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Comparative Comparison Of Residential Buildings In Yazd's Central Yard In Terms Of Thermal Behavior By Measuring The Total Thermal Load*

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ABSTRACT

Today, the effect of the thermal behavior of materials and spaces in the face of climatic conditions in creating thermal comfort for humans has been proven. Although the buildings usually use fossil fuels and cause heavy consequences such as climate change, favorable thermal behavior is observed in the native buildings of the cities of the central plateau of Iran, including the houses with a central courtyard in Yazd. Therefore, the main goal of this article is to compare the thermal behavior of buildings with a central courtyard in the dry climate of Yazd, to check to what extent central courtyards can provide suitable thermal behavior for these buildings. Modeling and simulation methods have been used in this research. Twenty buildings with a central courtyard were selected in Yazd region and then modeled in Design Builder software. In order to achieve optimal thermal comfort due to the different substructures of these buildings, the total thermal and cooling load should be divided by the square meter of the building. to obtain the values of the total thermal load of the building in terms of kilowatt hours per square meter to provide a basis for comparing these buildings with each other. In line with the purpose of the research, the lower the amount of heating and cooling required and, consequently, the total load of a building, the better its performance in terms of climate. The results of this research showed that the lowest values of the total heating and cooling load belong to single-yard houses. It is like Samsar 142 kwh/m2 and Tehrani ha House 162 kwh/m2 and Rasoulian House 181 kwh/m2. In this way, a comparative comparison can be made from the lowest to the highest amount of energy consumption in native houses in Yazd. According to this Yandi classification, a new typology of residential buildings in the central yard of Yazd can be obtained from the comparative comparison of the buildings in terms of thermal behavior based on the total thermal load. which is a proof of innovation in this research compared to similar researches in this field.

Keywords: *Residential buildings, central courtyard, thermal behavior, total thermal load, Design Builder, Yazd.*

1. Introduction

Climate and architecture is one of the important topics in studies related to the role of climate factors on housing and human living space. In the past, architects knew the effects of different imatic factors due to their experience and tried to reduce their adverse effects by considering solutions in addition to the optimal use of climatic factors in order to create comfortable thermal [16], [1], [4], [2].

The assessment of climatic conditions in relation to human comfort is the basis of architecture, urban planning, tourism, etc. activities. Therefore, it seems necessary to compare the comfort ranges in different living spaces, determine the comfort

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conditions in different climatic ranges based on thermal calculations of the building, the size and power of thermal devices and spatial communication, the amount of openings and also finally on The amount of thermal load of the entire building and in general has a direct effect on the amount of energy consumption and loss[3], [5], [10].

In connection with minimizing the energy loss in traditional architecture [11], many tricks have been devised that have been evidence of the great attention of designers to this category, which include: the orientation and compact texture of spaces [15], to The existence of micro-climates, wall cracks, middle space and front spaces, spatial diversity suitable for the season, use of the central courtyard and the way of arranging the spaces [12].

The central courtyard, along with the organization of different spaces around it, according to the circulation of the sun, caused different parts of the house to be assigned to each season of the year and a kind of seasonal circulation was created in the house [6], [8], [9].

In hot regions, various measures have been taken in the field of controlling radiant energy in the outer space, which include the use of bright colors for external bodies, the use of different shades, and improving the thermal properties of the materials used in the walls. , but before applying these measures, what is very important is to have suitable proportions of outdoor spaces such as yards, in such a way that it has the best performance against the conditions of sunlight in terms of when shade is needed and vice versa [14].

Professor Helmut Schram in a part of the book; "Dense horizontal houses" deals with the classification of houses with courtyards. All kinds of species; It classifies and introduces rectangular, L-shaped, U-shaped central courtyard house, fully enclosed on four sides, multi-yard houses, strip yard houses and multi-story yard houses in different cities [9].

The purpose of this article is to compare the thermal behavior of central courtyard houses in Yazd in all time periods of the year, whose annual weather information is extracted through the Yazd meteorological site and by entering this information into the simulated model of central courtyard houses. Dar Yazd, in the Design Builder software, you can get the total cooling and heating load of these houses that do not use mechanical equipment. Due to the variable size of the investigated houses, the total load obtained should be divided by the size of the house to obtain the final value in terms of kilowatt hours per square meter and make the houses comparable to each other. Therefore, in this way, it is possible to identify and analyze the houses that have the best and worst thermal performance and also provide optimal thermal comfort for its residents.

2.Literature Review

There are countless studies on thermal behavior in different cities, as well as addressing the category of thermal comfort and the effect of building form, materials, windows, type of canopy, and other things that affect the thermal behavior of a residential building, including It is possible to point out the cases that have been done mostly in the direction of houses with a central courtyard; Seflai (2003), with the aim of knowing the environmental design of the central courtyard houses in different cities of the hot and dry region of Iran, was able to check the correct proportions of the central courtyard with descriptive and comparative methods and show the correct proportions of the summer hall and the relationship between the central courtyard Check with the forum. Sohrabi (2014) investigated the climatic efficiency of the veranda and how it affects the adjacent residential spaces and presented the typification of the veranda in hot and dry climate and in his studies, how these factors affect the two dominant verandas in one of the traditional houses of Kerman city. shows with the help of measurement and simulation. Nikqadam (2012) has determined the climatic patterns and measures in native housing in different hot and humid climate regions of Iran, and in his studies, he shows the climatic role of the central courtyard in the hot and humid climate. Ahmadi (2013) compares the central courtyard houses and shows the central and fundamental role of the central courtyard in creating sustainable architecture. In this study, with a different method and using tables and analysis of the resulting numbers, the alignment of native architecture with the principles of sustainability has been proven. Zarei and Mirdehghan (2015) have investigated the effect of the central courtyard pattern in the houses of Yazd region and determining the role of the existing proportions between the central courtyard and the walls in adjusting the harsh conditions of hot and

