Optimization of Proportions of Central Courtyard based on Comfort Standards in the Traditional Qajar Period Houses in Boushehr

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Abstract

The traditional architectural methods used in the historical cities of Iran provide useful information on various fields related to architecture and urban planning. Of particular interest are the techniques used for designing open and closed spaces in houses located in the hot and humid climate zone. The proportions observed for the courtyard in such houses have a great role in determining the amount of radiation energy absorbed by various surfaces in the courtyard as well as in providing visual and thermal comfort conditions for the inhabitants. In this article, different examples of several courtyards were determined via field studies and the shaded areas resulting from various dimensions on different surfaces were analyzed at different times of the year using software models. Comparing the shaded area obtained from these samples with the Climate Need Table for Boushehr, we obtained the best sample in terms of sunlight and shade hours/times. These results were further compared with the long-term and short-term data obtained from Boushehr Meteorological Station. It was concluded that optimizing central courtyard proportions would increase shaded areas incident on courtyard surfaces, reduce walls temperature, reduce the cooling load of the building, and increase comfort inside traditional houses during the hottest period in Boushehr.

Keywords :Housing/House, Old/Historical Part of Boushehr, Vernacular Architecture, Central Courtyard

1. Introduction

Due to the various climatic conditions in Iran's hot and humid regions, open and closed spaces play an important role in the adjustment of climatic conditions in accordance with the inhabitants' comfort. To acquire a better understanding of this role, the climatic conditions of these spaces during the critical season should be measured and compared to long-term urban conditions obtained by calculating the mean climatoligical statistics over a span of several years. In this way, the positive and negative changes to the micro-climate introduced by construction can be revealed. To clarify these cases, the central courtyard conditions in several houses were studied for a period of time. The reason for selecting Boushehr as an example was its hot and humid climate which is typical in many other cities situated in hot and humid regions in Iran. Boushehr also has a long history of civilization as well as a rich architectural style. Study of the methods used in the historical architecture of this city can provide useful solutions for modern architecture. The present article was prepared based on software analyses conducted at various courtyards located in the historical part of Boushehr under hot summer conditions.

2. Research Questions

1. What architectural factors have made life possible during the past several thousand years in the hot and humid regions of Iran?
2. What architectural tricks (techniques) were used in the construction of traditional central courtyards in Boushehr?
3. How can we learn these successful secrets via software analyzing and recording meteorological data at the local and micro-scale climate?

3. Methodology

By comparing the long-term local and urban climatic data layers (mean values obtained from meteorological statistics), we determined the effect of traditional climate-based architecture on introducing climatic changes (both positive and negative). Such a comparison can trace successful architectural construction efforts in modifying the conditions at the local climate layer and show the quality and extent of these efforts in changing climatic conditions within the house to provide more thermal comfort for the inhabitants. Field surveys can be conducted at any time of the year. However, due to the limitations of providing long-term field data and the fact that usually, the most discomfort occurs during the heat wave in the summer, the authors decided to provide the required data for analysis during very hot days in the summer (July 11 and 12).

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4.Theoretical Fundamentals of Thermal Comfort Indexes

Thermal comfort conditions refer to those thermal conditions which suit 80% of the studied population. Assuming constant air velocity and disregarding sunlight, i.e., assuming that the population is in shade inside a building, most individuals feel physically comfortable at 21-26 degrees Centigrade and relative humidity of 30-60 percent. Now, if these comfortable conditions are changed, those present gradually start feeling uncomfortable. Therefore, temperature and relative humidity affect human comfort standards. Of course, the physical reaction exhibited to climatic conditions by people of different cultures and different geographical regions are different. For example, in Germany, 21 degrees C and 50% relative humidity are deemed as comfortable, whereas in equatorial regions, the comfort conditions are 23-29 C and 30-70% relative humidity.

Geographical Location and Climatic Conditions of Boushehr

The Port of Boushehr is located in southern Iran on the northern margin of the Persian Gulf, forming a triangular area. The Port is surrounded by sea on three sides and leads to land on the other side. The history of Boushehr goes back to the Elamite era (2000-1000 B.C.). Rayshahr Behnam lies in the southern part of modern era Boushehr.

Shading Requirements in Boushehr

The Climatic Need Calendar in Boushehr exhibits two mutually perpendicular axes representing days of the year and hours of the day. This calendar determines at what times during the hot season can proper shading be provided for securing people’s comfort in a city (usually with a hot climate). In hot climates, this calendar must be used between 66 and 75 percent of the year (Tahbaz, 2007:30). Design strategies must include using renewable energies, natural ventilation, and passive control methods. Studying the Climatic Need Calendar, one can realize that providing proper shading can be used throughout the year as an appropriate tool towards securing people’s comfort. However, it is during the period between June and September between 12:00 and 16:00 hours that providing non-evaporative cooling becomes inevitable.

