

Lessons from the Past:

Climatic Response of Iranian Vernacular Houses to Hot Climate Conditions

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Abstract

While in the historic urban fabric of Iranian cities, there are numerous traditional buildings that have stood up for more than one hundred years, today's buildings, in spite of advanced construction technologies, are not comparable with those traditional ones in terms of resiliency and durability. The sustainable vernacular strategies in design and construction of these traditional houses are the main reasons of their durability. This study discussed and analyzed the vernacular approach and climatic design of traditional Qajarian houses, which survived for at least one hundred years in Iran. Building orientation according to the sun, construction materials, compatibility with water sources and wind power, and finally structural organization are five parameters which have been analyzed in two buildings in the hot climatic region of Iran. Data collection relies on library research and empirical case study. This research shows the analyzed buildings' design and construction are the response to their climatic situation and are compatible with their contexts. While these buildings are located in two cities with some climatic differences -especially humidity-, their vernacular design strategies have some similarities. However, their differences due to their distinct climatic conditions are undeniable. Finally, the research displays that these buildings put into service climatic opportunities, which are the aftereffect of centuries of optimization of building orientation, material use and construction capabilities with less environmental impact.

Keywords: Vernacular, Traditional Building, Sustainability, Orientation, Material, Construction Techniques.

1. Introduction

The topographic diversity of the vast lands of Iran has shaped a variety of climatic conditions. Studying 27 climatic elements at annual scale indicates that Iran's climate has been formed by 6 factors. With the order of importance, these factors are temperature, humidity and clouds, rainfall, wind, dust, thunder. (Masoudian, 2003, 171, Rezaii, et al, 2015). There is numerous climatic classification theories and maps about Iran. According to Koppen-Geiger climate classification, Iran has six different climates (for more information see Peel, et al, 2007). However, this classification for Iran is not accurate.

Local scholars analyzed different climate conditions of Iran and suggested different classifications. According to detailed analysis of climate conditions in combination of climate responsive architecture in Iran, eight different climate zones with specific characteristics have been defined: Moderate, cold (consists of two sub-climates), hot-dry (consists of three sub-climates), hot-semi humid and finally hot-humid climate (Tahbaz, 2013, P.118, Tahbaz, et al, 2008). The national standard No. 14254 of Iran, also divided Iran's climate into 8 climate zones for non-residential buildings. However, due to the old Iranian climate classification, most of the scholars propose four climate typologies for Iran (Ghobadian, 2006, P. 34-36, Kasmai, 2013, P.83). This research relies on the old Iranian climate classification which is mostly for vernacular residential buildings.

“Vernacular architecture is the result of hundreds of years of optimization to provide a comfortable shelter in a local climate using available materials and known construction technologies.” (Bodach, et al, 2014). The concept of the vernacular design corresponds to the sustainable approach especially in terms of decreasing building's energy consumption. Around 40% of energy is consumed in buildings around the world (WBCSD, 2009), and the planet is suffering from different climatic problems. “Two degrees Celsius is the maximum temperature rise that we can endure and still have a planet that is compatible with expectations. A three-degree rise will result in a massive displacement of populations due to sea level rise and food shortage” (Pope, 2016). In this situation, defining sustainable-vernacular strategies especially about buildings which survived for decades provide clues to coordinate policies for future design.

This research tries to evaluate vernacular strategies of these two climate zones and compares them with together. Although in response to various climate zones of Iran, there are variety of vernacular strategies to fit with a specific context, climate responsive strategies of vernacular architecture in some categories –like hot- dry and hot- humid-have some similarities. However, it is obvious that they have some distinct differences due to their various climate conditions. The aim is to define vernacular strategies, which lead to the durability of these buildings through decades as a guide for coordinating future policies. It should be

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mentioned that to reduce generalization problematically, an empirical research based on numerous case study are needed to prove the similarity of these strategies. However, this article intends to ignite this discussion for future critical discourses.

2. Methodology

This study relies on qualitative methodology consist of the investigation, library research and analysis of the outcomes. While there are numerous house-cases remained from the Safavidkingdom (more than two hundred years ago) and Qajarian dynasty, this article has focused on the later and analyzed buildings from about one hundred years ago. Although selected buildings are not the only buildings that remained from Qajarian kingdom period, they are valuable buildings in term of architectural strategies and typology. In different parts of Iran, there are numerous houses, each of which is translated through the specificity of the climate and resources of its site. We selected two buildings and found them valuable and deserve to be analyzed in terms of sustainability, durability, and vernacular properties. Given the climatic characteristics of Iran's hot zones, five main factors have defined the analysis framework: building orientation, construction materials, structural techniques, compatibility with wind and water (precipitation). To evaluate building orientation, the simple three-dimensional model of buildings has been used. For other variables, analysis of data from library research and finally the comparison between buildings design strategies in two mentioned buildings have been used.

