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**Analysis of vernacular dwellings in Iraq:
A comparative study of Erbil citadel and old Akre**

**Irak'taki Geleneksel Konutların Analizi: Erbil Kalesi ve Eski Akre'nin Karşılaştırmalı
İncelemesi**

Riman Mohammed Said Bashir DHUOKI¹
Çiğdem ÇAĞNAN²

ABSTRACT

This research aims to analyze and compare vernacular architecture of Erbil Citadel and Old Akre, two historic settlements located in Iraq's Mediterranean climatic zone, with goal of identifying their embedded sustainable design principles and highlighting their cultural and environmental significance. Employing a qualitative research approach, the study draws upon detailed field observations, and a comprehensive review of academic literature to examine key architectural and structural elements. These include street configuration, dwelling attachment, open space organization, material selection, structural systems, roof construction, façade treatments, and design of doors and windows. Erbil Citadel, designated as a UNESCO World Heritage site, is characterized by compact urban planning, inward-oriented courtyard houses, narrow and meandering streets, and use of traditional materials such as mud brick and timber. These features contribute to thermal comfort, privacy, and efficient land use. In contrast, Old Akre presents an organically evolved terraced layout, adapted to steep mountainous terrain. It utilizes local stone and lime in construction and fosters a strong sense of community through shared rooftops and communal terraces that also serve functional purposes. The comparative analysis reveals how both sites demonstrate context-sensitive responses to climatic, topographical, and social factors,

¹ Yakın Doğu Üniversitesi Lisansüstü Eğitim Enstitüsü, Lefkoşa, Kuzey Kıbrıs. 20244154@std.neu.edu.tr ORCID: 0009-0000-0173-0863

² Yakın Doğu Üniversitesi Mimarlık Fakültesi, Mim. Böl., Lefkoşa, K. Kıbrıs. cigdem.cagnan@neu.edu.tr ORCID: 0000-0002-5506-7849

making efficient use of locally available resources while maintaining cultural continuity. These findings underscore importance of vernacular architecture as a viable framework for contemporary sustainable design. By extracting lessons from traditional practices, the study contributes to discourse on climate-responsive and culturally integrated architecture, advocating for a more inclusive approach to sustainable urban development that draws on historical and regional wisdom.

Keywords: *Vernacular architecture, Sustainable design, Thermal comfort, Mediterranean climate, Iraq.*

ÖZET

Bu araştırma, Irak'ın Akdeniz iklim kuşağında yer alan iki tarihi yerleşim olan Erbil Kalesi ve Eski Akre'nin geleneksel mimarisini analiz etmeyi ve karşılaştırmayı amaçlamakta; bu yapılarda gömülü olan sürdürülebilir tasarım ilkelerini belirlemeyi ve onların kültürel ve çevresel önemini vurgulamayı hedeflemektedir. Nitel bir araştırma yaklaşımı benimsenen çalışmada, detaylı saha gözlemleri ve akademik literatürün kapsamlı bir incelemesi yoluyla temel mimari ve yapısal unsurlar ele alınmıştır. Bu unsurlar; sokak düzeni, konutların yerleşim biçimi, açık alan organizasyonu, malzeme seçimi, yapısal sistemler, çatı yapımı, cephe düzenlemeleri ile kapı ve pencere tasarımlarını kapsamaktadır. UNESCO Dünya Mirası Listesi'ne dâhil edilen Erbil Kalesi; kompakt kent planlaması, içe dönük avlulu evleri, dar ve dolambaçlı sokakları ile kerpiç ve ahşap gibi geleneksel malzemelerin kullanımıyla karakterize edilir. Bu özellikler, termal konfor, mahremiyet ve alanın verimli kullanımı açısından katkı sağlar. Buna karşılık Eski Akre, sarp dağlık araziye uyarllanmış organik olarak gelişmiş bir teras yerleşimine sahiptir. Yapımında yerel taş ve kireç kullanılır; paylaşılan çatı ve teraslar yoluyla topluluk hissini güçlendiren ve işlevsel olarak da kullanılan ortak alanlar oluşturur. Karşılaştırmalı analiz, her iki yerleşimin de iklimsel, topografik ve sosyal koşullara duyarlı çözümler sunduğunu ve yerel kaynakları verimli kullanırken kültürel sürekliliği koruduğunu ortaya koymaktadır. Bu bulgular, geleneksel mimarinin çağdaş sürdürülebilir tasarım için geçerli bir çerçeve sunduğunu vurgular. Geleneksel uygulamalardan elde edilen derslerle, çalışma iklim duyarlı ve kültürel olarak bütünleşik mimarlık tartışmalarına katkı sağlamakta; sürdürülebilir kentsel gelişime yönelik daha kapsayıcı, tarihsel ve bölgesel bilgiye dayalı bir yaklaşımı savunmaktadır.

