Design Strategies Employed to Achieve Thermal Comfort in Traditional Religious Buildings in Iraq

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Abstract

Over the past decades, Iraqi traditional architecture has provided solutions to environmental problems, with a specific style of environmental design. Iraq is a region with a hot, dry climate and thus, without doubt, the architects and designers who practice in such a region could learn enormous lessons from them. This paper takes the view that design strategies used in traditional Iraqi architecture could be employed to overcome many environmental problems. It assumes that the use of these design strategies could reduce the use of mechanical means to adapt to the internal environments of buildings and thus reduce the consumption of electrical energy yet produce a good quality of thermal comfort.

This paper presents a study carried out to evaluate these strategies, which included measuring the environmental parameters of the internal environment of the al-Kulayni shrine building in Baghdad. To do so, it first employed a Digital Multimeter. It also administered a questionnaire to visitors to the place to ascertain their thermal sensations inside the building, at the time of taking the measurements.

The study reveals that the traditional architecture of the Al-Kulayni building provides an internal temperature 7 degrees Celsius lower than the air temperature outside the building. It thus concludes that the building system of the traditional Iraqi architecture is a sustainable system. It has achieved sustainable design outcomes and can be employed as an example to follow in order to achieve internal thermal comfort for the building users and to save fossil fuel-based energy.

Keywords: Traditional Iraqi Architecture, Religious Buildings, Thermal Comfort, Sustainable System, Dry Hot Climate.

Introduction

It is now known that the interference of human activities in the natural environment leads to global climate changes. Invariably, these changes add new dimensions to the ecological balance of the world (Yılmaz, 2006). Needless to say, that the concerns about global warming and the need to reduce greenhouse gas emissions require the use of passive strategies for indoor climate modifications to promote comfortable indoor environments (Rajapaksha, Nagai and Okumiya, 2003). Architecture aims to reduce the negative impact of buildings on the environment through moderation in the use of energy and materials while enhancing their efficiency (Eiraji and Namdar, 2011) .

Mosques are prominent public spaces in the society. However, they are classified as buildings with high energy consumption. In Malaysia, the cost of operating mosques is highly dependent on public funds and, statistically speaking, is particularly high in relation to electricity use. This is due to the use of air conditioners to cool the huge prayer halls, as they are not designed environmentally energy-efficient and thus do not achieve the required thermal comfort (Yudha and Setiyowati, 2016) without artificial means.

This research focuses on examining the design strategies in the religious traditional buildings in Iraq, which had a role in reducing the electrical energy consumption of the buildings and achieve thermal comfort. The research aims at the possibility of adopting these solutions and strategies in the modern designs of religious buildings to achieve such thermal comforts.

Literature Review

A number of studies dealt with the thermal performance of religious buildings. Norden and Misni (2018) have concluded that heritage and new mosques have similar building technologies in the construction and orientation towards the Qibla, despite the difference in the age of origin for the two categories, building materials, and glass areas. They also found that urban heat islands formed as a result of the surrounding climate in the heritage mosque building. Indeed, an internal temperature of up to 1.8 degrees Celsius higher than the outdoors is produced.

Jamal (2007) has concluded that the vaulting system works to reduce temperatures by a rate of 2-6 degrees Celsius and helps to obtain a kind of thermal stability in the summer. In winter, the heat loss process of the vaulted ceiling is higher than the flat ceiling. Thus, its effect will be negative, which requires certain treatments, and given that the cold period in Iraq is four months, and the other eight months are between hot and moderate, the research considers the vaulting system an appropriate treatment for the region. On the other hand, Fathimah, Sabarinah, and Nurul (2018) point out that a domed roof provides better thermal performance compared to a flat roof, because the opening at the top of the dome increases the wind speed inside.

Zureik (2021) has studied the effect of using the minaret of the mosque on-air exchange as an alternative to the solar chimney as a natural ventilation technique, which relies in its work on the principle of natural convection, as it works to extract hot air from the interior spaces of the buildings, and replace it with fresh air from the outside to achieve thermal comfort inside the buildings. This technology has been applied to the Comsol Multiphasic fluid dynamics program to conduct a numerical simulation of natural heat transfer to show the role of each minaret that turns into a solar chimney from within an engineering space that simulates the shape of a mosque. The numerical simulation process has led to the need to provide a high temperature difference at the level of the chimney, in addition to providing external ventilation to help increase the natural convection currents to achieve natural ventilation.