Table 1

Geographical Coordinates of Boushehr

Place Name	Boushehr
Latitude	2859
Longitude	5050
Altitude from SeaLevel	4 m
Census Year	1966, 1982

(Source: The Authors)

Table 2

Average Statistics for Boushehr during a 14-Year Period

Average Statistics (14-Year Period)		March-April	April-May	May-June	June-July	July-Aug.	Aug.-Sep.	Sep.-Oct.	Oct.-Nov.	Nov.-Dec.	Dec.-Jan.	Jan.-Feb.	Feb.-March
Degrees Centigrade	Average Min.Temperature	18.6	23.2	26.2	28.1	27.7	24.5	20.7	15.6	11.8	10.3	11	14.4
	Average Max.Temperature	28.9	33.6	35.2	36.6	36.5	35.9	32.2	26.2	20.8	18.5	19.7	23.9
Relative Humidity (%)	Max. Humidity Min. Humidity	72	68	68	73	73	79	78	80	83	85	84	78
		49	48	50	51	50	51	51	52	60	64	60	53
Monthly Rainfall		22.7	6.7	1.2	0	0	0	0	12.3	30.7	61.7	83.6	38.6

(Source: The Authors)

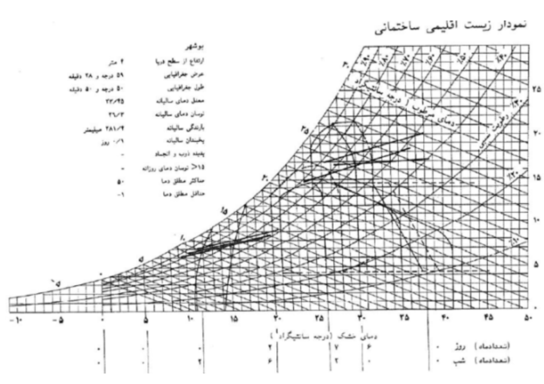

Fig.1. The Bioclimatic Chart for Boushehr;

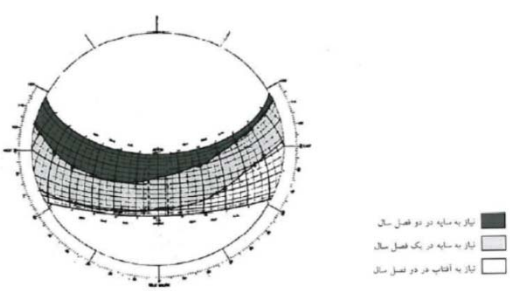

Fig.2. Sun and Shade requirements in Boushehr in various seasons; Source: Tahbaz & Jalilian, 2008

Characteristics of Some Traditional Houses of Value in the Histirical Part of Boushehr

Table 3
Characteristics of several native houses in the historical part of Boushehr; Source: The Authors

House Name	Plan	Neighborhood	Period	No. of Storeys	Central Court Yard	Vestibule	Shenashir		Taremeh (Porch)
							Internal	External	
Tabib		Behbahani	Qajar	2	Yes	No	No	Yes	Yes
Golshan		Behbahani	Qajar	3	Yes	4 Sides	No	Yes	Yes
Nozari		Kouti	Qajar	2	No	3 Sides	Yes	Yes	Yes
Taheri		Behbahani	Qajar	2	No	3 Sides	Yes	Yes	Yes
Azin		Kouti	Qajar	2	No	No	Yes	Yes	Yes
Rashidi		Kouti	Qajar	2	Yes	No	4 Sides	No	No
Rafii		Behbahani	Qajar	2	Yes	Yes	4 Sides	No	Yes
Rostami		Kouti	Qajar	2	Yes	Yes	No	No	Yes
Kamandi		Behbahani	Qajar	3	Yes	Yes	2 Sides	No	Yes
Moradi		Behbahani	Qajar	2	Yes	No	No	No	Yes

Effect of Courtyard Proportions on its Temperature

The courtyard in Old Boushehr is of a high architectural quality, designed in accordance with climatic conditions as well as people's native culture. On entering a traditional courtyard in Boushehr, one can see that it is different from the courtyards built in the central regions in Iran (Yazd, Kashan, etc.). The main difference lies in the dimensions, the side walls, and the relative position to thoroughfare. Obviously, courtyard walls play a more important role in increasing thermal load of the building than the floor. Therefore, for better comparisons, we classified the selected samples according to their length-to-height ratio and length-to-width ratio. The mean courtyard temperature in the hottest sun day was calculated through the ECOTECH software. The results are shown in Table 5. Fig 4 presents a better comparison for the three groups.