Anahtar Kelimeler: *Yöresel mimari, Sürdürülebilir tasarım, Termal konfor, Akdeniz iklimi, Irak.*

1. INTRODUCTION

Vernacular architecture is defined by its adaptation to local needs, materials, and cultural traditions, evolving over time to harmonize with the environmental, cultural, social, technological, and historical context of its surroundings. Despite its informal and often unplanned nature, this architectural style has profoundly influenced the development of design and architecture throughout history (Samalavičius & Traškinaitė, 2021). The term "vernacular" comes from the Latin *vernaculus*, meaning "native, domestic, or indigenous," emphasizing its deep-rooted connection to specific regions and communities. Vernacular architecture is characterized by building techniques that utilize locally sourced materials and traditional practices to address the unique needs of a region. Historically, vernacular architecture has been one of the most direct and practical ways to meet human shelter needs, yet it has been largely sidelined by the rise of modern architecture (Kutlu & Bekar, 2023). Recently, however, the growing urgency of sustainability and rising energy costs have prompted a resurgence of interest in this approach. Architects are revisiting regionalism and traditional building methods, recognizing their inherent energy efficiency and ecological benefits. These structures not only reflect the identity and cultural heritage of their communities but also offer sustainable solutions that align with contemporary environmental concerns (Usluer & Çağnan, 2021). A crucial aspect of vernacular architecture is its integration of the building with its surrounding environment. Housing is not merely about the physical structure; it also involves understanding and adapting to the unique climate, geography, and ecosystem of an area. Achieving sustainable housing goals requires an in-depth study of these environmental factors and the creative use of locally available resources and techniques. This approach ensures that housing is not only functional and resilient but also environmentally conscious and cost-effective (Noah & Çağnan, 2021). Furthermore, studying vernacular architecture across diverse environments can provide invaluable insights into the principles of sustainable design. Each region presents unique challenges and opportunities, from extreme climates to scarce resources, and vernacular solutions often embody ingenious adaptations to these conditions. By examining and integrating these time-tested methods with modern innovations, architects and planners can create designs that are not only sustainable but also culturally and environmentally meaningful. This blend of tradition and innovation underscores the enduring relevance of vernacular architecture in shaping a sustainable future for the built environment (Petrucchioli, 2016).

Erbil Citadel is a unique urban site located atop an archaeological mound, formed through the ongoing accumulation and evolution of various civilizations. Unlike other large mound, the evidence of this process in the Citadel has been preserved to the present day, offering a rare glimpse into a cultural evolution that is not found elsewhere.

Erbil Citadel is situated in the heart of Erbil, in Iraq. This expansive urban complex spans nearly 11 hectares and is built on an archaeological mound formed by the buildup of historical layers over at least six millennia. While it rests on a man-made mound, its layout resembles that of a hilltop town, positioned on the relatively flat surface atop the mound (HCECR, 2012; Jasim et al., 2020). Akre City is a historic location in Iraq and serves as the center of the Akre district, one of six districts in Duhok Governorate. Its historic area is recognized as a cultural heritage site in Iraq's national inventory, known as the Atlas of Archaeological Sites in Iraq, published by the Ministry of Culture and Information in 1970 through the Directorate General of Antiquities. The historic area of Akre is believed to have been inhabited as early as the 7th century BC. William Wigram and Edgar Wigram noted in 1922 that Akre is among the oldest settled regions in the area (Ismael & Hasan, 2023).

The research aims to analyze and compare the vernacular architecture of Erbil Citadel and Old Akre, two traditional sites in Iraq, to highlight their sustainable design principles and cultural significance. The study focuses on how these architectural styles adapt to local climatic and topographical conditions, utilize locally available materials, and reflect the region's cultural heritage. To achieve this aim, the study employs a qualitative research approach, utilizing various scientific publications and field analysis to investigate key architectural and structural features that contribute to sustainability. The research examines the elements such as Street Shape and Texture, Dwellings Attachment, Open Space Arrangement of Dwellings, Construction Materials, Main Structural Components, Roof Construction System, Facade Characteristics, and Doors and Windows. By doing so, it advocates for the preservation and adaptation of traditional building practices as a means to address modern challenges in sustainable urban development.

2. LITERATURE REVIEW

To gain a deeper understanding of vernacular architecture, especially in Iraq, it is crucial to review the principles of vernacular architecture both globally and within various Iraqi regions. This exploration sheds light on the similarities and differences in architectural styles, focusing on how they respond to environmental conditions, cultural practices, and local climates.

2.1. Vernacular Architecture and Its Insights from Iraq

In response to growing environmental challenges, there has been a renewed interest in the sustainable qualities of vernacular architecture. This form of architecture is often compared to contemporary buildings, which are typically linked to harmful environmental traits, such as high carbon footprints, excessive energy consumption, and pollution. Vernacular architecture, with its eco-friendly designs, passive technologies, and connection to traditional practices, offers valuable insights for creating more sustainable built environments.

It is no longer seen merely as a nostalgic relic of the past but as a source of knowledge that can guide modern construction (Olukoya & Atanda, 2020). Vernacular architecture, shaped by cultural, local, and regional influences, is created without formal professional expertise. It adapts to the local climate, available materials, and traditional craftsmanship while embodying the culture and way of life of the community. This architecture uses locally sourced materials and methods known to local craftsmen, helping define regional identity and distinction (Hu, 2023). As climates vary across regions, vernacular architecture responds to these conditions by incorporating techniques that improve energy efficiency and thermal performance. These methods, such as passive cooling, heating, and ventilation, align with bioclimatic design principles. By using natural materials and environmental solutions, vernacular architecture achieves a harmonious balance between sustainability and functionality (Raof et al., 2020).

