Sustainability Analysis of Climate Responsive Elements in Erbil Vernacular Architecture

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Abstract: This study conducts a sustainability analysis of the environmental impacts of climate responsive elements on Erbil vernacular architecture. Data was gathered from field survey, including taking photographs and measuring the dimensions of analyzed samples and from previous studies related to the climatic responsive elements in different regions. The outcomes of this study can be used to adapt the strategies used in vernacular architecture to contemporary buildings, to adapt them to the environment in Erbil and similar settings.

Keywords: Erbil, Vernacular Architecture, Houses, Courtyards, Sustainable Architecture, Hot-Arid Climate

1. Introduction

The most pressing challenge to humanity is increasing climate change due to the use of fossil fuels in energy. This problem is particularly relevant to structural engineers and architects, as the construction industry and human buildings consume incredible amounts of energy. In the Middle East and North Africa (MENA) the impacts of climate change are particularly severe in terms of increasingly hot and arid extremes of temperature. The legacy architectural conventions (i.e., since the 20th century) of reinforced concrete structures with high thermal mass, along with other related factors, mean that the region has very high cooling loads, contributing to further escalation of global warming due to increased electrical energy consumption to cool buildings.

Construction and buildings comprise 40% of all human energy consumption, of which 20% is due to construction itself, and 80% is due to the operation (i.e., habitation) of buildings (Liu et al., 2010). The increasingly critical impacts of global energy consumption, including environmental pollution in addition to climate change, and the increasing realization of the finite nature of fossil fuels since the oil crisis of the 1970s, have caused governments and industries to search for new solutions and concepts, including in construction, and increasing consumer demand for and legislative requirements of sustainability parameters have come to be a central concern of architectural design (Özen, 1999).

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Erbil is an ancient city in the Kurdistan Federal Region of Iraq. Its historic Citadel is currently undergoing major international preservation efforts to safeguard its remaining aesthetics and heritage, but in general, the city replicates the general MENA pattern of sprawling urbanization and reinforced concrete structures with no climate responsive properties. In the built environment of contemporary Erbil, most recently built houses lack ecological or environmental considerations, and consequently cannot provide a comfortable internal temperature, thus the inhabitants use mechanical instruments for cooling (and, to a lesser extent, heating in winter) in order to create more amenable conditions, increasing the energy consumption of buildings. This is in contrast to the elements or strategies used in traditional vernacular houses as solutions to local climatic problems, which have disappeared in contemporary buildings, despite being inherently simple and relatively cheap. Thus, the study explores such features and considers their potential inclusion as elements in new buildings, and in terms of retrofitting possibilities for existing structures to improve living conditions and reduce cooling loads.

The purpose of this study is to find out the environmentally used strategies, which are used in Erbil vernacular houses, their purpose of using and the techniques used during implementation. Analyzing these strategies for use in modern buildings with simple modifications can be applied without undermining the essential functionality of dwellings, with architectural design strategies to provide a comfortable indoor temperature with sustainable design strategies, materials, and techniques. This paper considers micro climatic elements inside each settlement block and within individual dwellings. It should be noted from the outset that Erbil is categorized as a dry summer subtropical region, so the vernacular houses must be studied according to climatically dry, hot conditions.

2. Erbil Vernacular Architecture

2.1 The Citadel Mound

The Citadel mound (Fig. 1.) is shaped like a shallow bowl, with the highest points on the north-east and south-west edges. It is up to 32 meters high, with 11 hectares enclosed by perimeter façade, measuring 15 hectares at the base (HCECR, 2012). The mound is entirely man-made, and the surface level represents the result of the accumulation of historical layers over millennia, with replacement houses built on the leveled remains of predecessors. Consequently, it is assumed that large voids exist under the existing mound, with extensive archeological remains.

Figure 1: Aerial view of Erbil Citadel Source: Google Earth (2015)

2.2 Alleyways

Within the Citadel there is a network of narrow alleyways historically developed for use by pedestrians, horses, and donkeys etc., unsuitable for modern vehicles. The alleyways differ in width according to their functions. Fig. 2. shows the different widths of alleyways and streets within the town.