Comparison of Mean Temperatures insideand outside the Courtyard

According to meteorological statistics obtained for a period of 14 years, the hottest days in Boushehr occur from late June to late July. Based on these statistics, the mean minimum and the mean maximum temperatures during this time are 28.1 C and 36.6 C respectively. These data apparently show that the most severe solar radiation absorption occurs in afternoons from late June to late July. For this reason, 10 samples (in three groups) obtained during this period were analyzed by ECHOTEC.

In the studied houses, between 25 and 35 percent of the grounds is allocated to the courtyard. In the studied houses, 15% to 17% of the built area was allocated to the courtyard. Due to intense solar radiation, the need to provide shading in houses in Boushehr is acute. The smaller courtyard dimensions and larger heights of side walls can provide some shading. The central courtyard floor in traditional houses of Boushehr is located some distance above the thoroughfare. The height if the courtyard is greater than its length and width dimensions. The taller walls and smaller yard dimensions cause the courtyard to act as a vent for the rooms and various spaces on different storeys, creating drafts within the house.

Fig.3. Right: Diagram of solar thermal energy incident on building walls and the situation of buildings with two undetached sides; Left: Right: Diagram of solar thermal energy incident on building walls and the situation of buildings with one undetached side (semi-detached); Source: Tahbaz & Jalilian

Table 4
Central court yard proportions in the traditional houses in Boushehr

Name	Floor		Area (m2)			Wall Height (m)			
	Height from Thoroughfare (cm)	Dimensions (m2)	Grounds	Courtyard	Building	North	South	West	East
Tabib	90	13.3x13.50	578	181	11038	10	10	10	10
Taheri	60	13.3x13.50	473	120	702	10.6	4	10.6	10.8
Nozari	40	9.80x8.60	319	80.90	476	10.15	10	10.15	10.15
Golshan	50	6.70x9.10	560	168.80	1176	8.65	12.60	12.6	12.6
Azin	40	12.00x7.50	330.60	88.95	4833.3	8.90	9	8.9	8.9
Rashidi	25	17.50x16.70	287.91	71.1	433.82	9.30	9.30	9.30	9.30
Rafii	30	14.80x21.30	316	40	552	10.60	4	10.60	10.8
Rostami	20	19.00x13.50	244.6	36.2	420	7.5	7.5	3.5	2.5

Kamandi	25	21x26	575	141	1013	11	10.90	8.3	11.5
Moradi	24	18x26	429	109	488	9.20	4.60	4.5	9.3

Table 5
Central court yard temperature in traditional houses in Boushehr

Characteristics	House				
	Tabib	Taheri	Nozari	Golshan	Azin
Central Courtyard Temp. (C)	18	20	17	18	17
Courtyard Temp.Diagram					
Characteristics	House				
	Rasidi	Rafii	Rostami	Kamandi	Moradi
Central Courtyard Temp. (C)	16	20	20	24	20
Courtyard Temp.Diagram					

(Source: The Authors)

Table 6
Comparison of mean central courtyard temperatures with max. and min. temperatures outside the yard;

Characteristics	Studied Houses (Samples)									
	1	2	3	4	5	6	7	8	9	10
Mean Temp. inside Courtyard	18	21	17	18	17	16	17	20	24	20
Mean Min. Temp. outside Courtyard (14-Year Period)	28.1									
Mean Max. Temp. outside Courtyard (14-Year Period)	36.6									

(Source: The Authors)

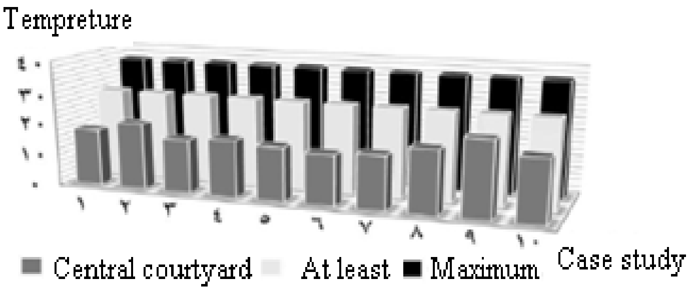

Fig.4. Comparison of mean central courtyard temperatures with max. and min. temperatures outside the yard; Source: The Authors

Research Parameters and Classification of Studied Samples

The length-to-courtyard height (N1) was calculated for all the samples (Table 7). Examination of this ratio shows that in 70% (10 samples) of the studies cases, this ratio was between 1 and 2. As this group actually presented the most frequency among the sample courtyards in traditional houses in Boushehr,, it was consequently selected as the basis for tests. Then, ratio N2 was measured for the selected samples (Table 8).The results were classified into three groups: Group A: N2=1.0-1.2; Group B: N2=1.2-1.4 Group C: N2=1.4-1.6.

