The Role of Functional Flexibility to Improve Energy Efficiency in Energy Consumption of the Case
Borojerdiha* house in *Kashan

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Abstract

Man raises level of his needs by falsifying the nature and construction of the built spaces. By examining various aspects and complex dimensions of the human, variable and different needs can be clearly seen. Therefore, an architectural construction, especially housing, should be able to set the access conditions to meet the highest level of the needs and achieve to the highest level of responsiveness to the needs of users. Thus, conditions such as flexibility, adaptability, variability and all the principles that lead to generate opportunities and capacities proportional to user's needs in a building has been double necessary. With looking at the traditional architecture, we find that, despite the limitations in manufacturing technology, the architects used their own strategies for responding to existing problems. Strategies such as the use of multi-functional space, embedding spaces in the three scales of tiny, medium and large scales as well as ability to separate or merge spaces, are some of these items.

By knowing, however, Iran's traditional home space is flexible, in this study, we sought to answer the question whether this flexibility in space has a role in the amount of energy consumption of the building?

If there is, it has an increasing or decreasing role? In order to answer this question, several examples of traditional houses in the hot and dry climates is simulated that, due to brevity it is not expressed in this study. Among them, for example, is expressed *Boroujerdi* House and energy consumption of the existing state compared with when a space had not seasonal versatility. Finally, it is concluded that flexibility, reduce energy consumption in traditional buildings.

Keywords: Flexibility, Energy Efficiency, *Borojerdiha* House.

1. Introduction

As you know the Iranians for their past architecture, architecture agents are known to be in harmony with climate globally (Mahdavinejad & Javanroudi, 2012). A recognition that the Iranian ethnics have gained from the natural flow of upon and under the ground over the years, the principles has brought for the architecture, which nowadays they are used by architects and are placed at the top of the Iranian architecture (Hashemi, Mahdavinejad & Javaroudi, 2013). Among the principles employed in the construction of houses, it can be pointed to: building layout, plan form, architecture organization and used materials etc which are all defined and regulated by the phenomenon of climate and each one is individually analyzable in terms of climate.

The native experience that have achieved over the years to provide the thermal comfort without the use of mechanical devices, today, can guide architects in the construction of modern buildings (Heidari, 2000). What is obvious in order to reduce energy consumption and create a safe, durable and comfortable living space; the most important factor is evaluating and recognizing the role of climate on residential buildings in the past.

Traditional Iranian architecture according to various climatic conditions has offered various solutions and promotes the various aspects of this valuable experience. Particularly today with technological advances, the method adopted in the past can be adapted to different needs and circumstances (Ghiasvand, Akhtarkavan & Akhtarkavan, 2008).

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One of the strategies used is attention to the flexibility, adaptability and variability in housing construction, which has a significant role in creating the conditions for the inhabitants of this region. This study intends to identify the most effective strategies to assess their role in the regulating of environmental conditions. It should be noticed the meaning of recognizing the past is not re-entrant to the past! Back to the past is not possible, and if we, in any way go back, apart from superficial imitation, we've got nothing. Rather, the purpose is registering characteristics, architectural techniques and concepts which still can remain as a guide for the next generation, and be criticized and evaluated in the direction of native knowledge evolutions. Studying climatic used concepts and inactive techniques can clarify how comfortable conditions were achieved by little energy consumption.

2. Research Question

1- How has been flexibility in traditional Iranian architecture?
2- Has flexibility been effective in promoting energy efficiency in function of traditional architecture spaces? And also how is it describable?

3. Method

This paper examines the impact of flexibility in energy consumption at Iran's traditional homes. Energy consumption examination method was modeling and numerical simulation and conclusion was made using logical argument (Groat, Wang, 2002). Theoretical data collection method was studying library resources and technique of this study was adjusting comparison between Case and Control.
Computerized simulation in a virtual environment provides possibility to examine the thermal behavior of detailed structural elements. Advanced modeling and simulation methods of numerical analysis software, are good alternatives to observational studies and their outcome is provided at any time and without numerical limitation. Also, there is the possibility to create a building in any form. In this research, Energy Plus software ver. 7 was used for simulation as energy software which is an independent simulation engine to analyze buildings thermal behavior due to a wide range of energy outputs in comparison to other simulation engines. This research was conducted to compare the thermal behavior, based on the amount of heating and cooling load consumed by (KW / H).
To have simulation methodology, since there is no environment for graphical modeling in Energy Plus first, the models are simulated in Autodesk Ecotect software, Version 2010, as a graphic medium and then the model geometry (saved as an idf file) is transferred to Energy Plus software to be thermally calculated. The weather simulation is based on *Kashan* city, in hot and dry climatic zone, in Iran.
Finally, the results are presented in the form of pictures and graphs extracted from this software (Mahdavinejad & others, 2013).

