Basic Studies and
New Technologies of
Architecture and
Planning

Naqshejahan

www.http://bsnt.modares.ac.ir/

Comparative Modeling of Summer and Winter Courtyard in Cold Climate

Esmail Zarghami [a], Somyeh Pourbagher[b]*

[a] *Associate professor, School of Architecture and Urbanism, Shahid Rajaee Teacher Training University*

Email: es_zarghami@yahoo.com

[b] *Master of Architecture, Shahid Rajaee Teacher Training University*

Abstract

Energy efficiency is one of the most important lessons which may be learnt from all kinds of traditional buildings especially in oriental countries such as Iran. It is very important to explain and rethink about courtyard as an invaluable archetypes in traditional architecture of Iran. Literature review of the paper show that courtyard in general, is a place in which family in all kinds, gather for inter-generation relationships. In traditional architecture of Iran courtyard enjoys some practical functions as well as metaphorical ideas. This paper is to make a comparative modeling of summer courtyard and winter courtyard for cold climate with particular reference to Iranian cold climate in North West parts in which most of winter times, conventional courtyards are useless because of harsh climate. Thus the research focuses on analyzing temperature of courtyard in once in case – winter courtyard; and then in control – summer courtyard. Methodology of the paper focuses on case – control techniques in which one sample plays the role of case and the other sample is considered as control. Ardebil traditional houses selected as case studies of the research for modeling. The results of the paper emphasize on efficiency of winter courtyard in comparison with summer courtyard.

Keywords: winter-courtyard, cold climate, summer courtyard, modeling.

1. Introduction

A summer courtyard is a courtyard without roof such as courtyards of dry and arid areas. A winter courtyard is a courtyard with a roof at its top such as glasshouse or greenhouse. The role of courtyard geometry in controlling the seasonal warming of outdoor space in cold climates is examined. Numerical and physical simulation methods are used to compare the effects of changes to courtyard proportion,

doi:

[DOR: 20.1001.1.23224991.1394.5.4.4.1]

configuration and orientation on the key microclimatic parameters of incoming short-wave radiation, outgoing long-wave radiation and wind shelter. Findings are presented in a manner which can easily be integrated into the design process. The degree to which courtyards encourage seasonal warming at high latitudes differs according to their architectural geometry. The importance of each of the courtyard's geometric parameters changes from one form to the next, but a yard's orientation is generally a secondary factor to its proportion and configuration. In many instances, the designer has a fair degree of flexibility in their choice of courtyard [1]. On the other hand, changes to courtyard geometry need not necessarily be architecturally significant to affect a yard's thermal conditions. Often a number of design options are available.

2. Methodology

Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation [6]. Thermal conditions differ from time to time and place to place by means of clothing, operable windows, fans, personal heaters, and sun shades [7] .Thermal Environmental Conditions for Human Occupancy [6] emphasize on different aspects of human thermal behavior and HVAC (heating, ventilation, and air conditioning) conditions. HVAC design engineers focus on thermal comfort for occupants of buildings or other enclosures.

The Predicted Mean Vote (PMV) model stands among the most recognized thermal comfort models. It was developed using principles of heat balance and experimental data collected in a controlled climate chamber under steady state conditions[8] .The main factors that influence thermal comfort are those that determine heat gain and loss, namely metabolic rate, clothing insulation, air temperature, mean radiant temperature, air speed and relative humidity [9]. Some studies show that psychological parameters such as individual expectations also affect thermal comfort.

Regarding to adopted methodology of the paper, modeling and simulation (M&S) is getting information about how something will behave without actually testing it in real life. The use of M&S within engineering is well recognized. Simulation technology belongs to the tool set of engineers of all application domains and has been included in the body of knowledge of engineering management. M&S has already helped to reduce costs, increase the quality of products and systems, and document and archive lessons learned. M&S is a discipline on its own. Its many application domains often lead to the assumption that M&S is pure application. This is not the case and needs to be recognized by engineering management experts who want to use M&S. To ensure that the results of simulation are applicable to the real world, the engineering manager must understand the assumptions, conceptualizations, and implementation constraints of this emerging field [10]. Technically, simulation is well accepted. The 2006 National Science Foundation (NSF) Report on “Simulation-based Engineering Science” [11] showed the potential of using simulation technology and methods to revolutionize the engineering science.

This paper focuses on graphical simulation and architectural modeling as a key to find the answers of research questions. Therefore this paper is to analyze temperature of courtyard in once in case – winter courtyard; and then in control – summer courtyard. Regarding to complexity of case studies, some abstract forms have been derived to build case (sample) and control (sample). Regarding to the hypothesis of the paper, it is very important to explain that how efficient winter courtyard is in comparison with summer courtyard.

