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The Analysis of Form, Settlement Pattern and Envelope Alternatives on Building Cooling Loads in Traditional Yazd Houses of Iran

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ABSTRACT

Environmental and energy problems have reached a globally dangerous point in recent years. Taking into consideration of these problems in building design could help to develop sustainable perspectives on built environment. There have been various traditional architectural solutions regarding bioclimatic conditions of settlement. Traditional architecture in different climatic zones prove that choosing appropriate values for energy efficient design parameters shows results in low energy buildings. This study aims to investigate the effect of settlement pattern, building form and envelope alternatives on cooling loads in Yazd as the representative city of the hot and dry climate zone of Iran by means of Design Builder V.3 building energy simulation software.

Key Words: *Form, Settlement Pattern, Envelope, Cooling Load, Yazd Traditional Houses*

1. INTRODUCTION

Population growth, increase in housing demand has been led to prefer fast construction techniques and high energy technologies in building industry. Creating the build environment and providing the comfort conditions without noticing bioclimatic elements is an important factor both for energy consumption and environmental issues in building design [1]. Since the big potential for significant energy savings, the most important steps about energy conservation are being taken in the construction sector. The majority of energy use in buildings is used to provide indoor comfort conditions during the operating period. Taking into consideration of microclimatic conditions, in order to design and ensure the comfort conditions of indoor environment is significant requirement. In this context, determining the shape of the climatic characteristics of the region inhabited settlements "climatic design", should form the basis of building design nowadays as in the past [2]. In recent days, most of modern constructions are trusting on mechanical cooling systems in hot-dry climatic region of Iran. Practically electricity is the only energy source for cooling. Especially in the regions of Iran with extreme

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climate conditions, this matter cause high demand in electrical energy to obtain indoor comfort [3]. The high consumption of electricity cause important problems like cut breaks in power supply because of elevated request of energy for cooling in similar regions [4]. Increased consumption for cooling energy means that, cooling systems based on electro-mechanical technology are not credible by itself for many buildings especially during hot summers [5]. Contrary to the most of modern constructions, it has been suggested that traditional architecture, with principles developed over many years, is more adaptable in the hot and dry regions of Iran [6]. Traditional architecture emerges varieties of regional and vernacular climate responsive technology [7]. Most of traditional constructions in the central region of Iran, are implemented with wind catchers, courtyards in the center, water pools, loggias and separately placed seasonal rooms. A traditional passive cooling system could be performed with all of these features which might change the effects of outdoor conditions (Fig. 1) [8].

Fig. 1. A Traditional house in the central region of Iran [8].

Most of traditional strategies of cooling in central regions of Iran, have stayed appropriate to work in unison and regional needs because of low energy sources of the respective area [5]. Because of this involvement, it is argued that many things should be learned to create a modern and continual design [8]. Region of Iran is situated in the dry geographic part. The dry climate of Middle East and Northern part of Africa continues into Iran. The average amount of rain in Iran is much lower than the average of whole world. Iran is categorized as a dry region although there are various conditions in case of climate. There are 4 climatic areas in Iran: 1. Mild climate of north, 2. Cold climate of high regions and mountains, 3. Hot and humid climate of south parts, 4. Hot and dry (hot and arid) climate of central region of the country. Hot and dry region includes most of the central area of Iran. During winter season it is cold-dry and hot-dry during summer. Yazd City is established in this area [9]. Many ancient cities with precious architectural design are located in the hot and arid area of Iran. Despite the modern buildings in Iran, design of constructions in this area, are integrated with the nature and have a harmonious correlation with the natural conditions. The world's most overbearing deserts are established in the central part of Iran, near center of Yazd. Deserts like Loot and Dashte Kavir, have enclosed Yazd Province. Hence Yazd is located in the desert, the architecture of this city look alike architecture design of several desert parts (Fig. 2) [10].

Fig. 2. Map of Iran and the location of Yazd [5].

Cities in the hot-dry areas could be compared to plants and cactus in deserts. Life spaces of these regions consisted of urban spaces, pathways, yards and buildings are completely protected against undesirable winds and at the same time desirable winds and sun radiation are used with special arrangements. Texture of city is intensified in the hot-arid regions. Walls are seethed and borders among them are unclear. To reduce area of each building, constructions are compressed, thus need for energy can be reduced for each house during long time period. High walls which are roofed by arches makes shadow on the houses therefore control on speed of wind of Kavir can be obtained. Usually texture of city constructed in the form of ways to achieve openings for desirable winds beside, direction for undesirable sand storms and winds are closed [11]. Some examples of traditional architecture in central Iran are seen in Fig. 3.