Iraq's traditional houses vary greatly across its regions, reflecting the country's diverse climate and local resources. The climate spans from a hot desert environment, where temperatures exceed 50°C, to colder mountainous areas with temperatures dropping as low as -10°C. Vernacular architecture in Iraq adapts to these varying conditions, with buildings made from materials like natural limestone, mud-brick, and reed, chosen for their suitability to the local environment. In central and northern Iraq, for example, homes often feature thick mud-brick or limestone walls for climate adaptation and natural fortifications for security. These houses reflect cultural values, blending with the surroundings while fostering tight-knit communities. The settlement patterns and building forms in these areas align with the microclimatic conditions and the collective skills of the community, showcasing the region's environmental sustainability (Rostam, 2017). In southern Iraq, the marshlands present unique physical characteristics, where dwellings are built on artificial floating islands made of reeds and mud. These homes are reinforced annually to protect against flooding. The marshlands are rich in biodiversity, home to many plant and animal species, and the communities here have practiced sustainable resource management for thousands of years. This lifestyle reflects a deep connection to the wetland environment, with traditional resource conservation methods passed down through generations. Overall, the vernacular communities of Iraq offer effective, sustainable solutions to the region's topographic and climatic challenges, demonstrating a harmonious cultural adaptation to their surroundings through shared building expertise (Znad, 2024).

2.2. Sustainable Architecture

The term "sustainability" encompasses a wide range of goals that often overlap with concepts like green architecture, environmental or ecological design, sustainable building, and other related terms, sometimes being used interchangeably.

Sustainability in architecture can also be defined by contrasting it with its opposite: it involves innovative thinking, processes, and methods that move away from conventional approaches in the operation, design, construction, and planning of the built environment, which often overlook wider social, economic, and environmental factors. Sustainable architecture represents a design approach aimed at reducing the environmental impact of buildings, optimizing energy efficiency, and improving the health and well-being of their occupants (Aliamin, 2021). One of the key principles of sustainable architecture is reducing resource consumption. This involves maximizing the efficient use of resources and materials throughout a building's lifecycle, from its construction to eventual demolition. Sustainable design focuses on incorporating recycled, reclaimed, and renewable materials to decrease dependence on raw resources. Sustainable architecture also prioritizes efficient water usage, significantly reducing the consumption of vital resources. Another essential element of minimizing environmental impact is the reduction of pollution and waste. Sustainable architecture seeks to minimize the environmental footprint of buildings by emphasizing pollution prevention and waste reduction (Iwuanyanwu et al., 2024). In sustainable architecture, energy efficiency is realized through a combination of passive design approaches. These approaches focus on optimizing factors like thermal mass, building orientation, and natural ventilation to reduce energy consumption for cooling, heating, and lighting. For example, placing windows strategically maximizes natural daylight, cutting down the need for artificial lighting. Additionally, leveraging thermal mass and prevailing winds in the design helps regulate indoor temperatures. A passive design that utilizes locally-driven techniques aims to create comfortable, energy-efficient, and affordable buildings, much like vernacular architecture. Both approaches emphasize sustainable design practices tailored to local conditions and resources, focusing on minimizing energy consumption while ensuring livability and cost-effectiveness (Gil-Ozoudeh et al., 2022).

3. METHODOLOGY

This study employs a qualitative research approach, integrating field observations, visual documentation, and a review of scientific publications to examine the vernacular architecture of Erbil Citadel and Old Akre. The analysis criteria were carefully selected based on their relevance to sustainable architectural principles and their recurring presence in vernacular building practices. These criteria were also informed by literature on bioclimatic and climate-responsive design, which emphasizes passive environmental strategies, material efficiency, spatial organization, and community integration.

The selected architectural and structural analytical categories are Street Shape and Texture, Dwellings Attachment, Open Space Arrangement of Dwellings, Construction Materials, Main Structural Components, Roof Construction System, Façade Characteristics, and Doors and Windows, allow for a comprehensive assessment of architectural responses to climate, topography, and social needs. Each of these elements contributes to sustainable performance by enhancing thermal comfort, resource use efficiency, and cultural resilience.

By aligning the analysis with sustainability-focused indicators found in vernacular and contemporary ecological design research, the study provides a framework that not only documents historical architecture but also extracts lessons applicable to modern sustainable development (Figure 1).

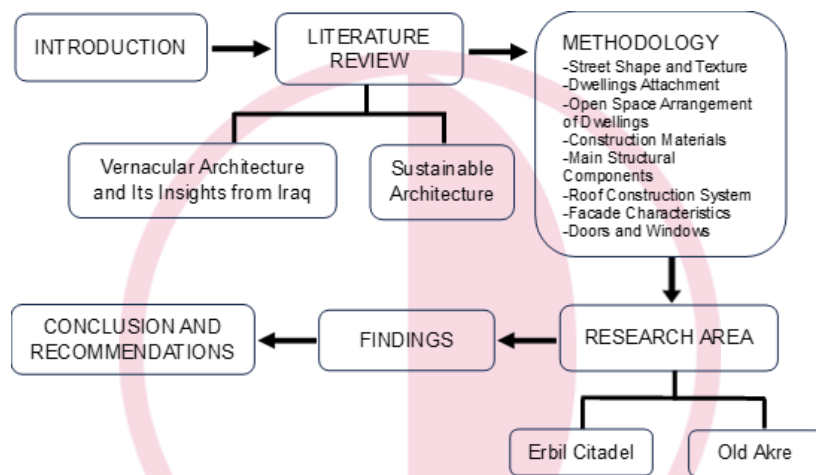


Figure 1. Research structure chart.

4. RESEARCH AREA

Erbil Citadel and Old Akre, found in different regions of Iraq, experience same unique climates based on their geographical locations (Figure 2). Erbil Citadel is situated on a mound, while Old Akre is located in a mountainous area.