[DOR: 20.1001.1.23224991.1394.5.4.4.1]

3. Typology and Case Building

It is important to make a case which may be analyzed instead of all presented samples. Therefore the first step might be typology. For typology and case building, it is important to gather a considerable number of outstanding houses and hierarchy them via their types. Our survey resulted in ten outstanding cases such as:

3.1. Ershadi House

Ershadi House is one of the monuments in Ardabil. This house is built in the late Qajar and has stone foundation made with mortar of sand- lime. This building has been recorded as a national monuments in 2002.

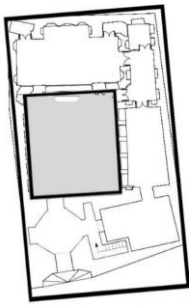

Fig. 1. Plan of Ershadi House

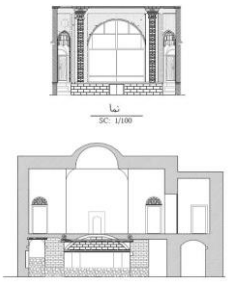

Fig. 2. Elevation and Section of Ershadi House

3.2. Asadi House

Asadi Hous is located in Asadi Street. This building is one of the old monuments in Ardabil City.

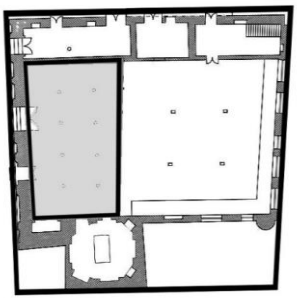

Fig. 3. Plan of Asadi House

3.3. Seyed Hashem Ebrahimi House

This house located in Shahidgah Alley and is still inhabited. On the walls, can be seen an inscription on which some poetry and Arabic verses from Holy Qoran.

[DOR: 20.1001.1.23224991.1394.5.4.4.1]

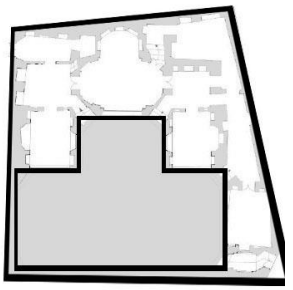

Fig. 4. Plan of Seyed Hashem Ebrahimi House

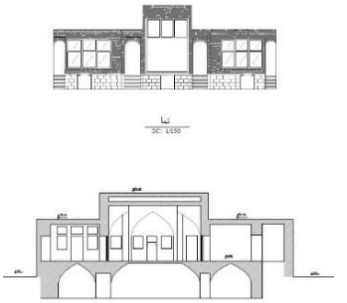

Fig. 5. Elevation and Section of Seyed Hashem Ebrahimi House

3.4. Khadem Bashi House

Khadem bashi house is located in Ochdokan (Sartipabad) locality and belongs to Qajar period. This building is one of the old monuments in Ardabil city. The building has a courtyard entrance and inside and outside yard.

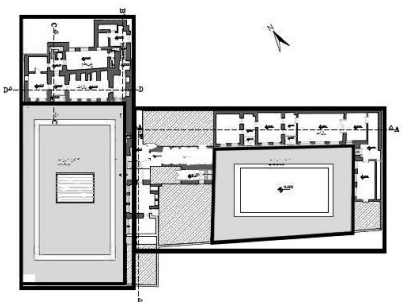

Fig. 6. Plan of Khadem Bashi House

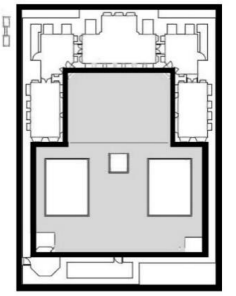

Fig. 7. Khalilzadeh House

[DOR: 20.1001.1.23224991.1394.5.4.4.1]

3.5. Khalilzadeh House

The building was built in Qajar period (1753), and belongs to Hashemi family. This building is located in Mansouriyeh locality. Architecturally is introverted and vestibule entrance is as a communication space that avoid direct physical and visual connections in the within spaces.

3.6. Manafzadeh House

This house is built in 1574 AH. The building has a rectangular plan, with brick façade and decorated with geometrical design. In this time it is the office of Art center [12].