4. Flexibility

4.1. The concept of flexibility

The word flexible is an adjective meaning to be changeable so that the change is easily done compatible with the circumstances (able to change or be changed easily according to the situation) and is equivalent to the Changeable word. Based on the above definition the concept of flexibility is the ability to easy change according to the conditions and return to its original state. This concept is also true in the field of architecture and is the spatial organization of man-made space and changing it in order to respond to the conditions, needs, and new functions in it. However, some spaces without the need of reorganization provide a lot of activities. Some spaces are changeable to respond to different requirements. Building designers are applied the word "flexibility" and "adaptability" to these two cases. These two terms are sometimes used synonymous and sometimes contradictory with each other. While these two words have the conceptual common backgrounds, they also have differences (Einifar, 2004). The difference is in the amount of change that can occur in a made house. Adaptive home in addition to the re-arrangement of furniture needs further changes. While in a flexible home, there is potential for greater changes toleration (Chan, 2000).

4.2. The need for flexibility in the architecture

The necessity of flexibility is verifiable in two dimensions: One is theoretically and the other is several experiments that there have been throughout the architecture history. Theoretically, they are continuous changes that occur daily, monthly and annual in environmental and human factors. These changes generally are classified in three categories: changes in performance, changes in population structure (people) and changes in the values. Architecture in order to adapt to these changes and maintain the quality of space is forced to change. Changes based on the definitions provided are considered flexibility. Also, there have been multiple experimental examples throughout the architecture history, in which some time after the operation of architecture, changes should be done inevitably to respond to the conditions.

4.3. Forms of flexibility

Pena and *Parshal* (2001), in their book called (Problem Seeking), stated that flexibility consists of multi-functional architectural characteristics, variability of the interiors and external expansion capabilities and believed that each of these concepts cannot alone be replaced by the concept of flexibility.

4.3.1. Diversity (multi-functional space)

This flexibility is dealing with two variables including time and space. In a space can occur multiple functions simultaneously along together or different functions can occur at different times.
Because this method has not required a large open space or new methods of construction, has been the most basic approach to achieve flexibility in traditional housing. Diversity in the house is possible by house map following a general pattern of formation and using of a base system of scrolling. For example, the yard that was in the center of the house was a place of sharing functions; meanwhile it also had the ability to transform into a collective space for guests. Diversity in the layers close to the yard was more than servicing and connector parts.

4.3.2. Adaptability (daily and seasonal movement)

Adaptability is the ability to match a space with new situations, new needs and demands. In Iran's traditional housing according to the following plans, house spaces and facade followed a general formation pattern, building system of stabilized spaces, adapting daily and seasonal life by adjusting the vertical and horizontal relationships at home and using different spaces at different times and seasons.
For example, the separation of winter and summer living space had a significant role in adapting the space to needs of residents. Usually the back side to the sun, with more depth and shadow creating ability, is used to in summer, and the front side to the sun is specific to winter spaces. Usually there is a porch on the front part of the summer-living space which has been used in the summer morning. In the western side of the courtyard, which received eastern light, there are shallow chambers which can be used all year round. Likewise, if there are any basement and upstairs, they cause various daily and annual displacements.

4.3.3. Variability (differentiation and integration)

In this case, the flexibility is meant ability to respond to familie's growth in different stages of life. In other words, these capabilities make the size change of residential units possible, in order to become either smaller or larger. Variability is accessible through two ways, adding to the existing house area or it's the spatial subdivision (without changing the area). It has been applied in the horizontal or vertical expansion of Iranian traditional houses and subdivision of the multi-yard houses or more minor partition around a central courtyard and uses it for extended family living in the different stages of life (Einifar, 2003).