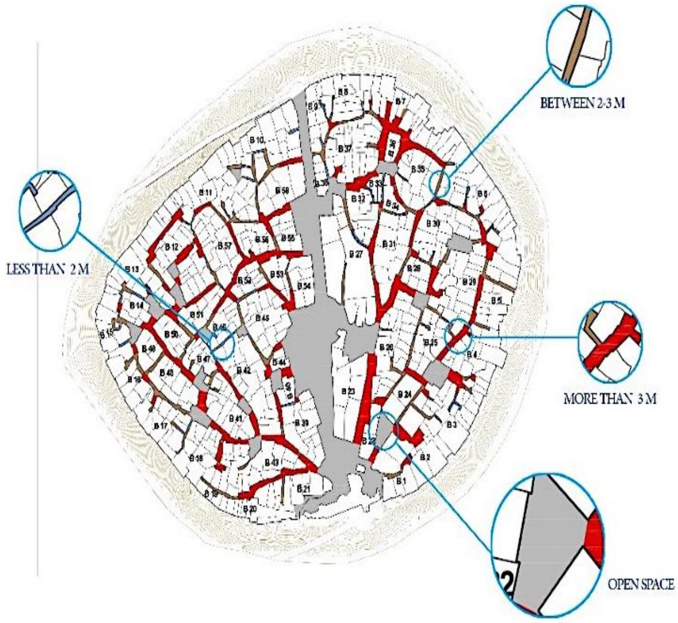

Figure 2: Erbil Citadel town alleyways

3. Sustainability Analysis of Erbil Vernacular Architecture

The most popular environmental strategies used in the built environment in hot regions are town planning, building orientation and form, wind factor, natural ventilation, solar shading, natural lighting, high thermal mass and material insulation, evaporative cooling and plants, and earth cooling (Canas & Mart, 2004; Nguyen et al., 2011), as explored below with reference to Erbil in the following sections.

3.1 Town Planning

As mentioned previously, the Citadel comprises a shallow, bowl-shaped mound of 32 m height, extending from a 15-hectare base to an 11-hectare plateau. The outside walls of the outer houses around the sides of the summit plateau comprise the perimeter walls of the Citadel itself, which is a distinctive characteristic of Erbil Citadel.

The elevation of the mound above the surrounding plateau helps it catch air flows from all surrounding directions. The shallow or oval shape of the mound helps provide the wind to the town in all sides, and protects it from wind pressure, while giving an aesthetic view to the Citadel.

The narrow alleys provide shading during the day and provide cool air flow (Keshtkaran, 2011). The overhangs and canopies of dwellings provide shading over the alleys (Indraganti, 2010), and their zigzagged courses reduce wind velocity and diffuse the wind to prevent the formation of wind tunnels (Abdulkareem, 2012) (Figure 2).

3.2 Building Orientation and Form

The entrance's shape limits visibility from the street into the house, protecting the family's privacy, in addition to helping block the wind (Abdulkareem, 2012). Most of the houses are closed to the outside opened to the inside, which means they central, enclosed courtyards onto which most rooms open, which provides a private, open space enclosed by the rooms and perimeter walls of the house. The courtyards have very important thermal functions in hot areas, particularly when they contain a pool or fountain, providing a cool inside zone away from the prevailing heat and aridity outside (Roodgar et al., 2011). This is an architectural feature used for passive cooling of houses throughout MENA and the Northern Mediterranean, often with hot air rising from the courtyard during midday to induce latent cooling through convection air flow, and cool air descending on the courtyard at night and flushing through the surrounding chambers (Keshtkaran, 2011).

3.3 Wind Factor

According to data obtained from Erbil Directorate of Meteorology, the prevailing wind direction is from the southwest during the hot months, with common wind from the east, south-east, south, and south-west (Figure 3).

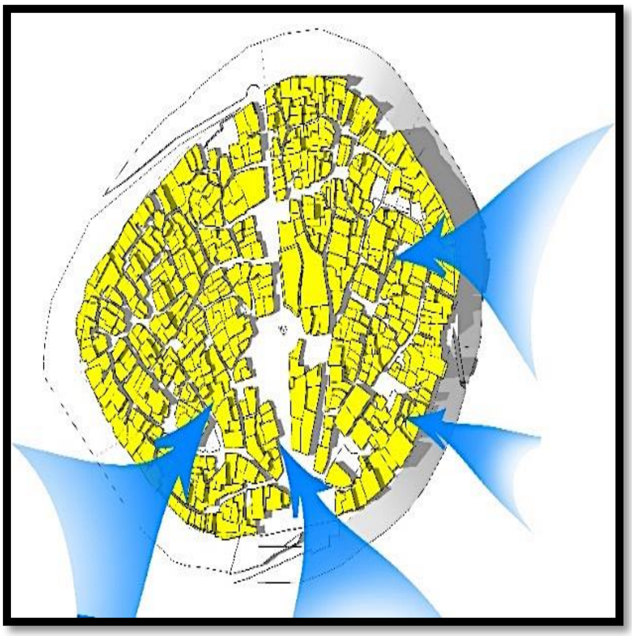

Figure 3: Prevailing wind direction in Erbil

3.4 Ventilation

There are different strategies used to provide ventilation for the houses in Erbil Citadel vernacular houses. The doors of upstairs rooms have small air vents above them, which provide good ventilation and cooling due to convection and help in air exchange during the summer months (Figure 4.)

