Documenting Traditional Earthen Construction Processes in the Ksar of Timimoun, Algeria

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ABSTRACT

Earthen construction represents one of the oldest and most widespread building traditions worldwide, offering context-responsive solutions recognized for environmental sustainability and climatic adaptability. The Ksar of Timimoun, located in the Gourara region of the Algerian Sahara, constitutes a significant example of earthen architectural heritage adapted to hot and dry desert environments. This ancestral heritage is under increasing threat due to rapid socio-cultural transformations, ongoing urbanization, and extreme climatic events, notably the catastrophic floods of 2004.

This study contributes to the resilience and sustainable conservation of Ksour in arid environments while investigating and documenting traditional earthen construction processes. It adopts a multi-faceted methodological approach, combining a comprehensive literature review on earthen architectural heritage in the Gourara region with empirical data derived from the "Introduction to Clay Construction Techniques" training course held at CAPTERRE Timimoun in February 2023. It is further complemented by in situ field observations and semi-structured interviews conducted with local master builders.

Particular attention in the study is given to the production of adobe bricks, the principal walling material of the Ksar. It also documents the local materials and construction techniques that underpin traditional earthen building practices in the region, highlighting the importance of material selection, preparation, and implementation in ensuring building performance and durability.

The study contributes by proposing a structured framework for documenting earthen construction processes based on field-derived knowledge. By formalizing these practices, the research supports the development of a knowledge base intended to assist experts and policymakers in preserving and reinforcing the resilience of the Gourara region's traditional earthen architecture.

KEY WORDS :

Earthen Construction, Vernacular Architecture, Timimoun, Adobe Production, Indigenous Knowledge

1 INTRODUCTION

Earthen architecture forms one of the most ancient and continuous building traditions globally. Its diverse manifestations range from the vast adobe mosques of Mali to the rammed-earth siheyuans of China. For this reason, earth has historically been a sophisticated environmental and cultural adaptation material, not just one of the options, in the Mediterranean and Saharan regions. The most stunning examples of this tradition are certainly the Ksour (i.e., the plural of Ksar), which are fortified earthen villages spread throughout the oasis belts of the Algerian Sahara.The Ksar of Timimoun, situated in the Gourara region, exemplifies this heritage(Charif & Belakehal, n.d.). Its very characteristic red-clay architecture is part of a landscape setting that includes palm groves and a foggara irrigation system, composing a very lively habitat. Its construction methods, social organization, and climatic adaptation have been forged together over centuries.
However, this heritage is increasingly vulnerable as two major contemporary threats converge on Timimoun: First, extreme climatic events, notably the catastrophic floods of October 2004, caused severe damage to earthen structures poorly adapted to sudden water exposure, unlike their traditional performance in dry conditions(Kassou et al., 2024). Second, rapid urbanization following Timimoun's designation as a provincial capital (wilaya) in 2019 has accelerated land-use changes, infrastructure projects, and the replacement of earthen houses with concrete block constructions(Charif et al., 2023; Kassou et al., 2024).

In this perspective, this paper discusses the vital issue of ancestral earthen building techniques confronted by modernization and climate change. For many years, master builders have accumulated generational empirical knowledge about adobe production, the choice of materials, and their maintenance. However, with the abandonment of traditional construction by the younger generations, this knowledge risks being lost. In addition, the documentation remains very fragmented, while the conservation policies generally favor imported materials. Therefore, this paper aims to document the traditional adobe production and construction processes employed in the Ksar of Timimounm, propose a structured framework for recording local earthen building knowledge; and Contribute to the resilience and sustainable conservation of Gourara's Ksour in arid environments.

The literature review is combined with field observations and empirical data gathered during a practical course on earthen construction taught at the CAPTERRE center in Timimoun, thus answering the Kerpic'26 call to consider earthen heritage as a "living site" in which knowledge and know-how constitute an integral part of the site.

2. Regional **Context*****: The Earthen Heritage of Gourara***

The Earthen Heritage of Gourara The Gourara region, a natural depression within the Algerian Saharan Atlas, hosts one of the densest ensembles of Ksour in North Africa. Timimoun, often called "the red oasis," occupies a strategic position at the edge of the Grand Erg Occidental.