Jamal (2018) has presented the design of the minaret as a double-sided air carrier supported by underground water pipes to enhance natural ventilation. This research has relied on a computational test and a computer program (CFD) to verify the results of the research, as it was concluded that increasing the velocity of airflow leads to a decrease in air temperature to 18 degrees Celsius and an improvement in humidity by 24% in the summer. In winter, the temperature rose by 6 degrees Celsius, and this is closer to the indicators of ASHRAE 62.1 (Abed Wahid Jassim, 2018). To improve the indoor thermal comfort, Nabeeha, Al-Azhaili, Al-Mu¨slu¨m and Siti (2022) has used a passive design approach to achieve comfortable conditions during low-occupancy daily prayer times without the use of mechanical intervention. The results have showed that a reduction of up to 4-6°C in the interior wall surface temperature can be achieved through an appropriate qibla wall design, which reduces the average radiation temperature of the building users by 2-4°C. Combined with ventilation bridges, thermal comfort can be significantly improved by at least 40% for the prayers during the hottest times of the day, and by up to 80% for the night prayers. The results indicate that suitable comfortable conditions can be achieved without the need for air conditioning for at least two or three of the five daily prayers (Azmi et al., 2022).

Traditional Religious Architecture

Historical background of Baghdad

The city of Baghdad was founded in the eighth century and became the capital of the Abbasid Caliphate. It is located along the Tigris River and soon after its founding, it became an important commercial, cultural, and intellectual center in the Islamic world (Akram, Ismail and Franco, 2016).

Islamic shrines

The region of Iraq is almost devoid of a shrine or a memorial or sacred have shrine, on whose land the prophets, saints, and scholars have lived and died, and their histories have recorded their passage through this land and their residence in them. Traveling in Iraq from its North to South often encounters the presence of maqams, holy graves and shrines of righteous saints, as they were the cause of growth and urban expansion in those areas. Cities often grew and expanded in them and became sprawling due to the presence of a holy grave or a shrine that people undertook to visit (Suhail, Alkilidar and Al-Khafaji, 2015).

Architectural design strategies in religious buildings

1- **The prayer house:** The prayer house is rectangular in shape and extends horizontally along the Qibla wall, but its depth is much less than that. The extension in the prayer house comes from the nature of performing the prayer in regular rows parallel to the Qibla wall behind the imam, with the preference for praying in the first row.
2- **The Sahn:** It is the unroofed part of the building. It is considered an extension of the building. It is used to perform events and congregational prayers.
3- **The minaret:** It is one of the important architectural elements into the construction of religious buildings. It is a tower adjacent to the religious building. The muezzin from above, at certain times, calls the believers in a loud voice to perform the prayer. The Prophet Muhammad, peace be upon him and his family, enacted this method.
4- **Arcades:** It is the passage confined between the wall of a building and arches based on columns.

Patterns of Islamic Shrine Architecture

Islamic shrines are divided architecturally into three basic styles:

1- The style of the one-space (simple) shrine is considered the pre-style of Islamic shrines. The architecture of this type of shrines began since the first Islamic centuries and continued until the emergence of the Ottoman Empire and beyond. The most important tombs built of this type are the first Seljuk tombs in Iran and Iraq.
2- The pattern of complex shrines (multiple or attached to activities): The appearance of this type of shrine indicates an increase in interest in them and their architecture. Two main types of complex shrines appeared:
    - The first type: It is not different from the simple fireplaces, but it is surrounded by an additional space around it called the arcade. The fireplace as a whole has a central shape, and the level of the fireplace may be higher than the level of the arcade to allow for natural lighting and ventilation. Minarets or external walls may be added.
    - The second type: By merging it with natural or utilitarian religious or worldly buildings such as mosques, schools, hospitals, etc., this forms a multi-functional complex. It usually follows the plan with a courtyard and four iwans. This method was followed in

the construction of shrines in an attempt to give them the legal aspect of what was stated in the prohibition. These are buildings on graves, and the rule has become to add shrines to schools, mosques, and khans (hospitals) since the Ayyubid era in the rule of Egypt and the Levant. Perhaps there is another more important reason, which is the desire of the rulers to continue the commitment, visits, and reconstruction of those shrines, which has prompted them to add other facilities to them that would be the focus of people's attention to visit them. They act as a media station for the rulers and promote them.

