Bima Journal of Science and Technology, Vol. 9(1B) Apr, 2025 ISSN: 2536-6041

DOI: 10.56892/bima.v9i1B.1296

Usability of Heritage Building Materials: A Case Study of Hadhramaut (Yemen) and Najran (Saudi Arabia)

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ABSTRACT

This study investigates the usability of heritage building materials in two prominent regions of the Arabian Peninsula—Hadhramaut in Yemen and Najran in Saudi Arabia—both known for their rich architectural traditions and extensive use of earth-based construction. Employing a mixed-methods approach rooted in comparative case study methodology, the research synthesizes secondary data from academic publications, conservation reports, and architectural surveys to assess the performance and adaptability of traditional materials, particularly mudbrick (adobe) and layered mud (teen), timber, stone, and traditional plasters like qadad. Findings reveal that both regions utilize similar materials, yet their usability differs based on environmental conditions, socio-political contexts, and conservation infrastructure. In Hadhramaut, mudbrick offers excellent thermal performance and ease of construction, but political instability and economic decline have hindered consistent maintenance. Conversely, Najran benefits from structured governmental conservation programs, though increased rainfall presents challenges to material longevity. Quantitative comparisons of climatic data, wall dimensions, thermal conductivity, and documented restoration costs underscore the role of local context in determining material viability. The study highlights key usability factors, including availability, durability, workability, environmental impact, and socio-cultural value. It concludes that traditional building materials remain viable for sustainable construction and heritage preservation, provided that conservation strategies are tailored to local realities. By reinforcing the importance of traditional knowledge and material science, the research contributes to the discourse on sustainable heritage architecture and offers insights for policy makers, architects, and conservationists working in arid and semi-arid regions.

Keywords: Heritage Architecture; Traditional Building Materials; Mudbrick and Teen Construction; Sustainable Conservation

INTRODUCTION

Heritage architecture and traditional building materials are invaluable for understanding the cultural, environmental, and technological contexts of past societies. They offer insights into sustainable construction practices, resource utilization, and community resilience. Preserving these structures is crucial for maintaining cultural identity and informing contemporary architectural solutions (Husa & Harun, 2023). Earth-based architecture, utilizing materials like adobe, rammed earth, and mudbrick, has been a cornerstone in arid and semi-arid regions globally. These materials are abundant, thermally efficient, and well-suited to extreme climates. For instance, in the central region of Saudi Arabia (Ushayqer, 2018), traditional adobe architecture has demonstrated environmental, social, and technical sustainability, adapting to the hot, arid climate through thick walls

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and passive cooling techniques (Mortada, 2016).

Figure 1: Maps of Hadhramaut & Najran (Afsa, 2021; Maps of India, 2023)

The Hadhramaut Valley is renowned for its high-rise mudbrick cities, notably Shibam. Often referred to as the 'Manhattan of the Desert', Shibam features multi-story buildings constructed from mudbrick, designed to withstand the harsh desert environment and tribal conflicts (Morris, 2021). On the other hand, Najran's architecture is characterized by multi-layered mud (teen) palaces, such as Al-Aan Palace (Mortada, 2016). These structures are built using sun-dried mud bricks and are designed to provide thermal comfort in the region's hot, dry climate. This research is therefore pertinent due to the unique adaptations to arid environments in regions like Hadhramaut and Najran.

The conservation of buildings constructed from traditional materials, such as those found in Hadhramaut, Yemen, and Najran, Saudi Arabia, is increasingly challenged by factors like decay and weathering. Mudbrick structures in these regions are highly vulnerable to environmental elements such as heavy rains, floods, and extreme temperatures, which lead to erosion and structural instability. For example, Yemen's Seiyun Palace, one of the largest mud-brick structures globally, has suffered significant damage due to neglect and harsh weather conditions, placing it at risk of collapse (The New Arab, 2020). Similarly, the Al-Qashla Palace in Saudi Arabia has been affected by flooding, highlighting the fragility of mud architecture in the region (Alsuhaymi, 2024). Compounding this issue is the loss of traditional knowledge and craftsmanship essential for the proper construction and maintenance of these buildings. In Yemen, the lack of formal training and institutional support has led to a scarcity of skilled artisans capable of performing authentic repairs and sustaining these historic structures (Mehta, 2005).

Furthermore, there is a critical need to understand the practical "usability" of these traditional materials today, beyond their historical significance. While mudbrick construction techniques have proven to be environmentally sustainable and resilient when well-maintained, there is a lack of comprehensive studies that assess their current applicability and potential for adaptation (The Architectural Review, 2009). The absence of comparative studies between the material usability of Hadhramaut and Najran architectural traditions further hinders the development of effective conservation

DOI: 10.56892/bima.v9i1B.1296

strategies. Such studies are essential to address shared challenges, exchange best practices, and create region-specific approaches that respect traditional craftsmanship while integrating modern requirements (Al-Sabahi, 2014). This research aims to fill these gaps by investigating the usability of heritage building materials in these regions, ultimately contributing to their preservation and sustainable adaptation.