5. Modeling

Considering the extensive discussion of flexibility in the structure, this research cannot check all of affecting factors and their role in reducing energy consumption. Thus, among the factors that have caused flexibility in architecture of the Iranian homes, the versatility factor (seasonal movement) has been evaluated and its role in reducing energy consumption in the old houses has been revised. *Brojerdyha* house in *Kashan* is selected as a case for this purpose.

5.1. Kashan

Kashan city is one of the oldest cities of Isfahan. It is on one hand next to the Zagros Mountains and on the other to desert plain. This city is located in the 33 degrees and 59 minutes of northern latitude and 51 degrees and 27 minutes of eastern longitude in the an altitude of about 982 meters above sea level. According to statistics provided since establishment of meteorological stations in *Kashan* (1966-2005), the city has hot and dry summers and cold winters so that the heat intense in the summer is sometimes up to 47 degree C and the severity of cold in winter, sometimes is to 10 degree C (1966-2005 Statistics). *Kashan*, with an annual rainfall of about 150 mm, is one of the most low rain and driest of Iranian cities.

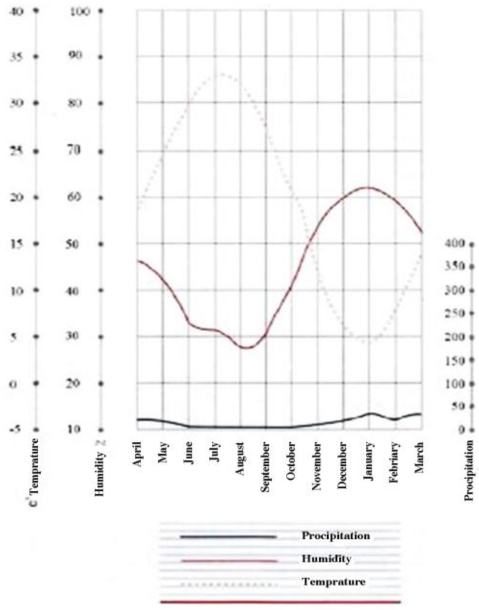

Fig. 1. Climatic information of *Kashan*.

5.2. Cases examined in hot and dry climate of Kashan

Borojerdiha house, was constructed at almost middle of *Qajar* period, 1292 AH, by Professor Hossein *Hosseini* for the settlement of *Natanzi* merchants who resided in *Kashan*. The house was built on a land area of approximately 1,700 m^2 , and consists of two main and side entrance, vestibule, hallway, yard, the summer-settlement, the winter-settlement, kitchens, roofed courtyards around and a large basement.

The main entrance is located in the building north; especially because the connection created between the house and the street is contributing to the splendor of the building. The vestibule is following main entry and through the same door, which is located across it finds a way to the yard. More than half of the land area is devoted to the yard. Summer–settlement (summer-living), which is the main part of *Boroujerdiha*'s house, is located in front of the main entrance and back to *qibla*. Summer–settlement consists of two rooms, a main hall, two roofed substation, a main roofed house, two quenches, an alcove and Tenby chamber.

The main porch is located on the symmetry axis of summer–settlement, which it is the second factor in the division of space and use of residents in the summer after the yard. Winter–settlement is located in the north near the doorway and is consists of one room, an alcove of five-door and a large and sunlight recipient porch. In the west it consists of three rooms, between summer–settlement and winter–settlement, which are related together through a common hallway.

The western part of winter–settlement joins the northern and southern parts of the building with two small rooms and a roofed chamber.

The basement is located in the following three sections: North, South and West which arte more used as cellar, storeroom and the service space.

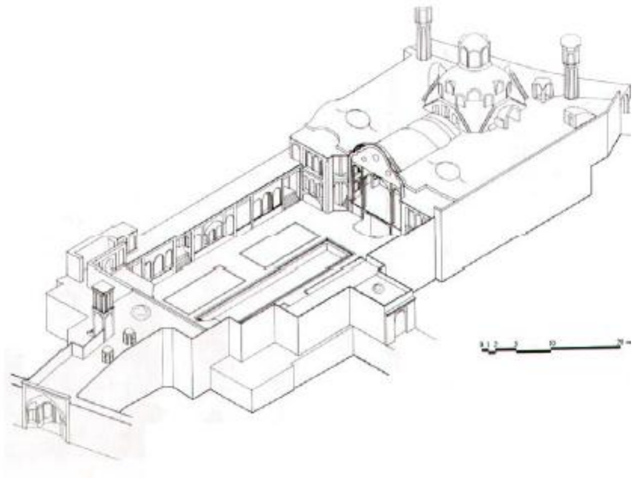

Fig. 2. Isometric of *Boroojerdiha* House (*Hajighasemi*, 1999)

