Studying the Thermal Behavior of Winter Sections in Yazd Traditional Homes and Its Optimum Situation

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ABSTRACT: For over the past several decades, there has been a great concern about energy crisis and lack of non-renewable resources. Residential buildings take more than 25% of the total energy consumption and more than 75% of energy consumption in these buildings is for heating, cooling and hot sanitary water. On the other hand, traditional buildings of Iran were designed according to ecological conditions upon which, winter or summer sections were built. In this article, first, winter section of Yazd traditional homes, which are in hot-arid region and its thermal behavior, will be studied. This computer simulation is done and validated with energy-plus software, and temperature changes of these sections were measured with lascar electronics data logger. The results confirmed its reliability. Second, sections with different proportions such as three-door room, five-door room and seven-door room in different orientations, and their thermal behavior are analyzed and compared. So the thermal behavior of winter sections in Yazd traditional homes during a year shows that in winter, the proportions of five-door room in northwest orientation is better than others.

Keywords: *Winter sections of Yazd traditional homes, Energy simulation, Three-door room, Five-door room, Seven-door room.*

INTRODUCTION

The indiscriminate use of non-renewable energy resources is a main concern in today's researches. Wood & Muncaster (2012) observed that, "the "developed world" as a whole has huge numbers of buildings designed and constructed to standards that were barely adequate in their day and inadequate for today and tomorrow; and those in the developing world are even poorer. "(Adeyemi, etal., 2014).Thereforeenergy efficiency, low-energy buildings, zero-energy buildings and plus-energy buildings are some of the efforts made for energy crisis. All of these strategies are emphasized on decreasing non-renewable energy consumption and its pollutionsand try to prevent uncontrolled and inefficient energy consumption, reduce production costs, and increase the public welfare (Yao & Zhu, 2011). Furthermore, buildings account for 45% of worldwide energy use and the urban residential sector is a significant consumer of energy in every country, and therefore a focus for energy consumption efforts (Jebaraj & Iniyan, 2006). So this problem has caused a great concern in recent decades to decrease the non-renewable energy consumption in residential buildings.

Over 1000 years, Iran traditional buildings have adopted strategies to coordinate with ecological conditions. In these buildings, often there are special sections for warm and cold seasons. Yazd province is in a hot-arid region. The architectures of traditional buildings set sections like three-door, five-door and seven-door in northwest and northeast orientations for cold seasons. Also they designed sections such as hall, coastal, and cellar in southwest orientation for warm seasons. These design principles are used in other cities in hot-arid area like Esfahan and Kashan.

According to what mentioned above, in respect with the concerns of the indiscriminate consumption of renewable energy resources, the study of climate design principles of traditional buildings that have the least consumption of non-renewable energy and the least pollution is very important. Therefore, in this article, the winter sections of Yazd traditional

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homes and their climatic measures are explained, and their thermal behavior is studied via computer simulation using energy-plus software.

Furthermore, different sections like three-door room, five-door room, and seven-door room in southwest and northeast are designed for cold seasons. Hence in this article, through thermal analysis and comparison of these sections in different orientations, the optimum situation defined.

Literature Review

The current building construction challenge is creating economical buildings that increasing life quality while reducing social, economical and environmental effects (Kamar et al., 2010). Achieving sustainability in architecture and construction is the goal emphasized more these days (Zabihi, Habib& Mirsaeedie, 2013). But it was introduced to Iran very late. In recent years, Iran traditional buildings are a treasure of strategies in sustainable architecture. But most of these research papers explained these strategies and their analyses are based on observations which have not been confirmed. So see research papers of Table 1.

Some of the research papers analyzed it scientifically. These research papers, study the climatic components of traditional buildings like wind Catcher, cellar, Shovadan, but also other

Table1: Descriptive-analysis researches

Number	Research paper	Publisher	Year
1	Sustainable Strategies in Iranian Houses (Babaei et al., 2012)	Life Science	2012
2	All Season Use Of Laary House (Summer Section Of The Double Courtyard) (Kazemi et al., 2012)	ICSAUD	2012
3	All Season Use Of Rasoulian House (Winter Section Of The Double Courtyard) (Kazemi et al., 2012)	IAHS	2012
4	Green Architecture in Clinical Centres with an Approach to Iranian Sustainable Vernacular Architecture (Kashan City) (Amiri Mohammadabadi & Ghoreshi, 2011)	Procedia Engineering	2011
5	Sustainability, Architectural Topology and Green Building Evaluations of Kashan-Iran as a Hot-Arid Region (Roodgara et al., 2011)	Procedia Engineering	2011
6	Sustainable Systems in Iranian Traditional Architecture (Eiraji & Namdar, 2011)	Procedia Engineering	2011
7	Traditional Sustainable Solutions in Iranian Desert Architecture to Solve the Energy Problem (Maleki, 2011).	IJTPE	2011

