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The effect of iwan as traditional shading element on indoor temperature: The case of Diyarbakır houses

El efecto del iwan como elemento tradicional de acondicionamiento en la temperatura interior: el caso de las casas de Diyarbakır

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ABSTRACT

In this study, the effect of the use of the iwan as a shading element was investigated. Summer iwans used in Diyarbakır traditional architecture are within the scope of the study. To determine the effect of iwan, use on climatic comfort, the relationship between the rooms, iwans, and courtyards of the houses within the scope of the study was analyzed among themselves and with the outdoor temperature. Indoor temperatures were determined by hourly measurements on three different days during the hot summer period. iwan can be said to give his best performance until 15.00. While the daily temperature change is the lowest in the room and the iwan, the maximum and minimum temperatures are generally the lowest in iwan. It was determined that many design parameters, such as the east wall of the courtyard, iwan opening, and iwan depth, affect the indoor comfort of the iwan together.

Keywords: Passive design strategies; iwan; shading device; hot and arid climate; Diyarbakır traditional architecture.

RESUMEN

En este estudio se investigó el efecto del uso del iwan como elemento de sombreamiento. Los iwan de verano utilizados en la arquitectura tradicional de Diyarbakır entran dentro del ámbito del estudio. Para determinar el efecto del uso del iwan en el confort climático, se analizó la relación entre las estancias, los iwan y los patios de las casas incluidas en el ámbito del estudio entre sí y con la temperatura exterior. Las temperaturas interiores se determinaron mediante mediciones horarias en tres días diferentes durante el caluroso periodo estival. Puede decirse que el iwan ofrece su mejor rendimiento hasta las 15.00 horas. Mientras que la variación menor oscilación térmica diaria se produce en la estancia y en el iwan, las temperaturas máxima y mínima suelen ser las más bajas en el iwan. Se determinó que muchos parámetros de diseño, como la pared este del patio, la apertura del iwan y la profundidad del iwan, afectan conjuntamente al confort interior del iwan.

Palabras clave: *Estrategias de diseño pasivo; iwan; dispositivo de sombreado; clima cálido y árido; arquitectura tradicional de Diyarbakır.*

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1. INTRODUCTION

Today's people spend most of their time indoors for living and working purposes. Indoor thermal comfort directly affects the quality of life [1]. Buildings are responsible for about 40% of the total energy consumed [2], [3]. A significant portion of this energy, around 50-60%, is spent on ventilation, heating, and cooling (HVAC) systems used to provide indoor thermal comfort [4], [5], [6], [7]. Energy-efficient building design is one of the most important methods to reduce energy consumption [8], [9]. The energy crisis of 1973 and increasing environmental awareness in societies have led countries to adopt energy-efficient building designs [10], [11], [12]. One of the most important criteria of energy efficient building design is to be designed according to the climatic characteristics of the environment [3], [13], [14]. Traditional architecture, shaped by climatic characteristics without advanced HVAC technologies, has developed important energy-efficient design strategies for indoor comfort [15]. Traditional architecture is, therefore, an important guide for sustainable building design [16], [17], [18].

The main problem of indoor thermal comfort in hot and arid climates is cooling [19], [20]. Therefore, passive cooling strategies have an important place in traditional architecture in hot and arid climates [15], [21], [22], [23]. One of the most important criteria of traditional passive cooling strategies is protection from solar radiation [24], [25]. Properly using solar protection strategies can reduce energy consumption for cooling by about 10-40%. Therefore, it is very important to investigate and adapt traditional passive cooling strategies to modern architecture[26], [27], [28]. Various shading strategies have been developed in the traditional architecture of hot and arid climates to protect from solar radiation. These include compact urban design [29], [30], the use of landscape elements [31], building orientation [32], [33], seasonal movement of users [34], [35], courtyards [36], [37], [38], and iwan [39], [40].

The iwan is an important solar protection strategy that shades openings and walls as a buffer between the interior and solar radiation [29], [41], [42]. The fact that the iwan prevents multiple openings from being exposed to solar radiation is very important for building energy conservation. This is because openings are one of the weakest thermal control points of the building envelope [8], [43]. Since the iwan also shades the walls, it can also block radiation from the walls to the interior [39], [44].