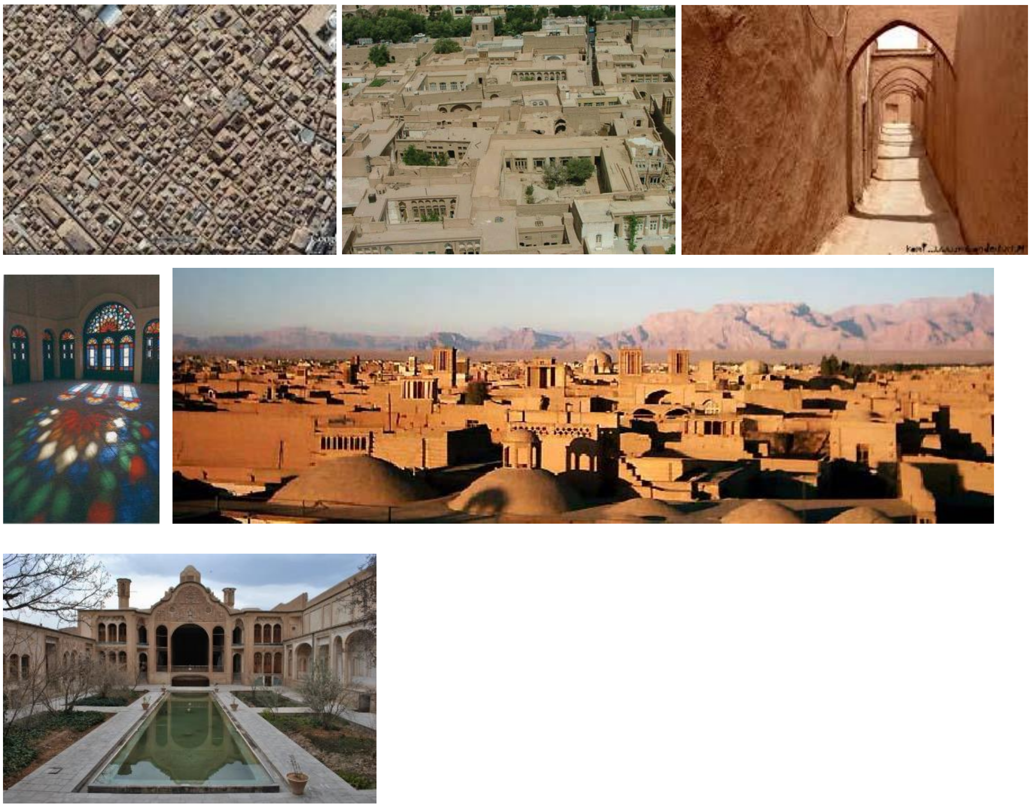


Fig. 3. Traditional architecture in central Iran [15-17].

It is believed that, traditional form of residence in the central part of Iran, is one or two floor surrounded by one/two courtyards. Mostly there are courtyards in the classic houses of Yazd city [12]. The most common form of houses in the central regions of Iran, are houses with one central courtyard [13]. Usually there is an open space shaped like a courtyard, which is bordered by loggias and rooms on two, three or four sides. There is a small pool placed in the center of courtyard with planting around. Most of the time house faces inward and high walls face outside and streets, to protect privacy in reply to classic social attitudes [8]. Courtyard is placed lower than street level. There is a relation between courtyard shape and size of shaded area, most of the time courtyard shape is rectangle [14]. To achieve solar radiation, winter rooms are located in the north side of courtyard. Summer rooms are established on the south of courtyard and receives the most of the shade which cools the room more than winter space. The central part of summer room, a semi-open space, which is called "talar" or "eyvan". There is an opening from "talar" to courtyard and usually a wind-catcher (badgir) located there for cooling. Walls are thick and comprised of brick or mud brick which are sundried or baked (Fig.4) [15]. Windows of rooms' surrounding courtyards, are open to courtyard and windows face to outside of house normally are located higher near roof level [16]. Wind and dust can be kept out from indoor space using small size windows also helps to promote privacy [17]. The walls adjoining courtyard, bring out a solid face to outside like a barrier for weather, strangers and damaging sand [12].

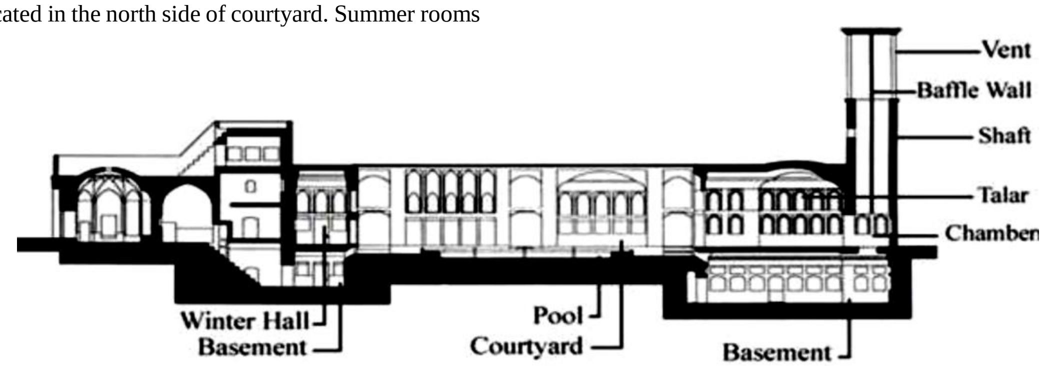


Fig. 4. Section of a traditional courtyard house in the city of Yazd [18].

Through Middle East, Pakistan to North Africa, wind catcher has been always determined as a traditional air deflector structure. The wind catcher, Badgir, an apparatus used in traditional ventilating and provided natural air conditioning in the buildings in hot and dry parts of Iran for centuries. There are air passages positioned vertically which divided wind tower, form ventilation at the top in one or more sides of the tower's head to catch the prevailing wind (Fig.4) [20]. Malgaf " receiver of wind" has been used by the Egyptians at 1300 years BC as an important criteria in local architecture for a long time. Malgaf has been used in hot and dry parts of Egypt to achive natural ventilation (Fig.5) [19]. Wind catchers in Iraq are similar to Malgaf in Egypt. Those of Iraq's have an opening in the thick mud brick or adobe walls on the roof of the summer living rooms to capture prevailing wind in order to cool air (Fig.6) [20]. Also there are wind catchers in hot areas like Afghanistan. In Herat, Afghanistan, wind catchers usually located on the dome shaped roof of rooms with a height of 1.5 meter (Fig.7) [21]. There is another type of wind catcher (Badkhor) in the old part of Hyderabad in Pakistan's Sindh province, which is seen on the roof of houses [22]. Badkhor is in the shape of square which is sided by two sheets vertically in size of wind catchers in Afghanistan (Fig.8) [21]. Wind catchers in United Arabic Emirates are similar to the Iranian wind catcher in warm and humid climate like the Bandar Lengeh, Kong, Qeshm located in south of Iran.

The wind cathers in UAE is in the shape of squares like shape of those in Iran and place on the flat roof which receive wind from four sides. The dimensions of these wind catchers are about 2.5 * 2.5 m and are not placed high to obtain fresh and cool blow of the sea [23].