The Style of the Kindergartens (Islamic thresholds):

This style was distinguished from its predecessors by its boldness of expression and its explicit power. It indicates its emergence exclusively in the Islamic East, which extends from Iraq to India. One architect includes eloquence of expression in reference to his function and the importance of those buried in it. The most important examples are the architecture of shrines during the last Indian Islamic kingdoms, the Safavid architecture and the Qajar architecture (Alkilidar, 2015).

Research Methodology

Data collection

Extensive data collection was done over a four-month period from April 2022 to June 2022. This included collecting measurements and gathering construction details of the building, in addition to the site survey to draw integrated engineering plans for the building. It should be noted that the field data acts as a background and context for the research.

1.1. The Case Study

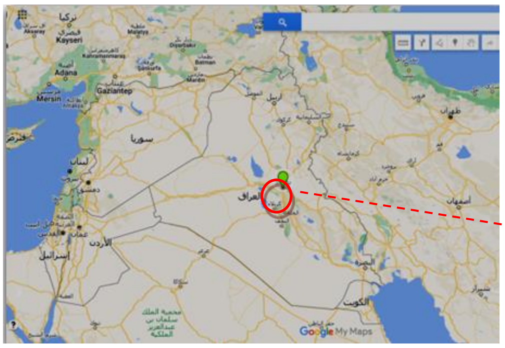
A preliminary survey of local religious buildings has been conducted in the city of Baghdad, Iraq. The shrines are sacred religious buildings that include the tombs of the saints and righteous people of the House of Prophethood. They have the same building style and architectural elements as mosques (a prayer hall, a minaret, a dome, and a central courtyard).

The shrine of Sheikh Al-Kulayni[1] was chosen as a case study. It is located in Baghdad, near the Al-Mustansiriya School, overlooking the Tigris River. This building was chosen based on these considerations:

- The shrine building is of medium in size (capacity 50-150) serving daily prayers and Friday prayers.
- It is located within the heritage fabric of Baghdad.
- An ancient building whose construction dates back to the Safavid era (at that time it was known as [2]the Safavid Mosque) in the year 329 AH.
- One of the ancient traditional buildings in Baghdad.

Fig. 1 Shows the location of the shrine building of Sheikh al-Kulayni
Fig. 2 shows the recent photos of the shrine building of Sheikh al-Kulayni
Summary of shrine characteristics are listed in the Table 1

[1] **Sheikh al-Kulayni**: Sheikh al-Kulayni (Jerusalem) is Sheikh Muhammad ibn Yaqoub ibn Ishaq al-Kulayni al-Razi, one of the leading Shia jurists and hadith scholars and the author of the book al-Kafi, which is considered the most important book of fundamentals for the Shia. Near the Martyrs Bridge in the Shorja area, next to Al-Mustansiriya School.



Map of Iraq

Location: Shorja - Baghdad

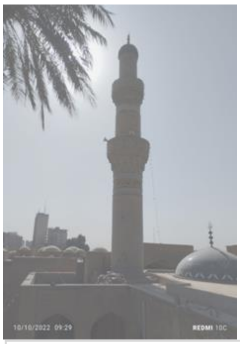
The names of the shrine spaces

The southern facade of the shrine

Fig. 1: The location of the shrine building of Sheikh al-Kulayni
Source: Google earth

Shrine entrance

The eastern facade of the shrine



Minaret

Domes	A shot of the shrine from Al-Shuhada'a Bridge	The central courtyard

Fig. 2: Images of the shrine building of Sheikh al-Kulayni
Source: Author

Table 1: Details of the case study shrine building
Source: Author

Characteristic properties	Description
Site area	1193.232m^2
Building orientation	292 NW (Oriented along Qiblah axis)
Total built-up area	800 m^2
Area of the main prayer hall	9 m * 21.25 m (~191.3 m^2 praying area)
Height of the main prayer hall	10.50 m at the sides; 15 m at the apex
Capacity within hall	~50-150 people

1.2. Building Construction Plan

The practical and detailed drawings of the shrine are used to understand the physical character of the building in the first phase of the study. The study included basic information on architecture, building design, materials, and any factors or aspects related to heritage and the new shrines. Studies focus on the floor plans and all corners of the building envelopes. Roof and wall materials and openings are the most important parts to understand and study the details. The layout of the prayer hall has been studied to support the weather data recorded and observed at the site and the buildings.