The aim of this study is to investigate the effect of using iwan for shading on indoor temperature in traditional architecture in hot and arid climate. In this scope investigates the effect of the iwan used in Diyarbakır traditional architecture on energy conservation as a cooling element with shading. The study uses field research, numerical data analysis, and a literature review. [39]

1.1. Literature review

The contributions of the iwan used in traditional architecture to thermal comfort have generally remained at the level of description and emphasizing its importance anecdotally in the literature [34], [45], [46], [47]. There are very few experimental and numerical studies on the contribution of the iwan to energy consumption as a shading element. Kalantari, Singeri, and Jourshari (2015) studied the effect of the iwan on energy consumption in traditional architecture in Tabriz city in Iran's cold and arid climate. As a result of this study, it was determined that the iwan in Tabriz's traditional houses is generally used for decorative purposes and rarely used as a climate-regulating element [44]. Eskandari, Saedvandi, and Mahdavinejad (2017) investigated the effect of iwan as a traditional shading element on energy consumption in four climates [39]. Eskandari, Saedvandi, and Mahdavinejad (2018) stated in their article on the effect of the iwan on energy consumption that there has been no previous study in this field and, therefore, could not compare the results [39]. Shaeri, Yaghoubi, and Habibi (2018) investigated the effect of the iwan on the talar room (the room behind the iwan) in terms of thermal comfort in the traditional architecture of the city of Shiraz in the hot and arid climate zone of Iran. The research analyzed the talar room in two ways, with and without iwan. As a result of the analysis, it was determined that the talar room with an iwan had 62% more favorable thermal properties than without an iwan [40].

In the searches made with Web of Science and Scopus databases, no numerical or experimental studies on the effect of the iwan on energy efficiency and indoor temperature other than those mentioned above were found. It is thought that this study can partially fill the gap in the literature on the effect of iwans on indoor temperature within the scope of numerical data. In addition, it is also important that it is the first study on the effect of iwans on indoor temperature in Anatolian architecture.

2. MATERIALS AND METHODS

2.1. The iwan as a shading element

The iwan in world architecture dates back to the Assyrian period. Its simplest form was first seen in Mesopotamia in the 1st century [48]. The Parthian and Sasanian versions [49] correspond to the general definition. Iwan is a semi-open space overlooking the courtyard [23], [50], [51]. Iwan, a Persian word, can be used differently in the literature [52]. Aivan [53], [54], evon [55] ayvan [56], or iwan [40], [46] can be given as examples of usage patterns.

While one side of the iwan faces the courtyard, the other three are usually covered with room facades. The rear facade can sometimes be completely enclosed [44], [45], [57]. It can be a single span or consist of two or more rows of arches [39]. The iwan is the transition and living space between the interior (room) and the exterior (courtyard) [58]. It was also generally used as a living space during hot summer [40]. The iwan directly affects the indoor comfort of the place where it is used [44]. One of the most important reasons for this is to prevent solar radiation from directly entering the interior during hot summer periods and to keep the interior cool [59] because this property was used as an effective shading element in traditional architecture in hot and arid climates [60] (Figure 1). It was generally used on the south side of the courtyard facing north to block solar radiation. However, it is also used on other fronts [15], [61].

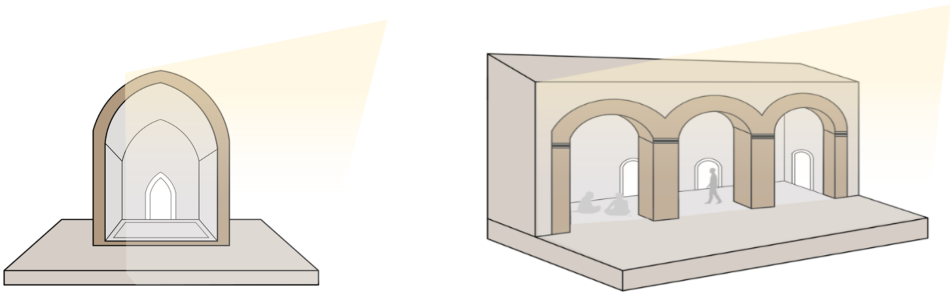

Figure 1. Use of the iwan for shading purposes (Sketch by Author)

In the hot and arid climate was often used in traditional architecture. Mexico [62], [63], India [64], [65], Bahrain [66], Iran [32] China [67], Iraq [68], Turkey [69], and Qatar [70] can be shown as examples of regions where it is used.