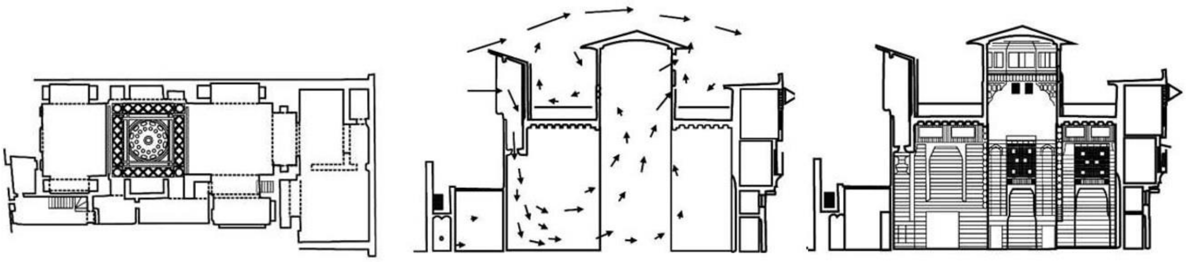


Fig. 5. Plan and section of the hall of Muhib Ad-Din Ash-Shaf'i AI-Muwaqqi, Cairo, Egypt , showing how the malqaf produce air movement internally. Arrows indicate the direction of airflow; arrow length corresponds to airspeed [19].

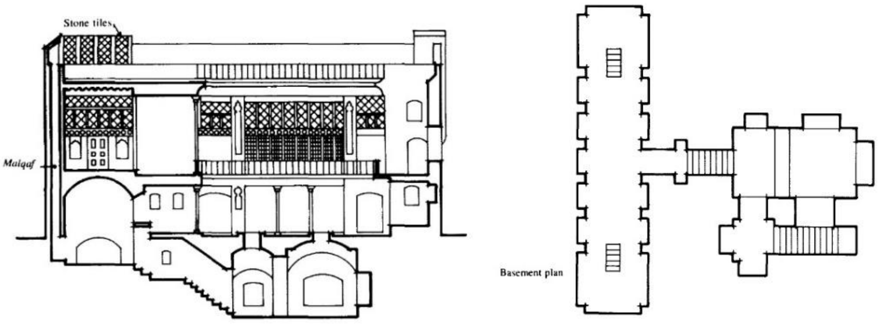


Fig. 6. Floor plans and section of a home with a basement living area in Al-Kufa, Iraq, with a narrow malqaf (windcatcher) and ceiling vents for ventilation [19].

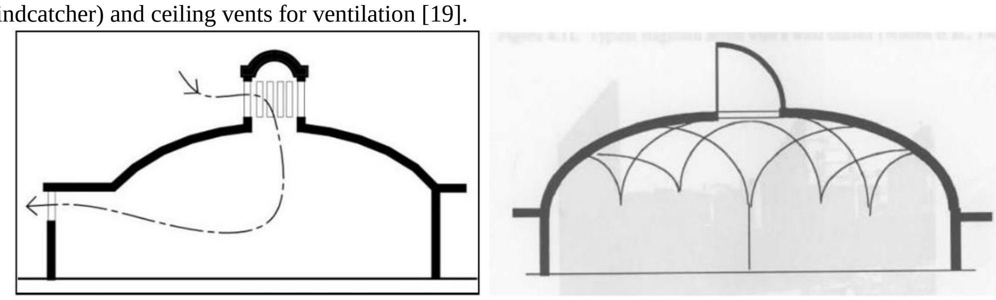


Fig. 7. Afghanistan Wind catcher [21].

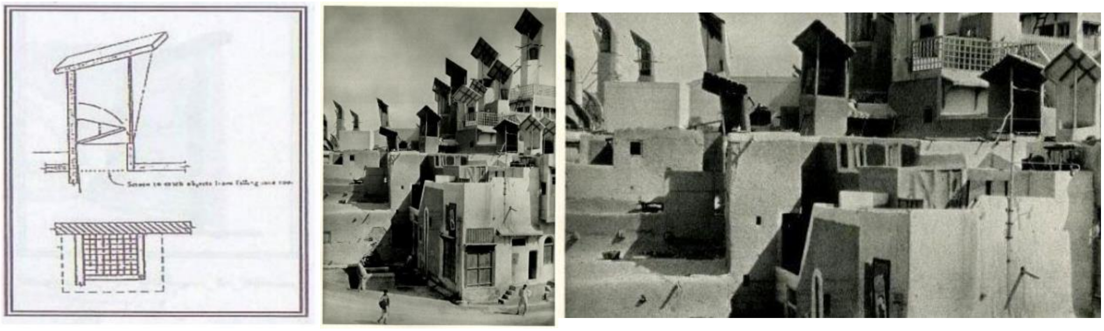


Fig. 8. Wooden wind catchers located on top of buildings in Hyderabad, Pakistan [22].

While Wind cathers are important in eastern architecture, the effects of form, settlement texture and envelope of constructions on cooling load are significantly essential to evaluate in hot and dry climate. Therefore these parameters were investigated in this study, based on the relevant design data of Yazd traditional houses. For this purpose, developed alternative parameters were evaluated by using Design Builder V3., building energy simulation.

2. MATERIAL AND METHODS

2.1. Aim and Targets

Substantially, there is great potential to construct climate sensitive modern buildings to consider current requirements of users by means of bioclimatic design. It has significant importance for the future applications on built environment based on traditional solutions. In this context, firstly, the impact of design parameters used in the traditional Yazd Houses on energy conservation should be evaluated. There are four climate in Iran and the most area of central of Iran covers by hot-dry climate. Based on “Climate Change and Climate Data” report of World Bank, hot-dry zone will be extended across the world because of global climate exchange [24]. Therefore characteristics of architectural design in hot-dry climate regions should be evaluated very clearly and in detail, considering of climate exchange scenarios for the future. In Iran, 40% of final energy consumption has held in the residential and services sector, according to 2006 istatistics [25]. From this perspective, the city of Yazd was choosen as prescriptive city of hot-dry region of Iran to investigate effect of parameters like building form, settlement pattern and envelope types of construction on the cooling energy saving.