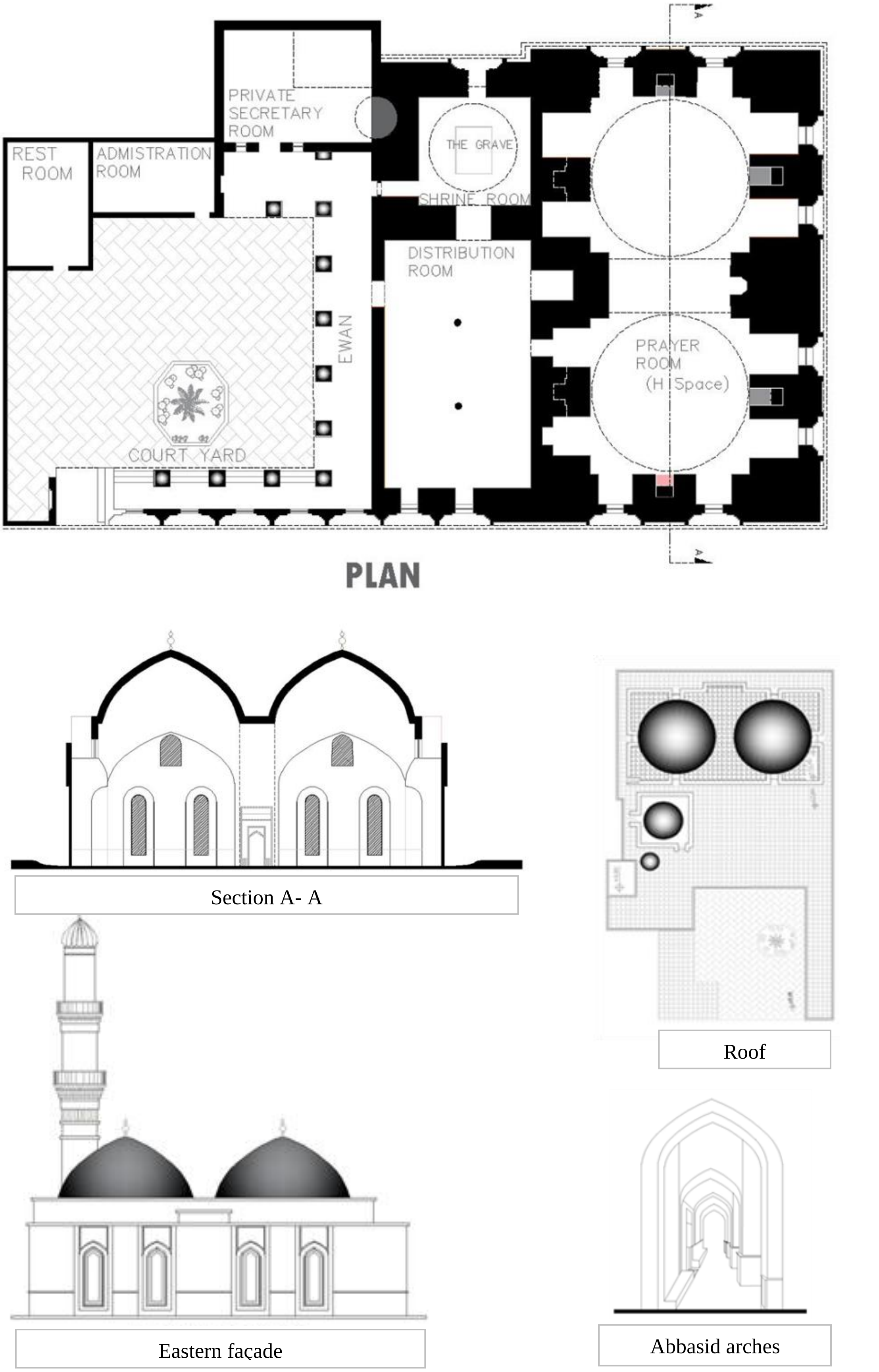


Fig. 3: The plans of the Al-Kulayni shrine
Source: Author

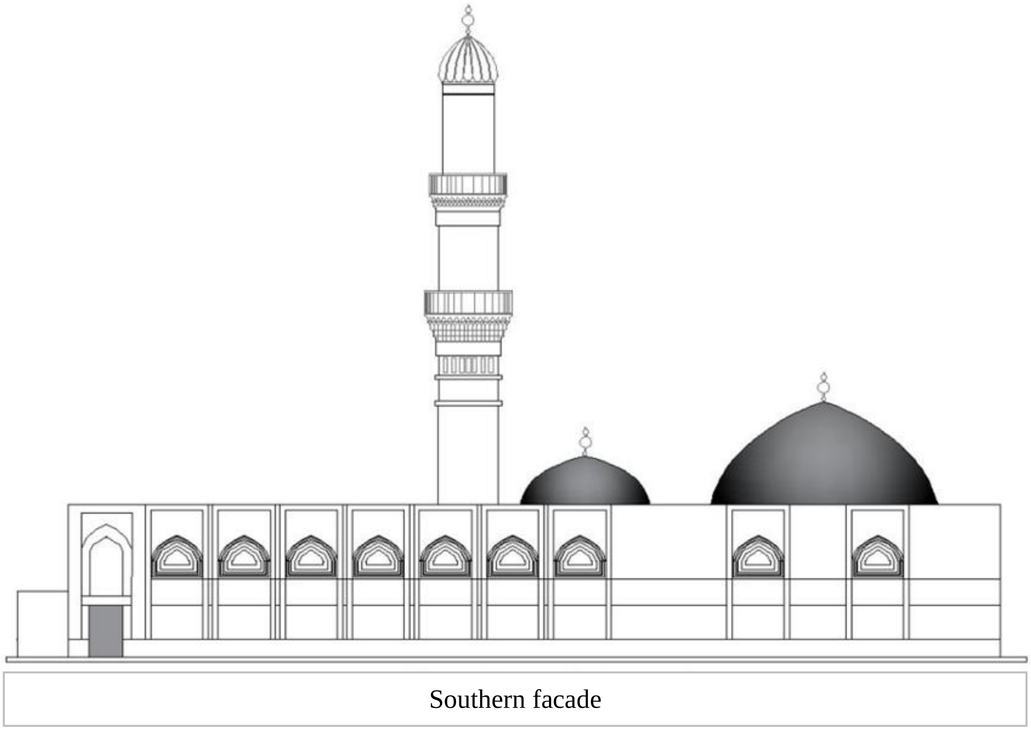


Fig. 4: Architectural Details of the Al-Kulayni Shrine
Source**:** Author

1.3. Calculations Tools

1.3.1 Questionnaire Survey

In this research, the thermal sensation of visitors to the building within the H space was studied, to find out the effect of traditional architecture on internal thermal comfort, by conducting a questionnaire for a random sample of visitors to the Holy Shrine who visit the shrine on a daily basis. The survey was conducted in April and July. 44 valid responses were collected for the study. The questionnaire was designed based on the ASHRAE principle.