The iwan used in Turkey is similar to the mak'ats used in Egypt [71]. The use of iwan in Turkey is particularly concentrated in the southeastern Anatolian region [46]. Kazmaoğlu and Tanyeli showed that, depending on the socio-cultural characteristics, houses in the Anatolian residential architecture grouping have iwans, unlike other housing typologies [71]. In his study of houses in Eastern and Southeastern Anatolia, Günkut Akın discussed houses with iwans as a separate group. He stated that houses with iwans were used, especially in the regions of Diyarbakır, Mardin, Şanlıurfa, and Gaziantep [47].

2.2. Location and climate of Diyarbakır

Southeastern Anatolia is one of the seven regions of Turkey and the smallest. This region is bordered by the southeastern Taurus Mountains in the north, Syria in the south, the Mediterranean region in the west, and the eastern Anatolian region in the east. This region has the most sunshine and the highest average annual temperature in Turkey (Ekolojist 2017) (Figure 2).

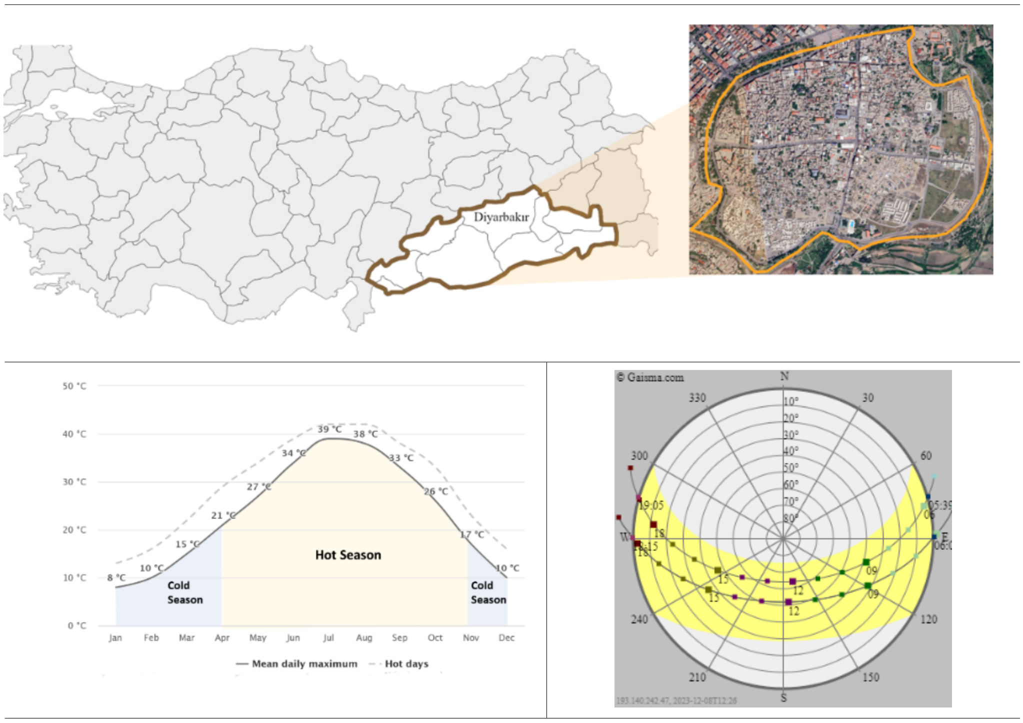

Figure 2. (a) Diyarbakır location and traditional settlement, (b) Diyarbakır hot and cold periods (edited from Meteoblue), (c) Diyarbakır solar path at the August and September equinoxes (Marsh 2014)

Diyarbakır is one of the nine cities in the region. Diyabakır (37° 55' N 40° 14' E) is located between Karacadağ Mountain and the Tigris River. Diyarbakir has a hot and arid climate. The hot periods (about eight months) are quite longer than the cold periods (about four months, from April to November) [23].