Table2: Scientific researches

Number	Research paper	Publisher	Year
1	Effects of Different Internal Designs of Traditional Wind Towers on Their Thermal Behavior (Hosseinnia et al., 2013)	Energy and Buildings	2013
2	The Study on Optimum Tilt Angle in Solar Chimney as a Mechanical Eco Concept (Mahdavinejad et al., 2013)	Frontiers of Engineering Mechanics Research	2013
3	An Experimental and Numerical Investigation of Shovadan Heating and Cooling Operation (Moradi & Eskandari, 2012)	Renewable Energy	2012
4	Numerical Simulation of Cooling Performance of Wind Tower (Baud-Geer) in Hot and Arid Region (Kalantar, 2009)	Renewable Energy	2009
5	Seasonal Analysis of the Thermal Behavior of Traditional Underground Wine Cellars in Spain (Mazarrón & Cañas, 2009).	Renewable Energy	2009
6	The Effect of Traditional Wind Vents Called Zarceras on the Hygro thermal Behavior of Underground Wine Cellars in Spain (Cañas & Mazarrón, 2009)	Building and Environment	2009
7	Experimental Investigation of New Designs of Wind Towers (Bahadori et al., 2008)	Renewable Energy	2008

research papers in other countries are considerable. See research papers of Table 2.

MATERIALS AND METHODS

Computer simulation provides a virtual environment for accurate analysis of the thermal behavior of buildings' sections. The methodology, modeling, and simulation techniques (Groat & Wang, 2002), with advanced numerical calculations software, is a suitable method to analyze the building thermal behavior. With this method, it is possible to make any building in any climatic conditions in a virtual environment, and the results do not have time or numerical limitations.

In this research, simulation is done with energy-plus software version 8. Energy-plus software is an independent simulation engine with no graphical interface; it is used to simulate buildings and models, and water and energy used in buildings. The results can be presented with numbers or graphs. First, the model is done in Ecotect version 2011 as a graphical interface; then, the model is transferred to energy plus software.

Winter Sections and the Adopted Solutions

The winter sections of Yazd traditional buildings are often on the earth and in northwest and northeast orientations. These sections are called three-door, five-door, and seven-door, based on their dimensions and proportions and the number of doors is not the reason. The three-door section is small-scale and is used as bedroom. Five-door is average-scale and is used as the living room. Seven-door is large-scale and is used for parties and for the rich. In these sections with adopted solutions, the least consumption of renewable energy was necessary to life's comfort and also there was no brunt to water and building material resources.

The first orientation is directed in northeast-southwest. So some of the spaces are in front of the sunshine and some are behind the sunshine, so winter and summer sections are built. Winter sections are in front of the direct sunshine. Furthermore, the section which is in front of the sun is transparent; so it can absorb the maximum of direct sunshine. Also the surfaces in front of those spaces are located in front of the sunshine. The sun rays reflected from these surfaces are effective to the environment temperature.

These sections are lower than others and this will help building comfort. The roofs are very thick and the underground places with 17 centigrade, under these sections and building half-open and hall-like in front of the entrance doors will prevent the heat waste.

Using suitable building materials such as adobe and brick in floor, walls and roofs is another solution. The building materials are very thick and have high thermal capacity; so they save their heat energy during a day and at night when there is no sunshine, they release this energy. So this will help to use the maximum of indirect sunshine absorption. In Figs.1-4, winter sections of Yazd Rasoulian home are shown.

Simulation

In order to study the thermal behavior of different sections of a traditional building "Rasoulian home" was selectedand first Its model was reconstructed in Ecotect;

then the model was transferred to energy plus software for thermal analysis. Fig. 5 shows the building model in Ecotect. The building materials of walls in the software are transparent and opaque, based on what used in the building. The simulation is done on 4 sample days; spring (April21), summer