Fig. 4 shows the points of locations referred to in the questionnaire.

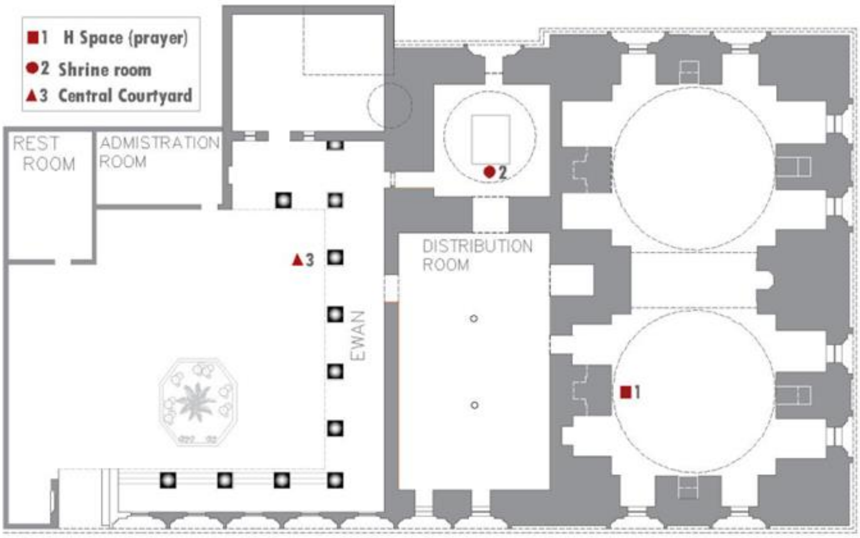


Fig. 5: Questionnaire administered locations
Source: Author

1.3.2 Digital Multimeter

Fig. 5 shows the equipment used for the calculations of the environmental parameters, along with the technical specifications. The calculation process was carried out to study each of the following:

1. Thermal comfort factors (air temperature, relative humidity and lighting)
2. The temperature of the materials used to wrap the building from inside and outside through the sensors in the device.