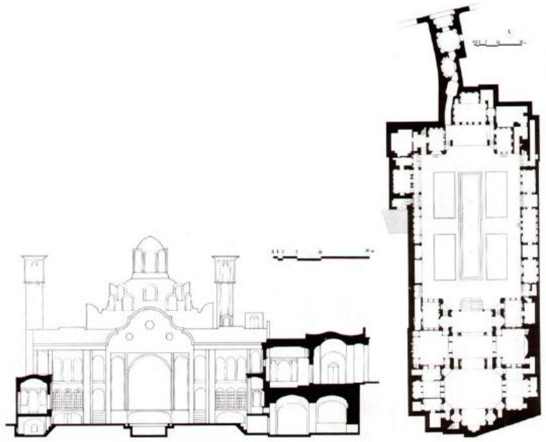

Fig. 3. Section and Plan of *Boroojerdiha* House

Fig. 4. Courtyard of *Boroojerdiha* House

6. Components and elements of Iranian House

As mentioned above, according to the spatial overall organization and effective factors in shaping Iranian houses including climate, spatial divisions adopt various forms and functions in this way. So, first of all, in this paper we address a brief description of existed spaces of historic housing type, and then will investigate the spatial characteristics of each species and their analysis. By definition (Pirnia, 1384, pp. 163-158, Memarian, 1386, Shirazi, 1382, p. 32, Keynezhad and Shirazi 1389, p. 7), these spaces include:

Summer-settlement: south side of the house that is located toward the north and does not receive sunlight which is used in summer and called "summer-settlement". This side of the house has semi-open porches which are not exposed to sunlight and placed in full shade and also, meanwhile, used the cool weather of central courtyard. These forums and porches were the main living space of the house, except in very cold situations.

Winter-settlement: Northern front (toward qibla) of yard is used as winter–settlement space at native house in order to take advantage of the sun in winter.

Entrance: a space connecting the exterior and interior of the house.

Vestibule (*Kryas*): after the entrance one entered vestibule or *Kryas*. The vestibule is something which came out of the interior of the house and the only place which is associated with the outdoors. Creating pause, spatial division, and waiting space are interesting functions of this element.

Yard or *MianSerra*: With its golden proportion and instruction direction provides a healthy and pleasant environment in all year round, and take the best advantage of the sun circuit and sunlight for its around spaces.

Porch: porches are multiplying both horizontal and vertical transparency. In the *Qajar* houses, overall south porch creates all the facade of houses throughout. There are a Tenby, a Pate, spring house, and other elements as the porch appendix.

Tenby: great and main room of the house - located in its center and main axis – where is generally the place for welcoming guests.

Rooms: In Iranian Houses the rooms were built in form of three-door, five-door, hall and each has their own characteristics.

Pate: A room in Tenby corner located on upper floor which generally overlooks Tenby

Alcove: It is a ripped abdominal space in the cross-shaped Tenbies or a small space back on to the back wall and facing toward the front wall.

Hall: A great and ceremonial room. This space is used for hot seasons and has a way to the open air.

Spring house: A space, which a pond is located in the middle of it and used as a cool space to sit and relax, as well as for storage and maintenance of meat and grain.

Stairs, staircases: Space where the stairs are located in.

Cellar: basement.

Cellar Hall: Hall-like space which is located in the basement.

7. Simulating of *Boroujerdiha* House

As mentioned, a critical factor which causes the versatility of the traditional houses is relocating residents to winter settlement section in winter (facing the sun) and to summer settlement in summer (back on to the Sun). In Table 1, the amount of energy consumption in winter-settlement section in winter and summer-settlement in summer are shown.