2.2. Assumptions and Limitations

In this study, reference building forms and settlement patterns were developed based on traditional Yazd houses. In order to compare the cooling energy performance of different envelope types and orientations, energy simulations were done by means of DesignBuilder software. Within this context, the impact of natural ventilation has been neglected on cooling loads. During the simulation of cooling energy consumption of selected forms, only the effect of envelope and orientaion alternatives were calculated according to the values of the regulation prepared by Iran Building & Housing Research Center (BHRC) [26].

2.3. Determination of Data Relating to Design Parameters

As part of the study, above mentioned parameters was evaluated by means of simulation calculations. Accordingly, to achieve the required data, traditional settlement patterns and building forms were used and specific envelope alternatives have been developed. The data for simulation alternatives and generated models are described below.

2.3.1. Building Form

The case study aims to determine appropriate building form alternatives for hot-dry region in Iran, traditional Yazd houses were analyzed to investigate the plan types [14]. Four reference plan type are defined based on location of courtyards in buildings: L, U, I and central courtyard plan (Fig.9). Different configuration of these plans in traditional patterns were observed. These forms were used at this study.

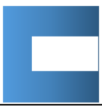
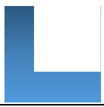
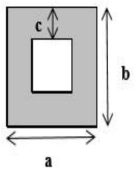
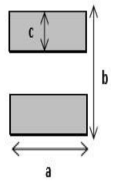
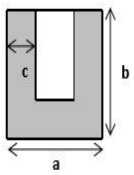
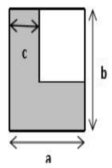
REFERANCE BUILDING FORM ALTERNATIVES			
			
Central courtyard plan	I Type plan	U Type plan	L Type plan

Fig. 9. Orientations used according to housing plan types in Yazd, Iran.

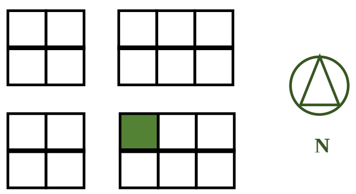
Area/Volume (A/V) ratio was used to identify alternatives for building form and the total external surface area (A) is included floor and the roof area. In order to investigate the effect of shape on building form, six different A/V alternatives are determined. These alternatives are A/V= 0.50, 0.60, 0.70, 0.80, 0.90 and 1.00 recpectively (Table1.).

Table 1.Building dimensions and A/V ratios.

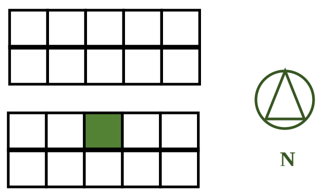
	A/V	a (m)	b (m)	c (m)	h (m)			A/V	a (m)	b (m)	c (m)	h (m)	
Central courtyard plan	0.5	27	27	8	8		**I type plan**	0.5	27	27	10.5	8	
	0.6	22	22	5.7	8			0.6	22	22	7.70	8	
	0.7	18	18	4.40	8			0.7	18	18	5.90	8	
	0.8	15	15	3.65	8			0.8	15	15	4.80	8	
	0.9	13	13	3.10	8			0.9	13	13	4.00	8	
	1	10	10	2.65	8			1	10	10	3.15	8	
U type plan	0.5	27	27	9.00	8		**L type plan**	0.5	27	27	10	8	
	0.6	22	22	6.40	8			0.6	22	22	6.70	8	
	0.7	18	18	4.90	8			0.7	18	18	5.20	8	
	0.8	15	15	4.00	8			0.8	15	15	4.20	8	
	0.9	13	13	3.40	8			0.9	13	13	3.55	8	
	1	10	10	3.00	8			1	10	10	3.15	8	

2.3.2. Settlement Pattern

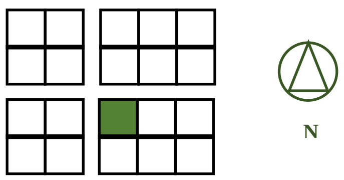
At this scope, there is a dense settlement pattern was observed during study of traditional Yazd city, The narrow streets and minimized amount of solar radiation on outer surface of buildings has been taking into consideration in building design. Constructions were built dense to provide more shaded area during daytime. In case study, based on traditional settlement pattern of Yazd, width of streets, were considered to be 1 m and 5 m. (Fig.10). [12].



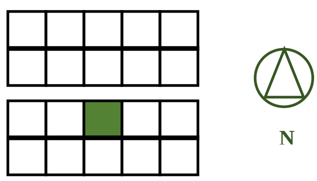
Case 1: two side of the building surrounded by contiguous buildings and 5 m. spaced street



Case 3: three side of the building surrounded by contiguous buildings and 5 m.spaced street



Case 2: two side of the building surrounded by contiguous buildings and 1 m. spaced street.



Case 4: three side of the building surrounded by contiguous buildings and 1 m. spaced street.

Fig. 10. Different type of settlement pattern used in the study.

2.3.3 Building Envelope Types for The Study

Traditional building envelope construction was choosen to create wall components of referance buildings, seen in Fig.11 [27]. Mud and adobe brick were used as main opaque components of walls which are common materials in traditional Yazd houses as a local material. Also organic and sustainable materials (thatch) are seen in the building envelope [12].

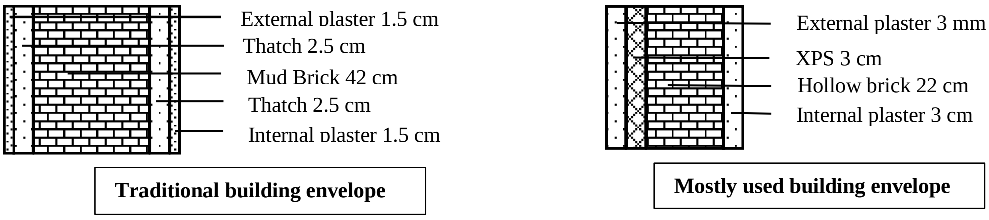


Figure 11. Layers of external wall.