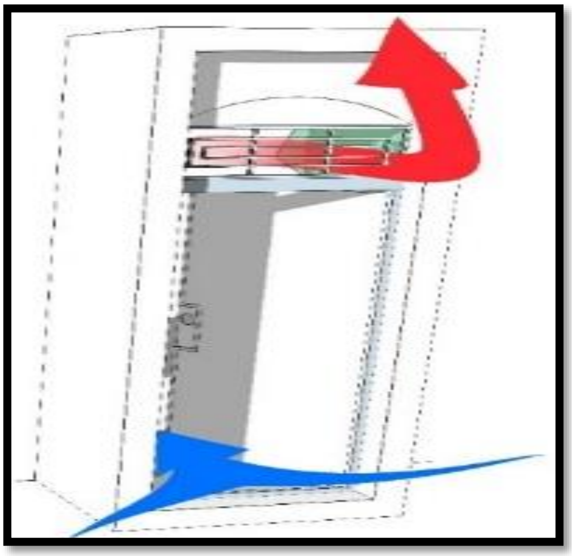

Figure 4: Door's ventilation

When the windows are opened, the cool air from the courtyard enters into the rooms, introducing pressure to accelerate the rise of hot air to be expelled through the upper windows and ventilation grilles (Figure 5).

Figure 5: Windows opened onto courtyard

Most houses heavily utilize the upper windows to benefit from convection and wind ventilation for fresh air and cooling, in addition to aesthetic purposes (Figure 6). According to the density law of air, hot air density is less than cold air density, so the hot air rises and cold air remains below (in the inhabited spaces), so in the summer the upper windows are opened to introduce cool airflow through the doors and to let hot air escape from the upper windows.

Figure 6: Windows ventilation mechanism

3.5 Ventilation

There are various techniques used for shading and protection from sun exposure throughout the world, but in MENA there is a notable dearth of vegetation for this purpose due to aridity and extreme heat in summer, consequently most solar shading devices use architectural elements themselves rather than additional shading solutions. The main strategies which are used in Erbil vernacular housing are narrow alleyways, canopies, rewaks, iwans, shanshil, and shading devices on windows (Okba, 2005).

The narrow alleyways are shaded during the day by their own high walls, which also protect the outer walls of the houses from direct sun exposure (Figure 7) (Keshtkaran, 2011). The maximum solar exposure of the most used part of alleyways – the pavement – is around midday, when the sun is at its zenith, and traditionally there would be cloth awnings (or clothes lines for drying clothes) extended over the alley to protect windows and the alley itself from direct solar exposure (and indeed to dry clothes or food).

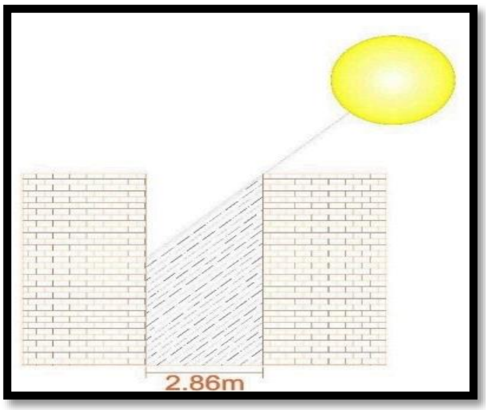

Figure 7: Alleyway section

Similar to alleyways, courtyards are shaded during most of the day (Manioglu & Yılmaz, 2008). The inner walls of the courtyard may be further protected from the sun exposure by the innate highness of the walls and surrounding rooms, or by projected awnings or eaves called tarmas, often as part of a veranda (rewak), usually placed in the north, east, and west to protect from direct solar radiation during the summer (Figure 8, Figure 9). Smaller, adjustable window shading devices are also used internally (in courtyards) and externally to protect windows form direct sunshine in the summer and rain in the winter (Singh, 2011).

