Middle-East Journal of Scientific Research 11 (3): 357-366, 2012
ISSN 1990-9233

Design with Climate-What Can We Learn from the past to Cope with Climate in Terms of Design Strategy and Usage Style of Courtyard Houses?

Ayhan Bekleyen and Neslihan Dalkılıç

Department of Architecture, Faculty of Architecture, Dicle University, Diyarbakır, Turkey

Abstract: This study examines the comfort conditions of seasonal living spaces in the indigenous courtyard houses (ICHs) of Diyarbakır, a city located in southeastern Turkey. This study aims to elucidate a particular characteristic of these houses: the seasonal movement around the courtyard. The purpose of the study is to test how the houses were designed to allow seasonal movement around the courtyard. Another purpose of the study is to help with the renovation of similar houses by examining, in detail, their energy-saving design. The data was collected by measuring the temperature in one of the ICHs at different times during 2009. The results show that ICHs meet the comfort conditions in the following rotation: the autumn room in September and October; the winter room in November, December, January, February and March; the spring room in April and May; and the summer room in June, July and August. Another finding was that there is a horizontal counterclockwise movement around the courtyard and vertical movement through the summer spaces at different times of the day. The ICHs in Diyarbakır, whose residents move according to the necessities of the climate, have the potential to inspire modern living spaces.

Key words: Courtyard house ・ Hot-dry climate ・ Spatial thermal comfort ・ Seasonal and daily mobility

INTRODUCTION

In the southeastern part of Turkey, there are a number of historical settlements, including Diyarbakır, where courtyard houses constitute an important part of the city's texture. Courtyards designed especially for hot, arid regions protect residents from external conditions and they have some cultural significance in addition to their climate advantages. The ICHs were designed to decrease the effect of high temperatures in summer and to provide the best comfort conditions throughout the year. Starting in the 1950s, these houses, some of which were built 700 years ago, lost their importance because of the increasing population and the demand for more houses in a different architectural style. As some recent studies have revealed [1,2], these past references were not used in the design of new houses. The lessons that could be learned from the architecture of the past were ignored. The neglect of this knowledge increased the energy consumption of the new buildings designed without an understanding of the region's climate. It has been stated by many researchers that an ICH provides the optimal conditions for expending less energy [3,4]. However, to our knowledge, this has not been proven by any scientific studies that involved temperature measurements. The purpose of this study is to examine the indoor temperatures of the spaces based on the data obtained in 2009 and to examine whether there are differences in the indoor temperatures of the spaces that are subject to seasonal movement.

Courtyard Houses in the Middle East: There are many studies that examine the climatic features of courtyard houses. Some of these studies indicate that there is a seasonal movement around the courtyard according to the position of the sun. These studies emphasize movement around the courtyard according to the season and the time of the day [5-13]. The spaces facing the north side of the courtyard are generally used in the summer, while the sections facing the south are used in winter. The residents continually move between these spaces according to the seasons. Within the context of this study, this kind of movement is called horizontal seasonal movement. It is possible to see examples of this movement in Arab, Iranian and Turkmen settlements.

Corresponding Author: Dr. Ayhan Bekleyen, Faculty of Architecture, Department of Architecture, Dicle University, 21280 Diyarbakır, Turkey.
Tel: +90-412-2488001-3505.

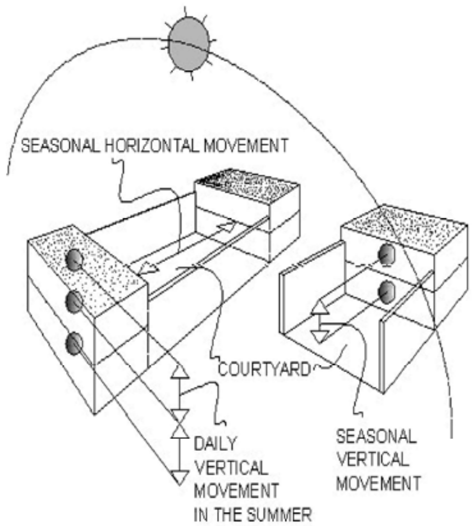


Fig. 1: Daily and seasonal movements of users in the Middle East

Another type of movement can be observed between the upper and lower floor spaces of the courtyard houses (especially in Baghdad houses), which is referred to as vertical seasonal movement in this study. Finally, there is the vertical daily movement, a type of movement observed in most of the traditional houses of the Middle East. The motive for all these movements is to be in a cooler space in summer and a warmer space in winter (Fig.1).