Thermal heat transfer coefficient (U value) of opaque building componenets was determined based on Iranian National Building Code, shown in Table 2.

Table 2. Required U value according to chapter 19 of Iranian national building code [28].

Chapter 19 of National Building Code, Iran- 2nd Group Buildings	
	U value (W/M²k)
Exterior wall	0.66
Ground floor	0.66
Roof	0.40

2.3.4. Orientation of Buildings in Different Plan Alternatives

In this work, it’s aimed to compare the performance of four different types of plan, in term of cooling loads depend on the building form. In Traditional Yazd Houses summer space called “Talar” is the most important part of the building. It is established at south and face to north, therefore, in all plan types, the volume of summer space are located in the south of courtyard facing north. Two building mass are located in the north-south direction in central-courtyard and I type plan. However, most appropriate status of orientation of L and U type plans, were determined by comparing present alternatives using simulation. In this instance, by simulating different orientation situations of L and U type reference building with 0.50 rate of A/V, alternatives with the lowest value of annually cooling energy expenditure were choosen (Table3)

Table 3. Status of orientation in U type and L type plans.

Orientation	
U type plan	L type plan
N ↑ 	N ↑ 

In order to investigate the effect of seasonal used spaces on cooling loadings, a characteristic feature of Yazd houses, zoning of seasonal room was established with the plan types (Fig.12). Cooling load of summer and winter room positioned in accordance with traditional houses applications, were calculated base on results of simulations according to the alternative plan types.

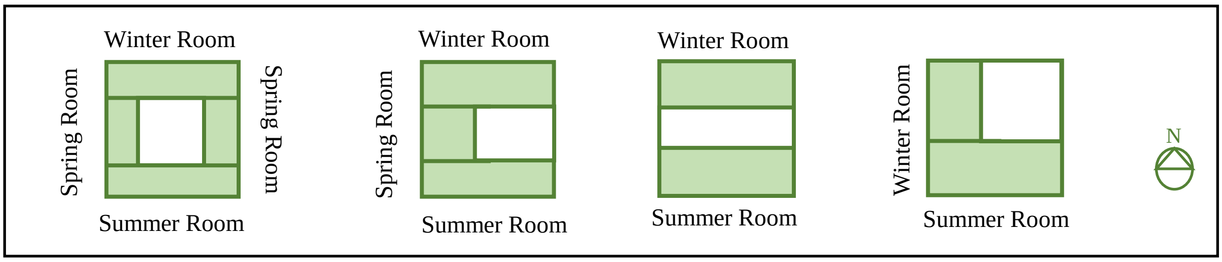


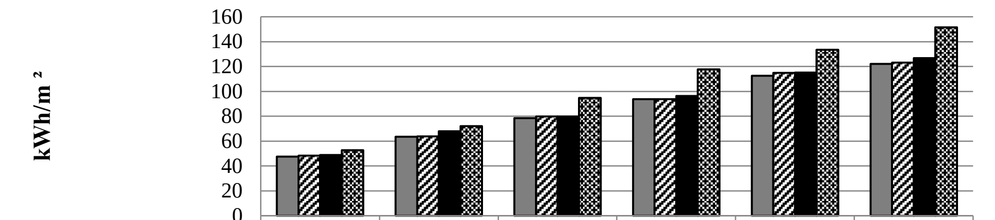
Fig.12. The positioning of the seasonal spaces.

3. RESULTS, COMPARİSON AND EVALUATİON

Within the contex of the case study, there were several simulations analysed for the parameters of building form, settlement pattern and envelope alternatives. Different building forms, which were developed using different combination of A/V rates, was evaluated for reducing cooling loads. It's also aimed to determine the impact of form and settlement pattern on energy conservation. The goal is to identify the alternative with the lowest energy consumption for cooling period. Simulations were performed, using building alternatives independent of the settlement pattern and alternatives inserted in each determined settlement texture then an annual cooling energy consumption of the building was calculated. In order to compare the results of alternatives , the obtained data were converted in to annual amount of energy per unit area (kWh/m²) .

3.1. Evaluation of Building Form on Cooling Loads

During the evaluation of results, it was observed that increasing the A/V ratio of different plan types, also raises the amount of cooling energy loads proportionally. In all settlement patterns, A/V ratio of 0.5 alternative has the lowest amount of annual total cooling load and the highest amount of annual total cooling load was in the A/V ratio of 1.00. The lowest cooling load was determined at I type plans and the highest cooling load was at L type plan.



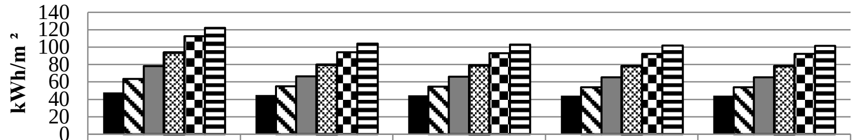
	0,5	0,6	0,7	0,8	0,9	1
I type plan	47,48	63,6	78,39	93,6	112,44	122,01
Central courtyard plan	48,24	63,77	79,68	93,74	114,78	123
U type plan	48,77	67,81	79,84	96,25	115,12	126,62
L type plan	52,74	71,96	94,73	117,64	133,42	151,42

Fig. 13. Comparison of the annual total cooling load depending on the building form.