Figure 2. Iraq map showing location of Erbil Citadel and Old Akre (Ali et al., 2016).

4.1. Erbil Citadel

Erbil Citadel is situated on a man-made mound, and its design resembles that of a hilltop settlement, located on the relatively level surface at the top of the mound (Figure 3). Most of the Citadel is currently occupied by residential homes, along with a few public and religious buildings. Historical records indicate that there were once additional administrative, religious, and military structures, including fortification walls that have since vanished. This layout contrasts with other fortified citadels that have preserved their ancient structures, complete with massive enclosing walls. Most historic buildings in the Citadel date from the mid-19th to the early 20th century, though some are older, originating from the mid-18th century onward. The historic architecture primarily consists of residential homes but also includes several mosques, a hammam, and other religious or social buildings, such as takiyas (used for gatherings of Sufi communities) and diwakhanas (houses for hosting guests or community meetings) (Mahmood, 2019), (Figure 4).



Figure 3. Erbil Citadel (HCECR, 2012b)



Figure 4. The outside facades of Citadel (HCECR, 2012a)

Erbil's climate is categorized as Mediterranean according to the Köppen climate classification. This means the city experiences mild, wet, and humid winters, alongside long, extremely hot summers. January is the wettest month, while no rainfall occurs between June and September. (Table 1) provides an overview of Erbil's climate conditions throughout the year. July sees the highest temperatures, reaching up to 42°C, while January has the minimum temperature recorded at 1.5°C (Sulaiman et al., 2022).

Table 1. Climatic Data of Erbil Citadel (Climate-Data, 2024).

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	6.3 °C (43.4) °F	8.3 °C (46.9) °F	12.5 °C (54.6) °F	18 °C (64.4) °F	24.6 °C (76.2) °F	31.2 °C (88.1) °F	35 °C (94.9) °F	34.6 °C (94.3) °F	29.4 °C (84.8) °F	22.7 °C (72.8) °F	13.4 °C (56.1) °F	8.2 °C (46.8) °F
Min. Temperature °C (°F)	1.4 °C (34.6) °F	2.6 °C (36.7) °F	6.1 °C (43) °F	11 °C (51.8) °F	16.6 °C (61.9) °F	22.4 °C (72.4) °F	26.2 °C (79.1) °F	25.9 °C (78.6) °F	21.1 °C (70) °F	16.1 °C (61) °F	7.8 °C (46.1) °F	3.3 °C (38) °F
Max. Temperature °C (°F)	12 °C (53.6) °F	14 °C (57.2) °F	18.5 °C (65.4) °F	24.3 °C (75.8) °F	31.2 °C (88.2) °F	38.1 °C (100.6) °F	41.9 °C (107.4) °F	41.7 °C (107.1) °F	36.7 °C (96) °F	29.5 °C (85.1) °F	19.8 °C (67.6) °F	14 °C (57.2) °F
Precipitation / Rainfall mm (in)	104 (4)	96 (3)	91 (3)	64 (2)	22 (0)	1 (0)	0 (0)	0 (0)	1 (0)	28 (1)	64 (2)	89 (3)
Humidity(%)	68%	67%	59%	49%	32%	19%	17%	17%	21%	31%	51%	64%
Rainy days (d)	8	7	7	6	3	0	0	0	0	2	5	6
avg. Sun hours (hours)	7.0	7.9	9.6	11.3	12.6	13.1	12.9	12.2	11.2	10.0	8.5	7.1

Street Shape and Texture: The urban layout of Erbil Citadel features an ovoid design defined by a complex network of narrow, winding streets that radiate from a central entrance. Major alleys extend outward from the southern Grand Gate, interwoven with a natural web of smaller pathways leading to more secluded residences. The irregular, twisting streets and unevenly shaped plots reflect a gradual, organic development process, characteristic of settlements that have evolved over time. The streets transition seamlessly from wider thoroughfares to narrower, more private zones near residential areas, often ending in cul-de-sacs or semi-private spaces. Public spaces naturally emerge at intersections, creating a dynamic hierarchy of spatial organization (Abdulkareem, 2012), (Figure 5).



Figure 5. Map showing street shape and texture in Citadel (HCECR, 2012b).

Dwellings Attachment: The typical house layout often includes two adjacent rooms, each with its own entrance, designed for both functionality and privacy. These houses are commonly attached along their sides or backs, with entrances opening directly onto the street. In some cases, multiple entrances lead to a shared courtyard or access point, forming small, community-oriented cul-de-sacs. The structures are usually one or two stories tall, and many features semi-basements that not only enhance privacy but also provide a sense of enclosure and thermal comfort (Mahmood, 2019), (Figure 6).



Figure 6. The houses are attached in Citadel (HCECR, 2012a).

Open Space Arrangement of Dwellings: The houses in Erbil Citadel are arranged in compact blocks, frequently sharing walls with neighboring structures to maximize space and enhance communal cohesion. Each house features a courtyard, a vital element of the design that provides natural ventilation, light, and a private outdoor space for the household. These courtyards are sometimes entirely enclosed by buildings, creating a secluded environment, but more commonly, they are flanked by rooms on two sides and bordered by the walls of neighboring houses or the adjacent alley. The typical layout includes two adjacent rooms, each with its own entrance, offering functional and flexible living spaces (Figure 7, 8). Entrances generally face the street, ensuring accessibility while maintaining a balance between openness and privacy. This arrangement reflects the traditional architectural approach, emphasizing both practical use of space and the cultural need for privacy and family-centered living (Gandreau & Moriset, 2013).