LITERATURE REVIEW

The concept of "usability" in heritage conservation encompasses the practical performance, durability, sustainability, and authenticity of traditional building materials. In arid and semi-arid regions, materials like mudbrick, rammed earth, stone, timber, and lime-based plasters have historically been employed due to their thermal properties and local availability. These materials offer natural insulation, regulating indoor temperatures in extreme climates (Jaquin & Augarde, 2012). However, their longevity depends on proper maintenance and understanding of their properties. For instance, the use of unsalted soil, known for its strength and stickiness, was preferred in traditional Najdi architecture to enhance the durability of mud bricks (Mortada, 2016). Assessing the usability of these materials today requires a framework that considers their physical properties, compatibility with modern conservation practices, and alignment with international guidelines like the Venice Charter, which emphasizes the importance of preserving the authenticity of historical structures (ICOMOS, 1964).

In Hadhramaut, Yemen, traditional architecture showcases the innovative use of mudbrick in constructing multi-story buildings, exemplified by the city of Shibam, often referred to as the "Manhattan of the Desert" due to its high-rise mudbrick structures (UNESCO, 2021). Techniques such as zabur (mudbrick reinforcement) and madar (timber support systems) were developed to enhance the structural integrity of these buildings. The application of qadad, a lime-based waterproof plaster, further protected structures from environmental degradation (Barashed & El-Azab, 2007). Despite their resilience, these materials face challenges due to neglect, conflict, and the erosion of traditional knowledge. The Seiyun Palace, one of the world's largest mudbrick structures, has suffered significant deterioration, highlighting the urgent need for conservation efforts that respect traditional methods while incorporating modern techniques (Wikipedia contributors, 2023).

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Figure 2: Old Walled City of Shibam (Yemen) (UNESCO, 2021)

Figure 3: Najran's Al-Aan Palace (Saudi Press Agency, 2024)

Similarly, Najran in Saudi Arabia boasts a rich architectural heritage characterized by multi-story mud houses constructed using cob techniques. These structures, built with locally sourced materials like mud, stone, and palm fronds, reflect the community's adaptation to the harsh desert environment (Ahmad, 2024). Decorative elements such as al-Sharareef, triangular parapets atop walls, not only serve aesthetic purposes but also have functional roles in defining roof spaces (Saleh, 2024).

However, the preservation of these buildings is threatened by modernization and a decline in traditional construction skills. Studies emphasize the importance of understanding soil properties and traditional construction methods to improve the structural quality of earthen buildings in Najran (Alshammari et al., 2021). Comparative analyses of Hadhramaut and Najran's architectural practices can provide valuable insights into sustainable conservation strategies that honor cultural heritage while addressing contemporary challenges.

MATERIALS AND METHODS

This study employs a mixed-methods comparative case study approach to investigate the usability of traditional building materials in Hadhramaut (Yemen) and Najran (Saudi Arabia). Data for this study is derived from secondary sources, including academic publications, conservation reports, architectural surveys, historical archives, and photographic documentation. These sources are gathered from academic databases, institutional repositories, and international

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heritage organizations such as UNESCO and ICOMOS. The analysis employs thematic and descriptive techniques, focusing on recurring patterns and contextual insights into material performance, conservation methods, and environmental resilience. Data triangulation is used to enhance the reliability of findings by comparing evidence across multiple formats and perspectives. This methodology ensures a grounded yet innovative understanding of how traditional materials can be sustainably preserved and adapted within diverse heritage contexts.

RESULTS AND DISCUSSION

Case Study I - Hadhramaut

Context

Hadhramaut, located in eastern Yemen, is characterized by its arid climate and unique architectural heritage. The region is renowned for its mudbrick cities, notably Shibam, often referred to as the 'Manhattan of the Desert' due to its high-rise mudbrick structures. Other significant sites include Tarim, known for its Islamic architecture, and Wadi Dawan, which features picturesque villages with advanced mudbrick construction (UNESCO, 2021).

Figure 4: Mudbrick cities in Hadhramaut including Shibam, Tarim and Wadi Dawan (Biblioasia, 2010)

Primary Heritage Building Materials

Heritage Building Materials	Description
Mudbrick/Adobe	Composed of local clay, straw, and water, mudbricks are sun-dried and used extensively in construction
Timber	Palm trunks and other local woods are

DOI: 10.56892/bima.v9i1B.1296

	utilized for structural support, including lintels and floors.
Plasters (Qadad)	A traditional waterproof plaster made from lime and volcanic ash, applied to protect walls from moisture.
Stone	Used primarily for foundations to provide stability and resistance against ground moisture

Sources: UNESCO (2021); Archleague (nd).