dry climate. The results of this study show that there is a direct relationship between the proportions of the yard and the walls; Because the windows have a better interaction with solar energy with their proper shading in the hot months and better reception in the cold months. On the other hand, the size of the yard provides a suitable space for creating a sub-climate, which moderates the radiation in the hot months and creates a calmer atmosphere in the yard during storms. Zainlian and Akhot (2016) have compared and analyzed the form analysis, the proportions of the yard, the depth of the yard, the angle of human view, the height pattern, the ratio of closed to open space, the area of greenery and water, the materials and the color of the yard wall. The results of this study show that in the houses of Yazd and Dezful, the yard is an important element and the role of the system of the house, but there are also structural differences; In other words, although it is possible to find the same type of placement of the yard in the house for both hot and dry and hot and humid climates, the structural differences of the yard in these two climates include differences in the height pattern, depth, view angle to the yard, proportions And the percentage of open space in the yard and finally the yard wall materials are inevitable and absolutely necessary. Moradi, Mateen and Dehbashi Sharif (2017) investigated the physical structure, patterns and various types of the central courtyard in traditional houses of Tabriz from the climatic point of view and the components affecting the thermal behavior in these courtyards. In this study, from the climatic point of view, the increase in the height of the walls, especially in the southern faces, has led to the creation of wide shadows on the surfaces adjacent to the yard and as a result, the quality of thermal comfort has decreased in cold seasons, which is not suitable for cold areas such as Tabriz. Therefore, the optimal condition is that the walls located in the southern part of the yard should be shorter than the northern walls in order to provide maximum radiation absorption for the adjacent surfaces of the yard in cold seasons. Yazdi, Mofidi Shemirani and Etisam (2018) have conducted a study for the physical analysis of the central courtyard and the summer hall of Yazd houses. In this study, which was conducted with a survey method and with qualitative and quantitative data, despite the slight differences in the environmental conditions, the central courtyard and the summer hall have close proportions and similar physical patterns; Also, the role of the central courtyard and the summer hall as a microclimate factor in creating cooling and ventilation of living spaces is very effective in the formation and order of buildings, especially residential houses, which can be considered in the design of contemporary residential architecture. Khaksar, Mofidi Shemirani and Nikkhah Shahmirzadi (2019), identified the most influential climatic variables on the formation of buildings in Meimand village in terms of thermal comfort of these buildings. The results of the study showed that the earth shelter buildings of Maimand village correspond to its climate in many aspects, which results in thermal comfort during the time periods of the year, and finally, the architectural solutions compatible with its climate can be a model for contemporary architecture in other regions similar to Maimand climate. be Karmi-Rad, Benazadeh, Zarei and Ghazalbash (2017), to investigate the influence of physical and environmental characteristics such as the percentage of open space, orientation, sky viewing angle, vegetation, water and specific materials, the thermal comfort and the amount of people using the studied space. they paid.

The results of the study showed that more shading is seen in the courtyards of houses that have the lowest sky visibility coefficient and area, which, as a result, create better external thermal comfort conditions for the residents. However, one should not ignore factors such as the shading of trees and the humid effect of water ponds in softening the microclimate of the central courtyards. Maleki, Ahmadi, and Maudat (2012), by dividing the spaces that make up Rasulian House of Yazd into three categories: open spaces, semi-open spaces, and closed spaces, and then examined the details of the components of each space separately. The results of the study showed that residential houses in Yazd city, like other parts of Iran, have been formed in harmony with the environmental, cultural, social and economic conditions. Each house has a central courtyard in the center and heart of the house and a manifestation of introversion. Also, elements such as wind deflectors are installed for thermal comfort. In general, the city of Yazd has old traditional architectural elements and materials related to the climate, and it has the ability to receive the correct answer to the hierarchy of human needs, which can work in new housing to meet the needs and achieve a better life. Kazemi and Mahmoodabadi

(2013), by investigating the thermal behavior of the winter part of the traditional houses of Yazd, which are located in a hot and dry region, were able to determine with this method that firstly, the temperature changes of these sections were measured with the Laskar electronic data logger, and secondly, the sections with different ratios such as Three-door, five-door and seven-door rooms in different directions and their thermal behavior were analyzed and compared in "Khane Rasouli", they showed that comparing sections with different dimensions such as three-door, five-door and seven-door in the direction North-west and north-east, it is concluded that the five-door section in the north-west direction has the best thermal behavior in winter. Samir Gadouh and Zamouri (2015), investigated the thermal environments and indoor lighting of the courtyards of buildings in a hot and dry area. The results of the study showed that the building with a courtyard has the greatest potential for natural light and thermal control, and it is the relationship between the morphological components and the qualities of the thermal and luminous environment of the adjacent spaces, and the courtyard plays a role in controlling, regulating and homogenizing the luminous environment. The three areas around a building with a courtyard(interior/exterior spaces/courtyard) interact in systematic ways to increase the thermal and lighting performance of the building and to solve the problem between daylight and protecting the building from the hot sunlight in hot and dry areas. have. Seflai, Shekoian and Mofidi Shemirani (2014) investigated the effect of courtyards as microclimate modifiers with the aim of sustainability of traditional houses in Iran. The results of the study showed that most Iranian courtyards are designed in such a way that they can act as microclimate moderators with the correct orientation, dimensions and proportions. Bagheri-Sabzwar, Masoumi and Terzefan (2015) studied a residential yard in Yazd with the help of different proportions and orientations of the yard to reduce energy consumption. To carry out this study based on the basic model obtained from student dormitories in Yazd in the hot dry climate of Iran, Energy Plus computer software was used. The results of this research showed that the proportions and orientation of the courtyard affect the cooling and heating load.

In this regard, there have been similar studies that, despite the thermal investigation of the central courtyard of native houses, the focus of the studies was different and other results were deduced, among which the following selected cases can be mentioned: Ahmadi (2011), houses It compares the central courtyard and shows the central and fundamental role of the central courtyard in the creation of sustainable architecture. Zarei and Mirdehghan (2015) have investigated the effect of the central courtyard pattern in the houses of Yazd region and determining the role of the existing proportions between the central courtyard and the walls in adjusting the harsh conditions of hot and dry climate. Zainlian and Akhot (2016) have compared and analyzed the form analysis, the proportions of the yard, the depth of the yard, the angle of human view, the height pattern, the ratio of closed to open space, the area of greenery and water, the materials and the color of the yard wall. Moradi, Mateen and Dehbashi Sharif (2017)

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One of the study gaps is that the thermal behavior of residential buildings in the central courtyard has not been investigated accurately in all time

periods of the year in a specific area. Comparative study and comparison of residential buildings in the central courtyard in terms of temperature and communication, none of the similar studies have addressed this issue, and thus this research has innovative and novel aspects.
The questions we seek to answer in this article are:
1-What is the role of the central courtyard in reducing or increasing the thermal load of the building?
2-What indicators can Design Builder specify in climate studies for houses with a central courtyard in Yazd?
3-What are the best and worst central courtyard patterns that can be effective in the heat load of the building?

