

# **The role of passive systems in providing comfort in traditional houses in Isfahan: a case study of the Karimi house**

Z. Khashei

*Islamic Azad University,*

*Khorasgan Branch (Isfahan) and Young Researchers Club, Iran*

## **Abstract**

This paper concentrates on the passive systems of vernacular houses in Isfahan, using the Khaneh Karimi (Karimi House) as a case study. Passive systems may serve as a solution for the energy crisis in the world and the advantage of vernacular houses in Isfahan is the use of these systems. The high effective temperature caused by intensive radiation and the low level of moisture in the summer and cold weather in the winter are considered as critical climatic conditions in Isfahan; one of the solutions is to design vernacular houses. This paper aims at describing the role of each of the architectural elements, as passive systems, in making comfort in vernacular houses in Isfahan. In this case study of the Karimi House, elements such as a Badgir (wind catcher), a Hozkhaneh (basin room) and the use of air conditioning, a hoz (basin) and a baghche (small garden) in Hayat Markazi are considered as passive cooling systems for providing moisture and air ventilation in the summer and an Ivancheh (small veranda), using solar energy through Hayat Markazi and suitable materials for reserving heat in the winter, are considered as passive heating systems. Finally, the role of architectural design for creating passive systems in accordance with regional climatic conditions is manifested, using a qualitative method and the description of a sample in this paper.

*Keywords: passive systems, heat comfort, critical climatic conditions, vernacular houses in Isfahan.*



1 Introduction

Any individual, even an employed one, spends at least one third of their day-night hours in their house and a human being relates closely to their house, more than any other architectural building, from the beginning of his/her lifespan to the end. Obviously, establishing climatic comfort within the framework of the residential unit is necessary. The vernacular architecture of Iran uses passive systems in compliance with climatic conditions for providing comfort, and employs nature for balance to create a microclimate within the framework of a house. In fact, the passive system is not anything but the building itself. The case study in this paper aims to survey the houses in Isfahan city, among which the Karimi House has been considered as a selected sample to be studied.

2 Introduction of Isfahan climate

The historical city of Isfahan is approximately 1590m above sea level in 32,37' North latitude and 51,40' East longitude in the heart of the Iranian plateau. As the Zayande-Roud River passes through Isfahan, it not only freshens the air by providing humidity and adjusts its climate, but also creates a mezoclimate in the Iranian plateau bed. This city is located in a climate with a hot-arid summer and cold winter (Kasmai [3]).

3 Introduction of Karimi house

Conformity of lifestyles with climatic conditions is a significant property of introverted houses in hot-arid climates, namely four season houses (Ghobadian [2]). This term is refers to a central courtyard surrounded by rooms and their application in accordance with the specific season of the year as required, according to the quality and the quantity of solar radiation. The application of spaces based on season and time schedule has led to internal space division into two categories of cold and hot and, also, the heat loss and the heating or cooling of the whole spaces are avoided in the comfort level. The Karimi house is a four seasons house, belonging to the contemporary Ghajar dynasty period of the 18<sup>th</sup> and 19<sup>th</sup> centuries.

Table 1: Isfahan climate characteristics.

The average maximum temperature	36-37
The average minimum temperature	-0.5
The highest daily temperature variation	18 Celsius degree corresponds to September
The maximum relative humidity	75 percent corresponds to December
The minimum relative humidity	19 percent corresponds to June
Mainly wind in spring and winter	west and southwest
Mainly wind in summer and fall	East, north, northeast and west



This house is comprised of an octagon yard and a large rectangular court and spaces in the northwest and northeast fronts of this large court, the important accumulation of house spaces, is found at its northwest front. It seems that the octagon yard plays the role of Birouni (exterior area, refers to a yard which is specified for men, outsiders and the professional affairs of the master of the house) and the rectangular one the role of Andarouni (the interior territory of the house, belongs to women and family members in general), respectively. This house is composed of spaces such as the entry, Hayat Markazi (central courtyard), Eyvancheh (small veranda), Talar (hall, a big room designed to serve guests, generally it is situated in the best place of the house), Seh-dari (a room with three doors, connects to the yard with three big windows. This is the bedroom of the house.), Hozkhaneh (basin room), Badgir (wind catcher), etc.