Fig.1: The seven-door of Rasoulian home

Fig.2: The five-door of Rasoulian home

Fig.3: The first floor of Rasoulian home

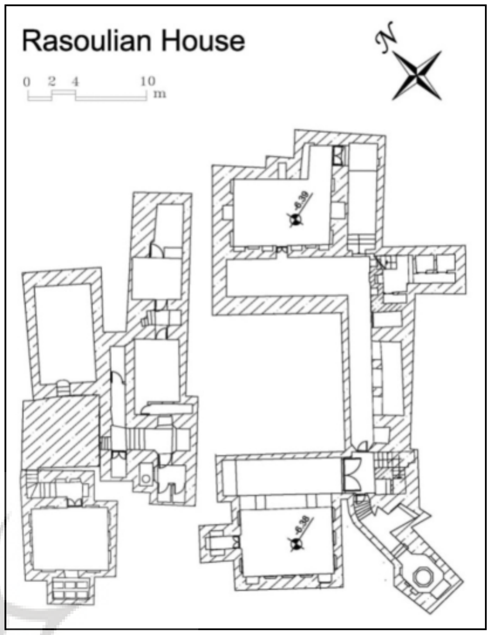

Fig.4: The basement of Rasoulian home

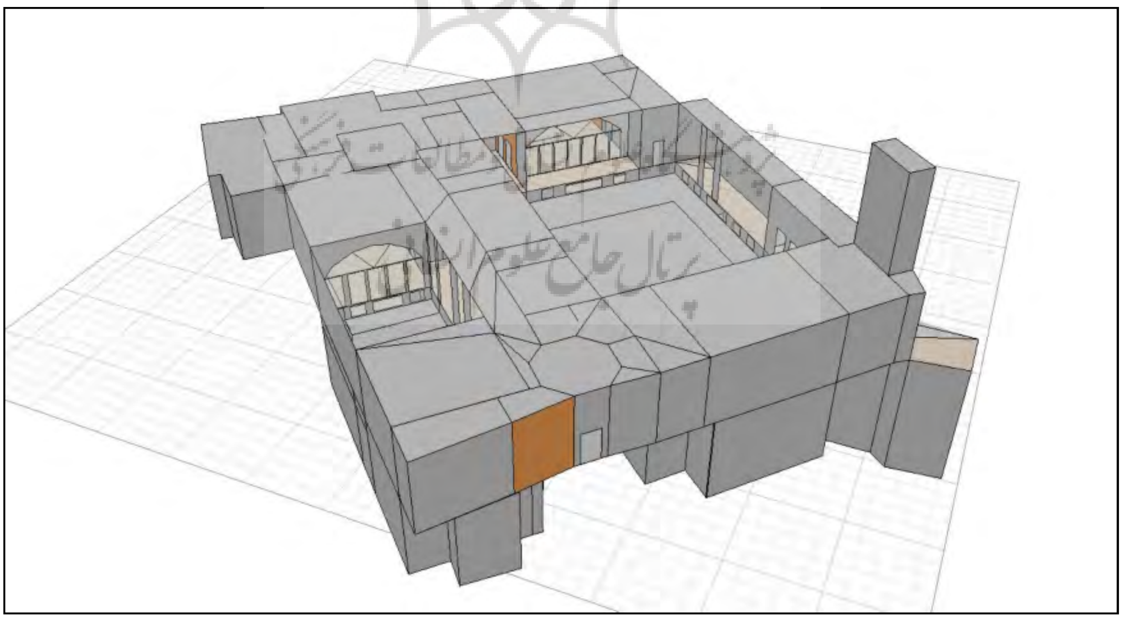

Fig.5: The building (Rasoulian home) model reconstructed in Ecotect

(July21), winter (January21) and autumn (October21) based on weather map of Yazd from energy plus[1].To compare the thermal behavior of these sections in different seasons, the Zone Mean Air Temperature was obtained from software in terms of hour and centigrade.

RESULTS AND DISCUSSION

Here is shown the thermal behavior of different winter sections in Yazd Rasoulian home in northwest and northeast orientations in the first day of every season. Also Table.3 presents the physical characteristics of these sections.

Table 3: Physical characteristics of the chosen sections

Physical characteristics	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Length (m)	8.14	7.85	5.92	6.93	4.16	4.35
Width (m)	7.07	6.32	2.38	4.05	3.68	3.59
Average height (meter)	4.77	4.74	4.47	4.83	4.83	4.83
Area (m^2)	57.55	49.61	14.09	28.07	15.31	15.62
The average temperature in the first day of winter (centigrade)	12.74	15.52	18.12	17.83	17.21	17.39
The out average temperature in the first day of winter (centigrade)	0.47	0.47	0.47	0.47	0.47	0.47