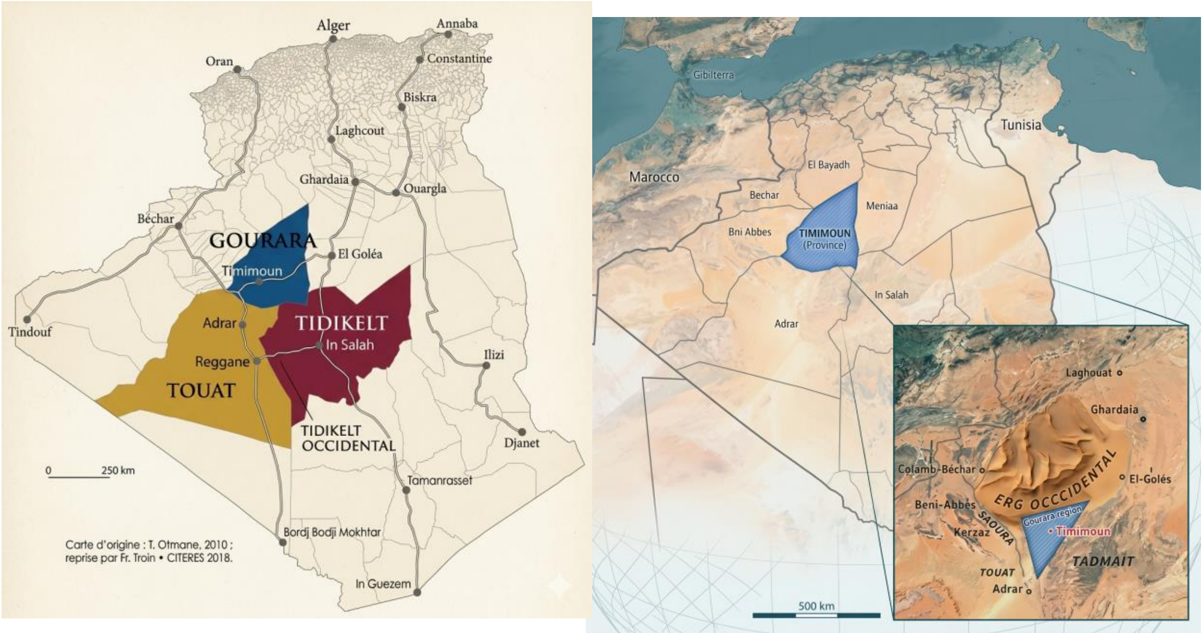


Figure 1: Figure 1: Location map description : Map showing Algeria,Gourara region, Timimoun. Indicate the Grand Erg Occidental

The local ferruginous red clay (known as touab ahmar) confers the characteristic reddish hue to most of Timimoun's buildings, giving the town a strong identity rarely found in other Saharan settlements(Guebboub, 2025).

2.1 Architectural Typology of the Ksar

The typical Ksar in Gourara is characterized by a dense, organic urban fabric comprising

Figure 2: Timimoun kser and oasis belt

interconnected dwellings, often multistory, organized around communal spaces and protected by perimeter walls.Timimoun dwellings exhibit several recurrent features:

• Agglomerated, multi-story volumes (typically two floors) that provide thermal mass and shade narrow street canyons;

• Small, strategically placed openings to minimize solar gain while allowing cross-ventilation;

• Flat roofs constructed from palm beams (djrid) covered with layered clay, serving as additional living space during temperate nights;

• Stone foundations (0.40–0.70 m deep) that elevate earthen walls above occasional floodwaters and capillary moisture(Kassou et al., 2024).

These features represent high thermal mass materials to smooth out extreme diurnal swings in temperature and urban geometry limiting direct solar exposure but maximizing shading and wind paths for cross ventilation.

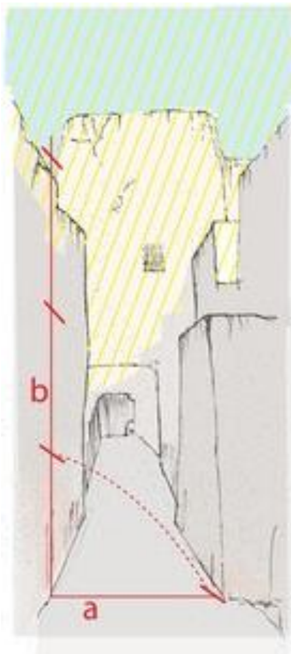



Figure 3: Timimoun Ksar street/alley

Field photograph of a narrow alley within the Ksar of Timimoun, showing red earthen walls on both sides, small openings, and the agglomerated multi-story volumes. The textural quality of adobe plaster is captured.

2.2 The Ksar as a Living Site Under Threat

The Ksour of Gourara are not archaeological sites but inhabited settlements. This is a crucial characteristic of the Ksar, as the built form shapes and reflects social organization, the natural environment, oasis agriculture, and the hydraulics of the foggara system (Kassou et al., 2024; Chouaib & Kalyoncuoğlu, 2022).The site organization of the Ksar above the palm groves, the latter lying above the drainage system, can be interpreted as adaptations related to water management, with defensive considerations and implications for community stratification. The mosque, public square (saha), and zaouia anchor collective life in this mutually constitutive system (Chouaib & Kalyoncuoğlu, 2022). Unfortunately, this living heritage faces mounting threats from rapid urbanization and population growth following Timimoun's elevation to wilaya status in 2019, the 2004 floods, climate change, and the abandonment of earthen practices in favor of concrete construction, endangering both structures and indigenous knowledge (Charif et al., 2023),(Kassou et al., 2024),(Khelifi, 2024).