2.3. Diyarbakir traditional house

Diyarbakir traditional houses generally have a courtyard design closed by building masses on one, two, three, or four sides. According to how the spaces form the courtyard, the houses can be divided into three main groups: outer courtyard, inner courtyard, and middle courtyard. The outer courtyard plan type is divided into three groups: L, U, and intermediate [72]. The locations of the rooms are generally determined according to their intended use. The north-facing rooms of the courtyard are defined as summer rooms, and the south-facing rooms are defined as winter rooms. The east and west facades were generally used as spring shelters [23], [73]. The most special spaces of the house are the spaces to the north and south of the courtyard, defined as the summer house. Due to their orientation, they are protected from the sun. The heights of the rooms in this direction are higher than those in the other facades [73]. The iwan in this part of the house is generally defined as the summer iwan. Orhan Cezmi Tuncer (1999) found that 168 of the 279 buildings he studied had iwans. In Diyarbakır houses, iwans could be built with one, two, or three openings. Generally, the house's largest and most spectacular iwan is in the summer section [74]. The summer iwan in Diyarbakır houses is one of the most important building elements used mainly for cooling purposes [75]. In traditional houses in Diyarbakir, iwans are used in summer, winter, and spring. However, since the study focuses on the cooling function of the iwan, the iwans in the spring and winter sections are not included.

2.4. Case study

Four traditional houses with summer iwans in Diyarbakır were investigated within the scope of the study. All the buildings within the scope of the study are in the Suriçi area, which was declared an urban conservation area in 1988. These buildings are the Ziya Gökalp Museum, Dengbej House, Cemil Pasha Mansion Harem Section, and Behrampasha Mansion (Figure 3).

Figure 3. The iwans within the scope of the study and their locations in the historical city structure

Ziya Gökalp Museum: The building has a central courtyard plan and is a single-story building. There are rooms on all four sides of the building. The only iwan of the building is on the south side. The iwan measures 3.57m*9.90m*5.37m and has a pool (Figure 4a).

Cemil Pasha Mansion consists of three sections: harem area, reception area, and service area. There are a total of three courtyards, with one courtyard serving each of the sections [76]. Although there is an iwan in the harem section, the iwan in the greeting section is on the southern side. That's why the Selamlık section was included in the scope of the study. The Selamlık section has an I-type plan, and the rooms are on the north and south facades. The iwan in this section measures 7.88m*7.09*4.18m and has a pool (Figure 4b).

Dengbej House: The building has a U-shaped plan with an outer courtyard. The north and west facades are two-story, and the south facade is one-story. The single iwan of the building is on the south side and measures 4.26m*6.72*4.68m (Figure 4c).

Behrampasha Mansion: The southern façade of the building has a U-shaped plan and is two-storied, while the other parts are one-storied. The only iwan of the building is on the south side. The iwan is located on the upper floor and measures 4.08m*8.50m*5.03m (Figure 4d).