Figure 5: Use of Mud Bricks in Hadhramaut (Biblioasia, 2010)

Assessment of Material Usability

Criteria	**Comments**
Availability & Sourcing	Local materials are abundant, reducing transportation costs and promoting sustainability
Cost	Utilizing local resources minimizes expenses, making construction economically feasible.
Durability & Performance	When maintained properly, structures exhibit resilience against the harsh climate
Workability & Skills	Traditional construction techniques require skilled labor, which is diminishing due to modernization
Environmental	Low embodied energy and recyclability make

DOI: 10.56892/bima.v9i1B.1296

Impact	these materials environmentally friendly
Socio-Cultural Value	The architecture reflects the cultural identity and heritage of the region
Compatibility	Traditional materials integrate well with modern amenities when adapted appropriately.

Sources: UNESCO (2021); Archleague (nd).

Case Study II: Najran

Context

Najran, situated in southwestern Saudi Arabia, shares a similar arid climate and boasts a rich architectural tradition. Key heritage sites include Al-Aan Palace and Emarah Palace, exemplifying the region's distinctive mud-brick architecture (Arab News, 2022).

Figure 6: Najran's Heritage Sites - Al-Aan Palace and Emarah Palace (Nicht noch ein Reiseblog. (n.d.).

Primary Heritage Building Materials

Heritage Building Materials	**Description**
Layered Mud (Teen)	Constructed in successive layers, providing thermal insulation and structural integrity
Stone	Utilized for foundations and lower courses to enhance durability
Timber	Incorporated for structural support and decorative elements, often sourced locally
Gypsum/Other Plasters	Applied to protect and decorate surfaces, contributing to the aesthetic appeal.

Sources: Arab News, 2025; Arab News, 2022; Saudi Press Agency, 2025

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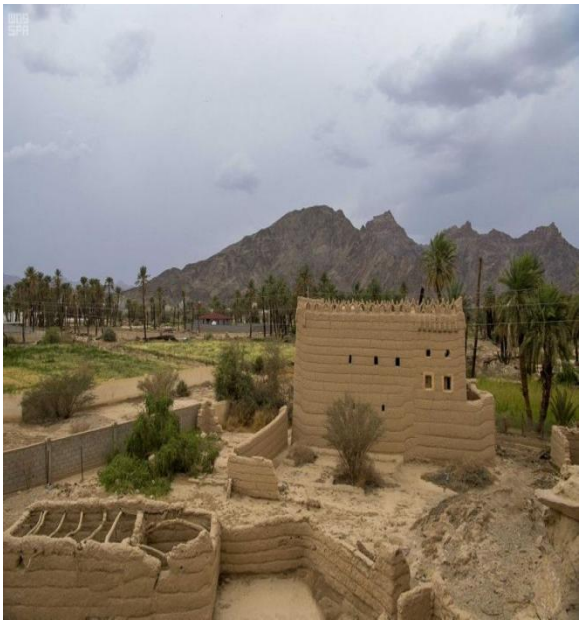

Figure 7: Mud Architecture in Najran Heritage Sites (Al-Amoudi, 2021)

4.2.3. Assessment of Material Usability

Criteria	Comments
Availability & Sourcing	Local materials are readily available, supporting traditional construction methods.
Cost	The use of indigenous materials keeps construction costs manageable
Durability & Performance	Structures demonstrate resilience when maintained, though they are susceptible to environmental wear.
Workability & Skills	Traditional building skills are declining, posing challenges for preservation.
Environmental Impact	The materials are eco-friendly, with low environmental footprints
Socio-Cultural Value	Architectural styles are integral to the region's cultural identity
Compatibility	Traditional materials can be adapted to meet modern requirements with thoughtful integration.

Sources: Arab News, 2025; Arab News, 2022; Saudi Press Agency, 2025

Comparative Analysis & Discussion

Overview of Material Properties and Usability

Both Hadhramaut and Najran utilize traditional earthen construction methods adapted to their respective climates. In Hadhramaut, particularly in Shibam, structures are built using mudbrick, leading to high-rise buildings known as the "Manhattan of the Desert" (UNESCO, 2021). Najran's architecture, exemplified by Al-Aan Palace, employs layered mud construction (teen) with stone foundations and wooden reinforcements (Al-Asad, 2011).