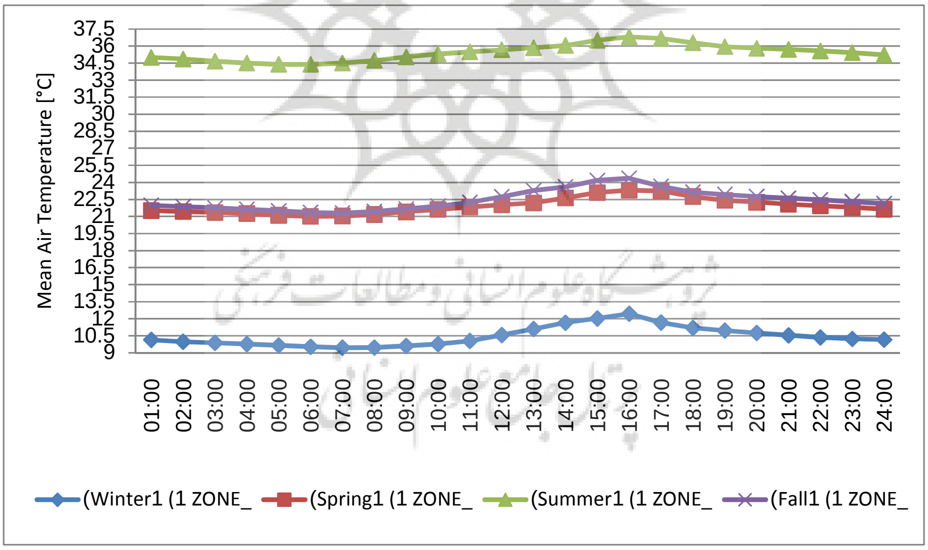

Fig.6: The thermal behavior comparison of seven-door section in northeast orientation in the first day of different seasons

The seven-door section in northeast orientation in the first day of different seasons. (Fig. 6)

Fig.6 indicates that The seven-door section in northeast has had the maximum temperature of 36.8 on the first day of summer and the minimum temperature of 9.5 on the first day of winter.

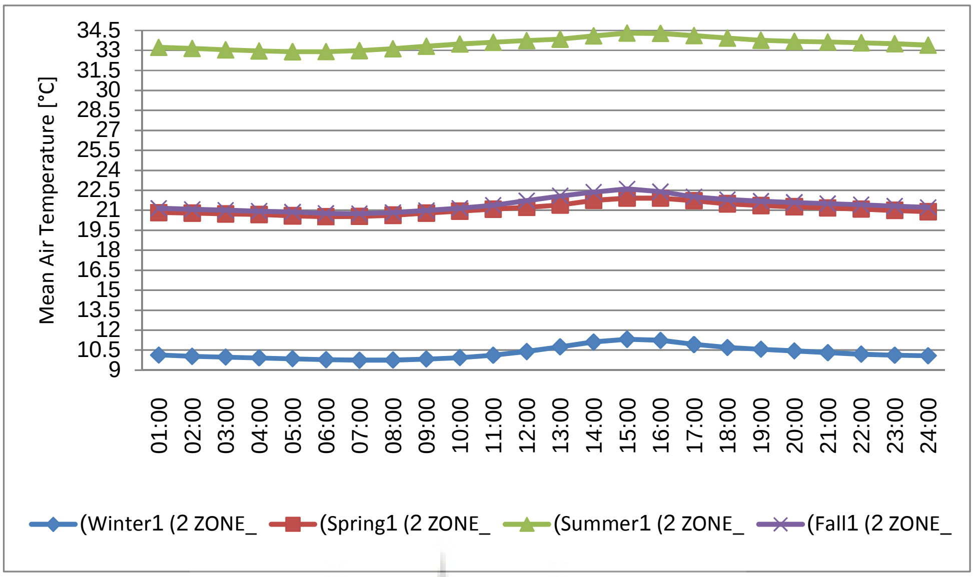

Fig.7: The thermal behavior comparison of five-door section in northeast orientation in the first day of different seasons

The five-door section in northeast orientation in the first day of different seasons. (Fig.7)

Fig. 7 indicates that the five-door section in northeast has had the maximum temperature of 34.5 on the first day of summer and the minimum temperature of 10 on the first day of winter.

The three-door section in northeast orientation in the first day of different seasons. (Fig.8)

Fig. 8 indicates that the three-door section in northeast has had the maximum temperature of 35.5 on the first day of summer and the minimum temperature of 11.5 on the first day of winter.