2.3 Climatic Adaptation

Gourara's hyper-arid desert climate is characterized by extreme diurnal temperature variations exceeding 15°C, summer maxima reaching up to 47.8°C, winter minima around 2.9°C, annual precipitation rarely surpassing 70 mm except during flash floods like that of 2004, and midsummer humidity as low as 8.5% (Kassou et al., 2024). Under these conditions, architecture and urban form had to cope with demanding challenges regarding thermal comfort and water consumption. (Kaihoul and Pitzalis 2023) considered that the typical earthen architecture of Ksour, like those of Timimoun, developed passive cooling strategies to counter the hostile climatic conditions of the Sahara Desert. (Nassima and Fahmi 2024) highlighted that these passive vernacular techniques guarantee a thermally comfortable indoor environment without mechanical cooling. This was confirmed by (Benslimane et al. 2020).

Thick adobe walls, typically 45–50 cm in depth, leverage high thermal mass to stabilize indoor temperatures, while the compact morphology generates shaded street canyons and semi-covered passages that deflect prevailing hot winds, favoring natural ventilation and pedestrian comfort in extreme summer conditions(Lamia et al., 2015; Mestoul, 2023; Terki et al., 2019). Furthermore, the strategic orientation of buildings minimizes direct solar gain on facades, contributing to a more stable internal thermal environment. The careful placement of small, recessed fenestrations and the integration of courtyards further contribute to mitigating solar heat gain while facilitating air circulation within the building envelopes.(Kaihoul & Pitzalis, 2023; "Ksour of the SAHARA Desert as A Great Lesson of Sustainable Urban Design in Hot Desert Oases," 2017)

All these empirically evolved passive design strategies evidence a high bioclimatic awareness level in achieving indoor comfort in an extreme desert climate (Douaa, 2024; Lamia et al., 2015; Mestoul, 2023; Terki et al., 2019).

3.RESEARCH METHODOLOGY

Given this research's objective to explore known and unknown local expert knowledge in a manner complementary to the already available written sources, the adopted approach is essentially qualitative and multidimensional.

The methodology is thus composed of four complementary elements.

3.1 Literature Review

A systematic review examined peer-reviewed studies on: Saharan earthen construction techniques (1985–2023); conservation challenges in Algerian Ksour; and climate adaptation strategies in vernacular architecture.It provides a technical and historical background on the context.

3.2 Empirical Data from CAPTERRE Training Course

Primary empirical data derive from the "Introduction to Clay Construction Techniques" training course held at CAPTERRE Timimoun (Centre d'Animation Pédagogique, Technique et de Recherche sur les Ressources Educatives) in February 2023. CAPTERRE serves as a regional hub for earthen architecture documentation and capacity building(Kassou et al., 2024). The author participated in the 5-day course, which included: theoretical sessions on clay mineralogy and soil selection; practical workshops on adobe molding, mixing, and drying; and on-site visits to active restoration projects within the Ksar.

3.3 Field Observations and In Situ Documentation

Following the training, systematic field observations were conducted in the Ksar of Timimoun, focusing on: existing adobe walls (crack patterns, erosion, recent repairs); active construction sites where ma'alem were producing adobe; and foundation details and drainage modifications post-2004.

3.4 Field Exchanges with Master Builders

During the field observation phase, informal exchanges were conducted with master builders (ma'alem) associated with CAPTERRE. These exchanges took place on active construction sites and at the CAPTERRE headquarters, where ma'alem were observed performing traditional construction tasks.

Rather than following a formal interview protocol, these exchanges were conversational and context-driven, allowing the ma'alem to demonstrate and explain their techniques in situ. Topics explored included, material sourcing and selection criteria, step-by-step adobe production sequences, seasonal timing of construction activities, traditional field tests (cigar test, pellet test) and perceptions of concrete versus earthen construction.

All exchanges were conducted in Arabic or Berber, with notes taken after each observation. The informal nature of these exchanges allowed for natural, unscripted demonstrations of traditional knowledge, aligning with the study's objective to document practices as they occur in their authentic context.

The triangulation of a literature review with field notes and oral history follows the methodology of Kassou et al. (2024) and enables triangulation between systems of knowledge.