#### **4 Hayat-e-Markazi (central courtyard)**

In both hot-arid and hot-humid climates the central courtyard (Hayat-e-Markazi) is regarded as the heart of houses in terms of spatial, social and environmental considerations. The central courtyard is an element that is connected to the culture and climate of Iran. In this article only the climate is referred to. The comforts offered by a courtyard – privacy, security, and tranquillity – are properties nearly universally desired in human housing. Though the pattern of the central courtyard has resulted from the climatic conditions of the hot-arid region, the compatibility of this composition, caused by changes in interpolations, existing plant action, organizing screens, etc, with other climatic conditions in hot-humid, foot of the mountain, cold or even mild-humid regions can be noted too. The spaces of the central courtyard facilitate living for large scales of family members and, thus, to accommodate a kind of residential complex (Ahmadi [6]). The yard plays such great role in central courtyard houses that the number of yards increases depending on the households' financial power (Ghobadian [2]).

During the afternoons and evenings, upon irrigation of the parterre and sprinkling the yard with water, the yard is used as the family members' concourse and, also, it has an application for night sleeping. The dual function of the yard in providing comfort in summer and winter means that it not only receives solar radiation in winter but also it gets airflow with appropriate temperature and humidity in summer by means of the central courtyard.

#### **5 Existing plant action and water in the central courtyard**

The existing plant in the sense of parterre and water in the sense of pool, may supply humid and fresh, air as well as shade in the yard. All spaces approaching the courtyard can lead to their receiving this humid and delicate air. In an indoor shaped rectangular courtyard with dimensions of 19m x 14m, 2% of the surface area has been dedicated to the parterre and 2.3% to the pool. In the outdoor octagon courtyard approximately 50% of the surface area is dedicated to the



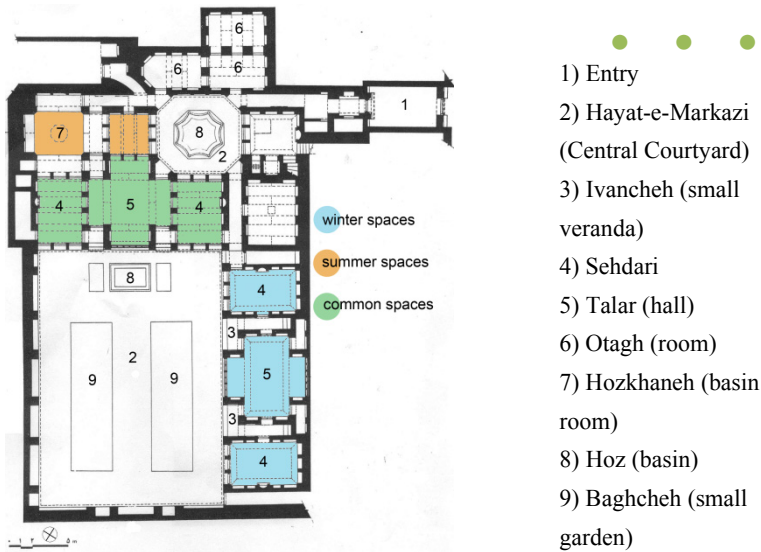


Figure 1: Plan of the Karimi house.

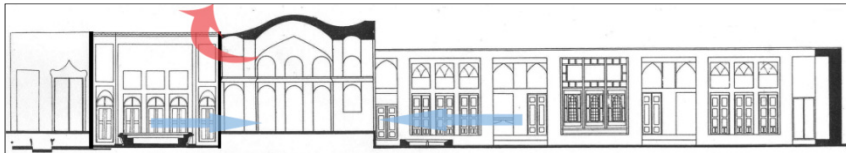


Figure 2: Existing wind in the central courtyard.

pool. Generally, in Isfahan, compared with other cities such as Yazd, the water pool is deeper. In conclusion, the central courtyard is an element made of space, which is limitedly involved in nature restoration (Ahmadi [6]).

## 6 Existing wind in the central courtyard

As a result of existing shade, the west facing indoor courtyards have a lower temperature in the summer afternoons. Due to it being expanded and lighter, less dense hot air indoor travels upward and, thus, it creates a pressure gradient between cool and hot air masses that allows air to escape out from both sides toward the sehdari and the hall located between these two structures. Upon its collision with the pool and the parterre, airflow becomes purified, cooled and humid and thereby natural ventilation is established in summer (particularly in the summer afternoons). Also, it is possible to make use of winds from the west and southwest in spring and summer by construction of a central courtyard.

Another remarkable thing to notice regarding the ventilation within this house is the utilization of a free plan in the design. The hall by the cross-shaped plan in the middle is in connection with seh-dari-s rooms and hozkhaneh. The interconnection of these spaces is caused by seh-dari which, when opened, would provide air convection toward every sector. Instead, it is also possible to close and separate these spaces by closing seh-dari-s. This will be very effective in preventing heat loss in winter.