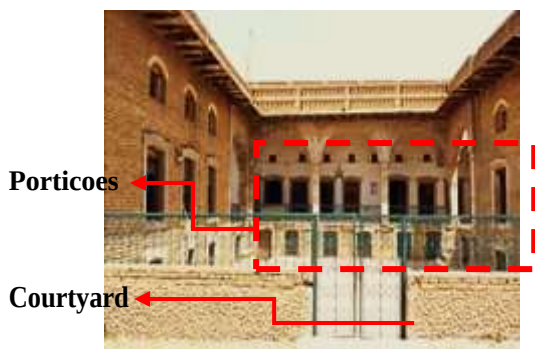


Figure 7. Erbil Citadel dwelling with courtyard (Gandreau & Moriset, 2013).



Figure 8. Inside Sheikh Jamil Afandi house courtyard (Mirani, 2010).

Construction Materials: These historic buildings are predominantly constructed from fired brick, typically bonded with mud mortar, a method that reflects the traditional craftsmanship of the region. In the Citadel, fired brick masonry with mud mortar, occasionally mixed with lime for added durability, is a hallmark of the architectural style. Modern additions, introduced in the late 20th century, incorporate more advanced brickwork techniques, blending historical aesthetics with contemporary construction methods. Timber frameworks are widely used for roofs and floors, showcasing a practical and sustainable design approach, while some porticoes are adorned with visible timber columns, adding to the architectural charm and structural integrity of the buildings (Gandreau & Moriset, 2013), (Figure 9, 10).



Figure 9. Dwellings construction materials in Citadel (Al-Yaqoobi, 2012).



Figure 10. Timber columns of porticoes in Citadel (HCECR, 2012b).

Main Structural Components: Many houses incorporate remnants of older structures, with no single building representing a single construction period. This layering of construction over existing structures and foundations reflects a continuous and dynamic process of regeneration, characteristic of an archaeological mound. The walls of the Citadel showcase a distinctive construction technique, featuring two outer layers encasing an inner rubble core, all bonded with mud mortar (Figure 11, 12). The brickwork is often irregular, with lateral walls built in the same manner but thinner, maintaining structural coherence. Wider, tile-like bricks strategically link the outer layers to the core, demonstrating a thoughtful balance between strength, flexibility, and resilience to environmental pressures. This method highlights the adaptive reuse of materials and the enduring ingenuity of the region's architectural traditions (HCECR, 2012b).



Figure 11. Section of wall in Citadel (HCECR, 2012b).



Figure 12. Wall construction in Citadel (Palumbo, 2011).

Roof Construction System: In the Erbil Citadel, the roofs are predominantly flat and supported by round timber beams, a design that ensures both practicality and aesthetic appeal. High-status homes often utilize poplar planks for their roofing, reflecting the wealth and status of the inhabitants, while traditional constructions rely on unshaped oak coppice poles, showcasing the resourcefulness of local builders. Above the beams, layers of compacted mud and lime are carefully applied, providing additional insulation and stability. This layered roofing system rests on woven matting and reeds, which further contribute to the building's thermal efficiency, keeping interiors cool in summer and warm in winter. This approach to roofing illustrates a blend of functionality and tradition, allowing for adaptation to the region's climate while maintaining the integrity of the citadel's architectural heritage (Abdulkareem, 2012), (Figure 13, 14).



Figure 13. Dwelling roof of Citadel (HCECR, 2011).



Figure 14. Dwelling roof of citadel restored in 1980 (Mirani, 2010).

Facade Characteristics: Today, the perimeter of the Citadel is defined by house façades built on or in front of earlier fortifications. These façades are closely aligned, creating the impression of a formidable fortress when viewed from outside. The earliest homes are noted for their intricately decorated brickwork. In later constructions, the façade may be shaded by a colonnade or porticoes, some of which have wooden columns with decorative capitals, while larger houses may feature an arcade with columns and alabaster arches.

The facades of Erbil Citadel were intentionally left unplastered and unwhitewashed, preserving the original appearance of the construction materials. The mud brick serves as the primary building material for the facades, highlighting the traditional construction methods that are well-suited to the local environment (Al-Shwani, 2011), (Figure 15, 16).

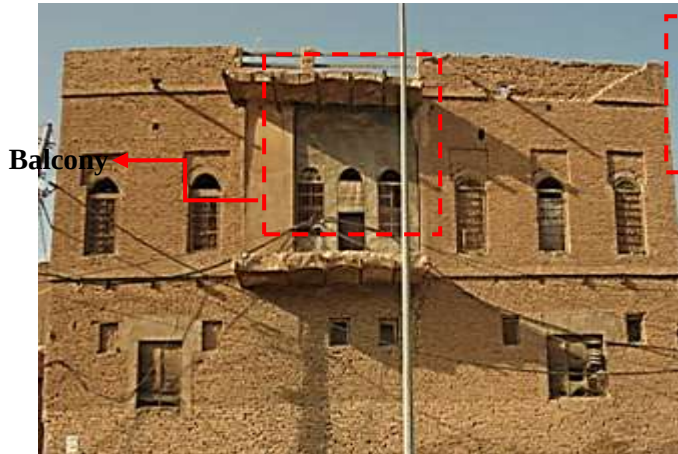


Figure 15. Dwelling facades of Citadel (Al-Shwani, 2011).