4.TRETRADITIONAL CONSTRUCTION PROCESSES AND MATERIAL SELECTION

In the Ksour of Timimoun, the so-called ma'âlem are experienced local craftsmen in earth construction, based on empirical knowledge accumulated over many generations. Their responsibility encompasses choosing the right materials, producing adobe, and assembling it, all through tactile judgments and oral knowledge. This knowledge, transmitted from older to younger ma'âlem (currently those over 50 years) was retrieved through interviews with local CAPTERRE-affiliated personnel (Charif & Belakehal, n.d.; Kassou et al., 2024).

4.1 Material Composition and Soil Testing

The standard adobe mix in Timimoun consists of three components:

- **Red clay** (*touab ahmar*): Sourced from specific wadi beds near the Ksar. Master builders describe ideal clay as "sticky when wet, cracking in angular shapes when dry."
- **Sand** (*rmel*): Coarse, non-saline sand from dune fields, added to reduce shrinkage cracking.
- **Chopped straw** (*teben*): Palm frond or cereal straw, cut to 3–6 cm lengths, providing tensile strength and lightening the mix (Charif & Belakehal, n.d.). Proportions are empirical rather than measured: Ma'alem judge the mix by color, consistency, and a set of field tests.

The most common are the "cigar test" and "pellet test." Such tests, relying solely on touch, have allowed the ma'âlem to determine the clay-aggregate ratio and moisture content needed to produce stable and durable earth bricks (Guebboub, 2025).

Cigar test

A moistened soil sample is rolled between the palms into a 1–2 cm diameter cylinder. If it holds together for 10–15 cm without breaking, the clay content is adequate. The test continues by bending or pushing the formed cylinder until it breaks: an optimal mix fractures into segments of 7–15 cm, signaling medium cohesion and balanced clay content, whereas longer unbroken lengths indicate excessive clay (Terki et al., 2019). Conversely, a short fracture length suggests insufficient clay, requiring further augmentation to achieve optimal plasticity. According to (Terki et al. 2019), this empirical cigar test was developed within the framework of the CRAterre standardized protocols since 1979 and was proven to characterize Saharan ksour soils, where the balance in cohesion is such that shrinkage and fragility problems are avoided in producing adobes (Dali et al., 2025; Zaghez et al., 2023).

Figure 4:Photograph of a master builder rolling a moistened soil sample into a cylinder between their palms

Pellet test

The pellet test, conversely, involves forming a small ball of soil and dropping it from a fixed height. A successful outcome, indicated by the pellet maintaining its integrity, signifies adequate cohesion without excessive plasticity (Terki et al., 2019). This immediate assessment of soil characteristics is crucial for determining the appropriate amendments needed for optimal adobe quality, particularly in regions where clay-rich soils are not always readily available (Zerboni et al., 2018). Even if these field tests are only qualitative, they provide valuable first-step characterizations of the materials and their behavior for the characterization of local soils with respect to their suitability for adobe construction, which often correlates well with quantitative laboratory analyses, as (Saliba et al. 2025) demonstrated.

4.2

Figure 5: Ma'alem Pellet test

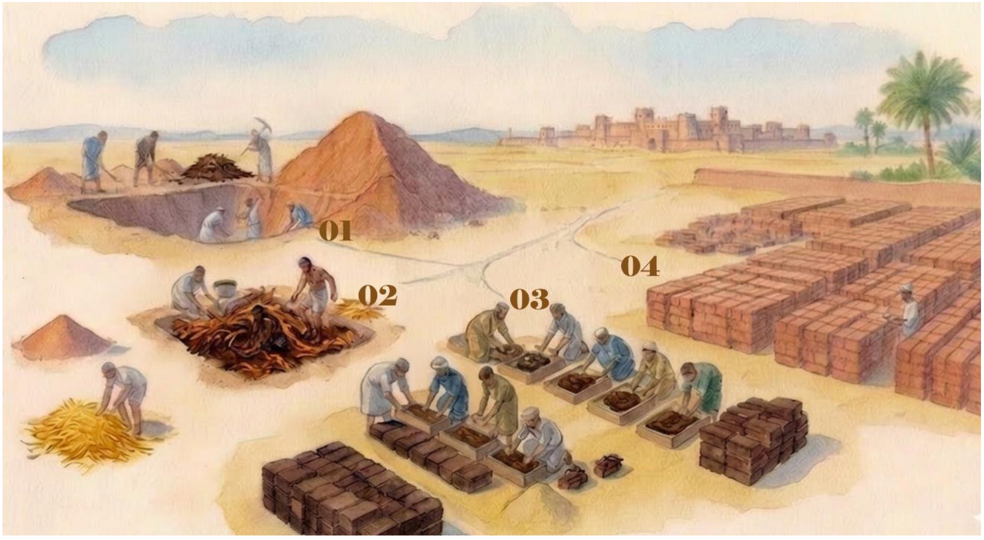
Adobe Production Sequence

The production process follows a consistent, repeatable sequence documented by multiple ma'alem.