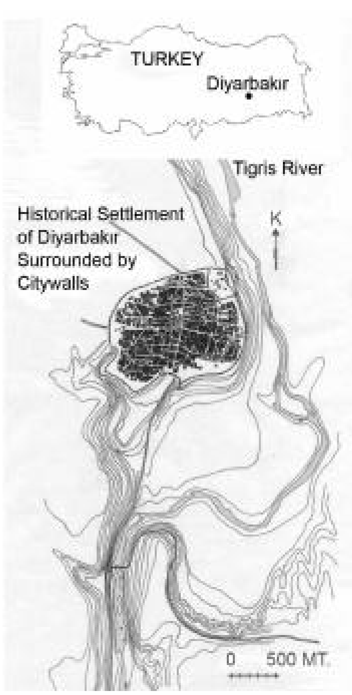
With one exception, the results of the above studies lack short-term or long-term experimental data. Scudo [7] examined the air flow related to temperature changes in a courtyard house. To the best of our knowledge, there is no study on the indoor temperatures of ICHs in Diyarbakır in different seasons. The purpose of the present study is to collect experimental data on the temperature changes in these houses.

Indigenous Courtyard Houses of Diyarbakır

Location and Climate: The city of Diyarbakır (37° 54' N, 40° 14' E, altitude 650 m.) is in southeastern Turkey in the northern part of Mesopotamia, the area between Tigris and Euphrates rivers. This historical settlement was constructed on a basalt layer on the western bank of the River Tigris and is surrounded by high city walls (Fig. 2). The city is full of beautiful examples of architectural works made of stone.

The temperature of the city is over 40°C in summer. In winter, it may be as low as-11°C. Briefly, the city has a hot and arid temperature and the average precipitation is low (40.7 mm).

General Description of the ICH in Diyarbakır: Because of the city walls that surround it, the historical settlement in Diyarbakır has a limited zone for a living area. In this historical city, the hot and dry climate caused



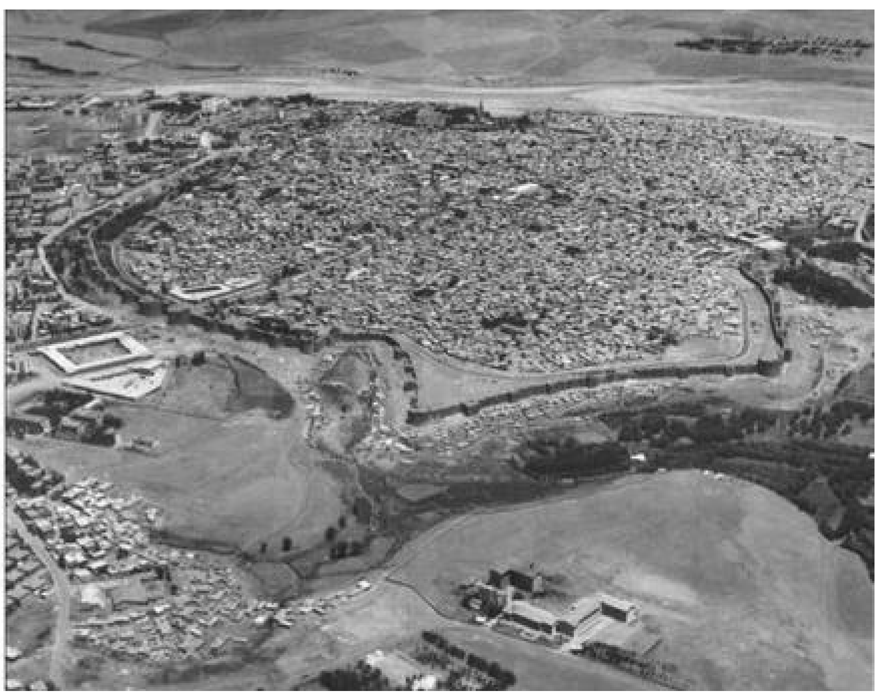


Fig. 2: Location and view of the historical settlement of Diyarbakır

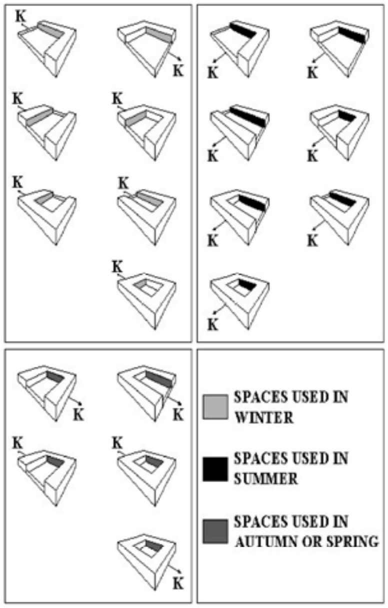


Fig. 3: Position of seasonal spaces around courtyard in the ICHs

the construction of living spaces designed around a courtyard (Fig. 3). The main reason for this organization was due to the adjacent outer spaces of courtyard houses not being exposed to sunlight. However, three of the inner walls of the courtyard receive sunlight. The openings of the spaces facing the courtyard affect the internal comfort temperature in spite of the fact that "the stone walls with a thickness of 0,50-0,60 m. and the flat earth-covered roofs with a thickness of 0,30-0,50 m. provide good thermal insulation and suitable thermal lag" p.329 [14].

The part of the house that faces the courtyard and is not exposed to direct sunlight is the summer living space, whereas the part that receives the highest amount of sunlight is the winter unit. The summer rooms, the summer iwans and serdabs, are on the south of the courtyard and face north. The units on the north of the courtyard that face south are the winter rooms and winter iwan, which receive sunlight all day. Some of the bigger houses also contain autumn rooms on the eastern parts of the courtyard and spring rooms on the west. The sample house in this study contains summer, winter, autumn and spring rooms.