Position of building blocks, depending on the plan types, has major effect on energy consumption. Because of received uncontrolled solar radiation energy, at east-west direction during summer, the location of winter room in west direction at L type raises the indoor temperature. Placing building mass in north and south, helps to get more closer and compact form when oriented each other. In hot-dry climate, building forms are compact so that external weather conditions affect less on indoor environment, helps to improve comfort by means of bioclimatic-passive design. In these structures, compactness is defined as A/V ratio related to outer surface area / volume of the building. Location of the courtyard and amount of the shaded area of the facade affect the cooling performance. At central courtyard and I type plans, courtyard is located at the center of building blocks. At U and L type, courtyard is located at the edge. At central courtyard and I type plans, energy consumption is lower than other plan alternatives (Fig. 13). The results showed that, in case of courtyard surrounded by the building mass, has important in acclimatization effect, which made courtyard more protected against external weather conditions. Dimensions of courtyards are also effective in the creation of shaded areas, therefore both appropriate courtyard configurations have effective solutions for reducing the cooling energy load in Yazd City.

3.2. Evaluation of the Effect of Settlement Pattern on Energy Consumption

Simulation alternatives were analyzed by means of different settlement patterns and cooling energy loads compared respectively. These assessments was carried out for I type plan which has the lowest cooling load. With this study, effect of neighboring buildings and width of the streets on settlement design were investigated. The performance results and assesment of settlement patterns were shown in Fig. 14. According to the obtained results, increase in rate of shaded areas provided by surrounding buildings, cause significant decrease in cooling loads. In this context, the lowest cooling load is provided by alternatives of the building located in the Case 4. Building blocks were located paralel to the street and three different sides of simulated building were surrounded by neighboring buildings. Solar protection was provided just from one facade through the narrow gap of streets so that the total effect of solar radiation on building decreases at Case4. Total annual cooling energy consumption for different A/V rates of the I type plan, were shown at Fig. 14. Among these different rates of A/V of I type plan, the lowest cooling load was obtained in the Case 4 and the highest cooling load was in the Case 0 (reference building). Maximum solar heat gain is the result of open position of the reference building with no blocking element which causes higher cooling loads.



	case 0	case 1	case 2	case 3	case 4
0.5	47,84	44,99	44,67	44,33	44,26
0.6	63,6	54,85	54,52	54,05	53,96
0.7	78,39	66,39	65,99	65,44	65,31
0.8	93,68	79,73	78,96	78,41	78,22
0.9	112,44	94,03	93,03	92,38	92,11
1	122,01	104,24	102,89	101,9	101,52

Fig. 14. Annual Cooling Loads For I Type Plan for Different Settlements.

During comparing of cooling load for each building alternative in Case4 and reference building proportionally, it is concluded that settlement patterns has a great impact on cooling load (Fig. 15).

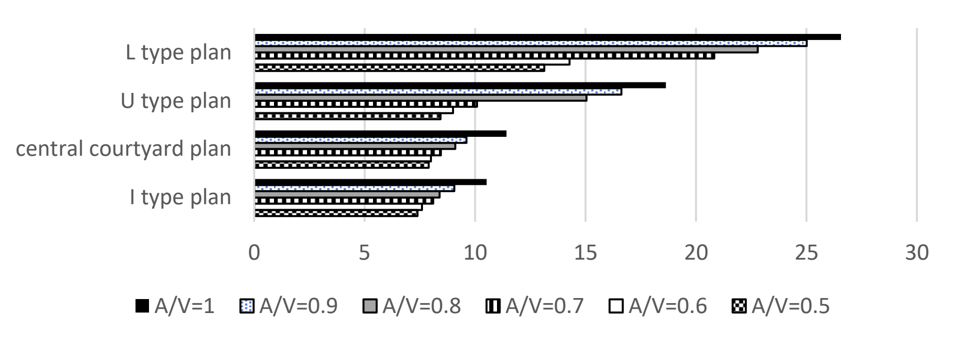
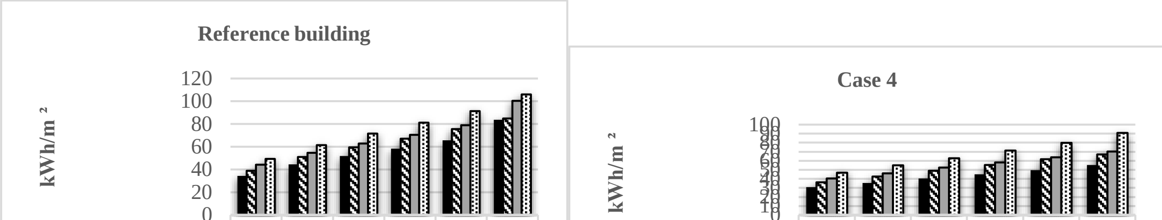


Fig. 15. Comparing the cooling loads proportionally for reference building and Case 4.

Based on the effect of buildings to each other, the cooling loads of alternative forms, three sided neighboring building is lower than alternative of two sided example. In addition, based on the evaluation of width of street, required amount of cooling load of alternative case with 1 m. street width 1.65% lower than that of 5 m. width. Results of these simulations showed that the settlement wich has narrow and shaded streets has more potential for passive cooling.

3.3. Evaluation of the Effect of Seasonal Used Spaces on Cooling Loads of Building

The building blocks are placed around the courtyard, in pursuance of received solar radiation according to their orientation, are functionalized for seasonal use. The energy consumption of these places is expected to be low according to orientation. In this scpoe, cooling loads of lowest and highest energy consumption for seasonal places are compared. According to the comparison of cooling load of places, the lowest consumption was observed at the ground floor of summer room. Depending on the different rate of A/V, total annual cooling load has been achieved as a result of simulations and was shown at Fig. 16. Position of summer room at the ground floor of, requires less cooling energy by staying in the shade of building blocks around. In addition because of no roof area, unlike the first floor, surface area is smaller and it has more potential for passive solar control. Accurate positioning of seasonal places, according to acclimatization criteria and as a result of seasonal space utilization, significantly reduces the cooling load of the building and constitutes comfortable spaces. Consequently, the cooling load is an important design criterion for hot-dry climate, simulation results show that the building provides by summer room of ground floor in I type plan has 20% lower the cooling loads.