Adobe dimensions

for Timimoun commonly include 15 cm × 15 cm × 30 cm (height × width × length) and these dimensions can reach up to 0.17 m × 0.17 m × 0.4 m (as seen in Ksar Timimoun) (Kassou et al., 2024). The source indicates that brick production can vary according to mold types and sizes, explaining these differences. The length being approximately twice the width is a geometrical property favoring the possibility of staggered laying in walls, a general principle of brick construction (Champagne et al., 2018).

The adobe production process can be outlined in four main steps, as illustrated in Figure (6):



1. Extraction of clayey soils through digging: Clayey soils are typically sourced manually from nearby quarries, wadi beds, or local deposits close to the oasis. Extraction in some Gourara ksour is regulated by customary rules on sites, quantities, and seasons to ensure sustainability.(Kassou et al., 2024)

2. Preparation of the clayey paste, which comprises several sub-steps: First, dry mixing of clayey soils with sand or tuff to ensure even distribution of aggregates (Kassou et al., 2024); Second, wet mixing through gradual water addition, often performed barefoot by ma'alem, to form a malleable paste into which chopped straw is incorporated for tensile reinforcement (Charif & Belakehal, n.d.); Finally, maceration, locally termed al-takhmār, entailing prolonged resting in pits with weekly stirring and re-wetting to enhance homogeneity and longevity (Kassou et al., 2024).

3. Shaping and molding: This step involves ma'alem pressing the malleable paste into wooden (or occasionally iron) molds, typically rectangular and fitted with handles for easy demolding, placed on a sand-sprinkled surface to prevent adhesion, compacting it firmly to eliminate voids before carefully lifting the form to release the raw brick.(Kassou et al., 2024),(Moles, 2014)

4. Sun drying (Kassou et al., 2024). This step which along with the preceding traditional sequence ensures the optimal mechanical properties of the adobe bricks, culminates in sun-drying, unlike industrial tunnel drying with controlled humidity and temperature; it relies on ambient environmental conditions (Salih et al., 2020). Adobe brick production is ideally conducted during spring or fall, when temperatures are moderate and sunlight less intense. Conversely, it

is prohibited during winter due to risks to builders, particularly in the barefoot wet mixing stage, in adherence to the principle: 'There should be neither harming nor reciprocating harm.' (Salih et al., 2020).

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4.3 Mortars and Plasters

Mortars and plasters are essential for the construction and maintenance of earthen structures in Timimoun's vernacular architecture, significantly enhancing their durability and performance.(Ben Charif & Belakehal, n.d.)

CompositionTraditional mixes typically comprise:

- **Clay** as the primary binder, providing plasticity and adhesion;
- **Sand**, added to improve workability and minimize shrinkage, with grain size influencing texture and strength;
- **Straw or fibers** for tensile reinforcement and crack prevention;
- **Water**, carefully dosed to achieve a workable consistency without weakening the mix.

In Timimoun, local builders adapt these proportions empirically, selecting regionally available clays and sands based on experience and environmental conditions.(Terki et al., 2019)

Application Techniques

Preparation begins with dry-mixing ingredients for uniformity, followed by gradual water addition and a short resting period to optimize plasticity. Mortars are applied in thin layers, allowing partial drying between coats to avoid cracking; plasters often feature a rough base layer topped by a finer finish for smoothness. Traditional trowels and wooden floats ensure precise texturing.(Charif & Belakehal, n.d.)

Practical Recommendations from Site Observations

In Timimoun's arid climate, mixes should be applied during cooler hours to mitigate rapid drying and cracking. Regular inspections facilitate timely repairs using compatible formulations. Engaging local ma'âlem reveals time-tested ratios and techniques, while small-scale tests allow adaptation such as lime additives for durability tailored to specific needs. Community knowledge thus bridges tradition and contemporary preservation. Mastering these elements with local materials, time-honored methods, and vigilant maintenance ensures the longevity of Timimoun's earthen heritage.(Charif & Belakehal, n.d.)

4.4 Structural Elements and Foundations

Crucially, load-bearing adobe walls in Timimoun are never placed directly on grade. Stone foundations, constructed from locally quarried limestone or granite cobbles, extend 0.40-0.70 m below ground and rise 0.20-0.30 m above grade. This important detail is often forgotten in modern reconstructions of "earthen" architecture and is probably the most important element that allows protection against rising damp and floods (Charif & Belakehal, n.d.).