MATERIALS AND METHODS

This study examined the thermal performance of an ICH in Diyarbakır and researched the validity of the theories put forward regarding the spatial design of these houses. The first thing done for the purposes of this study was to find a house that exemplified an ICH. It was crucial to find a house with living spaces around all sides of its courtyard that had all the features of an ICH. Another important factor was that the house that was chosen for the purposes of this study could not have heating or cooling devices. The only house in Diyarbakır with these features was the Cahit Sıtkı Tarancı house. Therefore, it was chosen as the sample house for use in this study. This house was not heated mechanically in winter or cooled in summer with air conditioners or similar devices. It also maintained its original structure.

The house belongs to the family of Cahit Sıtkı Tarancı, a famous Turkish poet and it reflects the main characteristics of ICHs with its large summer iwan, serdab, cellar and seasonal rooms around a central courtyard. With the basements on the north and east, all the blocks around the courtyard are two stories. Another advantage of this house was that there is not a high building near it to block the sun. This enabled us to obtain healthy results. Since it was not possible to find another house that met the requirements mentioned above, only this house was used as the sample for the study.

The temperatures in the house's living spaces were recorded by the researchers to prove there was seasonal movement around the courtyard. Data loggers were used to measure and record the temperatures (MicroLite, The Plug and the Record Mini Logger measure temperatures between 40 °C and 80 °C with a high level of accuracy to 0.3 °C). The temperatures in different parts of the house were measured. Four rooms in the east, west, south and north of the building were chosen (Fig. 4) to examine the seasonal temperature changes in the house. Temperature measurements were taken in these rooms between the 19^{th} and 23^{rd} of every month for five days. The data loggers recorded the temperatures every 15 minutes. The monthly temperatures of every space were averages of the five-day measurements. Accordingly, the temperatures of the rooms were compared to find which of them had better comfort temperatures. This provided information to test the horizontal seasonal movement in the house. In addition, in summer, the temperatures of the lower floor summer room, courtyard, iwan, serdab and the roof of the building were also measured to examine the daily changes of temperature in the house. The purpose was to examine the vertical daily movement in summer.

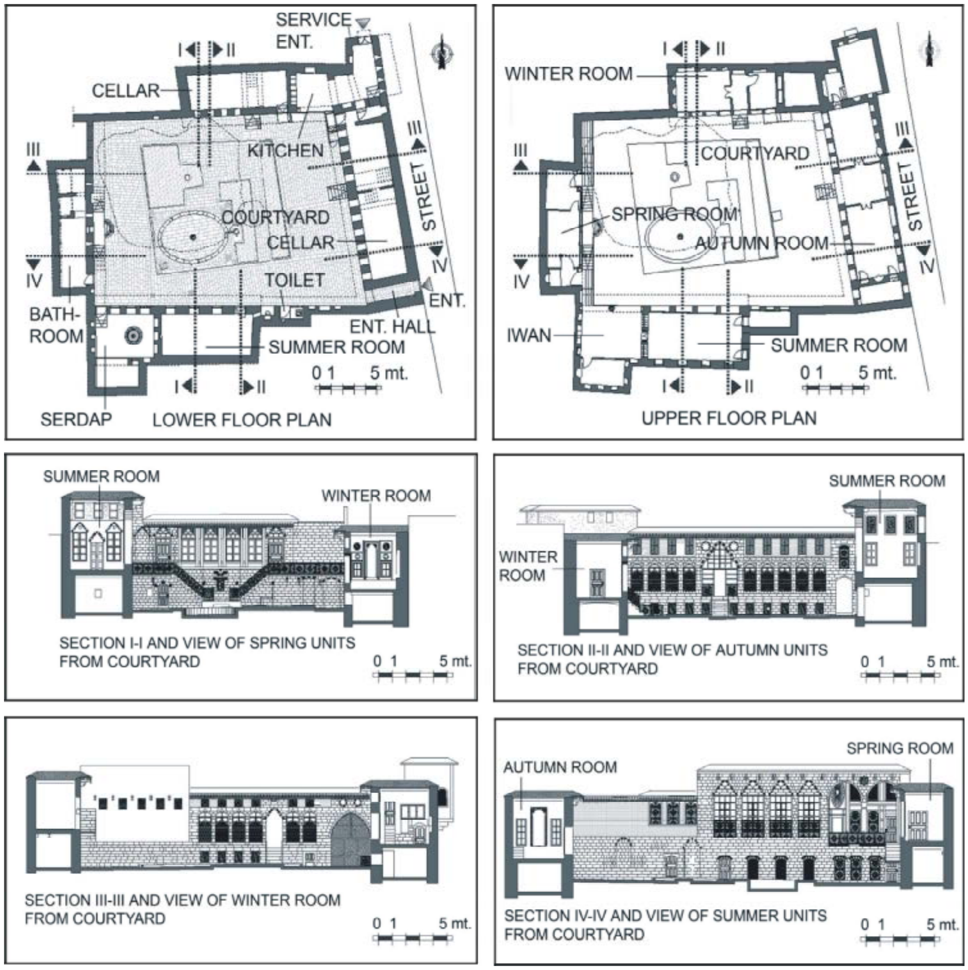


Fig. 4: Floor plans, sections and views of seasonal units from courtyard of Cahit Sıtkı Tarancı House (These drawings were made by M.Þakir Güler, Osman Bilden, Ferit Aydın, Muhittin Oruç with the supervision of Neslihan Dalkılıç)