Fig. 6 shows the internal space in which the measurements were taken (H space). This point is referred to from now on as (Prayer) in the text.

Fig. 6: Equipment used in data collection (Digital multimeter)
Source**:** Author

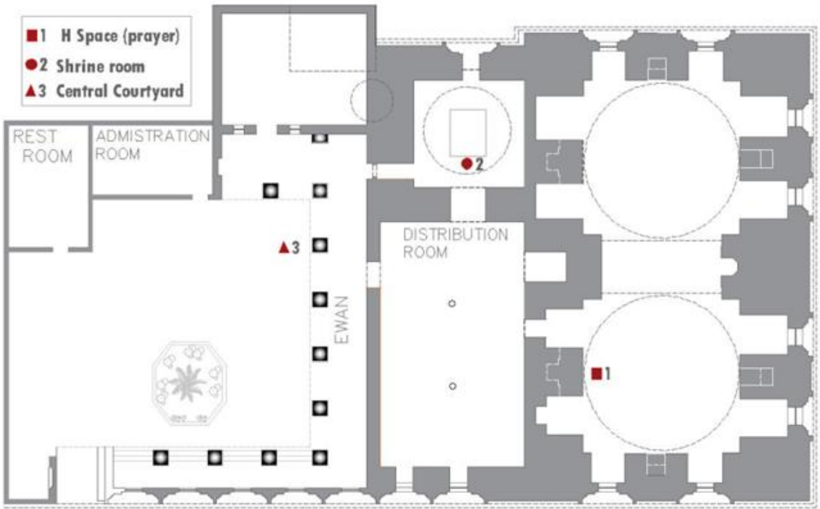


Fig. 7: Environmental parameters points
Source: Author

Note: All measurements were taken under natural environmental conditions (natural ventilation) without the use of mechanical cooling methods.

The data collection and study period of four months extended over the prevalent summer season in the region from April to July. Average temperatures in Iraq range between 48 °C (118.4 °F), in July and August, and below zero in January. Therefore, a typical hot month of July is aptly representative of the worst-case scenario in any Design Day for Iraq. Measured data are the temperature, relative humidity and lighting. The main users use the space in the shrine as early as 5.00 am and their activities will end at 10.00 pm. Hence, the data collection exercise was conducted with very careful consideration because this is a noble and holy place for Muslims to do their prayers five times a day.

- Studying the possibility of employing design strategies in traditional construction.
- Studying the effect of traditional building materials.

Results and the Discussion

1. Environmental Parameters

- **factors of thermal comfort**
  The thermal comfort factors of the case study building were measured by a digital multimeter for each aspect (air temperature, relative humidity, noise, and lighting). These measurements were taken for the months of April and July for all the spaces of the shrine (H space, the tomb room, and the central courtyard).

It was concluded that the shrine building provides an internal temperature approximately 7 degrees Celsius lower than the outside of the building (Table 2 and 3).

Table 2: April measurements of indoor Air Temperature [Outside air temperature is (32ºC)]
Source: Author

factors of thermal comfort	Shrine Room Space	Prayer Space	central courtyard
Air Temperature	24.3ºC	25.2ºC	25.4ºC
Relative Humidity	30% RH	25% RH	26% RH
Lighting	0247 Lux	0170 Lux	0386 Lux
Noise	52.6 dB	56.2 dB	64.5 dB

Table 3: July measurements of indoor Air Temperature [Outside is 38ºC]
Source: Author

factors of thermal comfort	Shrine Room Space	Prayer Space	central courtyard
Air Temperature	28.3ºc	25.2ºc	25.4 c
Relative Humidity	30% RH	26% RH	25% RH
Lighting	0163 Lux	0240 Lux	0270 Lux
Noise	57.6 dB	60.4 dB	80.0 dB

- **Finishing Materials**

The temperature of the interior finishing materials for the H space, the tomb chamber, and the central courtyard were measured. It was concluded that these materials have less solar gain, as their temperature is 8 degrees Celsius lower than the air temperature outside the building, due to the width of the inner walls of the shrine, whose thickness averages about 1 meter. (Table 4 and 5).