The 2004 floods disproportionately destroyed buildings whose stone foundations had been removed or bypassed by later renovations.(Kassou et al., 2024)

4.5 The Knowledge of the Ma'alem

Technical descriptions alone omit the diagnostic skill of master builders.field exchanges with master builders consistently described assessing soil quality by:

- **Taste** (sweet versus saline soil rejected);
- **Smell** (musty or organic odor indicates unsuitable deposits);
- **Feel** (ideal clay produces a "soapy" slickness between fingers).

Such heuristics, elaborated over many generations, correspond to an empirical knowledge of the behavior of materials that predates by many centuries the field of soil mechanics. preserving this intangible knowledge is as urgent as preserving the walls themselves.

5.DISCUSSION : A STRUCTURED FRAMEWORK FOR DOCUMENTATION

This is the paradox of the findings in Timimoun: local knowledge on earth construction, on the one hand, is very robust, having survived many centuries of proven performance; on the other hand, it is very fragile, being transmitted orally and hence vulnerable to rupture between generations. This section develops a conceptual framework for intangible know-how to be converted into documented knowledge for experts and decision-makers.

5.1 Principles of the Framework

Drawing on our field observations, an effective documentation framework should be:

- **Field-deployable** (low-tech, usable by local builders without advanced equipment);
- **Multi-scalar** (addressing material, component, building, and settlement levels);
- **Bilingual** (Arabic/French and Berber as needed);
- **Dynamic** (allowing updates as techniques evolve or climate changes).

5.2 Components of the Proposed Framework

While the framework explicitly considers the existing protocols for documenting intangible cultural heritage developed by UNESCO, in particular, the guidelines on safeguarding the knowledge of master builders as living human treasures, the semantic standards of CIDOC-CRM were introduced to raise methodological standards and ensure the credibility and interoperability of this framework with international initiatives in the documentation of intangible cultural heritage.(Crouzet et al., 2025; Karakul, 2019; Nafis et al., 2021; Zlodi, 2023)

The framework organizes documentation into five modules:

Module 1: Material Inventory Soil source locations (GPS, photos), field tests (cigar, pellet), straw type, water source (salinity).

Module 2: Production Log Batch date, weather, mix proportions (volume-based), drying duration, brick quality at days 7, 14, and 28.

Module 3: Construction Record Foundation type/depth, wall thickness, bonding pattern, reinforcement (palm wood lintels), plaster layers.

Module 4: Maintenance History Repair dates, crack mapping, mortar composition for repointing, flood/wind/seismic damage notes.

Module 5: Oral Knowledge Archive Video/audio recordings of *ma'alem*, glossary of local technical terms, annotated co-produced diagrams.

5.3 Complementing Traditional Knowledge with Low-Cost Digital Tools

Charif et al. (2024) have shown that, with low-cost photogrammetry (smartphone or consumer drone), one can obtain 3D models of earthen walls with a level of accuracy on the order of centimeters, which allows the quantitative monitoring of crack opening or erosion rates.At the CAPTERRE headquarters in Oasis Rouge, such tools have been tested successfully for documenting restoration progress.

However, in this regard, the framework integrates photogrammetric surveys under the sixth module, digital health monitoring, and only after the first five core modules have been completed through community participation.

5.4 Policy Implications

At present, the Algerian building code and associated regulatory technical documents (RTDs) do not recognize rammed earth or adobe as structural materials. Hence, for any building requiring a permit, structural materials are limited to reinforced concrete and steel.

this way, state policy currently militates against earthen construction, even when it would be climatically and economically more rational.

If adopted by the regional planning authorities, the proposed documentation framework would thus facilitate the elaboration of evidence-based standards regarding earthen construction (minimum foundation depth, maximum wall slenderness, etc.); the issuance of permits for ma'alem-driven constructions; and their recognition by insurance companies or disaster compensation schemes as insurable assets.

6.CONCLUSION

The Ksar of Timimoun is, indeed, at a crossroads.Built with red earthen materials, its vernacular architecture embodies accumulated experience over centuries in terms of locally adapted materials, with a soil selection process that better insulates than any air conditioner; and its settlement pattern reflects social and water availability concerns.

This heritage is now confronted by the growing risk of floods, especially after the 2004 floods that heavily impacted earthen architecture; the rapid urban development after Timimoun became a wilaya in 2019; and the disruption of the oral transmission of ma'alem knowledge. The first major contribution is the detailed documentation of Timimoun's traditional methods for adobe production and construction.

Special attention is given to the role of the stone foundation, placed at least 0.40 to 0.70 m below the ground and at least 0.20 to 0.30 m above ground level, for protection against floodwaters-a detail overlooked in most contemporary "earthen" building reproductions.