3. Conceptual Frameworks: Parameters

Remaining durable over the time, a building should be protected against the disturbing environmental condition. Furthermore, design strategies should convert environmental threats to the opportunities for the building. Vernacular design strategies take into consideration not only response to the environmental situations but also wisely benefit from natural resources. In this study, five main parameters have been selected to analyze the vernacular design strategies of mentioned buildings in order to define their sustainability and durability. These parameters have been selected according to Iran's specific cultural-environmental situations as the following:

1- Building orientation: This factor discloses how these buildings use from or protect against sun radiation. "Due to the absence of mechanical means, traditional buildings use solar passive measures to achieve thermal comfort conditions" (Bodach, et al, 2014). According to the critical importance of shadow during summer, this factor will be discussed based on the three-dimensional model of buildings.

2- Construction materials: Vernacular buildings usually benefits from using locally available materials, embodied energy and compatibility of heat capacity with an exact climate. Furthermore, these factors have been assessed in this article to analyze in which extends the mentioned buildings used the local materials.

3- Wind force: Sustainable vernacular buildings react to wind force by conducting, absorbing and preventing it in various climate regions. For instance, whereas vernacular buildings in cold climates protect themselves –by decreasing surface/volume ratio, filleting corners, etc- from inappropriate wind, in humid weathers, strategies help to improve wind movement in order to increase natural ventilation in buildings. In this research, the manner which the analyzed buildings treat with wind force has been taken into consideration.

4. Water: Durable houses in different climates have made water into their service. The solutions vary from water storage in a cistern to guide it across the building. This article aims to recognize the practical solutions which have been used in the hot climate to benefit from water resources and decrease its harmful impacts.

5. Structure and technique: Due to Iran's seismicity, durable buildings have been definitely considered especial construction systems against it. This parameter will analyze main architectural construction system in mentioned buildings to define the main strategies to protect buildings. In the following paragraphs, these factors will be discussed in two buildings in the hot climate of Iran to recognize solutions which may be practical even in contemporary architecture.

3.1 Hot-dry climate

Case study: Broujerdi's house, Kashan, Iran

In term of climatologically classification, Kashan has situated adjacent to Lout dessert in a hot-dry climate, a city with cold winters and hot summers. "The construction of Broujerdi's house, as attested by the inscription running around its reception hall, dates back to 1875. According to reliable account, the construction of 'biruni'ⁱ and 'andaruni'ⁱⁱ ensemble was completed in 1892, 18 years after it begun. Originally, the edifice included the biruni and andaruni sections. The andaruni located at the northeast and east of the ensemble is still a private property. It has an elongated courtyard at the opposite ends of which stand its two important spatial ensembles. The facades of these two fronts are taller than that of the two other. The first ensemble forming the southwestern front of the courtyard, is the more important part of the edifice and include a large majestic reception hall of "hasht-o-nim-hasht"ⁱⁱⁱ (similar to octagon) shape surrounded on two levels by various rooms and other spaces" (Haji ghasemi, 1996, 34).

"In front of reception hall, an area connected the hall to the 'eivan'^{iv} overlooking the courtyard. At the other end of the courtyard, another spatial ensemble stands, which in comparison with the southwestern one, appeared quite unassuming. On a long side of courtyard along the southwestern wall, three rooms and service areas are disposed and the opposite wall displays an arcade at the center of which a shallow columned eivan is visible. The façade of this front is the symmetric copy of the opposite" (Haji ghasemi, 1996, 34). This building uses wind catcher to improve human comfort during summer, which is the critical season in hot-dry climate. The southern part

(Biruni) of building, where used during summer, named “summer residence” and the northern side (Andaruni), where was used during winter is called “winter residence.” See figures 1 through 5.

3.1.1 Building Orientation

Kashan's ron (the city's development direction) is from the north-east to southwest. The ron is affected by several factors like sun radiation, precipitation, prevailing wind,

city's topography, vegetation and so forth (Feizollahbeigi, 2009). This building, like its other neighbors in the desert, has been surrounded by adjacent buildings that will result in lower heat gain by the walls. Beside of benefit from natural light, appropriate orientation will provide a large amount of solar energy absorption during winter and it may improve effective shadow in summers.

