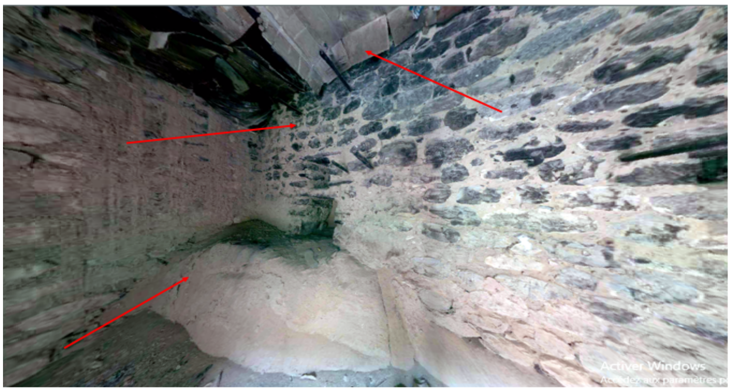

Photo 8: House 10 is built on the retaining wall of the ksar. Source : Authors.2024.

Cracks due to lack of rigidity of the collaborating elements:

The diagnosis of the through crack in photo no. 133 is that the deformability of the foundations under the effect of the load thrusts of the facade wall has led to shear or flexural fractures depending on the size of the openings and the elasticity of the wall materials. In this case, the wall was added at a later date by the owner of house 10 on the first floor, with poorly spaced and randomly arranged openings of irregular dimensions.

Photo 9: Punching crack caused by poor load distribution on the wall. Source : Authors.2024.

Cracks caused by differential settlement of the foundations

In the case of house 10, the pathology due to differential settlement of the foundations is different from that diagnosed on the caravanserai. Here, the long, through cracks have formed on both sides of the opening (the door) (photo no. 10). Although the house has a stone base wall, this has not prevented the formation of a heterogeneous load on the wall due to an extension to the first floor made by the owner of the house. The sloping ground also contributed to the disorder.

Photo no. 10: Differential settlement of foundations due to sloping ground and additional loads. Source : Authors.2024.

Cracks caused by the triple action of damp, loads and wind

On the first floor, one of the pathologies visible in a space (bedroom) is very typical. We can see (photo no. 11) the corner crack is caused by the floor load and the poor junction of the transverse wall. The formation of this continuous, non-through fracture leads to a loss of continuity in the wall, which may reduce its monolithic nature.

This disorder has accentuated the appearance of the crack in the middle of the wall, which is continuous and through-going. This is due to rainwater infiltration, which has created a fault in the wall, as well as head erosion, causing the wooden beam and the wall to lose their support. The wind then completed the damage by tearing away the already damaged part of the floor.

Photo 11: Damage caused by overloading, damp and wind. Source : Authors.2024

Conclusions.

This article has provided an exhaustive diagnosis of the various pathologies affecting the selected sample, which is representative of all the buildings in the Khanguet Sidi Nadji ksar. A detailed analysis of the state of conservation of the selected buildings, using 3D scanners, revealed that many of the dwellings are in a very advanced state of deterioration. This situation is both worrying and alarming. The buildings in the ksar are extremely vulnerable to water, which is the main cause of all the damage observed. In this respect, water plays a deleterious role for the built structures, comparable to that of a virus attacking the human organism.

The gradual abandonment of the ksar by its inhabitants has had harmful consequences for the condition of its buildings. In addition, the inappropriate use of contemporary materials incompatible with the nature of the soil has accelerated the deterioration of these buildings. Lack of regular maintenance and design errors have also exacerbated these problems. To remedy this situation effectively, it is imperative to tackle the root causes of the deterioration observed. To this end, an in-depth diagnosis is essential. This will enable us to identify precisely the factors that have led to the deterioration of the ksar's buildings. Targeted measures can then be put in place to resolve the specific problems and ensure the proper preservation and restoration of these historic structures.

REFERENCES

1. https://www.meteoblue.com/fr/meteo/historyclimate/climatemodelled/khangat-sidi-nadji_alg%C3%A9rie_2492113 . Consulté le 06/12/2022. 20 :37.
2. BENDJELID A, Yousfi B. (2003) synthétise toute une série de travaux portant sur la mobilité ... 21 | 2003, mis en ligne le 30 septembre 2012, consulté le 27 avril 2022.
3. BENDJELID A, Kouzmine Y, 2011, « Le Sahara et ses marges », Insaniyat, no 51-52, CRASC.
4. BISSON Jean (1956). Le Gourara, étude de géographie humaine. D.E.S, Institut de recherches sahariennes, Alger.
5. BISSON Jean, Yann Callot. (1990) ; Les hommes et la sécheresse autour du Grand Erg Occidental (Nord-Ouest du Sahara algérien). Science et changements planétaires / Sécheresse. 1(2) :124-133.
6. COIGNET Jean , Laurent Coignet (2012.) La maison ancienne Constructions, diagnostic, interventions. Éditeur : Eyrolles
7. COLLOMBET, R. (1989). L'humidité des bâtiments anciens : Causes et effets, diagnostic, remèdes. Paris, Ville de Paris, France : Publications du Moniteur.
8. MONJO-Carrió Juan, (2011). Le diagnostic dans la restauration. Les études pathologiques, in workshop PG Patrimoine architectural et urbain, EPAU d'Alger, Janvier. P. 01
9. Xavier Casanovas, (2008). "La réhabilitation et la revitalisation urbaine", la méthode *Réhabimed*, une approche multidisciplinaire à la réhabilitation urbaine. In Actes du colloque international, Oran, 19-21 octobre 2008,
10. Kouzmine, Yaël, Dynamiques et mutations territoriales du Sahara algérien, vers de nouvelles approches fondées sur l'observation, Thèse de doctorat en géographie, Université de Franche-Comté, 2007, 424p.
11. Otmane T., (2010), Mise en valeur agricole et dynamiques rurales dans le Touat, le Gourara et le Tidikelt (Sahara algérien), Thèse de Doctorat en géographie,
12. SELKA, Mohammed Chihab. (2019), Evolution de l'architecture défensive de Tlemcen à l'époque médiévale : techniques, matériaux et critères d'intervention, Thèse de doctorat en sciences. Département d'architecture. Université de TELMCEN.