Table 4: Temperature readings for building finishing materials for April [Outside is 32ᵒC]
Source: Author

Finishing Materials	Shrine Room Space	Prayer Space	central courtyard
Marble	24ᵒC	24ᵒC	29ᵒC
Bricks	/	25ᵒC	28ᵒC
Dye	24ᵒC	25ᵒC	32ᵒC

Table 5: Temperature readings for building finishing materials for Jule [Outside is 38ᵒC]
Source: Author

Finishing Materials	Shrine Room Space	Prayer Space	central courtyard
Marble	30ᵒC	30ᵒC	36ᵒC
Bricks	/	31ᵒC	37ᵒC
Dye	30ᵒC	31ᵒC	39ᵒC

2. Questionnaire Survey Results

2.1 Thermal Sensation

It was found that the percentage of achieving thermal comfort within space H and the satisfaction of visitors to the place is 47.7% for the average comfort for the month of April. In July, the rate was 62.8%.

Chart 1 shows the thermal sensation of the questionnaire sample.

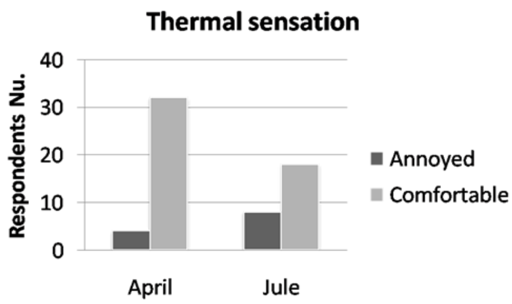


Chart 1: Thermal Sense of H space
Source: Author

2.2 Relative Humidity

As for the relative humidity of the building, it was voted by 89.7% of the visitors to the place for the month of April, that the space is neither wet nor dry. Approximately the same percentage were recorded in the month of July. Although the building overlooks the Tigris River and the sun's rays do not enter the space, and according to the visitors' opinion, the voting rate reached 44.8% (the solar radiation sometimes reaches). It is concluded that the correct orientation of the building and the number and area of windows are among the elements of successful environmental design.

Chart 2 shows the feeling of relative humidity of the questionnaire sample.

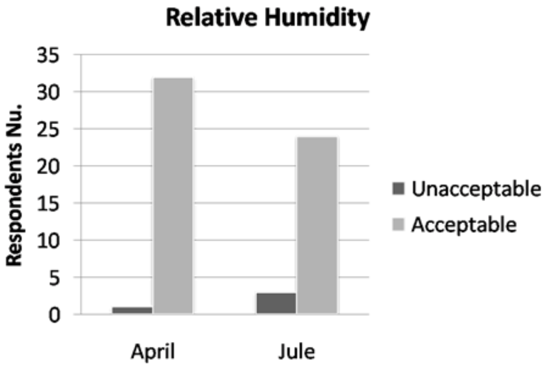


Chart 2: Relative Humidity of H space
Source: Author

Environmental Design Strategies

The most important environmental design strategies adopted in the construction of the Al-Kulayni Shrine building, which achieved the principles of sustainable design through the results of the research, can be summarized in table 6.

Table 6: The Environmental Design Strategies for Al-Kulayni Shrine
Source: Author

Principles of sustainable design	Environmental Design Strategies
Climate Condition	Thermal comfort Daylight Natural ventilation
Building material	Local material
Indoor air quality	Daylight Natural ventilation
Building envelope	Increase the thickness of the walls Vaulted ceiling Window shading

Conclusions

The phenomenon of global warming and the decline of fossil fuels necessitated the provision of thermally comfortable environments based on environmental design strategies and environmental standards to reduce the interference of mechanical devices in conditioning the interior spaces of buildings. There is a need to reduce the consumption of electrical energy, as well as to reduce the emission of greenhouse gases. This study aimed to determine the strategies for designing traditional buildings in Baghdad, especially Islamic-style buildings, and the influence of Islamic architectural elements in achieving comfort for the interior of the building. The results confirm the effectiveness of traditional architecture at the present time after many changes occurred in the local climate of the city of Baghdad, where the Al-Kulayni shrine building achieved a decrease in the internal temperature by 7% from the external air temperature, and the application of these strategies was indexed for the principles of sustainable design.

The research recommends that these treatments be among the foundations of environmental design and the employment of Islamic architecture elements in the development of environmental treatments for newly built religious buildings.

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