3.Research Methodology

The research method in this article is based on the comparison by computer software that compares the thermal behavior of the houses in the central courtyard of Yazd to determine the optimal thermal comfort for its residents according to the climate characteristics of the studied area, which has its own capabilities and limitations. evaluates The climatic data studied in this article includes all the monthly measurements of the climatic elements of the synoptic stations of Yazd province in the statistical period of 10 years (2013-2023), which has been processed as an information base, and of all the climatic characteristics, i.e. temperature, Humidity, rainfall, direction and speed and amount of wind, direction of sunlight and hours of sunshine which control the set of temperature conditions of the human body, are given to the software on an annual basis so that a one-year dynamic simulation can be done and can be done at any moment. Measured the cooling and heating load of the houses. In the following, the process used in this article, which includes the four steps of Figure .1, is described:

First stage: modeling; After collecting and drawing the houses with a central courtyard in Yazd city, twenty houses are modeled according to the materials and type of roof and walls and cold and hot spaces.
Second stage: recording the collected information; At this stage, due to the non-use of mechanical equipment in these houses, a set point has been considered for them to determine the cooling and heating needs of the houses according to the outputs.
The third stage: simulation; The models are taken into the Design Builder software and the necessary settings for climate, materials, etc. are made in the software.
Fourth stage: analysis of findings; Design Builder has extracted the total thermal or cooling load in terms of kilowatt hours per square meter in order to provide a basis for comparing these houses with each other. Therefore, any building that has a lower total load than the others has a better thermal behavior and vice versa.
In the following, the selected houses in this research are targeted and based on the pattern of the central courtyard, which is the basis of this research, as well as the location of the city of Yazd. Among these, in order to use different types of residential buildings in the central courtyard, From the other single-yard, two-yard and multi-yard types, several items were selected from each. On the other hand, according to the available documents and the examination of the houses whose buildings are currently available, visible and accessible, about twenty houses that having all the above conditions were separated and selected, which is introduced in table 1.
The study samples are classified according to the structure of the building into three types: single-courtyard, double-courtyard and multi-courtyard, number 1 to 3 according to Table 2.

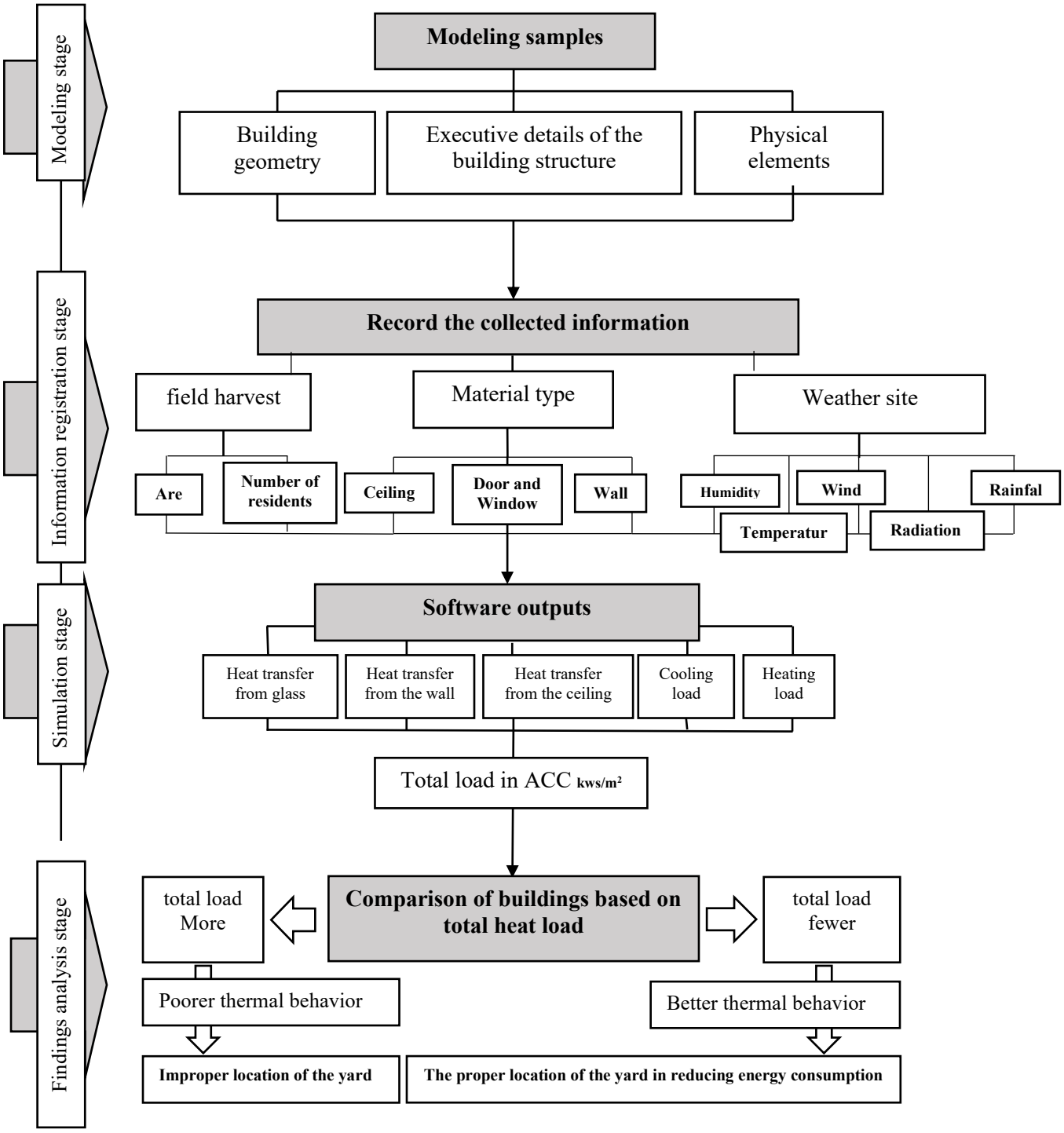
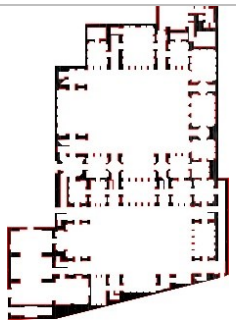
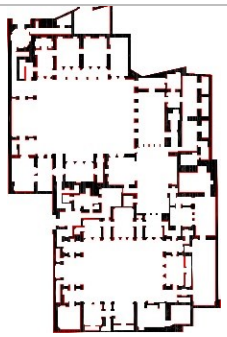
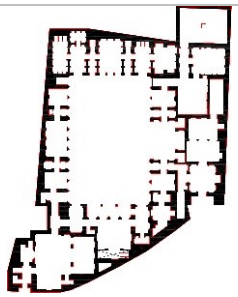
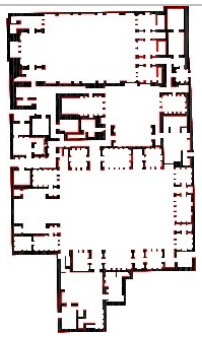
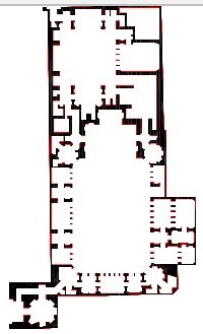
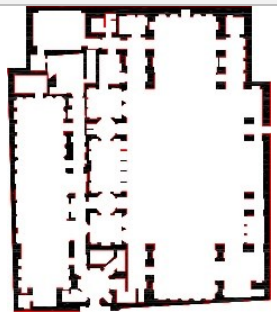
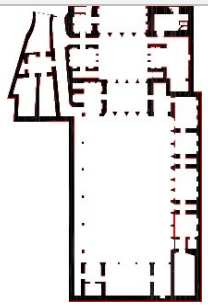
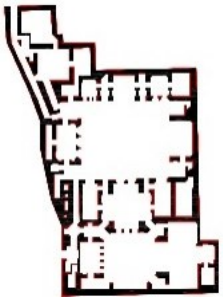
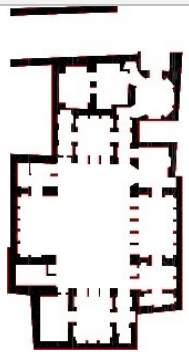
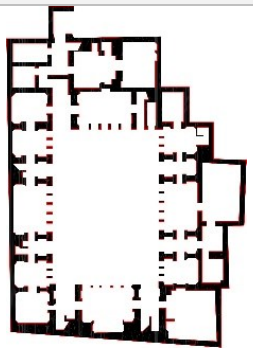
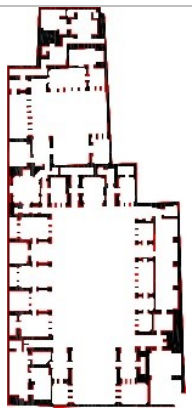
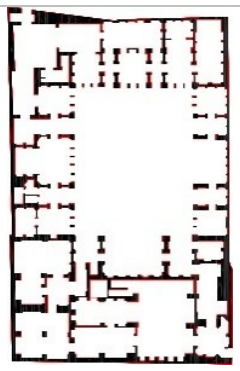
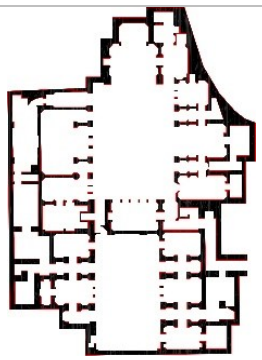
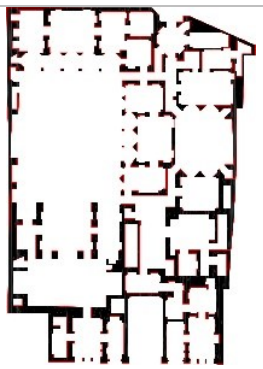
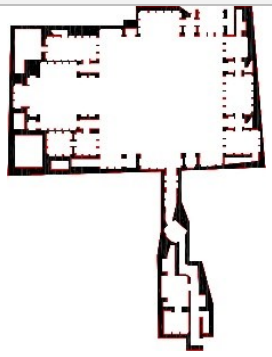
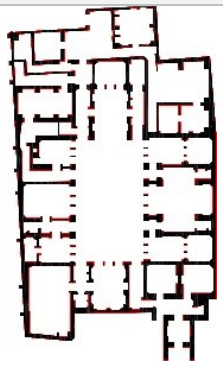
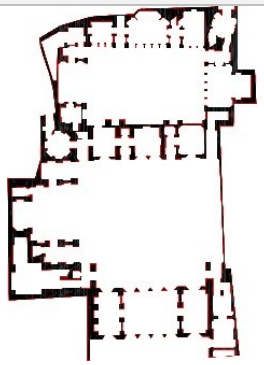
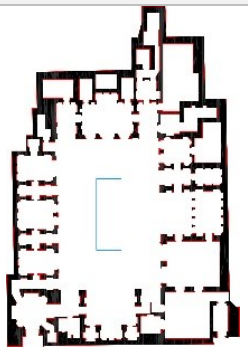