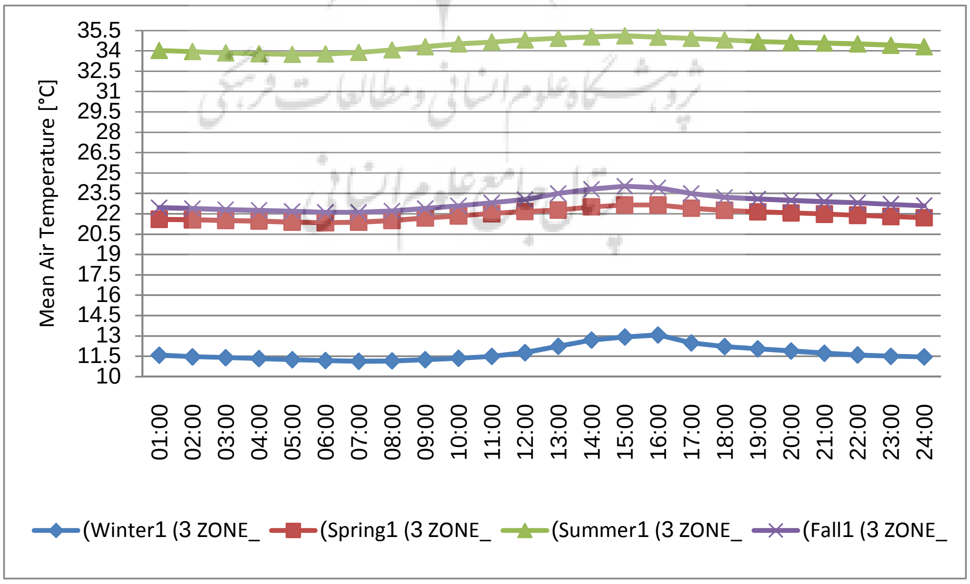

Fig.8: The thermal behavior comparison of three-door section in northeast orientation in the first day of different seasons

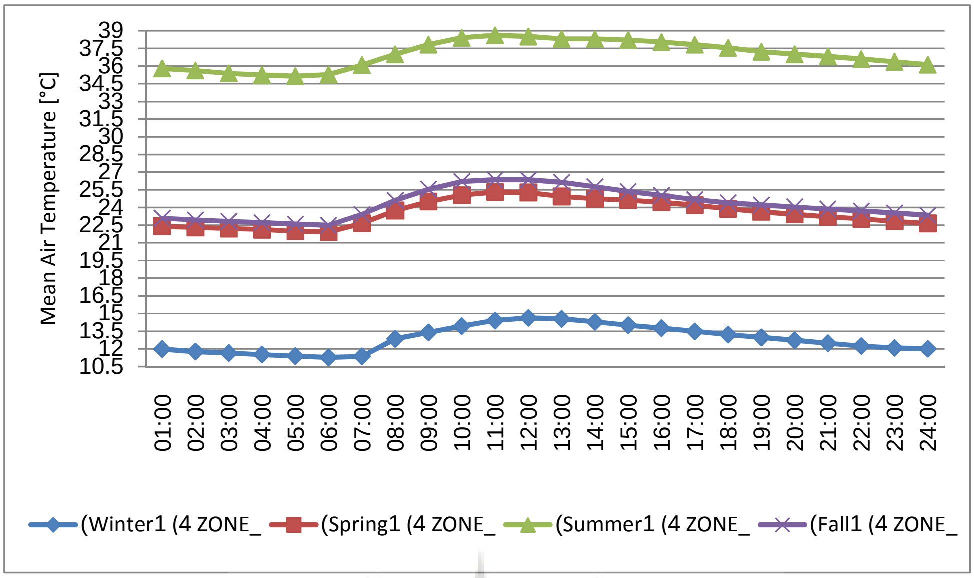

Fig.9: The thermal behavior comparison of five-door section in northwest orientation in the first day of different seasons

The five-door section in northwest orientation in the first day of different seasons. (Fig.9)

Fig. 9 indicates that the five-door section in northwest has had the maximum temperature of 38.5 on the first day of summer and the minimum temperature of 11.4 on the first day of winter.

The three-door section in northwest orientation in the first day of different seasons. (Fig.10)

Fig. 10 indicates that the three-door section in northwest has had the maximum temperature of 37.2 on the first day of summer and the minimum temperature of 9.8 on the first day of winter.