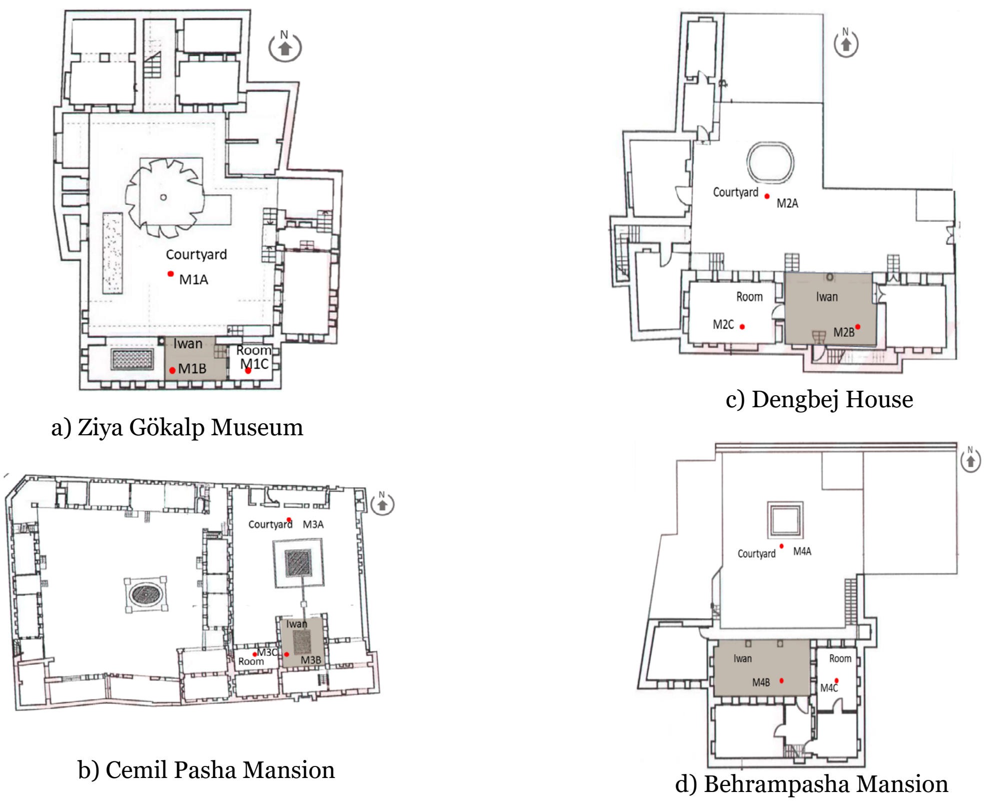

Figure 4. Building plans and temperature-measured areas within the scope of the study (Edited from Yıldırım 2002)

2.5. Method

The study uses field research, numerical data analysis, and an extensive literature review. A literature review was conducted on sustainable building design, traditional architecture, Diyarbakır traditional houses, the use of iwan in the world, the use of iwan in Diyarbakır traditional houses, and the effectiveness of iwan as a shading element.

Within the scope of the field research, four Diyarbakır traditional houses were examined. Physical and temperature measurements were taken from the courtyard, iwan, and rooms facing the iwan of these houses. The primary rationale for undertaking measurements in diverse spatial contexts pertains to the assessment of the indoor temperature of the iwan in relation to that of other spaces and the manner in which these spaces influence each other. The reason for not directly comparing the temperature of the iwan with the outdoor air is to analyze the effect of the relationship between the courtyard and the iwan on the indoor temperature. Comparison with the room is to determine the effectiveness of the iwan, a semi-open space, compared to the room, which is a closed space.

The buildings included in the study were selected according to the purposeful random sampling method. The buildings reflect the general characteristics of large-scale, traditional Diyarbakır houses previously included in the literature. The iwan, room facing the iwan, and courtyard features of these buildings are similar to serve the purpose of the study. The summer iwan of these buildings is directly oriented towards the north façade (+5°...-5°). The iwan has no additional shading elements such as tree shade, spaces around the courtyard, or an upper-story overhang. If there is a pool inside, it can be prevented from being filled with water. Iwans that do not have any landscape elements, or if they do, they can be moved to another area on the measurement day. The measurement room is oriented to the north in all buildings, and one facade faces the iwan. These rooms do not use air conditioners, ventilators, high-level heat-generating lighting, or mechanical devices that will affect the heat on the measurement day. The thickness of the room walls that will affect the thermal insulation is similar and averages 60-70 cm. Care was taken to ensure that there was at least one area in the courtyards without additional shading, and the temperature was measured in this area.

A laser meter and a 5-meter tape measure were used for physical space measurements. Micro Lite USB Data Logger 5016 was used for temperature measurement. In order to prevent the devices from being affected by surface temperatures, they were placed suspended so as not to touch the surface. The height of the devices from the floor is 150cm. A total of 12 devices were measured simultaneously in all buildings every 60 minutes from 3 different points for each date. The measurements were made on 10.08.2023 when the Eyyam ı Bahur temperatures, which cause high temperatures, were effective, 16.08.2023 when the heat wave from Basra was effective, and 28.08.2023 with seasonal normal temperatures. Hourly measurements were taken between 07.00 and 19.00. This time interval was determined according to the sunrise and sunset on a hot summer day in Diyarbakır. The hourly temperature data of the study area were taken from Sur/Ünal Heliport, the closest observation network to the region, through the 15th Regional Directorate of Meteorology.

The points where temperature measurements were taken are shown in Figure 8. The measurement points are coded separately for each room's courtyard, iwan, and room. They are M1A, M1B, and M1C for Ziya Gökalp Museum, M2A, M2B, and M2C for Dengbej House, M3A, M3B, and M3C for Cemil Pasha Mansion, and M4A, M4B, and M4C for Behrampasha Mansion. The devices in the courtyard are placed close to the centre and at points where there are no blocks to interrupt solar radiation. The devices inside the iwan were placed at the deepest points of the iwan, furthest away from the water element and the openings in the walls that can be opened and closed. The devices in the rooms are placed in the centre, away from the surrounding walls and openings.