Figure 16. Decoration in Citadel (Cravero, 2011).

Doors and Windows: The doors and windows in Erbil Citadel vary in size, reflecting the unique characteristics of each dwelling. Typically, rectangular or arched, their shapes contribute to the architectural charm of the structures. The windows are often enhanced with decorative wrought metal grilles at the front, which not only serve functional purposes, such as security and ventilation, but also add an ornamental touch (Figure 17). These features further accentuate the historic appeal of the buildings, blending aesthetic elegance with practicality in the citadel's design (Al-Shwani, 2011).



Figure 17. Design of doors and windows in Citadel (HCECR, 2012b)

4.2. Old Akre

Throughout history, various significant powers have ruled the area, including the Medes, Assyrians, Romans, Islamic empires, and the British, all of whom have left a rich legacy. The city features the emblem of the Bahdinan Emirate, which governed it from 1376 to 1843. The historic area of Akre was established on the steep hillside beneath the old castle, overlooking the orchards in the valley. It includes three residential neighborhoods: the Jewish neighborhood, Gorava, and Qapaki, along with the historic bazaar. In the historic area, the buildings are organically arranged on the hillside, creating a terraced appearance (Spät, 2019), (Figure 18).



Figure 18. Old Akre (Municipality of Akre, 2012).

Akre is renowned as the City of Four Seasons due to its distinct experience of all four seasons. The city has a Mediterranean climate according to Köppen climate classification, characterized by hot summers and rainy winters. Summers are warm, with maximum temperatures reaching up to 38°C, while winters are relatively cold, often dropping below freezing, and snowfall is common (Table 2). The Mediterranean Sea and the region's mountainous terrain play a significant role in bringing rain to Akre (Ismael, 2015).

Table 2. Climatic Data of Old Akre (Climate-Data, 2024).

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	2.1 °C (35.8) °F	4.2 °C (39.6) °F	8.7 °C (47.6) °F	13.9 °C (56.9) °F	19.9 °C (67.9) °F	27 °C (80.5) °F	31.2 °C (88.1) °F	30.9 °C (87.7) °F	25.8 °C (78.4) °F	18.8 °C (65.8) °F	10 °C (50.1) °F	4.3 °C (39.8) °F
Min. Temperature °C (°F)	-2.5 °C (27.5) °F	-1.1 °C (30) °F	2.5 °C (36.4) °F	7 °C (44.6) °F	12.1 °C (53.8) °F	17.8 °C (64) °F	22.1 °C (71.8) °F	22 °C (71.5) °F	17.4 °C (63.3) °F	12.1 °C (53.7) °F	4.5 °C (40.2) °F	-0.3 °C (31.4) °F
Max. Temperature °C (°F)	7.6 °C (45.7) °F	9.8 °C (49.7) °F	14.5 °C (58.1) °F	19.9 °C (67.8) °F	26.4 °C (79.5) °F	33.9 °C (93) °F	38.1 °C (100.6) °F	38.1 °C (100.6) °F	33 °C (91.4) °F	25.4 °C (77.8) °F	16 °C (60.8) °F	10 °C (50) °F
Precipitation / Rainfall mm (in)	149 (5)	140 (5)	142 (5)	104 (4)	39 (1)	3 (0)	0 (0)	0 (0)	1 (0)	39 (1)	93 (3)	137 (5)
Humidity(%)	71%	71%	66%	62%	47%	26%	21%	20%	24%	39%	58%	68%
Rainy days (d)	8	8	9	8	5	1	0	0	0	3	5	7
avg. Sun hours (hours)	6.4	7.0	8.6	10.8	12.4	13.2	13.0	12.2	11.2	9.8	8.1	6.6

Street Shape and Texture: Public areas emerge naturally at intersections, creating a dynamic spatial hierarchy that reflects the organic growth of the community. The structures are interconnected by a complex network of narrow, zig-zag alleys, some of which lead to cul-de-sacs, adding an element of discovery and surprise for those navigating the space. The historic buildings, often of significant architectural value, are connected vertically by staircases, which offer views of the surrounding area while contributing to the layered spatial experience (Figure 19, 20). As user explore, the network of alleys transitions unpredictably from lively public spaces to more intimate, private areas, blurring the boundaries between public and private life (Ismael, 2024).



Figure 19. Map showing street shape and texture in Old Akre (Ismael & Hasan, 2023).



Figure 20. Staircases as vertical movement in Akre (Malaika & Raswol, 2014).

Dwellings Attachment: Because of the terraced layout, it's common for residents to engage in activities on the roofs of the houses below, fostering a sense of shared space and community. Most of these buildings are one or two stories tall, and at times, multiple houses share the same roof, creating informal communal areas. Despite the presence of lower houses, the design ensures that the views of those above are never obstructed, promoting a sense of openness. This effective use of space fosters social cohesion and interaction, reflecting the trust among residents. The terraced design of the historic buildings not only maximizes available space but also enhances the area's sense of community, highlighting the value and significance of Akre's historic area as a unique and well-integrated urban environment (Ismael, 2024), (Figure 21).



Figure 21. Dwellings arranged on hillside (Ismael, 2015).