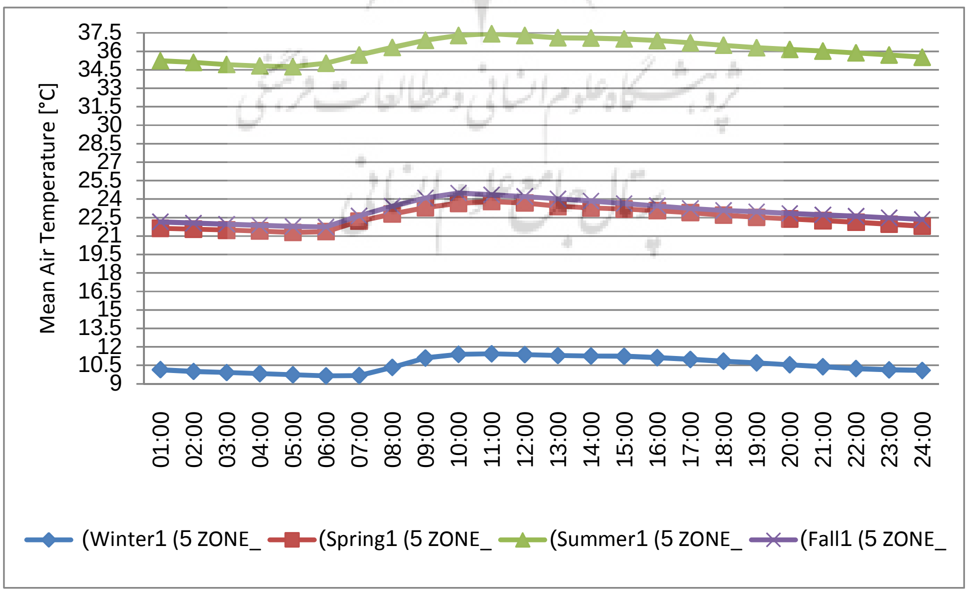

Fig.10: The thermal behavior comparison of three-door section in northwest orientation in the first day of different seasons

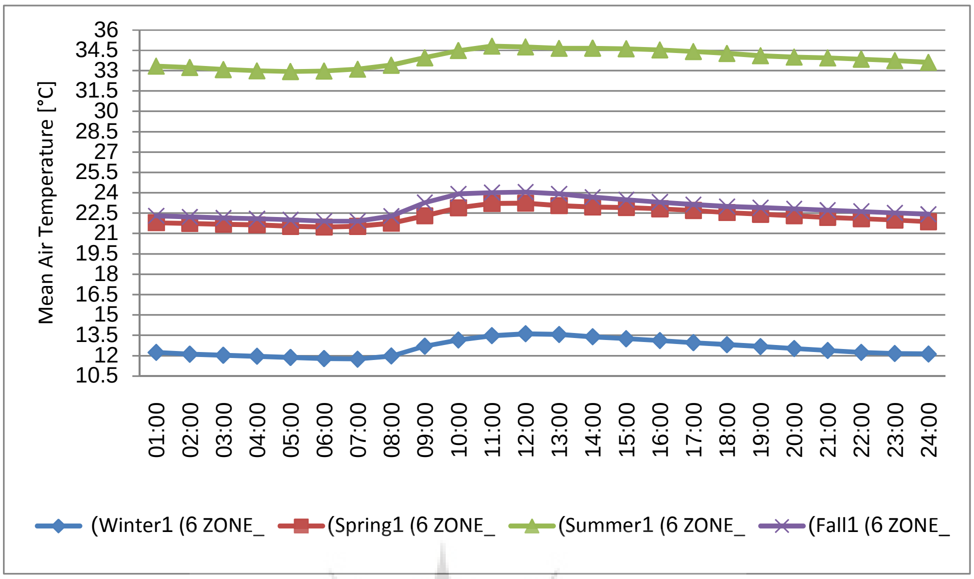

Fig.11: The thermal behavior comparison of three-door section in northwest orientation in the first day of different seasons

The three-door section in northwest orientation in the first day of different seasons. (Fig.11)

Fig. 11 indicates that the three-door section in northwest has had the maximum temperature of 35 on the first day of summer and the minimum temperature of 11.7 on the first day of winter.

The Thermal Behavior Comparison of Winter Sections in the First Day of Winter. (Fig.12)

Fig. 12 shows that on the first day of winter, the five-door section in northwest has had the best performance and the five-door section in northeast has had the weakest performance.