3. FINDINGS AND DISCUSSION

Courtyard, iwan, room, and outdoor air temperatures were compared. The temperature difference between the outdoor, courtyard, iwan, and room, which shows the spatial grading of traditional Diyarbakır houses from outside to inside, was used to determine the thermal performance of the iwan. This gradation shows its effect on average temperatures.

In the measurements, the average temperature was highest in the outdoor environment (38.82 °C) and lowest in the iwan (30.22). The average temperature of the iwan is 8.6 °C, 7.12 °C, and 0.97 °C lower than the outdoor, courtyard, and room, respectively. The purpose of shading elements can be explained as providing indoor thermal comfort without damaging visual comfort [77]. The fact that the iwan is a semi-open space that directly views the courtyard and has a temperature approximately 20% lower than the outdoor environment shows that it has successfully achieved its purpose of use as a shading element. In the study carried out by Rijal et al. (2013), appropriate indoor temperatures are shown as one of the most effective factors in providing thermal comfort, which shows the importance of the iwan with low indoor temperature in providing thermal comfort [78].

In addition, the use of appropriate shading devices has been proven in previous studies to minimise the need for energy intensive mechanical cooling systems. Therefore, effective temperature control of the eyva has the potential to reduce energy consumption for cooling purposes [27], [79]. The lowest daily maximum temperature and minimum temperature are usually in the iwan. The daily temperature difference change is close to each other in the iwan and room and is the lowest. This is also important for user use. Although the temperature in the iwan is generally lower than the other spaces, it seems to show its best performance until 15:00. This shows that the iwan is less affected by the change in outdoor temperature. However, after 15.00 h, the sun's angle of incidence decreases, exposing the iwan to direct solar radiation. Another reason is the accumulated increase in the surface temperature during these hours (Table 1, Figures 5, 6 and 7).

Table 1. Temperature measurements and daily average changes in the spaces

	Outdoor	Courtyard	Iwan	Room
9 Aug.				
Mean	39.93	38.25	31.81	31.24
Min.	31.80	29.30	30.96	30.79
Max	44.30	44.51	32.59	31.90
16 Aug				
Mean	38.26	38.55	31.06	32.39
Min	28.20	29.07	29.50	31.74
Max	43.50	42.00	31.84	32.73
07 Sept.				
Mean	38.27	35.21	27.80	29.93
Min	29.80	23.95	26.34	29.30
Max	43.60	46.71	28.66	30.38
Mean	38.82	37.34	30.22	31.19

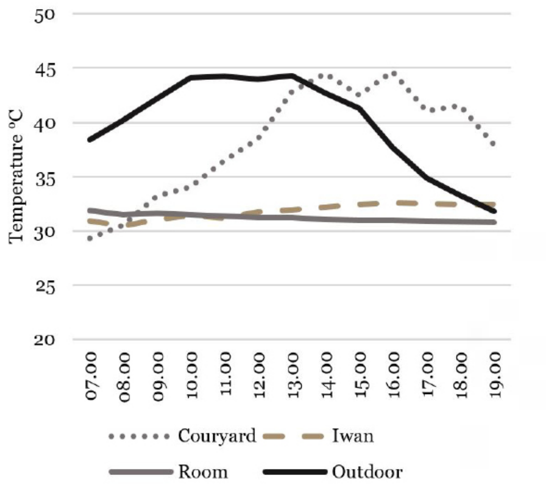

Figure 5. On August 9, the air temperature outside, in the courtyard, iwan and room

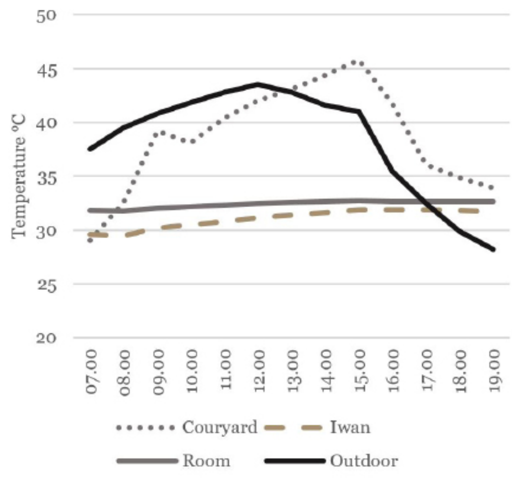

Figure 6. On August 16, the air temperature outside, in the courtyard, iwan and room