Ultimately, for investigating the effect of the proportions on the provided shading, samples with similar orientations were selected from GroupsA, B, and C. Subsequently, the ECHOTEC and the meteorological data for the hottest day of every month were used to simulate the shading created in 2-hour intervals in the central courtyard surfaces.

Effect of Varying Proportions on Courtyard Walls

To prevent any additional effects on the shadings provided by walls, all wall surfaces were assumed to be free from any openings, glass, and other ornaments. Thus, the results can reflect only the shading produced by wall proportions. It mus be ppointed out that in the traditional architecture of Boushehr, the energy intensity absorbed on the walls is reduced through such methods as building arcades within living areas, ornamental brickwork on surfaces, building ornamental/functional roofs, etc. Photograph 1 shows an example of such design methods. The diagrams in Table 10 show the shading created on northern walls of the case samples during the hottest day of the year at 13:00 hours. Upon simulation of the shading for northern walls of the three samples, the images obtained for various hours of the day were further processed through software and the corresponding shaded areas were calculated. The results showed that the proportions in the houses of Group A led to the most shading on the northern walls.

The Effect of Varying Proportions on the Shading of the Floor

Using the N1 and N2 parameters, the shading received on the floor was simulated and then measured for the three samples during the sunny hours in 22-hour intervals. Tables 11, 12, and 13 show variations of shading on the floor of the courtyard for different samples at 13:00 hours.

Calculation of the Floor Shadings in the Samples

Upon simulating the shading during various hours, the obtained images were processed further via image-processing software to calculate the shading provided on the floor of the courtyard in each group. The obtained results for different seasons were tabulated in several tables for each group. Individual and collective evaluations of groups were then carried out.

5. Findings

Since the degree of shading varies at different times of day and night, the shading percentage obtained for each sample was compared with the Climate Need Table to see if the amount of shading was appropriate. On the other hand, according to the 14-year meteorological survey in Boushehr, the highest temperatures occurred in Junne, July, and August between 12:00 and 16:00 hours.. Therefore, shading was needed most during these months. The results showed that Group A samples produced the maximum shading on the courtyard floor. The courtyard walls in Group A also produced the most shading. These findings were in good agreement with those in similar studies where the effect of courtyard confinement ratio was studied on the incident radiation on various surfaces in the courtyard. The results are shown in Fig 4 . The obtained information showed that, assuming a constant length-to-height ratio in the courtyard, if the length-to-width ratio is changed from 1 to 1.6, then a significant difference is produced in the incident shading. Due to the intensity of sunlight in Busshehr, we conclude that this would have a considerable effect on the thermal comfort conditions inside the house.

6. Conclusion

He traditional architecture of Qajar Period Houses in Boushehr has provided a solution to the unfavorable weather conditions with due attention to the specific cultural, social, political, and economic elements in this region. The studies conducted on courtyards in the historical part of Boushehr reveal subtle points about how traditional architects had found ways to adapt certain spaces for providing thermal comfort for the inhabitants in the summer. The degree of shading provided and the temperature in the courtyard depend on various factors like building orientation, climatic conditions, temporal/seasonal conditions, dimensions, and and shape of the courtyard. The provided shading on the floor and walls of the courtyard in the houses built in the hot and humid regions has a significant effect on reducing the cooling load on the building. By properly proportioning the length, width, and height of a building and providing optimal shading on the floor and walls, we can reduce the wall temperature and the temperature of the air layers adjacent to it. Thus, though natural currents and ventilation, the temperature in the yard is reduced and thermal conditions in the surrounding spaces improve. The mean statistical data for Boushehr in the 14-year period show the minimum and maximum temperatures to be 28.1 and 36.6 degrees Centigrade respectively. The mean temperature obtained from the simulation for the internal areas of the courtyard on July 11 at 13:00 hours was 17 C, that is, at least 10 degrees cooler than the mean minimum temperature and 19.5 C cooler than the mean maximum temperature outside the building.