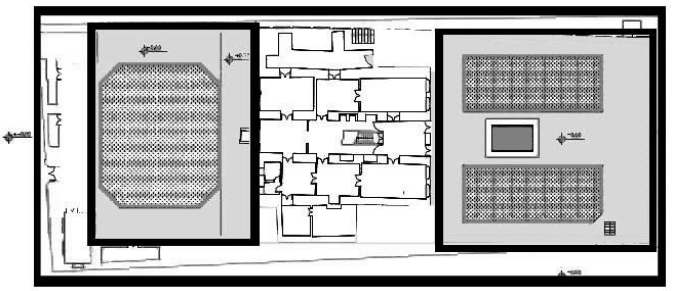

Fig. 8. Plan of Manafzadeh House

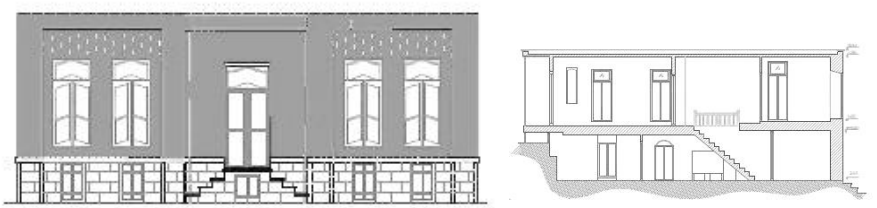

Fig. 9. Elevation and Section of Manafzadeh House

[DOR: 20.1001.1.23224991.1394.5.4.4.1]

3.7. Rezazadeh House (Museum of Martyrs)

This building is located in Ochdokan locality and belongs to late Qajar period. Entrance is through the vestibule to the courtyard. The building have an area of 640 square meters on two floors. The first floor has two rooms with a central corridor and the second floor has two rooms and a hall or Shahneshin in the middle. It was used as a State Administration of Cultural Heritage Building, but from last year was devoted to Museum of Martyrs [12].

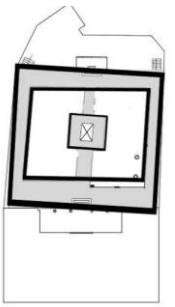

Fig. 10. Rezazadeh House (Museum of Martyrs)

3.8. Mirza Ebrahim Sadeghi House

This old and historical house is located in the Ochdokan locality, and Sartip Abad Alley in the city of Ardabil. This house known for its artistic and decorative designs (1,750 square meters) has been built in a land with an area of 1,450 square meters. At present it is in good condition, although it is not used for residential purposes.

Fig. 11. Mirza Ebrahim Sadeghi House

3.9. Vakil-ol-Roaya House

This old house is located in Tava locality, included multiple courtyard, headquarters and inner units. In its design, central hall has way to peripheral units. On the western side of the outer courtyard, is located veranda and a beautiful hall. The East side of central hall have an overlooking to the courtyard. This edifice despite its artistic and historical value, and it is being destroyed because of lack of attention. Its

[DOR: 20.1001.1.23224991.1394.5.4.4.1]

historical background is intertwined with that of the city and the events of the twentieth century. This house used to be the gathering place for the opponents of the Mashrouteh (Constitution) Movement [12].

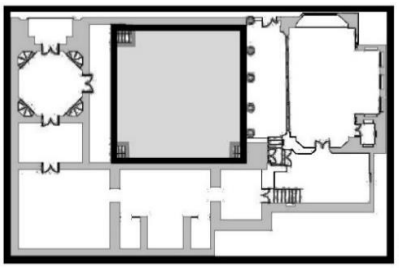

Fig. 12.Vakil-ol-Roaya House [13]

3.10. Moravej House

The building was built in 1532. Architecturally, the building is introverted and vestibule entrance is a communication space that prevent direct view of inside spaces.

Fig. 23. Moravej House Source: [12]

In the center of the plan is located one central hall. The building is became the research center of Ayatollah Moravej from 2001 [12].

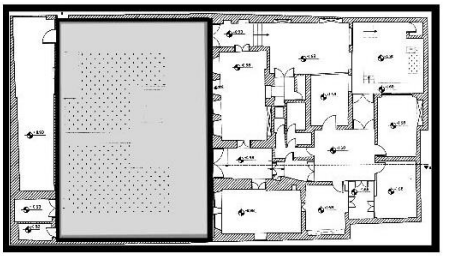

Fig. 34. Plan of Moravej House Source [14]

The results of case studies concluded a sample which represent Ardebil Houses. Our typological survey shows that the representative case may include a courtyard which surrounded in three parts i. e. north, east and south. Regarding to the hypothesis of the paper such sample may be resulted in two sample the

[DOR: 20.1001.1.23224991.1394.5.4.4.1]

first one is which it has a summer courtyard – courtyard without roof; and the second one winter courtyard - courtyard with a roof at its top. Therefore two major samples of this research are the same in form and type and differs in their courtyards, one courtyard has a roof and other is without roof.