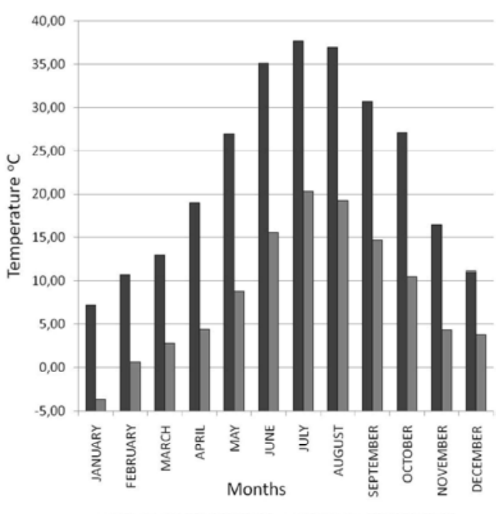


Fig. 5: Temperature data for Diyarbakır (National Meteorological Office)

The temperature/time graphics of these spaces were analyzed and compared to the comfort temperature to find out which living space was more appropriate for the season. To find the comfort temperature, the mean values of the city's monthly outdoor temperatures (Fig. 5) were provided by the Meteorological Office [15]. To determine the indoor comfort temperatures, the following Humphreys [16] formula was used to calculate neutral temperatures according to average outdoor temperatures. In the formula

$$T_n = 11.9 + 0.534\ T_{om,}\ [16]$$

T_n is the neutral temperature (predicted indoor comfort temperature) in buildings without heating or cooling devices (naturally ventilated buildings) and T_{om} is the mean monthly outdoor temperature.

Table 1: Predicted indoor comfort temperature and min.-max. comfort temperature for Diyarbakır

	T_{om} (°C)	T_n (°C)	Min. and Max. Comfort Temperature T_n ± 2.5°C
January	1.4	12.6	10.1-15.1
February	05.6	14.9	12.4-17.4
March	07.9	16.1	13.6-18.6
April	11.8	18.2	15.7-20.7
May	18.2	21.6	19.1-24.1
June	25.9	25.7	23.2-28.2
July	29.5	27.7	25.2-30.2
August	28.6	27.2	24.7-29.7
September	22.9	24.1	21.6-26.6
October	18.5	21.8	19.3-24.3
November	09.8	17.1	14.6-19.6
December	07.1	15.7	13.2-18.2

T_{om} is the mean monthly outdoor temperature
[National Meteorological Office]
T_n is the neutral temperature (predicted indoor comfort temperature)

The neutral (comfort) temperature has a range that can tolerate ± 2.5°C. Therefore, in the monthly graphics, the values that are 2.5 °C above the calculated neutral temperature are given as the maximum comfort temperature, while the values that are 2.5 °C below the neutral temperature are accepted as the minimum comfort temperature. Table 1 shows the minimum and maximum comfort temperatures of each month.

In their previous studies, the researchers examined these houses in detail [1,2,17-20]. Detailed drawings of the houses have been prepared. These experiences provided a better interpretation of the data obtained from this study.

RESULTS AND DISCUSSION

In this part of the study, the monthly temperature measurements of the seasonal rooms are presented in diagrams to show horizontal seasonal movement. Each of the seasonal rooms was examined separately and the results are summarized below. The data related to the daily temperature changes in the summer living spaces are also presented. This provided evidence for vertical daily movement in the summer.

Autumn Room: The indoor temperatures of the autumn room were examined and it was found that the temperature of the room is closest to the comfort temperature in September and October. As can be seen in Fig. 6, in September, the indoor comfort temperature was calculated as 24.1 °C. Compared to the other parts of the house, the temperature of the autumn room was closer to the comfort temperature in most parts of the day (between 00:00-03:30 and between 12:00-22:00, a total of 13.5 hours). It has been determined that the autumn room (Fig. 7) has the best comfort temperature in autumn.