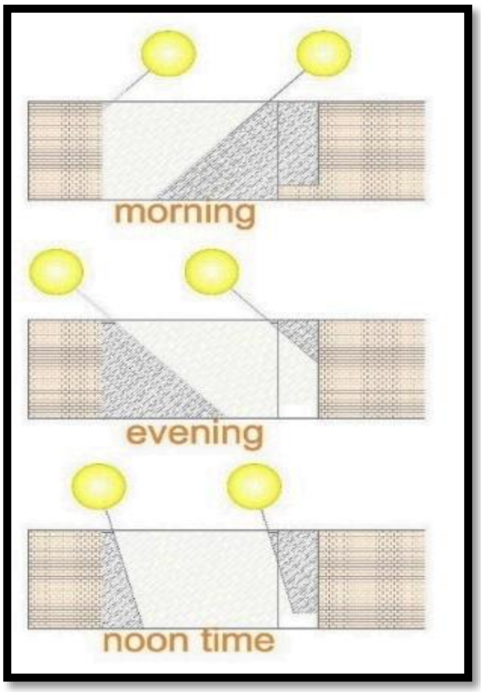

Figure 8: Courtyard sun exposure

Figure 9: Rewaks

3.6 Natural Lighting

In Erbil, and MENA in general, the main problem encountered in sustainable architecture is that the most effective solutions to reduce energy consumption and promote passive cooling inevitably involve avoiding solar radiation, which reduces natural lighting for inhabited spaces. Consequently, providing sufficient lighting for internal zones is a major design issue in hot and arid regions. The strategies used in Erbil vernacular houses for this purpose include the following.

The courtyard plays an important role to provide the sufficient lighting to the interior spaces (Priyaa et al., 2012). Since the houses are closed to outside and opened to inside, the outer windows are either small or above eye level, reducing the volume of lighting infiltrating rooms, while courtyards conversely provide a major source of luminance.

The windows facing onto internal courtyards are the main source of natural light within rooms. The fact that external (i.e. outward facing) windows are generally small in size is likely due to privacy concerns as much as to avoid heat gain, and windows in external walls around the perimeter of the Citadel (i.e. in the Citadel wall) have larger windows, where there is no privacy issue (Canas & Martin, 2004), providing sitting or storage areas in the thick walls, and which can be opened to harness prevailing winds, in addition to providing maximum lighting to internal zones (Figure 10). Additionally, the upper windows set higher in walls are inclined down to the inside face in order to provide maximum lighting (Figure 11).

Figure 10: Windows in the outer edge

Figure 11: Inclined upper window

3.7 High Thermal Mass and Material Insulation

Erbil vernacular houses building envelopes are composed of local materials with high performance against heat gain and heat loss. The walls are constructed from clay bricks and the roofs are made of timber, reed and soil composites. The walls are of varying dimensions, ranging from 60cm to 180cm; the perimeter walls are thicker than interior walls and partitions (Bodach et al., 2014).

Most roofs in Erbil vernacular houses include composite materials (usually comprising three layers), with good insulation properties (Figure 12). Some basements and bath houses use vaulted brick ceilings.

Figure 12: Roof composite

3.8 Evaporative and Plant Cooling

Fountains are often used in the center of courtyards to increase air cooling (Dili, 2010; Mohammadabadi & Ghoreshi, 2011; Kadr, 2013) (Figure x), which is often associated with some plants or even trees, which improve the air quality for the house and also shade the courtyard itself to promote evaporative cooling. Using water and plants as climatic elements can be seen in most houses and certainly all courtyards, but fountains are reserved for the most palatial dwellings (Roodgar et al., 2011; Kadr, 2013; Khalili & Amindeldar, 2014).

3.9 Earth Cooling

Semi-basements can be seen in most of the larger houses, especially in the Saray Quarter, the elite area historically inhabited by merchants and nobles. The semi-basements are essentially earth-bermed rooms that provide very comfortable areas that are cool in summer and warm in winter. Semi-basements usually provide the coolest space in the house on very hot and dry summer days (Foruzanmehr, 2015). This is essentially due to the ground temperature, which is relatively hotter in winter and cooler in summer than the surrounding ambient air temperature (Kadr, 2013; Khalili & Amindeldar, 2014).

4. Results and Conclusion

This analysis has identified various sustainable solutions in the vernacular architecture of Erbil, including numerous climate-responsive elements devised by the historical designers and inhabitants of traditional houses to meet their environmental and socio-cultural requirements.

In order to reduce the operational energy use in buildings, especially in houses and inhabited properties, there is an essential need to perform studies on the traditional houses in the area. This offers insights into how people traditionally lived in challenging environments and contexts without any mechanical instruments to cool and heat their dwelling spaces. While it would be inappropriate and potentially counter-productive to simply attempt to reiterate the past by copying historical architectural styles, it is insightful to consider and potentially benefit from low-cost, sustainable techniques that have historically, empirically provided sustainable solutions for economical and environmentally friendly living.

Analyzing the techniques used to provide and produce sustainable buildings determines climate-responsive elements and how to describe them with their functions and importance of the location in the houses. Erbil Citadel contains over 500 vernacular houses presenting a portfolio of design solutions from across the centuries, using local and sustainable techniques and materials suited to the local culture and environment. The climate-responsive active elements identified and analyzed in this research manifest tangible cultural heritage and have immense aesthetic and architectural value in their own right, in addition to their general sustainability characteristics and economic and environmental implications, with immediate socio-cultural relevance and pertinence to the construction context of Erbil, Kurdistan and MENA generally.

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