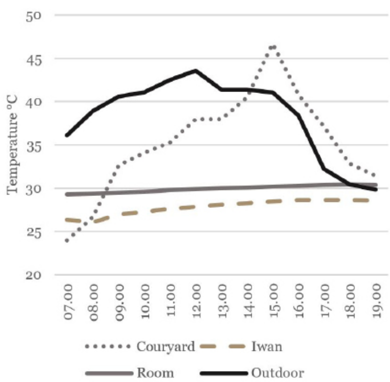

Figure 7. On September 7, outdoor, courtyard, iwan and room air temperature

These features of the iwan show that it has a significant potential for use on hot summer days in Diyarbakır traditional architecture. It is especially effective during daylight hours when the sun's angle of incidence approaches 90 degrees. The most important reason for this is its use as a shading element (Figure 8).

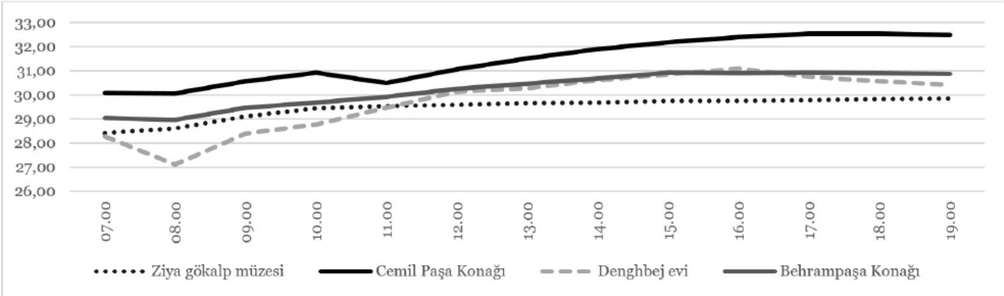

Figure 8. Hourly average temperature changes of the iwan

When the hourly average temperature changes of the iwans within the scope of the study are analyzed, it can be said that the least change is in the iwan of Ziya Gökalp Museum. In addition, the average temperature is the lowest in Ziya Gökalp Museum. The fact that the IL*IH iwan opening is also the highest in Ziya Gökalp Museum supports this situation. In fact, even if the shading characteristics of the iwan are the same, the larger the opening, the cooler it gets due to natural ventilation and cooling (Table 2).

Table 2. Iwan dimensions and average temperature data

	IW	IL	IH	IV	IW*IL	IW*IH	IL*IH	EAT (°C)
Ziya Gökalp Museum	3,57	9,90	5,37	**189,79**	35,34	19,17	53,16	**29,46**
Cemil Pasha Mansion	7,88	7,09	4,18	**233,53**	55,87	32,94	29,64	**30,23**
Dengbej House	4,26	6,72	4,68	**133,98**	28,63	19,94	31,45	**29,75**
Behrampasha Mansion	4,08	8,50	5,03	**174,44**	34,68	20,52	42,76	**31,44**

IW: iwan depth, IL: iwan length, IH: iwan height, EAT: iwan average temperature

It can be said that the depth of the iwan does not directly affect the indoor temperature individually. However, Eskandari et al. (2018) determined that the most suitable iwan depth is 1.5m in computerized analysis [39]. In the current study, when the iwan depths are proportioned according to 1.5m, it can be said that the iwan closest to these dimensions is in the Ziya Gökalp Museum. In this context, the fact that the coolest iwan is also in the Ziya Gökalp Museum supports this situation.

A certain proportion does not seem to exist between the IW*IH measurements, showing the side wall areas and the temperature change. In his study, Eskandari stated that the side walls of the iwan do not significantly affect the indoor temperature (Eskandari, Saedvandi, and Mahdavinejad 2018). The results of the current study support this situation. There is a direct correlation between the daily average temperature changes and the ratio of the east wall of the courtyard to the height of the iwan and the daily temperature change of the iwans (Table 3).