Winter Room: In November, the temperature of the winter room was closer to the indoor comfort temperature (17.1 °C) than the other parts of the house examined in this study. The temperature of the room was between the minimum and maximum comfort temperatures for this month. In December, January and February, none of the seasonal rooms had a temperature between the minimum and maximum comfort levels. However, when the temperatures were compared, the winter room had

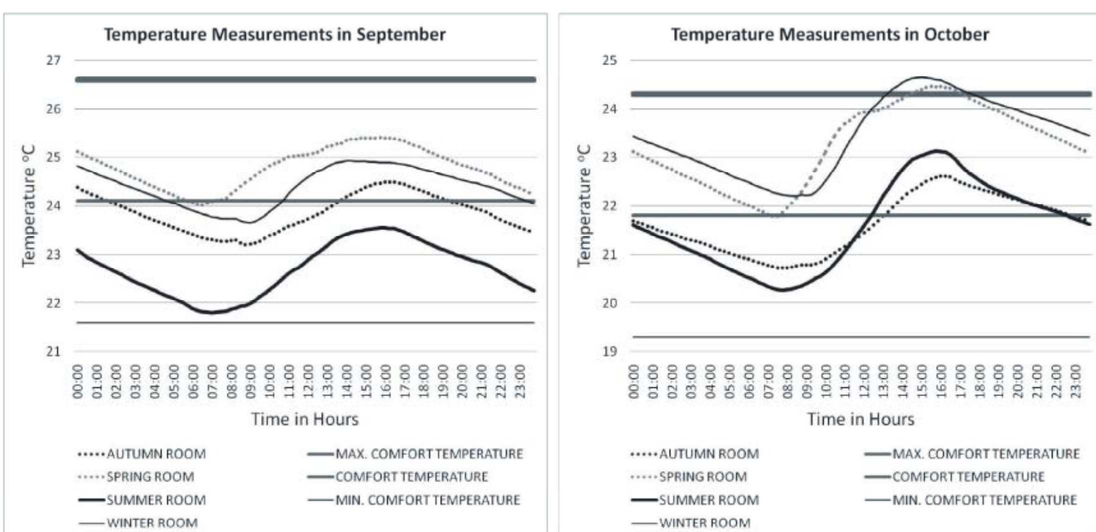


Fig. 6: Mean indoor temperature of the seasonal rooms of the ICH in September and October