## 7 Existing light in the central courtyard

Considering the spaces formation around the central courtyard in four-seasons houses and their use in accordance with the required radiation and desired season, the spaces have been formed into northwest and northeast fronts in the Karimi house's yard. The northwest front privileges the utmost important position because of its benefiting from solar radiation and being magnificently glorious. In fact, the air equinox in Isfahan has decreased the importance of the nasard (shady sections, refers to the part of the building that is not exposed to the sun, this favours the southern section of the yard that receives the shade) sector of the house and the spaces of the north front have achieved a four-season function. Since Safavid's dynasty and king Abbass, the first Isfahan became the capital of Iran and the structure of Isfahan, Isfahani roon (roon refers to direction) changed to northwest-southeast, which corresponds to the climate conditions of the area. In fact, observing the climate axis has been so important that it became superior to the holy keblah axis. (Holy axis refers to the direction in which Muslims hold their prayers (kaba). This is the south western direction.) The use of northern west-southern east in the Karimi house provides the best condition to get sunshine in the winter and shade in the summer. Intense sun rays increase naturally with the widening of sun rays angles, which can be controlled by the tabesh band (vertical and horizontal curtains between doors). In Talars, also, white cotton cloth is used to protect the wood in front of oroses from the sun's rays as a movable curtain. The vegetation planted in parterres are deciduous and do not create unwanted shade in winter. Also, in summer the flower vases around the pool would prevent solar radiation from reflecting into water, which causes eye dazzling

## 8 Material of the central courtyard

Khesht (unbaked brick), as the main building material, has a high thermal capacity, i.e. it receives heat gains later during daytime and loses it later at night. Therefore, Khesht is able to adjust to the range of diurnal thermal changes. On the other hand, Khesht has a low thermal transmission and may be considered as good insulation. The tough and colourful texture of the Khesht makes the absorptions of the sun's rays limited and at the same time scatters the reflections of light. Because of the brightness of the external surfaces, and their great thickness, the use of carrier walls affects the increase of the minimum temperature of the building.



The wooden framework of the orosi and doors (especially those used in sash windows) is so constructed that apart from providing an ornamental (decorative) design for stained glass surfaces, it appreciably reduces the thermal exchange between the indoor and outdoor environment, without any noticeable decrease in lighting level (the function of wood as a heat insulator is also important). Orosi (sash window) is a netted window that goes up and down. It is ornamented with colourful glass and wood. Halls are usually covered with sash windows. Using small pieces of glass in the construction of sash windows is in accordance with the glass blowing industry of that era. The application of diverse colours altogether in an abstract form would turn the light entrance into a matter of religion.

## 9 Hozkhaneh

Hozkhaneh (basin room) is an elevated covered area enclosing a pool in its middle, which is usually connected with other spaces. In setting the spaces of the house, the corner spaces of the house are dedicated to secondary applications such as the kitchen, steps, etc., because of the lack of light from the yard. However, during the Ghajar dynasty, new solutions were found to use these spaces better. To solve this problem a skylight from the ceiling made the creation of new spaces possible. One of these spaces in the Karimi house is the hozkhaneh, creating a pleasant place for the summer. These climate-oriented thoughts show how these limitations were used to create new spaces according to the climate.

The hozkhaneh may be connected with the seh-dari or hall and the hozkhaneh in the Karimi house with a cross-shaped plan and an octagon pool in the middle is also connected with its adjacent seh-dari-s and hall. Light is allowed from reticular windows and colourful glasses into the roof, creating a fantastic reflection of light and colour playing on the water surface. The wind catcher also works over this space and in connection with the hozkhaneh it conducts the outdoor air into the hozkhaneh.

### 9.1 Summer daytime

During daytime the air above the hozkhaneh has a higher temperature than the air below it because of its adjacency to a hot mass of materials as well as its



Figure 3: Orosi and tabesh bands.



Figure 4: White movable curtain.

exposure to direct solar radiation. In general, hot air both from this sector and the whole house escapes by absorption through the window of the hozkhaneh or wind catcher along a path where there is no wind blowing. In addition, when the air enters from the hozkhaneh window or the wind catcher, it loses heat and becomes moist as it passes over the pool. Then, this cooled air is transmitted to different sectors.

## 9.2 Summer nighttime

At night, the air above the hozkhaneh is cooler than that below because of a thermal reflection with a high wavelength from the mass of roofing materials and existing cool air outside. Therefore, high dense cold air comes down and the lighter hot air moves upward and escapes out from the window of the hozkhaneh or wind catcher. This cold air and the air coming down from the wind catcher become wet when passing over the pool and, then, move to other sectors.