Table 3. Analysis of the effect of courtyard and iwan dimensions/ratios on temperature

	CW(m)	CL(m)	CHN (m)	CHE (m)	CHW (m)	CHN/IH(m)	CHE/IH(m)	CHW/IH (m)	EDC (°C)
Ziya Gökalp Museum	16,01	13,72	7,49	5,76	3,51	1,39	1,07	0,65	**1,41**
Cemil Pasha Mansion	22,82	21,32	3,97	3,57	9,37	0,95	0,85	2,24	**1,83**
Dengbej House	11,82	13,27	5,8	3,48	5,68	1,24	0,74	1,21	**2,13**
Behrampasha Mansion	13,37	10,97	3,82	3,38	3,50	0,76	0,67	0,70	**2,41**

CW: courtyard depth, CL: courtyard length, CHN: courtyard north wall height, CHE: courtyard east wall height, CHW: courtyard west wall height, IH: courtyard height, EDC: iwan daily temperature change

As the ratio of the height of the east wall to the iwan wall increased, the temperature change decreased. The ratio of the height of the eastern wall of the courtyard to the height of the iwan is Ziya Gökalp Museum, Cemil Pasha Mansion, Dengbej House, and Behrampasha Mansion from large to small. The daily temperature change is also the same. In this context, it can be said that the eastern courtyard wall plays an active role in the iwan temperature. The increase in the height of the eastern façade can be shown as the reason for this, as it allows the sun to cut the solar radiation until it reaches the vertical position.

It can be said that more than one design strategy rather than a single measure is effective on the interior temperature of the iwan. In this context, it can be said that only the opening, courtyard wall size, or depth of the iwan interior temperature affects the interior temperature together, not alone. The fact that more than one physical feature was analysed in the study conducted by Eskandari et al., (2018) supports this situation [39]. In addition to Ziya Gökalp Museum iwan temperature can be shown as one of the important examples of this situation. The fact that no single measure is directly proportional to the average temperature of the interior of the iwan individually supports this situation.

4. CONCLUSION

This study investigates the effect of iwans used in traditional architecture in hot and arid climates on indoor temperature as an outdoor shading space. Temperature measurements, physical space measurements, and a literature review were conducted to determine the climatic comfort effect of the iwan. As a result of the analyses and evaluations, the effect of the iwan on the indoor temperature and the design parameters affecting the indoor temperature, which have not been analysed sufficiently, have been revealed. These parameters depend especially on the physical properties of the iwan and the spaces to which the iwan is connected. These parameters depend especially on the physical characteristics of the iwan and the spaces to which the iwan is connected.

Iwans, frequently used in Diyarbakır traditional architecture, are within the scope of the study. In order to evaluate the effectiveness of the iwan comparatively, the outdoor temperature, as well as the rooms and courtyards of the houses within the scope of the study, were analyzed. Temperature measurements were carried out in the summer period of 2023. As a result of the studies;

(1) The average daily temperature of the iwan is lower than the other spaces. The most effective hours of the iwan are around 15.00.
(2) The daily temperature variation is lowest in the iwan and the room.
(3) Daily maximum and minimum temperatures are lowest in the Iwan
(4) In the analysis of the iwan depth, it can be said that 1.5 m is ideal. This supports the study of Eskandari, Saedvandi, and Mahdavinejad (2018) [39].
(5) The ratio of the height of the east wall of the courtyard to the height of the iwan affects the indoor temperature of the iwan.
(6) It can be said that the iwan opening affects the indoor temperature.
(7) The iwan side walls do not significantly affect the indoor temperature. This supports the study of Eskandari, Saedvandi, and Mahdavinejad (2018) [39].

These parameters, which have been found to be effective in providing indoor thermal comfort, can be examined in the analysis of iwans in the traditional architecture of different regions. For the future, the author proposes to study the effectiveness of the iwan used in the traditional architecture of hot and humid climates.

DECLARATION OF COMPETING INTEREST

The authors of this article declare that they have no financial, professional or personal conflicts of interest that could have inappropriately influenced this work.

AUTHORSHIP CONTRIBUTION STATEMENT

Ruşen Ergün: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing.

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