Table 1

The amount of energy consumption in winter settlement section and the summer settlement in the summer

Energy consumption		Month
Cooling load	Heating load	
summer settlement	winter settlement	
138000.0088	23154920.72	**January**
1585232.299	10981568.61	**February**
2607266.44	4299099.626	**March**
7737237.7	0	**April**
16216268.95	0	**May**
25958744.57	0	**June**
31934120.65	0	**July**
31674794.33	0	**August**
26261388.87	0	**September**
14674050.4	0	**October**
5850815.277	4110036.883	**November**
199140.1475	19808370.81	**December**
164837059.6	62353996.65	**Total**

Table 2

The amount of energy consumption in winter settlement section and the summer settlement after 180 degrees rotation

Energy consumption		Month
Cooling load	Heating load	
summer settlement	winter settlement	
0	14538058.79	**January**
0	1897630.106	**February**
68061.28717	1676031.833	**March**
2795437.937	0	**April**
13837689.95	0	**May**
24832300.54	0	**June**
30035839.47	0	**July**
26135928.56	0	**August**
15673263.59	0	**September**
3560000.631	0	**October**
0	155037.6522	**November**
0	10243545.71	**December**
116938522	28510304.09	**Total**

Now situations are reviewed that versatility (seasonal relocation) does not exist. In other words, winter settlement space also is used in summer, as well as summer settlement space in winter. Therefore, to simulate the conditions mentioned, building has been rotated 180 degrees around the north-south axis. So the winter settlement space is placed in the yard's other side (south side of the yard) and summer settlement space is placed in the north. Now the energy consumption in winter-settlement space in winter is compared with energy consumption in the summer-settlement space in summer (Table 2).

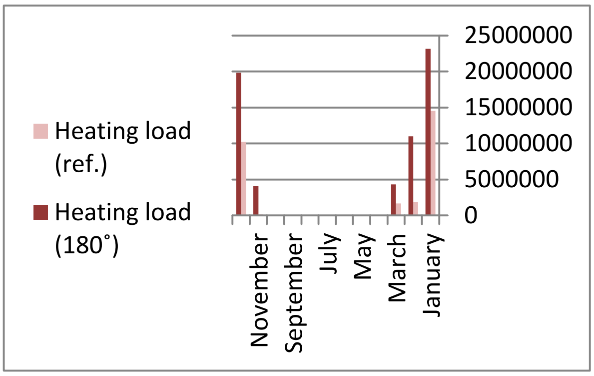

Fig. 5. Comparison of energy consumption in a flexible and inflexible space in winter.

8. Energy efficiency

Regarding the above mentioned arguments, we compared energy consumption rate in the first case (flexible space) to the second mode (inflexible space) in winter (Fig. 5) and summer (Fig. 6).

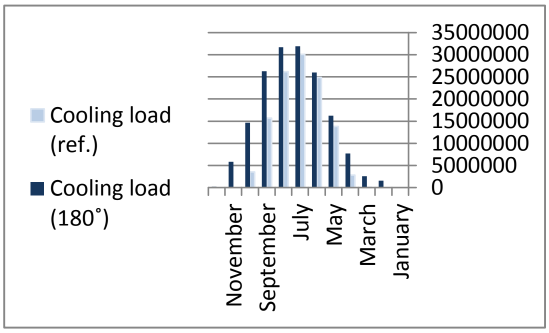

Fig. 6. Comparison of energy consumption in a flexible and inflexible space in winter.

As indicated in Fig. 5, in winter, if there is not versatility in space the energy consumption rate increases about 2.18 times, and about 1.4 times in summer.

9. Discussion and analysis of data

With comparison and analysis of the data tables, it was found the assumption that versatility reduces energy consumption is true. As the results of *Boroujerdi* House simulation in *Kashan* show, If people do not have seasonal relocation in winter, it will cause energy consumption to increase about 2 times. Also, if the residents do not move in the summer season the rate of energy consumption will increase about 1.5 times.

10. Conclusion

Traditional Houses in Iran, although have formed as a building with stabilizing elements and the bearing walls, but several-function areas, by daily and seasonal moving and transposition in different directions of the houses, subdivision and unification of spaces, have created several scales of flexibility. But what can be concluded from this study is that flexibility, in addition to enhancing the quality of space and comfort by choosing a suitable space in different seasons, reduces the energy consumption both in winter and summer. In fact, it can be stared that what we had in traditional architecture, has been clever use of space. But today what we should receive from this architecture is intelligent understanding of these techniques and applying them in designing today spaces, in order not to be deprived of this valuable heritage of architecture.

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