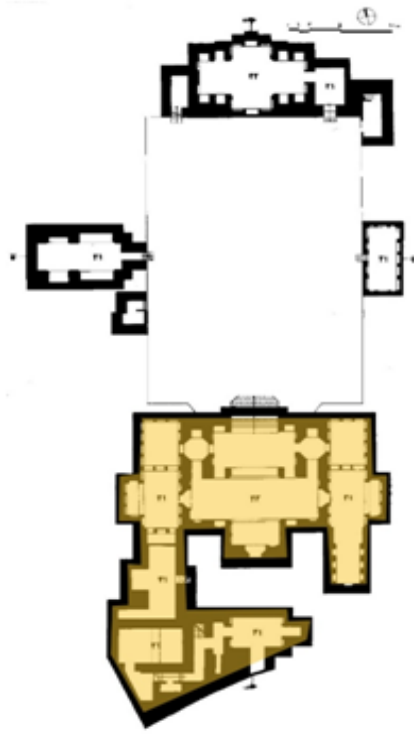


Fig. 1. Underground floor plan
(Source: Haji ghasemi, 1996, 34)

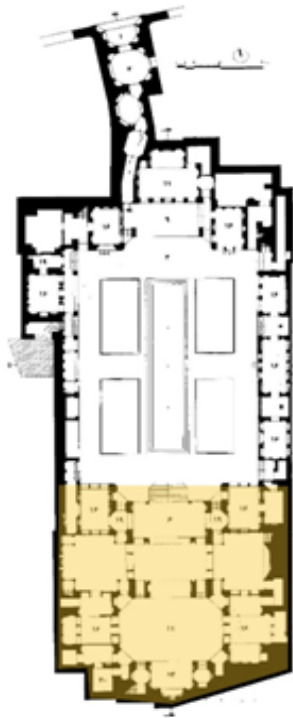


Fig .2. Ground floor plan
(Source: Haji ghasemi, 1996, 34)



Fig. 3. First floor plan
(Source:Haji ghasemi, 1996, 34)



Fig. 4. Section A-A
(Source: Haji ghasemi, 1996, 34)

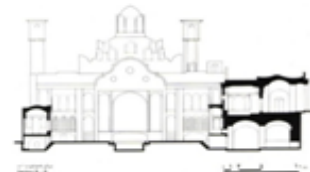


Fig .5. Section B-B
(Source: Haji ghasemi, 1996 34)

comparison between the city's development direction (ron) and the houses' direction, proves their similarity. The house has been built on 25 degrees from the north axis, directs exactly toward the Kashan's ron (figure 6-7). A three-dimensional model of the building has been

analyzed with Ecotect analysis software in order to visualize both shading and incident light. The figures 8-9 represent this house's model at two strategic spots: summer and winter solstice.

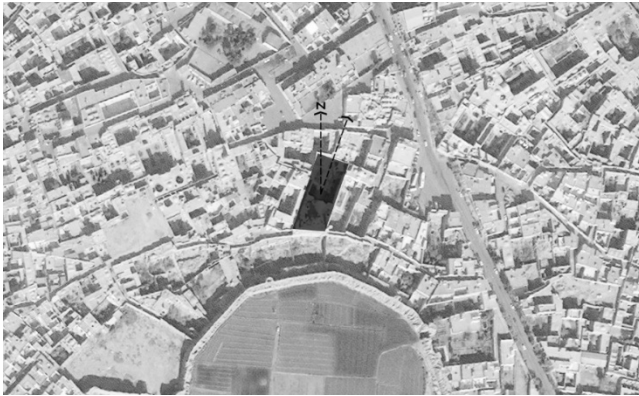


Fig .6. building orientation
(Source: wikimapia.org (edited))

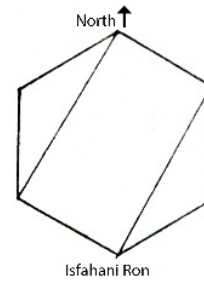


Fig. 7. Kashan's ron
(Source: Pirnia, 2005,

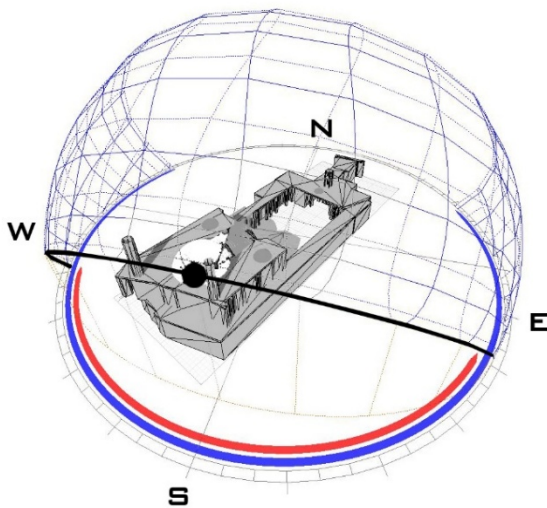


Fig. 8. Solar radiation and Shadow in 21 December
(Source: The Authors)