The results obtained from analysis of the studied samples indicated that first, square-shaped central courtyards are the most frequent type of courtyard in Boushehr. This leads to reduced surface-to-volume ratio for the building which in turn prevents heat transfer from outside to the internal spaces. Second, of the studied samples, those with length-to-width ratios between 1 and 1.2 (square courtyard) and length-to-height ratios between 1 and 2 (medium depth) provide the best shading conditions. This is in spite of the fact that less shading would be inconvenient during colder seasons. However, due to the small number of cold days and their temperatures, we can disregard such inconveniences. By changing the sample height and creating calculated ornamental elements on the walls, the shading pattern on the walls and the floor can be improved. In today's world where global efforts are increasing towards reducing pressure on the environment by resorting to more natural design solutions and using passive methods of cooling and heating to reduce energy consumption, reconsideration of our traditional architectural models seem to be necessary. Studying these models and finding ways of reintroducing them in modern construction techniques (in both high and low density buildings) would be an effective solution for achieving the goals set forth for sustainable development through reducing pressure on energy resources in the country.

Table 7
The length-to-height ratio (N1) obtained for the studied houses

Sample	1	2	3	4	5	6	7	8	9	10
Ratio	1.35	2.36	5.25	0.78	1.33	1.88	2.36	3.61	1.95	3.72

(Source: The Authors)

Table 8
Classification of selected houses in terms of length-to-width ratio

Ratio N2	1.40-1.60 (Group C)	1.20-1.40 (Group B)	1.0-1.20 (Group A)
Samples	5,7,8,10	2,9	1,3,4,6

Table 9
Classification of selected samples based on length-to-width ratio

Group	Group A-House No.4 (Golshan)	Group B-House No.7 (Rafii)	Group C-House No.9 (Kamandi)
Sample Size from each Group	N1=1-2 N2=1-1.2	N1=1-2 N2=1.4-1.6	N1=1-2 N2=1.2-1.4

Fig.5. Increasing walls shaded area in Tabib House in Boushehr by using arcades;
(Source: Cultural Heritage Organization, Boushehr Province)

Table 10
Shaded area on walls during the hottest day in 2010 (16:00 hours)

	Sample	Dimensions (m)	Shaded Area Diagram	Shaded Area (%)
A	Golshan	9.10x12.60		38.5
B	Kamandi	12.9x21		10.4
C	Rafii	4x4.8		28.15

(Sources: The Authors)

Table 11
Shaded area on the floor of the central courtyard obtained for Sample A (13:00 hours); Sources: The Authors

Month	March-April	April-May	May-June	June-July	July-Aug.	Aug.-Sep.	Sep.-Oct.	Oct.-Nov.	Nov.-Dec.	Dec.-Jan.	Jan.-Feb.	Feb.-March

(Sources: The Authors)

Table 12
Shaded area on the floor of the central courtyard obtained for Sample A (13:00 hours)

Month	March-April	April-May	May-June	June-July	July-Aug.	Aug.-Sep.	Sep.-Oct.	Oct.-Nov.	Nov.-Dec.	Dec.-Jan.	Jan.-Feb.	Feb.-March

(Sources: The Authors)

Table 13
Shaded area on the floor of the central courtyard obtained for Sample C (13:00 hours);

Month	March-April	April-May	May-June	June-July	July-Aug.	Aug.-Sep.	Sep.-Oct.	Oct.-Nov.	Nov.-Dec.	Dec.-Jan.	Jan.-Feb.	Feb.-March

(Sources: The Authors)

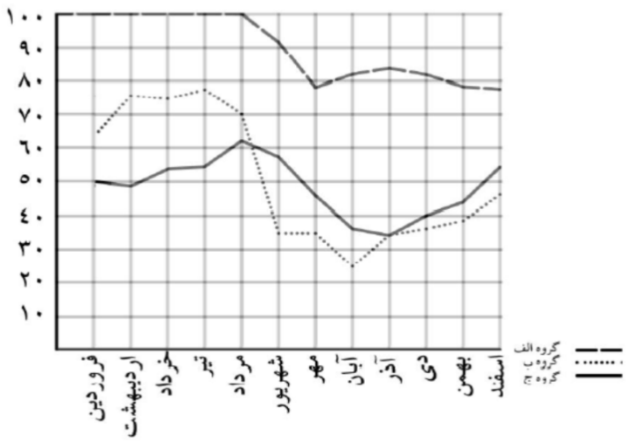

Fig.6 . Shaded area on the floor off the courtyard at the hottest hour every month in 2010;
(Source: The Authors)

Footnotes:

1. For further study, see:
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