Figure 1. Conceptual model of research, the process of doing work (Source: Author, 2023)

Table 1. Plans of selected native courtyard houses in Yazd city(Source: Author, 2023)

			
The house of the Fateh ha	The house of the Golshan	The house of the Akhavan Sigari	The house of the Arabs
			
The house of the Mortaze	The house of the Rasulian	The house of the Kermani	The house of the Malek
			
The house of the Alireza(Arab)	The house of the Bi Bi roghayeh	The house of the Rohanian	The house of the Shafia pour

			
The house of the Lari ha	The house of the Meshkanian	The house of the Gerami	The house of the Koroghli
			
The house of the Semsar	The house of the Tehrani ha	The house of the Olomi ha	The house of the Rismanian

4.Research Findings

the first step to conduct this study is to model the selected houses in the Design Builder software, and the models of these houses are displayed in the form of Table 3 after matching the existing situation.

Table 2. Conceptual model of the typology of native houses in the courtyard of the center(Source: Author, 2023)

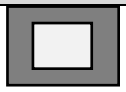
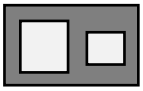
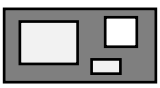
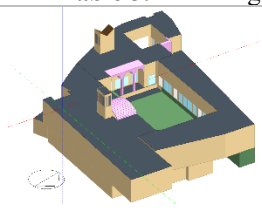
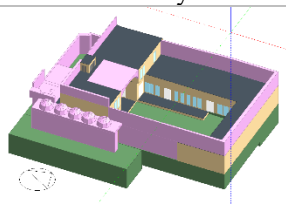
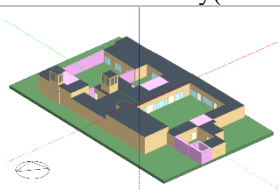
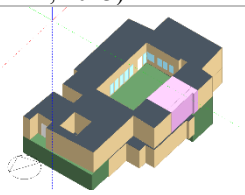
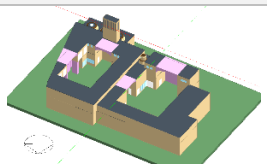
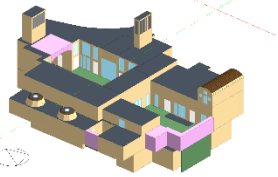
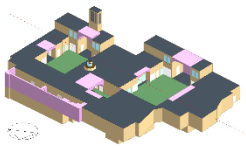
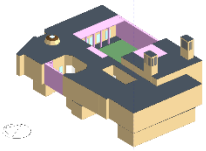
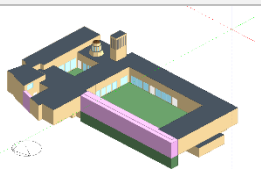
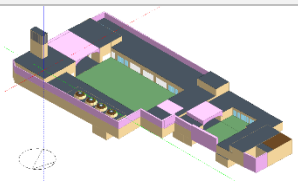
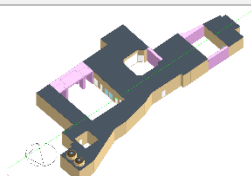
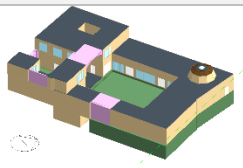
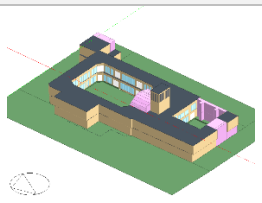
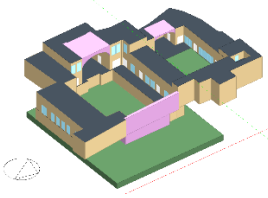
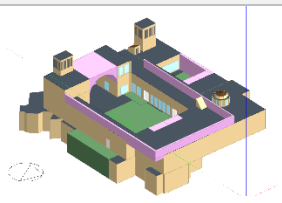
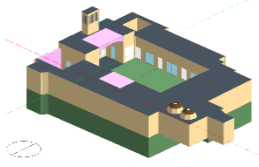
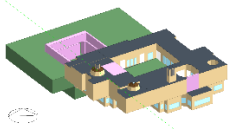
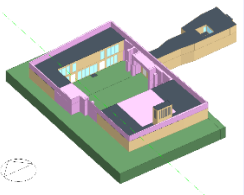
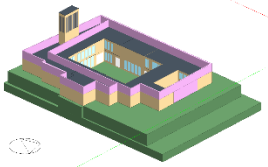
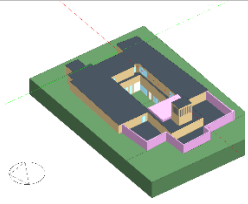
Type	Title	Pattern	Thermal behavior
1	single-courtyard,		A
2	double-courtyard		B
3	multi-courtyard		C

Table 3. Modeling of houses with courtyards selected natives of Yazd city(Source: Author, 2023)

			
The house of the Akhavan Sigari	The house of the Alireza(Arab)	The house of the Arabs	The house of the Bi Bi roghayeh
			
The house of the Fateh ha	The house of the Gerami	The house of the Golshan	The house of the Koroghli
			
The house of the Kermani	The house of the Lari ha	The house of the Malek	The house of the Meshkanian
			
The house of the Mortaze	The house of the Olomi ha	The house of the Rasulian	The house of the Rismanian
			

The house of the Rohanian	The house of the Semsar	The house of the Shafia pour	The house of the Tehrani ha

Convergent theories focus more on the psychology of the environment in the area of the territory and try to take advantage of the de-tension of the environment by recognizing the effective sensory and physical components to provide people with peace and comfort. On the other hand, divergent theories focus on the theories related to crowding and density, and express it as an emotional and personal matter, the training and education of which seems to be quite complicated and impossible, and it cannot be measured. given because it depends on the mental and psychological ability of people and its control is almost returned to the person of the audience, which is out of reach of the researcher and it is not possible to implement a written and detailed planning based on this. One of the important topics in residential environments is the effects that social and shared environments have on the behavior of residents[13].

In many researches that have investigated the relationship between the social dimension of the environment and mental health, factors such as security and protection, privacy and preservation of the territory, neighborhood relations and residents' After modeling selected houses with courtyards from native houses in Yazd city, take them into Design Builder software and adjust climate settings such as temperature, rainfall, humidity, radiation direction, etc. through the relevant icons for Yazd city. set to receive them directly from the weather site. The wall and ceiling materials are clay and mud, and the type of glass is simple glass, which is placed on the side of the central courtyard. The canopies have been installed according to the plans taken from Yazd city.

With these settings, the outputs of the Design Builder software are based on the items of the amount of heat transfer from the glass, wall and ceiling, as well as the amount of cooling and heating load and incoming radiation from the central courtyard and finally the total load for each of the studied houses on a monthly basis. was determined and the annual average of the examined items is presented in Table .3

Table 4. Comparison table of the output of Design Builder software from the climate analysis of native houses in Yazd city(Source: Author, 2023)

	Yazd houses	Heat transfer from glass (Wh/m2)	Heat transfer from wall (Wh/m2)	Heat transfer from ceiling (Wh/m2)	Cooling load (Wh/m2)	Heating load (Wh/m2)	Incoming radiation (Wh/m2)	Total load (kWh/m2)
1	Fateh ha	31721	126509	57846	182750	144537	105849	327
2	Rasulian	19945	51761	37552	80900	99907	50822	181
3	Olomi ha	21413	85116	44077	112367	105024	74029	217
4	Kermani	26586	63122	52681	109374	104771	61126	214
5	Gerami	26455	82889	47133	120464	110014	84311	230
6	Rohanian	20949	101265	55929	133942	120591	73232	255
7	Rismanian	20783	89166	54295	122594	107486	65824	230
8	Semsar	20787	53121	32698	71572	70883	45825	142
9	Mirtaze	27923	65086	36810	55093	126568	83635	182

10	Lari ha	15314	51552	56545	49535	166783	57425	216
11	Malek	22552	118113	81738	178821	142534	105977	321
12	Bibi righayeh	18354	91463	49701	105982	114503	52724	220
13	Akhavan Sigari	16495	69368	50439	103434	111638	45535	215
14	Tehrani ha	13508	36191	44189	69308	92972	28983	162
15	Shafia pour	36134	49322	50379	52985	135147	74467	188
16	Arab ha	36066	108875	82685	183947	136053	122613	320
17	Alireza (Arab)	19389	85557	47151	105678	113451	63067	219
18	Meshkania n	17636	69736	45473	104625	92720	63070	197
19	Koroghli	14001	63829	42494	88155	110834	37549	199
20	Golshan	17848	59398	46138	94276	105185	55809	199

Based on the output table of the Design Builder software from the climatic analysis of native houses in Yazd city, the following analytical charts can be extracted that in each of the examined items, the houses that have the best value in the examined item with the size and color of the house Those that have the worst value in the examined item are marked with red color. In this way, it is possible to compare the best and worst state of thermal behavior and thermal comfort in all the houses under investigation. As can be seen in the graphs below, in terms of heat transfer from the glass, the Tehrani ha house has the lowest amount and the Shafia pour house has the highest amount. In terms of heat transfer from the wall, Tehrani ha house has the lowest amount and Fateh ha house has the highest amount. In terms of heat transfer from the ceiling, the Semsar house has the lowest amount and the Arab ha house has the highest amount. The highest cooling load belongs to the Arab ha house and the lowest amount belongs to the Lari ha house. In terms of heating load, the highest amount belongs to the house of Lari ha and the lowest amount belongs to the house of Semsar. For incoming radiation, the highest amount belongs to the Arab ha house and the lowest amount belongs to the Tehrani ha house, and finally, the highest total consumption load belongs to the Fateh ha houses and the lowest total consumption load belongs to the Semsar house.