## 10 Badgir (wind catcher)

The Badgir (wind catcher) is a traditional architectural element that is an integrated part of residential houses of hot-arid and hot-humid regions of Iran (Mahmoudi [4]). The main function of the wind catcher is to receive and conduct airflow into the internal space and therefore it is referred to as the Badgir. Wind catchers are usually positioned in the summer-dwelling sector of houses and are connected to spaces such as the hall, hozkhaneh, basement (cellar) and yard, etc, and give natural cooling in these spaces by air convection and evaporative cooling. Dividing the Badgir's internal space by using separate blades results in simultaneous air entering and exiting through separate outlets into the space. Consequently among other functions of the wind catcher, one can mention hot air drawing out from inside of an edifice as a result of the chimney effect.

Susan Roaf has categorized the Badgir on the basis of a number of sides receiving wind in the wind catcher (Roaf [7]). According to Susan Roaf's categorization, the Badgir of the Karimi House is of a four-sided type that is in connection with spaces such as the hozkhaneh, seh-dari and hall. With an approximate height of 4m from the roof surface, this wind catcher is placed at the four seasons front (north facing of yard) and contributes to passive cooling through air convection and evaporative cooling. It conducts the airflow into the indoor space in spring and summer. As the air passes over the hozkhaneh, due to its exposure to evaporative cooling, this airflow gets cool and humid and, thereafter, disperses within the space. The Badgir's opening is located within the indoor space to prevent hot air escaping from the wind catcher (chimney effect) in fall and winter. The existing wind catcher in the Karimi house allows the absorption of wind from the east, west and north in spring and summer for the four seasons sector of the house (north facing of the yard), which has access to west, east and southwest winds.





Figure 5: Summer daytime.

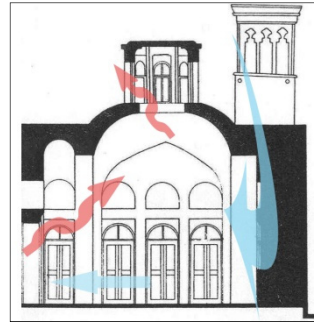


Figure 6: Summer nighttime.



Figure 7: Andarouni (the interior territory of the house).

## 11 Ivancheh

Ivancheh refers to half-open spaces that are shallow and roofed, limited from three points and open from one point. This half-open space acts as an obstacle for the reflection of the radiation. The other function of this indirect entrance is to reduce the ventilation of the weather from the inside and outside as a result of commuting in winter to these rooms. Ivanchehs are used in the Karimi house to enter sehदारis and the Talar in the east. Of course, the four seasons section Talar is connected to the yard by oroses, which can go up in summer to have access to the yard to use the air in the yard, hoz and the gardens.

## 12 Conclusion

The facts that are expressed about Isfahan climates by figures and diagrams, revealing this city's climatic crises and facilities, are reflected in the architecture



of traditional houses, which can provide a solution for the crises. In Isfahan, thanks to the present moderate climate, it is not necessary to expend costs and supply materials to build summer-dwellings (as a demonstration of sustainable traditional architecture), unless they are specifically required where the land dimensions demand it. Therefore, the north facing of the yard playing a four seasons role, incorporates the elements of passive cooling systems, and these systems are designed in Isfahasn houses to confront the winter cold, giving prevention from radiation as well as providing ventilation and humidification in the summer.

Table 2: Passive cooling systems classification in the Karimi house.

Passive cooling systems	Central yard through air ventilation with proper temperature and humidity in the summer, obtained from water pool, garden, flower vases and shades
	Badgir
	Hozkhaneh
	Use of free plan for better natural ventilation
	Using horizontal and vertical curtains (shields) and white cotton cloth (as orosi room shade provider) to control radiation
	Taking the summer function of Ivan for Talar with orosi windows (orosi room)

Table 3: Passive heating systems classification in the Karimi house.

Passive heating systems	Central yard through the use of sun's ray based on the quality and quantity of radiation required for the winter
	Proper northwest-southeast orientation to get direct solar energy
	Application of spaces according to the season and time (division of internal spaces to hot and cold parts)
	The use of Khesht (unbaked brick) because of high heating capacity, low heating transmission, low radiation absorption and scattered high reflections
	The use of Ivancheh as a heating obstacle
	The use of wooden networks in orosies and Sedaries to reduce the use of glass in windows (wood is also good insulation)
	Application of great thickness of the walls to increase the minimum temperature of the buildings



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