Reference building:

	0,5	0,6	0,7	0,8	0,9	1
summer room, ground floor	34,3	44,44	51,77	58,23	65,61	83,83
winter room, ground floor	38,83	50,91	59,6	67,12	75,51	84,8
summer room, 1st floor	44,31	54,55	62,93	70,48	78,8	100,33
winter room, 1st floor	49,27	61,39	71,62	81,1	91,45	105,95

Case 4:

	0,5	0,6	0,7	0,8	0,9	1
summer room, ground floor	30,69	35,4	40,4	44,94	49,6	55,17
winter room, ground floor	36,2	42,7	49,1	55,47	61,8	66,9
summer room, 1st floor	40,57	46,26	52,6	58,17	63,71	70,3
winter room, 1st floor	46,8	54,9	62,8	71,14	79,9	90,7

Fig. 16. Comparison of cooling load for seasonal rooms, I type plan.

3.4. The Impact of Thermophysical Properties of Building Envelope on Cooling Load

To ensure the indoor comfort conditions in hot-dry climate, the building envelope should have high thermal capacity, and longer time lag effect by means of thermal mass. Therefore, envelope of the traditional Yazd house consists of local and sustainable building components (adobe brick,etc.) with these features; however nowadays the building components are made without considering these local passive parameters.

The performance of traditional and alternative envelopes designed in accordance with U value of hot-dry climate given in Iranian National Building Code, were compared in Table 1. The reference building with A/V rate of 0.50, shown at Fig. 13, was made of envelopes with traditional and alternative materials and simulated to compare with the same form with a different envelope in term of energy consumption. The energy consumption of traditional envelope is lower than alternative envelope in each type of plans, during investigation of cooling load of two envelope alternatives with the same U value, to provide same environmental conditions. According to the results of simulations, the cooling load of traditional envelopes, which is taken into account as a priority in building design in hot- dry climate, is significantly lower; since the traditional envelope has the features like long time lag effect and higher thermal capacity of the mass. All of these are necessary bioclimatic passive design considerations for hot-dry climate. Despite having the same U value of alternative envelope, the cooling loads for traditional envelope with 0.50 ratio of A/V, 11.18% in I type plan, 10.32% in central courtyard plan, 7.8% in U type plan and 4.6% in L type plan is lower than alternative envelope.

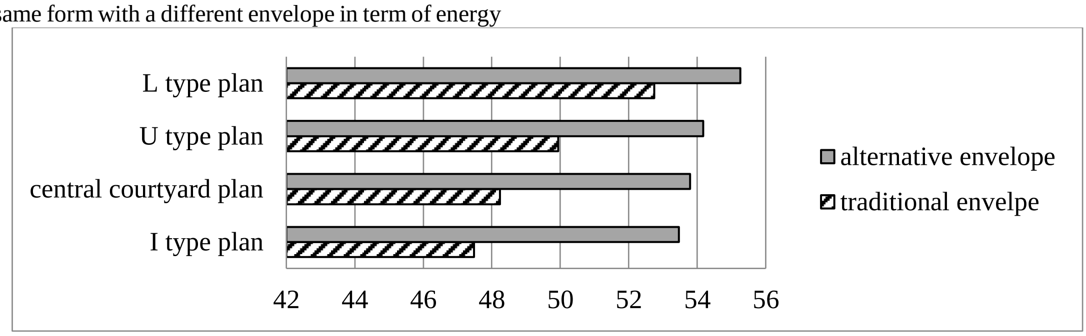


Fig. 17. The comparison of cooling load for traditional and alternative building envelope with the same U-value for reference building (A/V=0.5).

Simulated indoor temperature values of two alternative envelope for I type plan with 0.50 A/V rate, at 21 July in case of disabling active of reference building, was shown at Fig. 20. It was obtained that indoor temperature of traditional envelope is lower than alternative one. As a result of this study it was obtained that the performance of traditional envelope dependent to the material is better than alternative envelope about 2.64%.

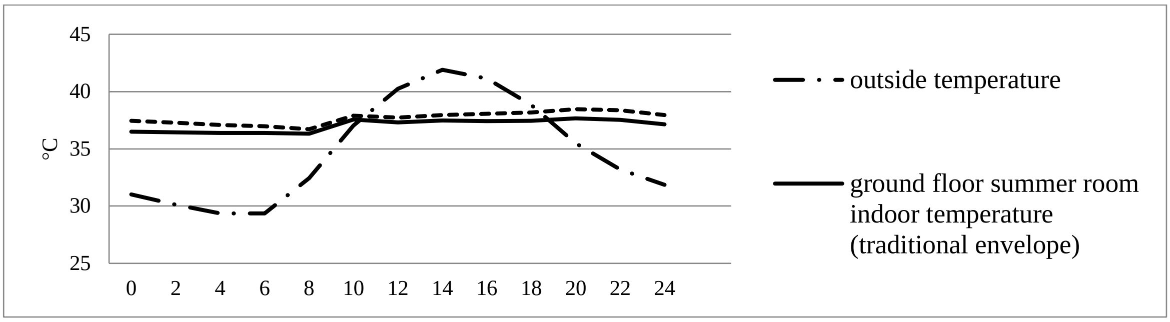


Fig.18. Comparison of indoor temperature for traditional and mostly used building envelope with the same U-value On July 21(I type reference building, A/V=0.50).

4. CONCLUSION

Within this study, it is aimed to specify the importance of traditional architectural parameters for houses in hot-dry climatic region of Iran. It was emerging that, some criteria like form, settlement pattern, alternatives of building envelope and bioclimatic design parameters could be effective on buildings cooling load. Simulation tools make possible to evaluate the effect of these parameters and develop energy-efficient building design from concept phase through to completion of building. In this study, the form and settlement pattern alternatives, type of building envelopes obtained from traditional Yazd houses have been analyzed by using Design Builder V.3. software. According to the results, it had been determined that less energy is consumed to achieve comfortable environment at traditional Yazd houses. But today as a result of growing urbanization, designing of buildings without paying attention to bioclimatic approach, more energy is consumed to maintain indoor comfort, therefore design of buildings compatible with climatic condition should be noted to avoid excessive energy consumption. In accordance with the results obtained from the study, energy-efficient bioclimatic buildings should be designed with the right analysis and decision making steps.