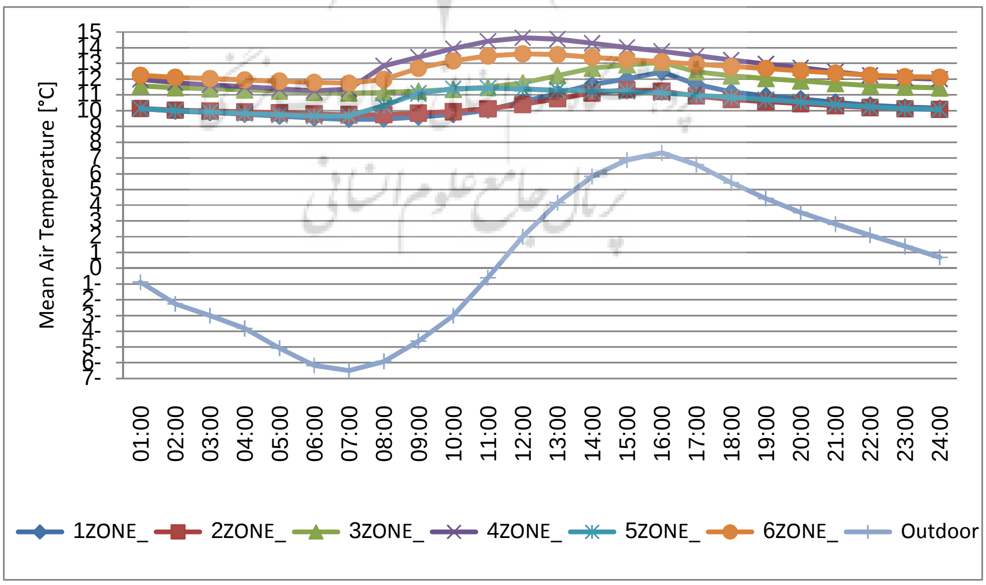

Fig.12:The thermal behavior of winter sections in the first day of winter

Validation

To validate computer simulation, on July 21st, 2013, the weather temperature in four main sections (five-door, wind catcher, cellar and coastal) was measured from 8 A.M to 6 P.M with lascar electronics data logger type EL-USB-2-LCD[2]. This equipment measured and saved more than 16379 between -36 to +80 centigrade or -31 to +176 Fahrenheit. Its accuracy is ±0.5 centigrade or ±1 Fahrenheit. Figs.13-16 show the measured results and simulation results in five-door section, wind-tower room, cellar and coastal.

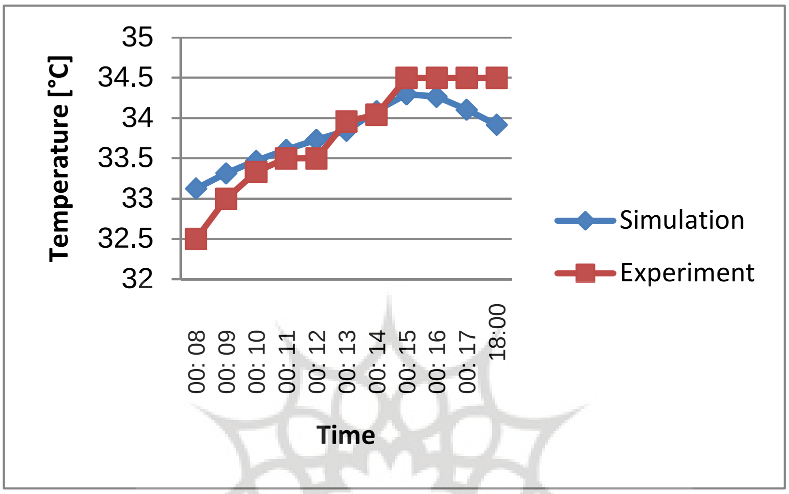

Fig.13: Comparison of measured results and computer simulation results in 2013/7/21 (five-door section)

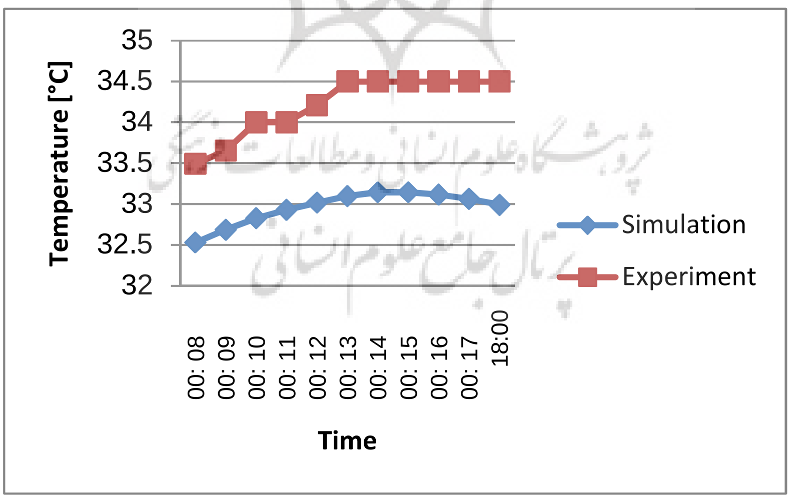

Fig.14:Comparison of measured results and computer simulation results in 2013/7/21 (wind tower section)