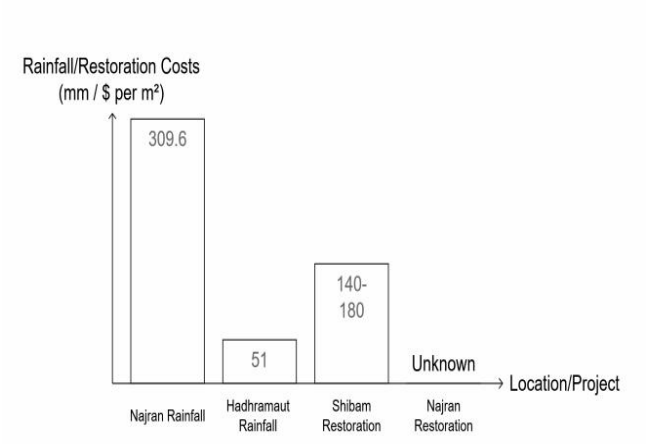

Figure 8: Comparative overview of Hadhramaut & Najran Comparison (Author)

Quantitative data reveals that Najran experiences higher annual rainfall (~309.6

DOI: 10.56892/bima.v9i1B.1296

mm) compared to Hadhramaut (~51 mm), influencing material durability and maintenance needs (World Bank Climate Data, 2020). Restoration costs also vary; for instance, the Shibam Urban Development Project reported costs between $140–$180 per m², while Najran's Al-Aan Palace restoration in 2018 had lower costs, although specific figures are not publicly disclosed (UNESCO, 2021; Al-Asad, 2011).

4.3.2 Comparative Table of Material Properties and Usability Factors

Parameter	**Hadhramaut (Shibam)**	**Najran (Al-Aan Palace)**
Primary Material	Mudbrick	Layered Mud (Teen)
Thermal Conductivity	~0.57 W/m•K	~0.41 W/m•K
Compressive Strength	2.0–2.5 MPa	~1.8 MPa
Annual Rainfall	~51 mm	~309.6 mm
Maintenance Cycle	Replastering every 3–5 years	Longer intervals due to construction techniques
Restoration Cost per m²	$140–$180	Not publicly disclosed
Structural Design	High-rise mudbrick towers	Multi-story structures with stone and timber
Environmental Adaptation	Thick walls for thermal mass	Use of stone foundations to mitigate moisture
Cultural Significance	UNESCO World Heritage Site	Regional architectural heritage

Sources: UNESCO (2021); Al-Asad (2011); World Bank Climate Data (2020).

This study highlights the differences and similarities between the traditional mudbrick architectural heritage of Najran (Saudi Arabia) and Hadhramaut (Yemen), both of which embody strong cultural, environmental, and religious underpinnings in their material use and spatial configuration. To support the broader understanding of heritage usability, this research draws insights from other global frameworks, such as the one proposed by Syed Ariffin et al. (2015) for digitalizing tangible heritage in Malaysia.

Their conceptual framework is based on a bottom-up, community-centered Stakeholder Consultation Model, emphasizing policy context, theoretical perspectives, and local issues. It also includes an indicator selection methodology, focusing on integrating both tangible and intangible heritage. While the Middle Eastern case studies emphasize material sustainability and privacy, the Malaysian model introduces digital archiving, data centers, and virtual galleries as innovative approaches to preserving heritage (Syed Ariffin et al., 2015).

CONCLUSION

This study explored the usability of heritage building materials in two culturally and climatically distinct regions: Hadhramaut in Yemen and Najran in Saudi Arabia. Through a comparative analysis of qualitative and quantitative secondary data, it is evident that both regions have developed unique yet comparable mud-based construction techniques—mudbrick in Hadhramaut and layered teen in Najran—tailored to their environmental conditions and cultural contexts. The study has shown that the choice and usability of heritage materials such as

DOI: 10.56892/bima.v9i1B.1296

mudbrick (teen) in Najran and Hadhramaut are closely tied not only to climate adaptability but also to longstanding cultural and religious traditions. As noted in recent comparative architectural studies, privacy and modesty significantly influence spatial configurations and material applications in traditional Muslim societies (Aliyu, Ismail, & Dodo, 2024). These findings suggest that future interventions in heritage conservation or low-cost housing in these regions should consider such socio-religious values to maintain cultural continuity and community acceptance. Hadhramaut's drier climate reduces moisture-related degradation, though socio-political instability has hampered consistent conservation. In contrast, Najran's higher rainfall necessitates enhanced foundation and waterproofing strategies, which have been better supported by modern conservation efforts and national heritage initiatives. Overall, this study reinforces the relevance of traditional earthen materials in contemporary heritage preservation and sustainable architecture. It underscores the need for context-specific conservation strategies that align with environmental conditions, cultural values, and material properties. Future research should focus on in-situ performance assessments and explore hybrid techniques that integrate traditional knowledge with modern building science.

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Bima Journal of Science and Technology, Vol. 9(1B) Apr, 2025 ISSN: 2536-6041

DOI: 10.56892/bima.v9i1B.1296