Open Space Arrangement of Dwellings: In Old Akre, the terraced layout defines open spaces where the roofs of lower-level homes serve as balconies or terraces for the homes above (Figure 22). This innovative design maximizes limited space and allows residents to enjoy communal and private areas simultaneously. The linear organization of these terraces integrates open space into the natural slope of the terrain, creating a smooth transition between public and private realms. This seamless blend fosters a sense of interconnectedness among residents, enhancing the social fabric of the area while preserving the intimate, communal atmosphere of the historic district (Malaika & Raswol, 2014).



**Terraced
Layout**

Figure 22. Old Akre dwellings with terraced layout (Ismael, 2024).

Construction Materials: The traditional materials used in Akre's historic architecture, including natural and curved stones, lime, and wood, are carefully chosen to harmonize with the local environment. Natural stones, curved to suit the terrain, form the foundation of many structures, while lime is used for its durability and insulation properties, and wood adds warmth and flexibility. This reliance on locally available materials not only ties the architecture closely to its surroundings but also emphasizes sustainability and functionality. The materials' natural origins reflect Akre's commitment to maintaining a built environment that respects both its cultural heritage and the demands of its landscape (Malaika & Raswol, 2014), (Figure 23, 24).



Figure 23. Used materials for construction in Old Akre (Ismael & Hasan, 2023).



Figure 24. Lime plaster for interior finishes in Old Akre (Ismael & Hasan, 2023).

Main Structural Components: The thick masonry walls of Akre are constructed using local natural stones, sometimes bonded with mud mortar, providing strength and stability (Figure 25). These materials are well-suited to the region's climate, offering thermal mass to regulate indoor temperatures. Lime plaster is typically used to finish the interior, creating a smooth, breathable surface that enhances durability while allowing the structure to maintain moisture balance. This simple yet effective construction system not only reflects the traditional building practices of the area but also ensures a comfortable living environment, blending practicality with the region's architectural heritage (Ismael, 2015).



Figure 25. Wall construction of Akre (Spät, 2019).

Roof Construction System: The flat roofs of Old Akre are supported by round timber beams, which provide a sturdy framework for the structure. Unshaped oak coppice poles are laid over the beams, creating a natural, yet resilient surface. To enhance weather resistance and thermal comfort, a layer of reeds and matting is first placed, followed by compacted mud and lime. This layered roofing system effectively insulates the interior, protecting it from harsh weather conditions while maintaining a comfortable temperature inside. The combination of these traditional materials reflects a deep understanding of the local environment and an emphasis on sustainability in building practices (Ismael & Hasan, 2023), (Figure 26, 27).



Figure 26. Dwelling roof of Akre (Ismael, 2015).



Figure 27. Roof intergration with wall of dwelling in Akre (Ismael & Hasan, 2023).

Facade Characteristics: In Old Akre, the facades prominently feature stone as the foundational material, underscoring its natural availability and durability. The use of local stone not only contributes to the strength and stability of the buildings but also enhances the aesthetic harmony with the surrounding landscape. Some dwellings in the area feature balconies, adding verticality to the structures while offering residents outdoor spaces with scenic views. These balconies blend seamlessly with the architectural style, reflecting the traditional design principles of integrating private and communal spaces within the historic context of Akre (Ismael, 2024), (Figure 28).

Flat Roof



Balcony

Figure 28. Dwelling facade of Akre (Ismael & Hasan, 2023).

Doors and Windows: The doors and windows in Old Akre display variations in size, reflecting the individuality of each dwelling and contributing to the unique character of the neighborhood. Their shapes are typically rectangular or arched, enhancing the architectural appeal. Many windows are further embellished with decorative wrought metal grilles at the front, serving both functional and ornamental purposes (Figure 29, 30). These metal details not only provide added security but also contribute to the aesthetic richness of the buildings, highlighting the historic craftsmanship and adding to the overall timeless beauty of Old Akre's architectural landscape (Malaika & Raswol, 2014).



Figure 29. Different types of windows in Old Akre (Ismael, 2015).

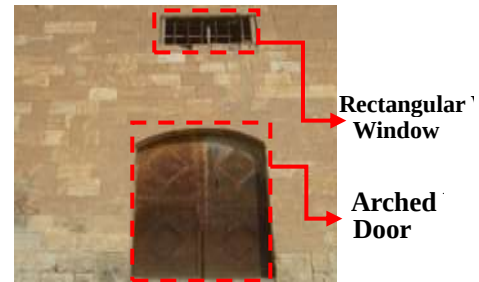


Figure 30. Door of dwelling in Old Akre (Ismael, 2015).

5. FINDINGS

The comparative analysis of Erbil Citadel and Old Akre reveals distinct architectural and urban design features shaped by their environmental, topographical, and cultural contexts (Table 3). In terms of street layout, Erbil Citadel exhibits a meandering pattern, with streets narrowing near residential zones and culminating in cul-de-sacs or semi-private spaces. Public nodes are located at intersections, indicating a hierarchical spatial arrangement. In contrast, Old Akre's narrow, zigzagging alleys and staircases reflect the adaptation to steep terrain and support vertical circulation, linking different elevation levels across the settlement. Dwelling attachment in Erbil is characterized by structures connected at the sides or backs, often with shared entrances or courtyards, contributing to spatial compactness. In Old Akre, houses are arranged in terraces along the hillside, with overlapping rooftops and shared open spaces. This configuration allows efficient land use and supports communal interaction in a topographically constrained environment. Regarding open space, Erbil Citadel dwellings typically include courtyards enclosed or partially bordered by adjacent buildings. These courtyards provide natural light, ventilation, and private outdoor areas. In Old Akre, the sloped layout results in the rooftops of lower homes serving as open terraces for the upper homes, forming a layered system of semi-private outdoor areas. In terms of construction materials, Erbil Citadel primarily uses fired brick bonded with mud mortar, occasionally reinforced with lime. Timber is used for flooring and roofing structures. Old Akre employs local stone, lime, and wood, materials that respond effectively to the region's climatic and geological conditions. Structural systems differ accordingly. Erbil Citadel walls typically consist of double layers with a rubble-filled core. The construction method enhances structural stability and insulation. In Old Akre, thick stone masonry walls bonded with mud mortar and finished with lime plaster provide both thermal mass and structural integrity. Both settlements use flat roofs supported by timber beams. In Erbil, layers of reeds, matting, and compacted mud with lime are applied for insulation. Old Akre follows a similar system, demonstrating consistency in climate-responsive design despite geographic differences.