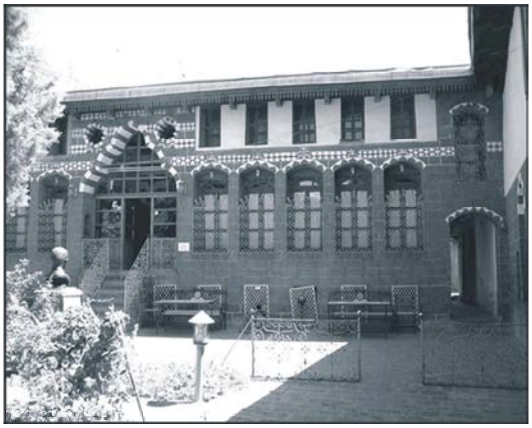


Fig. 7: View of autumn room from the courtyard

Fig. 8: View of winter room from the courtyard

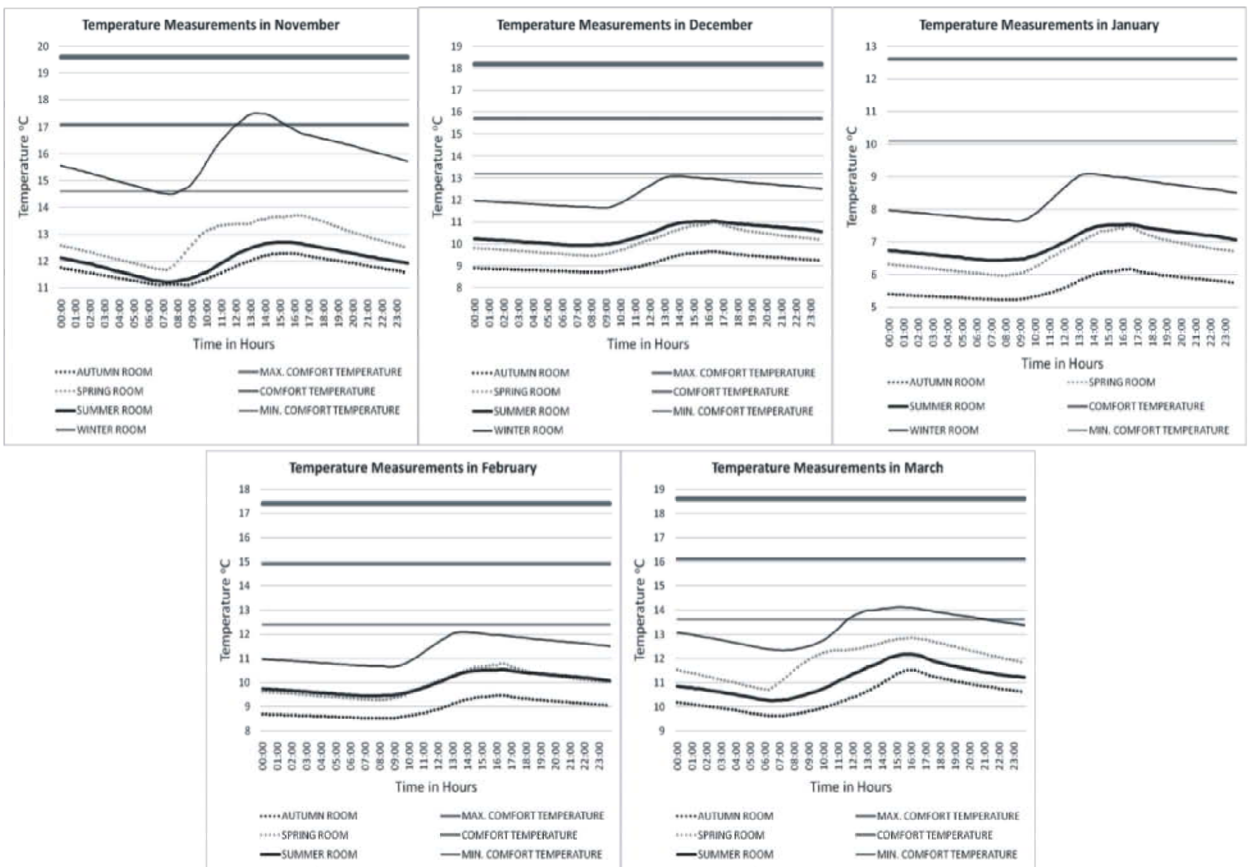


Fig. 9: Mean indoor temperature of the seasonal rooms of the ICH in November, December, January, February and March

the highest temperature of all the rooms. In March, the temperature of the winter room was slightly above the minimum comfort level (between 12:00-21:00, 9 hours). According to these findings, it can be said that, although it does not meet the comfort conditions, the winter room (Fig. 8) is warmer than the other spaces from December to March (Fig. 9).

Spring Room: The indoor temperature of the spring room was closest to the indoor comfort temperature in April and May. It was ascertained that the average temperature of the spring room (18.2 °C) was closest to the indoor comfort temperature during most times of the day (between 00:00-12:00 and 22:00-24:00, 14 hours). In May, the comfort temperature was determined to be 21.6°C.

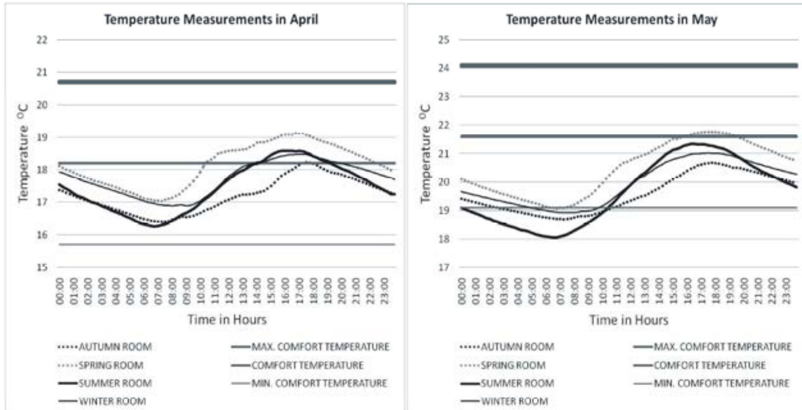


Fig. 10: Mean indoor temperature of the seasonal rooms of the ICH in April and May

Fig. 11: View of spring room from the courtyard

The spring room had the closest average temperature (Fig. 10). These results suggest that the spring room (Fig. 11) is the most convenient room of the house in spring.

Summer Room: According to the data obtained from measuring the indoor temperatures of the house, the summer room is (closest to the comfort temperature) the coolest room in summer (Fig. 12). However, it was also found that the temperature of the winter room was close to that of the summer room in June, July and August. This result was interesting because it was anticipated the winter room would be the hottest room since it faced south and received sunlight during the day. The researchers noticed that the summer room in this building had seven upper windows, three facing east and four facing south (Fig. 13). It was hypothesized that these windows might cause a temperature increase. Therefore, the temperature of the summer room in the lower floor was measured in August in addition to the other rooms. It was found that the summer room in the lower floor was 1.54 °C cooler than the room in the upper floor (Fig. 14). This finding verifies the theory that the upper windows in the upper floor room caused the unexpected result.