As shown in the results, it is possible to make low energy consuming and comfortable environment with necessary analysis by means of simulations during the design phase. However, a bioclimatic design compatible with the environmental conditions and accurate analysis of climatic data should be considered. Development of a settlement model integrated with renewable energy sources and climate compatible design for hot- dry region, is intended to apply in housing sector specific for Iran. Thence, today and in the future, more healthy and sustainable environment will be created for users.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

REFERENCES

[1] La Roche, P., “Carbon-Neutral Architectural Design”, Taylor & Francis Group, 97-136, (2012).

[2] Arslanoğlu, N.,The Analysis of Bio-climatic Approaches on Contemporary Multiplex Housing Building in Istanbul, MSc.Thesis, Yıldız Teknik University Institute of Science and Technology, İstanbul, 4-19 (2008).

[3] Foruzanmehr, A., “Integrating Vernacular Passive-Cooling Systems into Modern Buildings in Iran”, Proceedings of UK-India-Sri Lanka Young Scientists Networking Conference: Towards Sustainable Energy Technologies And Low-Carbon Buildings For Climate Change Mitigation, Delhi, India, (2008).

[4] Bahadori, MN., Mazidi, M., Dehghani, AR., “Experimental investigation of new designs of wind towers”, Renew Energy, 33(10), 2273–2281, (2008).

[5] Foruzanmehr, A., Residents’ perception of earthen dwellings in Iran. International Journal of Urban Sustainable Development, 5(2), 179-199, (2013).

[6] Foruzanmehr, A., Vellinga, M., Vernacular architecture: questions of comfort and practicability. Build Res Inf. 39 (3): 274–285, (2011).

[7] Fardeheb F., Examination and classification of passive solar cooling strategies in Middle Eastern vernacular architecture. Passive Sol J. 4 (4):377–417, (1987).

[8] Foruzanmehr, A., “Thermal Comfort And Practicality: Separate Winter and Summer Rooms in Iranian Traditional Houses”, Architectural Science Review, 58 (3), 1-11, (2015).

[9] Hyde, R. “Bioclimatic Housing: Innovative Designs for Warm Climates”. Earthscan, UK&USA: Earthscan, 173-193, (2008).

[10] Keshtkaran, P., “Harmonization between Climate and Architecture in Vernacular Heritage: A Case Study in Yazd”, Iran. International Conference on Green Buildings and Sustainable Cities, 21, 428-438, (2011).

[11] A’zami, A., Yasrebi, S.H., Salehipoor, A., “Climatic Responsive Architecture İn Hot And Dry Regions Of Iran”, International Conference Passive and Low Energy Cooling for the Built Environment, Santorini, Greece, (2005).

[12] Ghobadian, V., “Climatic Analysis of the Traditional Iranian Buildings”, Tehran, Iran: University of Tehran press, 123-158, (1998).

[13] Memariyan, G., “Ashnaii ba Memari Maskooni Irani: Ghoone Shenasi Darunghara (Introduction to House typology in Iran, Courtyard Houses)”, Tehran, University of Science and technology, (1994).

[14] Pirnia, M. K., “ Iranian Architecture”, Tehran: Soroushe Danesh Publication, (2008).

[15] Tolou Behbood, K. Taleghani, M., Heidari, S., “Energy Efficient Architectural Design Strategies in Hot-Dry Area of Iran: Kashan”, Emirates Journal for Engineering Research, 15 (2), 85-91, (2010).

[16] Saljoughinejad, S., Rashidisharifabad, S., “Classification of Climatic Strategies, Used in Iranian Vernacular Residences Based on Spatial Constituent Elements”, Building and Environment, 92, 475-493, (2015).

[17] Monshizade, A., “The Desert City as an Ancient Living Example of Ecocity. Case Study: Yazd”, Ecocity World Summit 2008. 7th International Ecocity Conference, San Francisco USA.

[18] Haji-Qassemi, K., Karbassi, C., “Ganjnameh” (Cyclopaedia of Iranian Islamic Architecture), Iran: Shahid Beheshti University Publicatin, (1998).

[19] Fathi, H., “Natural Energy and Vernacular Architecture”, The University Of Chicago Press, London, (1986).

[20] Bahadori Nezhad, M., Dehghani, A. R. “The Wind Catcher, Engineering Masterpiece of Iran”, Yazda:Tehran (2008).

[21] Roaf, s., “The Wind Catcher of Yazd”. Ph.D thesis, Department of Architecture, oxford polytechnic, (1988).

[22] Mahyari, A., “The Wind Catcher”. Ph.D thesis, Sydney University, Australia, (1996).

[23] Bahramzadeh, M., Sadeghi, B., Sabok Rou, S., A Comparative Study to Compare the Wind Catcher Types in the Architecture of Islamic Countries, Journal of Basic and Applied Scientific Research, , 3(2s), 312-316, (2013).

[24] Internet: Climate Change 2014 Synthesis Report Summary for Policymakers. https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf

[25] Institute for International Energy Studies, "Iran's Hydrocarbons Energy Balance 2006", Ministry of Oil and Gas, (2006).

[26] Kari, B. & Fayaz, R., Evaluation of the Iranian thermal building code. Asian journal of civil engineering (Building and Housing), 7(6), 675-684, (2006).

[27] Cho, S., Mohammadzadeh, N., “Thermal Comfort Analysis of a Traditional Iranian Courtyard for the Design of Sustainable in Iran Residential Building”, IBPSA Building Simulation conference, France, (2013).

[28] Chapter 19 of National Building Codes, Iran Ministry of Housing and Urban Development, (2010).