Chart 1. Comparison of the amount of heat transfer from the glass in the native houses studied in Yazd(Source: Author, 2023)

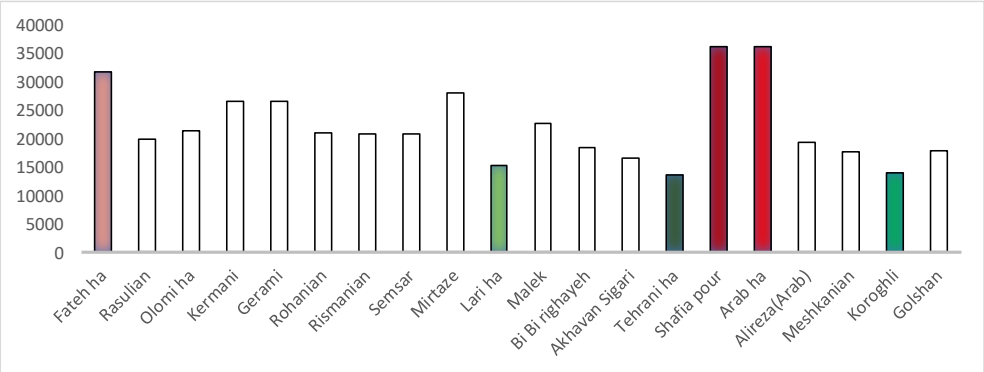


Chart 2. Comparison of the amount of heat transfer from the wall in the native houses studied in Yazd (Source: Author, 2023)

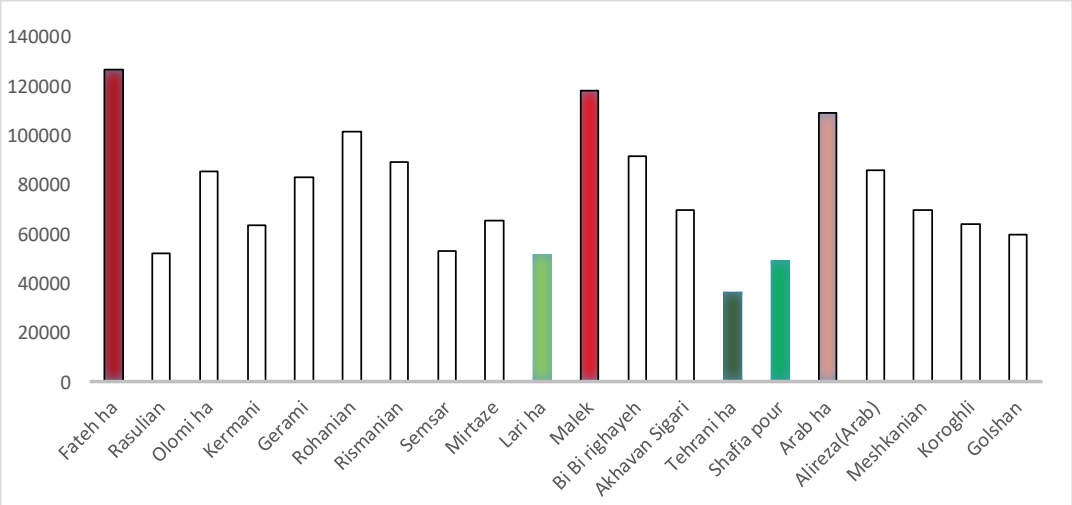


Chart 3. Comparison of the amount of heat transfer from the ceiling in the native houses studied in Yazd (Source: Author, 2023)

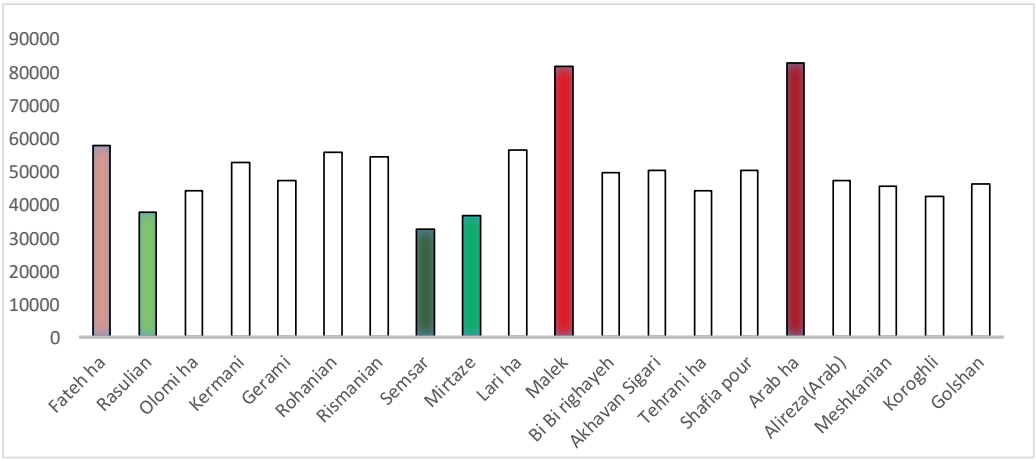


chart 4. Comparison of cooling load in native houses studied in Yazd (Source: Author, 2023)