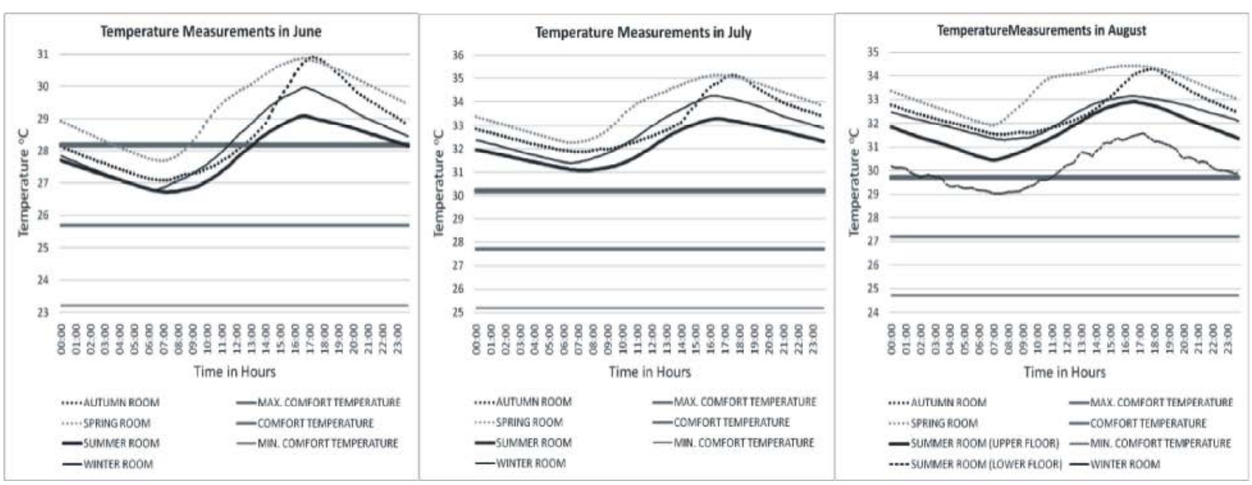


Fig. 12: Mean indoor temperature of the seasonal rooms of the ICH in June, July and August

Fig. 13: Interior view of upper windows of summer room in upper floor

Fig. 14: View of summer rooms in lower and upper floor from courtyard

Another interesting result was the fact that the winter room was not the hottest room. When the building was examined, it was noticed that the winter room was not exposed to direct sunlight in summer because of a large tree in the courtyard (Fig. 15).

In general, the results indicate that seasonal rooms in ICHs have the best comfort conditions for the intended seasons (Table 2). This proves that there is seasonal movement around the courtyard every season.

Fig. 15: View of winter room not exposed to direct sunlight in summer because of the large tree in the courtyard

Table 2: The months in which each room is probably used

Seasons	Months	In ICoHD, spaces used in various seasons and their using periots
Autumn	September, October	Autumn Room
Autumn, Winter, Spring	November, December, January, February, March	Winter Room
Spring	April, May	Spring Room
Summer	June, July, August	Summer Room

Although the indoor temperature of the summer room was close to the comfort temperature in June, it exceeded the maximum comfort temperature in July and August. Some other spaces in the house have temperatures that are closer to comfort temperature than the summer room. For example, the serdab had the best comfort temperature for these two months all day (Fig. 16). The roof, which is traditionally used for sleeping in summer, had the comfort

Fig. 16: View of iwan(a) and serdap(b) from courtyard (left); the interior view of serdap (right)

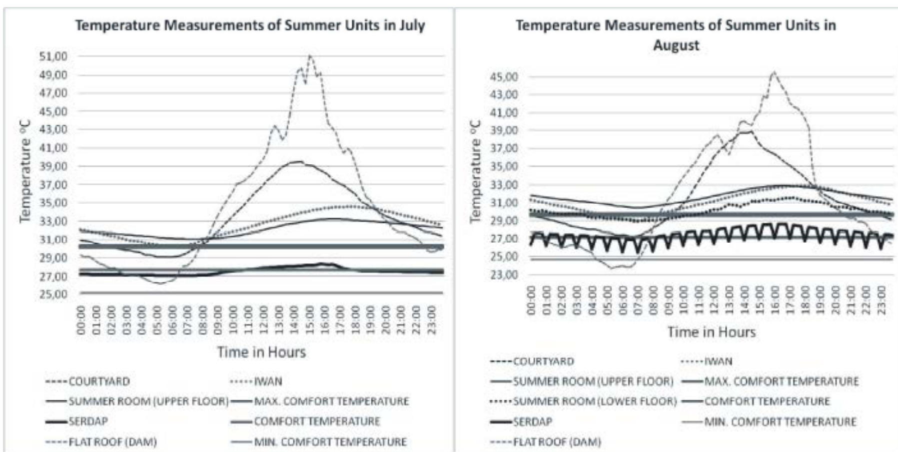


Fig. 17: Mean temperature of summer units of ICH in July and August

temperature overnight in July (22:45-8:00) and in August (20:30-8:15). The roof was the coolest space in the house between 03:15-6:30 in July and 03:15-7:45 in August. The highest and lowest temperatures of the roof were 51.16 °C (15:00) and 26.19 °C (05:15) in July and 45.56 °C (16:00) and 23.76 °C (05:15) in August. The summer room in the upper floor did not meet comfort conditions in these two months. The other summer room in the lower floor met comfort conditions between 03:15 and 10:45. The iwan met the comfort temperature for 45 minutes in July (06:00-06:45) and 3.5 hours a day in August (22:45-09:00). The courtyard had a temperature within the comfort conditions between 02:00-07:45 in July. It also had comfort conditions between midnight and early in the morning in August. Finally, it was noted that, in summer, the upper floor summer room does not meet comfort conditions. However, the iwan reached the comfort temperature early in the morning, the lower floor summer room until noon and the serdab almost all day long. The roof and the courtyard are both temperature efficient for sleeping at night. The results indicate the spaces designed for summer usage exhibit the comfort conditions at different times of the day in summer (Fig. 17). This is evidence for the fact that there is vertical movement in the house in summer.