Secondly, a framework is proposed for documentation through five modules, which transforms the hitherto intangible knowledge of the ma'alems into tangible evidence for experts and policymakers.

Thirdly, the article illustrates how the methodology can be both respectful of local knowledge and compatible with the conservation sciences, presenting empirical data from the

CAPTERRE training course and the interviews carried out locally, including ma'alem heuristics such as tasting, smelling, and feeling soil.

Two other broader conclusions emerge from this.Living places require living knowledge: documentation alone will not suffice; this framework must be embedded within capacity-building programs for intergenerational transmission and apprenticeships, as tested at the CAPTERRE headquarters in Oasis Rouge.

Resilience is dynamic, not static. What worked for the traditional vernacular architecture over centuries in an extremely arid climate must now be adapted, not replaced, for a context of new pluvial extremes: deeper foundations; lime additions; branch repairs; or buttress repairs of cracks.Further studies are required to measure the thermo-hygrometric performance of Timimoun adobe under the present and future climate scenarios using low-cost photogrammetry for crack monitoring and field-testing this framework in other Ksour of the Gourara.

Indeed, the protection of Timimoun's vernacular architecture should not be an antiquarian quest but a question of cultural identity, environmental necessity, and climate justice.

The answers lie in the ma'alems, and the challenge for us is to listen, document, and propose policies that will allow their knowledge to continue to guide the future.

REFERENCES

1) Benslimane, N., Biara, R. W., & Bougdah, H. (2020). Traditional Versus Contemporary Dwellings in a Desert Environment: The Case of Bechar, Algeria. *Environmental Research Engineering and Management*, *76*(4), 118–130. https://doi.org/10.5755/j01.erem.76.4.21595

2) Champagne, A., Baleux, F., Calastrenc, C., Comet, A., Guinaudeau, N., Klein, A., Lacroix, C., Laurent, A., & Mattalia, Y. (2018). PCR Sainte-Christie-d'Armagnac (Gers), année probatoire. *HAL (Le Centre Pour La Communication Scientifique Directe)*. https://hal.science/hal-02139911

3) Charif, H. B., & Belakehal, A. (n.d.). *NILE'S EARTH INTERNATIONAL CONFERENCE 96 DOCUMENTING EARTHEN CONSTRUCTION PROCESSES AND TECHNIQUES. CASE STUDY OF KSAR TIMIMOUN, ALGERIA*.

4) Charif, H. B., Belakehal, A., & Zerari, S. (2023). Earthen Architecture in Southern Algeria: An Assessment of Social Values and the Impact of Industrial Building Practices. *Open Archaeology*, *9*(1). https://doi.org/10.1515/opar-2022-0324

5) Chouaib, G., & Kalyoncuoğlu, B. B. (2022). Understanding the cultural landscape value of traditional agrarian landscapes of African Sahara Desert: The case of Timimoun, Algeria. *Journal of Design for Resilience in Architecture and Planning*, *3*(1), 82–95. https://doi.org/10.47818/drarch.2022.v3i1045

6) Crouzet, L., Pöllinger, A. L., & Langenberg, S. (2025). Craft and Repair Heritage: From Capture to Dissemination in Digital Space. *The international Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 367–374. https://doi.org/10.5194/isprs-archives-xlviii-m-9-2025-367-2025

7) Dali, A. I., Zerari, S., Gandreau, D., Gandreau, D., & France, Crat., École Nationale Supérieure d'Architecture de Grenoble,. (2025). In-situ investigation of earthen building materials in the Ksour of the Ziban region, Algeria: A comparative study between Chetma and Lichana. *Research on Engineering Structures and Materials*. https://doi.org/10.17515/resm2025-621ma0111rs

8) Douaa, E. E. A. A. (2024). CLIMATIC CHALLENGES AND URBAN LANDSCAPE DESIGN RESPONSES IN HOT CLIMATES: INSIGHTS FROM NORTH AFRICA. *Regional Problems of Architecture and Urban Planning*, *18*, 22–30. https://doi.org/10.31650/2707-403x-2024-18-22-30

9) Guebboub, L. S. (2025). Valuation of the Bricks of Adobes Made with the Local Raw Materials for the Rehabilitation of the Saharan Ksour in Algeria. *Journal of Civil Engineering and Architecture*, *19*(9), 444–444. https://doi.org/10.17265/1934-7359/2025.09.004

10) Kaihoul, A., & Pitzalis, E. (2023). *Climate-Responsive Design of Vernacular Architecture in Hot-Dry Climates: Lessons from the South of Algeria*. https://doi.org/10.59287/nmsr.1248