Façade treatments in both cases are left unplastered, exposing the natural texture of the building materials mud brick in Erbil and stone in Akre. Some buildings in both locations include balconies, although these are more commonly observed in Akre due to the terraced terrain. Doors and windows in both settlements vary in size and are typically rectangular or arched. Decorative wrought-iron grilles are present, serving both security and ventilation functions while contributing to visual coherence.

Table 3. Comparison analysis of Erbil Citadel and Old Akre vernacular architectural characteristics.

Comparison Elements	Erbil Citadel	Old Akre
Street Shape and Texture	Meandering streets with transitions from wide to narrow, leading to cul-de-sacs. Public spaces at intersections	Narrow, winding alleys with sudden shifts from public to private spaces. Vertical connections via staircases
Dwellings Attachment	Houses connected at sides or backs, with shared street entrances and cul-de-sacs. One or two stories, semi-basement	Terraced houses on hillside, often with shared rooftops. One or two stories, with communal roof use
Open Space Arrangement of Dwellings	Houses feature courtyards bordered by structures, often with neighboring walls	Linear terrace dwellings built along the slope, with shared roof spaces for open areas
Construction Materials	Fired brick masonry with mud mortar, occasional lime; timber frameworks for roofs and floors	Natural stone, lime, and wood used in construction
Main Structural Components	Two outer layers with a rubble core held by mud mortar. Irregular brickwork and thinner lateral walls	Thick masonry walls with natural stones, mud mortar, and lime plaster interior

Table 3. Comparison analysis of Erbil Citadel and Old Akre vernacular architectural characteristics (cont.).

Roof Construction System	Flat roofs supported by round timber beams, compacted mud/lime mixture, reeds, and woven matting	Flat roofs supported by round timber beams,
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		compacted mud/lime, with reeds and matting
Facade Characteristics	Unplastered, unwhitewashed facades revealing mud brick. Some dwellings feature balcony	Unplastered, unwhitewashed facades revealing stone. Some dwellings feature balcony
Doors and Windows	Varied sizes and shapes (rectangular or arched) with decorative wrought metal on windows	Varied sizes and shapes (rectangular or arched) with decorative wrought metal on windows

The objective comparison indicates that both sites apply region-specific architectural strategies that respond to environmental constraints and cultural practices. These findings form the basis for further assessment of sustainability performance and architectural resilience in vernacular settlements.

6. CONCLUSION AND RECOMMENDATIONS

This comparative study of vernacular architecture in Erbil Citadel and Old Akre highlights how traditional built environments respond effectively to climatic, topographical, and social conditions using locally available materials and context-sensitive design approaches. While the two sites differ in geography, one a man-made mound, the other a mountainous hillside, they demonstrate shared principles of sustainability through passive environmental strategies, community-oriented planning, and efficient material use. Erbil Citadel presents an inward-oriented layout, using courtyard-based housing, compact urban form, and thermally adaptive materials such as mud brick and timber. Old Akre, with its terraced structure, integrates seamlessly with the landscape, applying stone and lime construction and shared rooftop spaces to optimize land and social interaction. These findings confirm the viability of vernacular architecture as a foundation for sustainable urban development. More importantly, the study contributes to the development of a methodological framework for sustainable design by identifying and analyzing architectural criteria such as spatial organization, material selection, and construction systems that directly influence environmental performance.

These elements can inform the adaptation of vernacular principles in contemporary architecture, particularly in regions with similar climatic or topographical conditions. Based on the findings, the following recommendations are proposed to support the formation of a sustainable design methodology:

- Establish a Sustainability Framework: Develop a structured set of criteria based on vernacular features such as passive ventilation, local materials, compact spatial organization, and social integration to guide sustainable architectural assessment and design in similar climatic and geographic contexts.
- Adapt Vernacular Strategies into Contemporary Design: Translate key findings into practical design principles for modern architecture, emphasizing thermal performance, material efficiency, and the use of communal open spaces.
- Integrate into Architectural Education: Include vernacular architecture case studies and sustainability-based design thinking in academic curricula to strengthen awareness of climate-responsive and culturally relevant practices.
- Encourage Pilot Applications and Practice-Based Research: Promote collaboration between researchers, architects, and communities to apply vernacular principles in experimental sustainable housing or urban regeneration projects.
- Support Conservation through Policy: Advocate for planning policies that protect vernacular heritage while encouraging its adaptation to current environmental standards, ensuring the continuity of traditional techniques within sustainable development frameworks.

By grounding future sustainable design practices in the proven principles of vernacular architecture, this study offers a transferable methodological base for resilient, context-specific architectural solutions in Iraq and beyond.

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