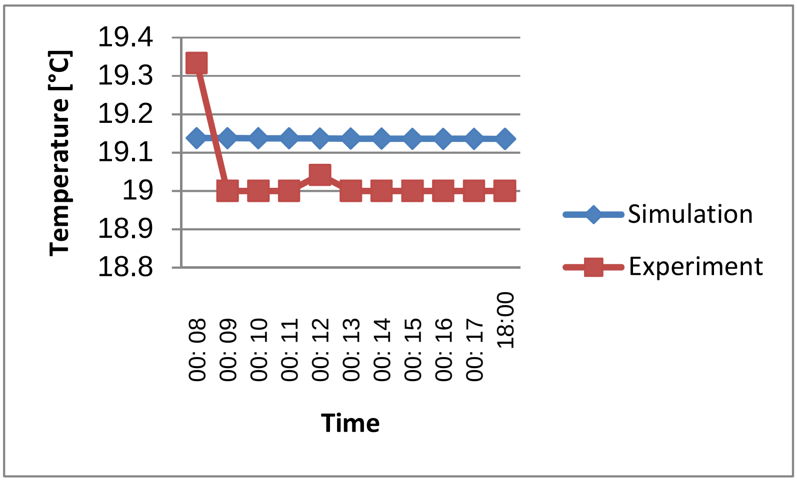

Fig.15: Comparison of measured results and computer simulation results in 2013/7/21 (coastal section)

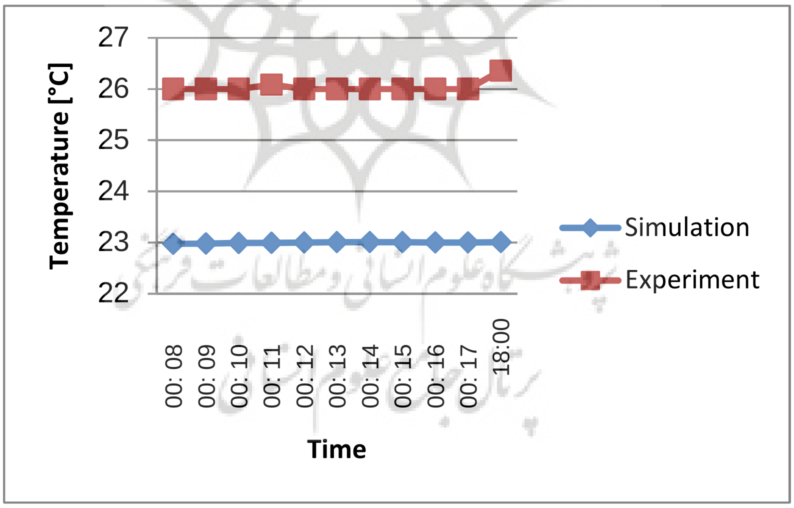

Fig.16: Comparison of measured results and computer simulation results in 2013/7/21 (cellar section)

Generally, comparison of the measured amounts and the amounts obtained from computerized simulation shows a slight difference in temperature and this suggests the reliability of the amounts measured by the computerized simulator.

CONCLUSION

Yazd traditional building architects tried to coordinate the design with the ecological conditions and in all of their designs set special places for cold and warm seasons. In every section, they adopted special solutions. In winter sections solutions like absorbing direct sunshine, transparent walls in front of the sunshine, using thermal capacity of building materials to save energy, building half-open sections in front of the entrance doors are considerable.

Based on observations and computer simulation analyses, the thermal behavior of winter section in Yazd traditional homes in the first day of every season is illustrated. With regard to comparison between sections with different dimensions like three-door, five-door, and seven-door in northwest and northeast orientation, it is concluded that

five-door section in northwest orientation (zone 4) has the best thermal behavior in winter, by creating The average temperature 17.83 in the first day of winter. These space, its length are 6.93(m), width 4.05 (m), average height 4.83 (m), and area 28.07 square meter.

If we use these sections in summer, the five-door in northwest orientation (zone 4) has the best thermal behavior.

ENDNOTES

1.http://apps1.eere.energy.gov/buildings/energyplus

2.High Accuracy Humidity, Temperature and Dew Point Data Logger with LCD: This standalone data logger measures and stores up to 16,379 relative humidity and 16,379 temperature readings over 0 to 100%RH and -35 to +80°C (-31 to +176°F) measurement ranges. The user can easily set up the logger and view downloaded data by plugging the data logger into a PC's USB port and using the supplied software. Relative humidity, temperature and dew point (the temperature at which water vapor present in the air begins to condense) data can then be graphed, printed and exported to other applications.

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