11) Karakul, Ö. (2019). The Effects of Tourism on Traditional Craftsmanship for The Sustainable Development of Historic Environments. *European Journal of Sustainable Development*, *8*(4), 380–380. https://doi.org/10.14207/ejsd.2019.v8n4p380

12) Kassou, Y., Alkama, D., & Bouzaher, S. (2024). Earthen Architectural Heritage in the Gourara Region of Algeria: Building Typology, Materials, and Techniques. *Heritage*, *7*(7), 3821–3850. https://doi.org/10.3390/heritage7070181

13) Khelifi, L. (2024). Re-evaluating Vernacular Climatic Morphologies for Sustainable Development in Southern Algeria. *E3S Web of Conferences*, *585*, 1023–1023. https://doi.org/10.1051/e3sconf/202458501023

14) Ksour of the SAHARA Desert as A Great Lesson of Sustainable Urban Design in Hot Desert Oases. (2017). *International Journal of Advances in Scientific Research and Engineering*. https://doi.org/10.7324/ijasre.2017.32568

15) Lamia, K., Bensalem, R., & Semmar, D. (2015). Thermal and Airflow Characteristics of Transitional Spaces In a Traditional Urban Fabric Case Study of a Covered Walkway in Timimoun (South West Of Algeria). *VFAST Transactions on Mathematics*, *7*(2), 1–1. https://doi.org/10.21015/vtm.v7i2.360

16) Mestoul, D. (2023). Study on the ancestral rules of bioclimatic urban fabric in southern Algeria. *Journal of Physics Conference Series*, *2600*(8), 82034–82034. https://doi.org/10.1088/1742-6596/2600/8/082034

17) Moles, O. (2014). Building with earth in Sahraoui Camp. Pedagogical support. 2010-2015. *HAL (Le Centre Pour La Communication Scientifique Directe)*. https://hal.archives-ouvertes.fr/hal-02905052

18) Nafis, F., Aghoutane, B., & Yahyaouy, A. (2021). Semantic integration of Moroccan cultural heritage using CIDOC CRM: case of Drâa-Tafilalet zone. *International Journal of Cloud Computing*, *10*, 548–548. https://doi.org/10.1504/ijcc.2021.120393

19) Nassima, T., & Fahmi, T. (2024). CHALLENGES OF PRESERVING ARCHITECTURAL HERITAGE AMID SOCIAL AND ENVIRONMENTAL DECLINE: A CALL FOR THE OFFICIAL CLASSIFICATION OF KSAR NEGRINE IN TEBESSA PROVINCE, ALGERIA. *International Journal of Innovative Technologies in Social Science*. https://doi.org/10.31435/ijitss.4(44).2024.3031

20) Saliba, J., Al-Shaar, W., & Delage, M. (2025). Comparison of Field and Laboratory Tests for Soil Suitability Assessment in Raw Earth Construction. *Applied Sciences*, *15*(4), 1932–1932. https://doi.org/10.3390/app15041932

21) Salih, M. M., Osofero, A. I., & Imbabi, M. S. (2020). Critical review of recent development in fiber reinforced adobe bricks for sustainable construction. *Frontiers of Structural and Civil Engineering*, *14*(4), 839–854. https://doi.org/10.1007/s11709-020-0630-7

22) Terki, Y., Rakotomamonjy, B., Hacini, M., Benhachmi, T., Henous, M., Belouaar, A., Eldjouzi, A., Moriset, S., Okbaoui, C., Almama, A., Sanchez, N. M., Nasri, S., Hajmirbaba, M., Gandreau, D., Wheeler, S., Karimi, H., Kassou, Y., Ferreira Mendes, M., Letiec, J. M., … Meghnine, Y. (2019). *Guide de réhabilitation de l'habitat en terre à Timimoun*.

Zaghez, I., Attoui, R., & Saou-Dufrêne, B. (2023). Preservation and Sustainability of Earthen Architecture. The Vernacular Ksar of Khanguet Sidi Nadji in Algerian Sahara as a Case Study. *Research Square (Research Square)*. https://doi.org/10.21203/rs.3.rs-2644252/v1

Zerboni, A., Bernasconi, A., Gatto, M. C., Ottomano, C., Cremaschi, M., & Mori, L. (2018). Building on an oasis in Garamantian times: Geoarchaeological investigation on mud architectural elements from the excavation of Fewet (Central Sahara, SW Libya). *Journal of Arid Environments*, *157*, 149–167. https://doi.org/10.1016/j.jaridenv.2018.06.010

Zlodi, G. (2023). Information and Documentation Perspective to Intangible Cultural Heritage in the Context of Digital Humanities Research. *Studia Ethnologica Croatica*, *35*(1), 115–148. https://doi.org/10.17234/sec.35.8