CONCLUSIONS

Many studies around the world have examined the relationship between the local features of traditional architecture and the natural environment. The main purpose of these studies is to provide an opportunity to transfer the information obtained from studying traditional usage to modern architecture. Traditional architecture created some solutions that are in harmony with nature and provide comfort conditions for residents. Traditional buildings find the optimal balance between the inner and outer spaces.

This study, which was conducted in southeastern Turkey, revealed results that can serve the above purpose and be used as a reference for the future studies. The temperatures of different parts of the house were proven to be different, especially in summer. Therefore, there is a vertical daily movement in summer and a horizontal seasonal movement throughout the year. The ICH is the result of a design strategy that agrees with its environment. It is a sustainable building tradition that provides lessons from the past.

The directions of the openings in the ICH affect temperatures within the space. The results of this study reveal that, in the design of the new buildings, the directions of the openings should be considered carefully. The design strategy of the ICH and the passive environmental control system used by its inhabitants is very effective in providing thermal comfort for its users. This architectural system, which is based on natural materials and traditional construction techniques, was designed to provide comfortable living conditions for human beings. The design of the ICH carries many clues for the architecture of modern housing. As a result, this housing type has the potential to inspire the design of future houses.

REFERENCES

1. Bekleyen, A., M. Yıldırım and H. Sarıgöl, 2004. The tradition of building houses with iwan in the southeastern Anatolia: Traditional summer houses (kiosks) in Diyarbakır. Yapı, (275): 89-94 [in Turkish].
2. Bekleyen, A. and N. Dalkılıç, 2007. Combination of modernity and tradition (Diyarbakır): is it possible to design future dwellings considering the concept of climate based traditional houses? In the Proceedings of 19th International Building and Life Congress, pp: 277-287.
3. Erginbaş D., 1953. Diyarbakır houses. Istanbul Technical University Faculty of Architecture, Istanbul [in Turkish].
4. Sözen, M.Ş. and G.Z. Gedik, 2006. Evaluation of traditional architecture in terms of building physics: Old Diyarbakır houses. Building and Environment, 42(4): 1810-1816.
5. Cantacuzino, S. and K. Browner, 1976. Houses and Remedy 3: Rehab, in Isfahan, Special Issue. Architectural Review, 159(951): 305-314.
6. Abdulac, S., 1982. Traditional housing design in the Arab countries. In Urban Housing, Ed., M.B. Sevcenko, Cambridge: Aga Khan Program for Islamic Architecture, pp: 2-9.
7. Scudo, G., 1988. Climatic design in the Arab courtyard house. Environmental Design: Journal of the Islamic Environmental Design Research Center, (1-2): 82-91.
8. Herdeg, K., 1990. Formal structure in islamic architecture of Iran and Turkistan. Rizzoli International Publication, New York.
9. Al-Azzawi, S., 1996. Seasonal impact of climate on the pattern of urban family life: Indigenous courtyard houses of Baghdad region of the hot-dry climates. Renewable Energy, 8(1-4): 283-288.
10. Al-Azzawi, S., 1996. Daily impact of climate on the pattern of urban family life: Indigenous courtyard houses of Baghdad region of the hot-dry climates Part I: Daily shifts or daily movements in summer. Renewable Energy, 8(1-4): 289-294.
11. Memarian, G. and F.E. Brown, 2003. Climate, culture and religion: aspects of the traditional courtyard house in Iran. Journal of Architectural Planning and Research, 20(3): 181-198.
12. Ragette, F., 2006. Traditional domestic architecture of the Arab Region, Axel Menges, American University of Sharjah, Sharjah.
13. Bekleyen, A. and N. Dalkılıç, 2011. The influence of climate and privacy on indigenous courtyard houses in Diyarbakır, Turkey. Scientific Research and Essays, 6(4): 908-922.
14. Özdeniz, M.B., 1991. Bioclimatic Analysis of Traditional Turkish Houses. Environment International, 17(4): 325-336.
15. National Meteorological Office, 2010. Temperature values, Diyarbakır.
16. Humphreys, M.A., 1978. Outdoor Temperatures and Comfort Indoors. Building and Research Information, 6(2): 92-105.
17. Güneli, Z. and A. Bekleyen, 1995. Determination of the factors that affect the form of the old houses in Diyarbakır. Yapı, (163): 68-74 [in Turkish].
18. Dalkılıç, N., 1999. The typologies of plan, facade and elements of traditional houses in Diyarbakır, Master thesis, Gazi University, Ankara, Turkey, [in Turkish].
19. Dalkılıç, N. and I. Aksulu, 2001. Diyarbakır city, traditional housing architecture. Gazi Art Journal, 2: 53-69 [in Turkish].
20. Gür, Ş.Ö. and A. Bekleyen, 2003. The failure of man-environment studies in influencing design decisions. In People, Places and Sustainability, Eds., G. Moser, E. Pol, Y. Bernard, M. Bonnes, J.A. Corraliza and M.V. Giuliani. Göttingen: Hogrefe and Huber Publishers, pp: 94-106.