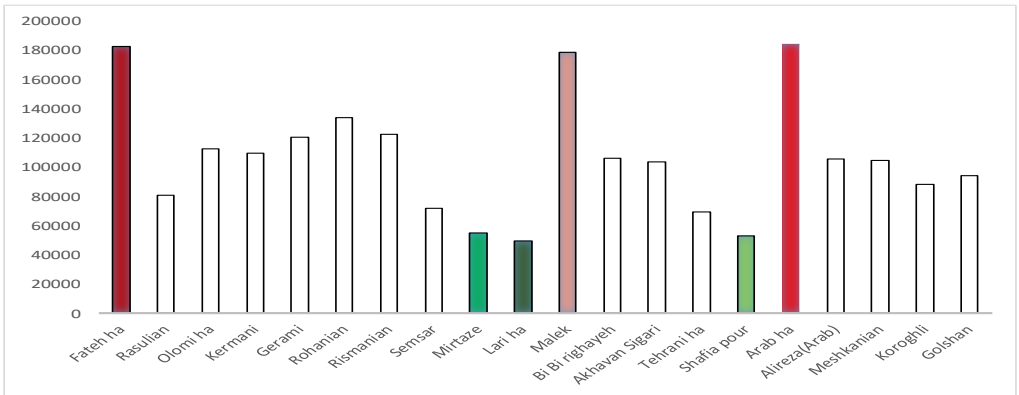


Chart 5. Comparison of heating load in native houses studied in Yazd (Source: Author, 2023)

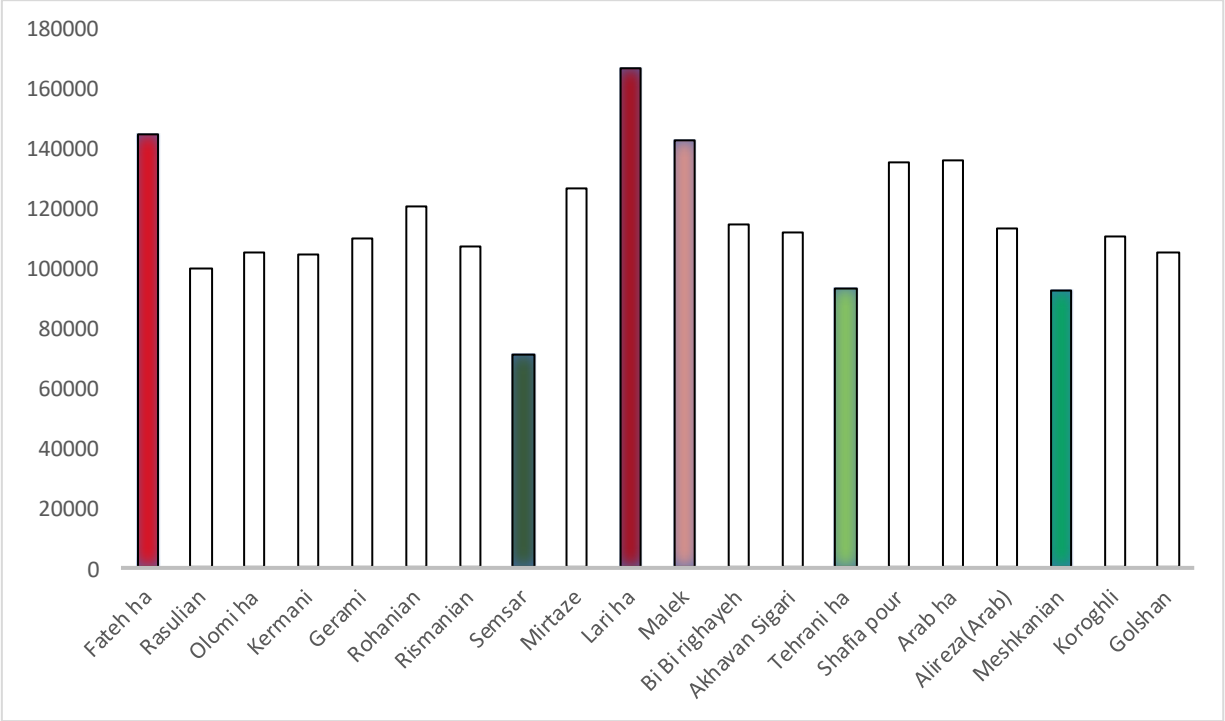


Chart 6. Comparison of Incoming radiation in native houses studied in Yazd (Source: Author, 2023)