4. Climatic Analysis

The long duration of cold season in the climatic environment of the ensemble is another important factor influencing the ensemble which makes the protection of ornaments on external bodies as well as internal tiling and decoration difficult. On the other hand, cold weather and frost in winters adversely affect construction materials and brick structures. Moistening of the feet of the walls due to recurrent precipitations of the cold season also influences the ensemble. By devising a comprehensive plan for monitoring the ensemble, it has been attempted to control and study the influence of climatic elements as well as to offset the degree of damages incurred by such factors [13]. The regional climate specifications of the experiment are given in Table1.

Table1. Atmosphere specifications of location in Ardabil in 2012-2013 crop year

Parameter	Local	Mehr	Aban	Azar	Dei	Bahman	Esfand
Rainfall	Ardabil	8.3	25.6	26.7	11	28.5	24.1
Average minimum temperatures	Ardabil	7.3	4.8	0.3	-2.4	1	1.1
Average maximum temperature	Ardabil	21.9	16.9	8.9	6	11.1	11.9
Average daily temperature	Ardabil	14.6	10.9	4.6	1.8	6.1	6.5
Average minimum humidity	Ardabil	42	48	60	41	45	43
Average maximum moisture	Ardabil	97	94	94	82	84	84
Average humidity	Ardabil	70	71	77	62	65	64
Total sunshine hours	Ardabil	244	168.4	120.1	173	170.5	154.8

Parameter	Local	Farvardin	Ordibehesht	Khordad	Tir	Mordad	Shahrivar
Rainfall	Ardabil	10.7	48.1	57.3	0.7	16	6.4
Average minimum temperatures	Ardabil	2.4	4.2	9.3	11.3	12.4	11.5
Average maximum temperature	Ardabil	16.9	18.2	22.9	23.8	22.3	25.2
Average daily temperature	Ardabil	9.7	11.2	1.16	17.6	17.4	18.4
Average minimum humidity	Ardabil	40	45	44	43	52	43
Average maximum moisture	Ardabil	87	86	89	85	91	92
Average humidity	Ardabil	64	66	67	64	72	68
Total sunshine hours	Ardabil	214.5	247	280.1	346.9	253.9	275

Source: [15]

5. Sample Study

In this section two kinds of summer courtyard and winter courtyard analysed to show how these two types differ especially in winter-time period.

[DOR: 20.1001.1.23224991.1394.5.4.4.1]

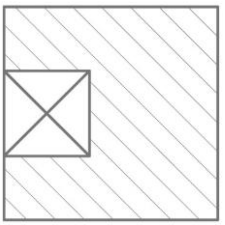

Fig. 45. Sample plan for analysis

6.1. Sample I- Summer Courtyard

In this part of the paper, a typical summer courtyard is studied regarding to its efficiency and thermal behaviour. Regarding to paper assumptions, a summer courtyard is a courtyard without roof such as courtyards of dry and arid areas. In the related diagram, summer courtyard may be seen. The main courtyard in summer-courtyard type in winter period suffers from harsh and cold weather.

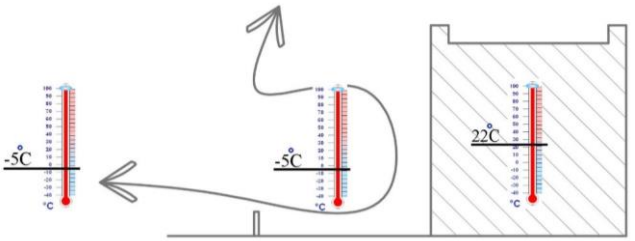

Fig. 56. The main courtyard in summer-courtyard type in winter period suffers from harsh and cold weather

The diagram shows that there are lots of deficiencies especially in winter time. In winter period in harsh times, the thermometers show about -5^{c} in average. Our study show for the typical courtyard the temperature is about -5^{c} and inside the house is about +24^{c}. Therefore in most of the times in winter, the courtyard may be useless because of harsh climatically character.

6.2. Sample II- Winter Courtyard

In this part of the paper, a typical winter courtyard is studied regarding to its efficiency and thermal behaviour. Regarding to paper assumptions, a winter courtyard is a courtyard with a roof at its top such as glasshouse or greenhouse. In the related diagram, interaction of cold and hot areas may be seen interactively. The diagram shows winter-courtyard as a buffer zone for this type of design which shows efficient approach to energy efficiency.