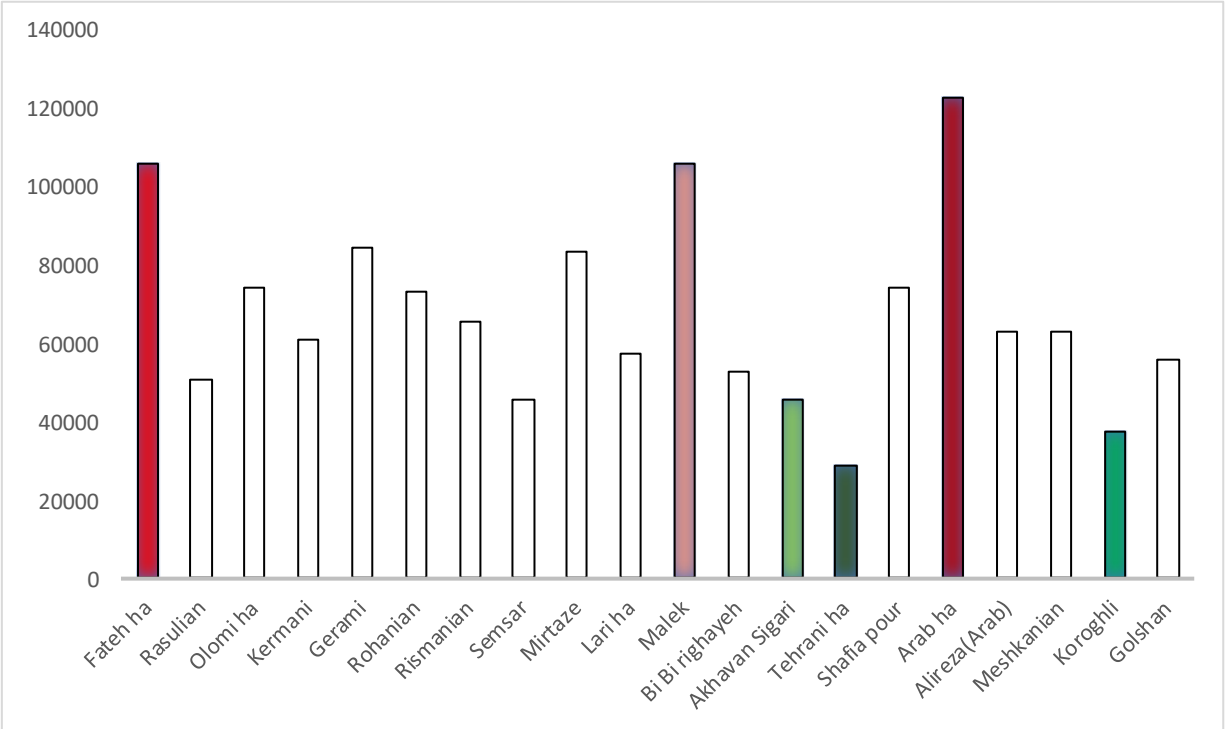
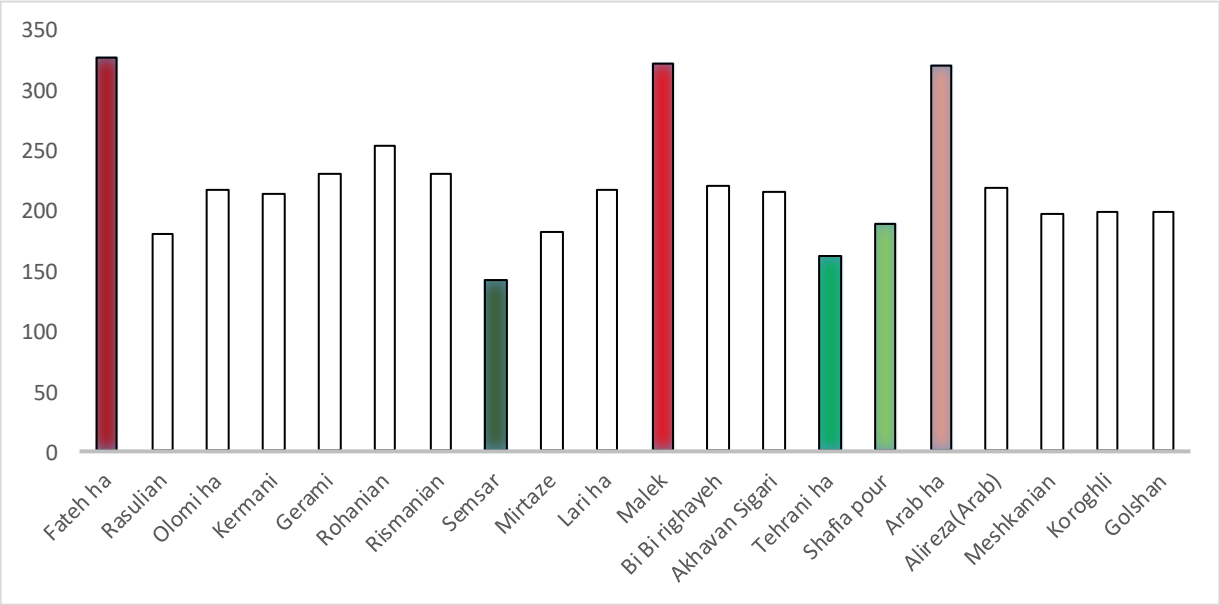


Chart 7. Comparison of Total load in native houses studied in Yazd (Source: Author, 2023)



5.Discussion

Measuring the thermal load of the building in hot and dry areas such as Isfahan, Yazd, Kerman, etc. has been done by Design Builder software in various studies, but what is the role of the type and proportions of the yard in houses with a central courtyard pattern in hot and dry climates? reducing or increasing the thermal load of the building, is one of the less studied cases, and especially a theoretical framework for the effect of the type and proportions of the central courtyard on the thermal load of the building as an innovation and creativity in this research, which has been proven.

Based on the analysis of the software results and the comparative comparison of the houses in the central courtyard of Yazd in terms of thermal approach, the following results can be obtained by comparing the total thermal load of each building (Chart 7).

1-According to the results of the heat load of the whole building and the typology of the central courtyard, it is possible to prove the truth of the claim that there is a significant relationship between the number of courtyards and the amount of heat load of a building (Table 4).

2- For the heat load of all the houses of Fateh ha, Malik and Arab ha, the first to third place for the highest heat load of the building has been assigned to them, so in these buildings, the yard did not play

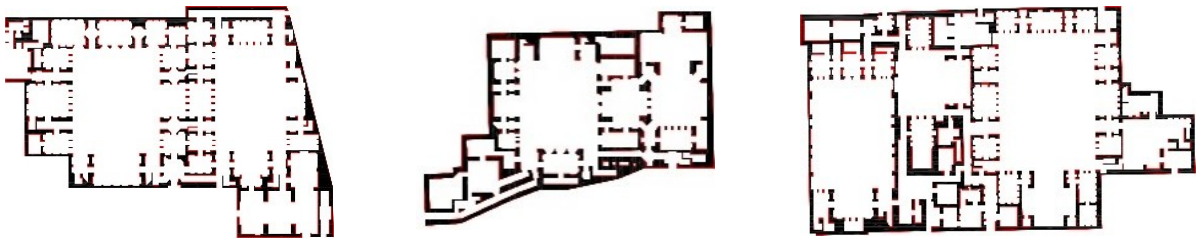
a role in reducing the heat load of the building. An important factor that can be seen in these houses is that these buildings have two courtyards. Therefore, such a ruling can be issued in this section (Table 5).

Increasing the number of yards in native houses can increase the thermal load of the building.

Table 4. Typology table of residential buildings in the central yard of Yazd with thermal approach, (Source: Author, 2023)

Type A	Central courtyard residential buildings with optimal energy consumption	Rasoulian, Samsar, Mortaz, Tehrani, Shafipour
Type B	Central courtyard residential buildings with moderate energy consumption	Olomi ha, Kermani, Gerami, Rohanian, Rismanian, Lari ha, Bi bi Righayeh, Akhavan Sigari, Alireza(arab), Meshkanian, Koroghli, Golshan
Type C	Central courtyard residential buildings with high energy consumption	Fateh ha, Malek, Arab ha

Table 5. Multi-yard houses with the highest heat load in the studied buildings (Source: Author, 2023)



The house of the Fateh ha | The house of the Malek | The house of the Arab ha

3- For the lowest thermal load, Samsar, Tehrani and Shafipour houses have occupied the first to third place, therefore they have been selected, so in these buildings, the role of the courtyard in reducing the thermal load of the building can be emphasized. An important factor that can be seen in these houses is the low ratio of space to mass in these buildings, which usually can be imagined as 60 for the mass and 40 for the yard and less. Therefore, such a ruling can be issued in this section. (Table 6) the lower the ratio of the yard to the mass in native houses, it can reduce the thermal load of the building.

Table 6. Houses with a low mass-to-yard ratio with the lowest thermal load in the studied buildings (Source: Author, 2023)

The house of the Semsar | The house of the Tehrani ha | The house of the Shafia pour

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