[DOR: 20.1001.1.23224991.1394.5.4.4.1]

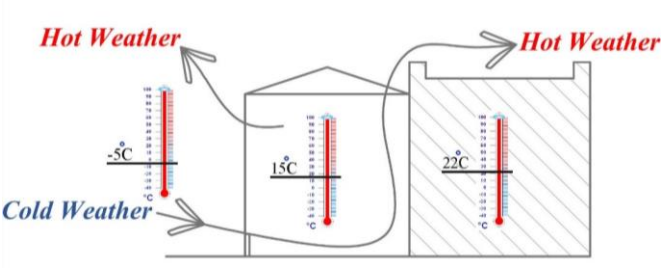

Fig. 67. The diagram shows winter-courtyard as a buffer zone for this type of design

The diagram shows that there are lots of efficiencies especially in winter time. In winter period, almost the outdoor climatically character is harsh. In harsh times, the winter courtyard is in better condition than outdoors. For this study outdoor is about -5^{c} in average. Our study show for the typical courtyard the temperature is about $+15^{c}$ and inside the house is about $+24^{c}$. Therefore in most of the times in winter, the courtyard may be useful despite summer courtyards.

6. Conclusion

Energy efficiency and other related areas in building industry play their crucial rolls for better future. The research shows the roots of this types of energy efficiency in core of traditional architecture of Iran. In which inter-generation relationships happen. Therefore the diagrams shows meaningful efficiency for winter courtyard. Regarding to technical considerations, it is important to emphasize the role of winter courtyards in cold climate though there are lots of technical points which should be considered such as flexibility and other practical issues. The results emphasize on usage of winter courtyard especially in cold parts such as Ardebil.

References

[1] Rogers P. An Analysis of Climatic Influences on Courtyard Design for Cold Climates. A Thesis Submitled to the Faculty of Graduate Studies in Partial Fulfillment of the Requirements for the Degree of ,MASTER OF ARCHITECTURE ,Department of Architecture,University of Manitoba Winnipeg, Manitoba February, 1999 .

[2] M. Mahdavinejad, K. Javanroodi, L. H. Rafsanjani, Investigating Condensation Role in Defects and Moisture Problems in Historic Buildings. Case Study Varamin Friday Mosque in Iran, World Journal of Science, Technology and Sustainable Development, 10 (4) (2013) 308-324.

[3] M. Mahdavinejad, M. Ghasempourabadi, H. Ghaedi: The role of form compositions in energy consumption of high-rise buildings (case study: Iran, Tehran), Advanced Materials Research 488-489 (2012) 175 – 181.

[4] M. Mahdavinejad, S. Matoor, N. Feyzmand, A. Doroodgar: Horizontal Distribution of Illuminance with Reference to Window Wall Ratio (WWR) in Office Buildings in Hot and Dry Climate, Case of Iran, Tehran, Applied Mechanics and Materials, 110-116 (2012) 72-76.

[5] by N. Golamirostam, A. Hojjati, M. Mahdavinejad, M. Mirlohi: Natural Energy Efficient Materials for Rock Cut Architecture in Case of Kandovan, Iran, Advanced Materials Research, 935 (2014) pp. 202-206.

[6] ANSI/ASHRAE Standard, Thermal Environmental Conditions for Human Occupancy, 55-2013.

[7] Fergus, N; Humphreys, M. Adaptive thermal comfort and sustainable thermal standards for buildings. Energy and

[DOR: 20.1001.1.23224991.1394.5.4.4.1]

Buildings , 2002, 34 (6) 563–572.

[8] Fanger, P. Thermal Comfort: Analysis and applications in environmental engineering. McGraw-Hill Ole , 1970.

[9] Brager, R. Developing an adaptive model of thermal comfort and preference. ASHRAE Transactions 1998. 104 (1) 145–67.

[10] (http://en.wikipedia.org/wiki/Modeling_and_simulation) (2014-10-20).

[11] National Science Foundation (NSF) Blue Ribbon Panel (2007). Report on Simulation-Based Engineering Science: Revolutionizing Engineering Science through Simulation.

[12] (http://www.mehrnews.com/detail/News/2261492) (2014-10-12).

[13] Iranian Cultural Heritage, Handicrafts and Tourism Organization, SHEIKH SAFI AL-DIN KHANEGAH and SHRINE ENSEMBLE IN ARDABIL,UNESCO World Heritage Convention Nomination of Properties for Inclusion on ,The World Heritage List,Tehran, 2009.p, 453.

[14] (www.ichto.ir) (2014-10-20).

[15] (Meteorological Ardabil Province)

[DOR: 20.1001.1.23224991.1394.5.4.4.1]