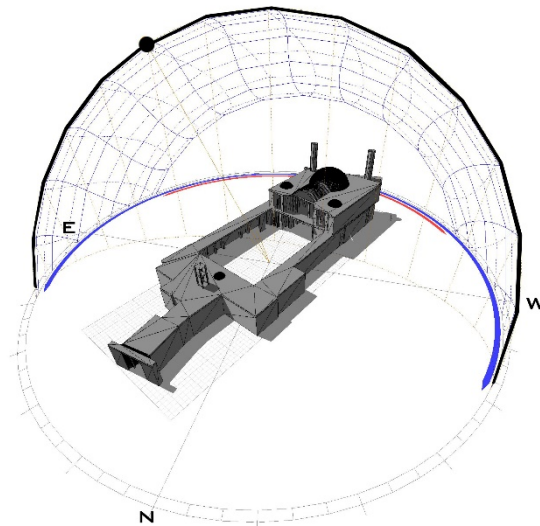


Fig. 9. Solar radiation and Shadow in 21 June
(Source: The Authors)

As figures 8-9 display, at the winter solstice, sunlight casts on the north part of the building, in the southern interior façade of the courtyard, which is the winter residence, and evidently, it affects on heat adjustment of the house in cold days. On the other side, in the summer solstice, the southern part of building, the north interior courtyard façade, which is the summer residence, has received less solar radiation

And covers with shadows. It is not the whole story. In summer, roof's convex form reflects some of the sunrays and at the same time makes shadows on itself, which totally leads to reduce direct solar radiation on the roof. Natural light passes through checker-pattern windows (is called Moshabak in local literature), which is installed on the basement's wall. Moshabak not only helps to improve the aircirculationin the basement floor but also lets the light goes inside it.

However, it prevents direct sunlight in south façade and helps to decrease its façade's temperature.

3.1.2 Material

Four rudimentary factors which effect human heat-comfort' are air temperature, radiation temperature, humidity and air movement. If we add clothes factor and activity rate to these four items, finally six parameters will appear to be critical. In specific conditions, different items like the individual position, sex, age, economic, moral factors, and culture are effective (Heidari, Ghafari, 2010). Among these items, the temperature is the most significant factor that plays a major role in defining human comfort. Because of a large number of hot days during the years in hot-dry climate, using materials with high thermal expansion factor is not a proper choice. Instead, using materials with high heat capacity like the brick, adobe^v and thatched are more beneficial.

In these areas due to lack of wood as an appropriate material, other suitable and available materials, (brick, and adobe) are used for construction. Borujerdi's house was built with brick, mud and adobe. Building's walls were covered with thatch and Symgel^{vi}. These materials led to further integration and helped the structural walls to distribute forces evenly. These bright materials reflect sunlight and prevent the absorption of excessive heat and light. Rooms' floors, hallways, and courtyard are covered with brick which's locally available materials that have been used in Iranian vernacular architecture. Tiles, plaster, and symgel have been used as façade material in this building. Therefore, all materials used in this building have the ability to absorb light and reflect heat, which both are practical and beneficial due to the hot condition of Kashan. Moreover, the materials with high thermal capacity increase the time lag of heat transmission, so these materials adjust their temperature with radiation inside and into the air at night.

3.1.3. The Wind

Due to the arid climate of Kashan, the wind in the warm and cool seasons will play an important role in comfort condition. As Figure 10 shows, in Kashan "the lowest wind speed is in the autumn and the highest amount occurs in late winter and early spring. In January and May, wind direction in Kashan is 360° (North), in February, March and April, is 270° (West) and in June, July, August, October, November, and December wind direction is 45° (northeast)" (Gorji Mahlabani, et al, 2011).

Due to unfavorable winds from the east and northeast, two factors must be considered in the design of the buildings in Kashan. Firstly, better building's orientation to repel or mitigate the unfavorable wind and secondly, the appropriate size of building's yard. In reviewing the orientation of the buildings, it can be seen that the building has the low façade surface to deal with undesirable winds. Yard proportions should make air circulation to soften the undesirable winds and take advantage of it.

Windcatcher of Broujerdi's house is predominantly in northern and southern parts of the summer residence. The



Fig.10. Various wind directions in Kashan
(Source: wikimapia.org (edited))

wind catcher is octagonal and it can receive the maximum wind from all sides. (Figure 14). The wind catcher moderates the heat during the summer and guides it into the summer residence. In the space below the wind catcher, a pond is located to make the incoming wind wet. This moisture in the air is very desirable due to Kashan dry air. Because of Chimney effect, wind catcher's role differs from day to night (Figure 15-16). On cold days, the wind catcher shuts down and the residential place has been changed into the winter residence.

"The thickness of the wind catcher's walls and its whole's dimension were designed in a manner that allows ascending the light warm air inside the air trap which is sucked by upper elevations. As a result, cool air flows from windows and doors into the house and continues all the night. If the wind blows at night, the air will circulate in the opposite direction in the wind catcher. It is clear that the cold air flowing from the wind catcher which has been heated during the day will warm the inlet air a little. Nevertheless air circulation again refreshes the inside temperature. During daytime, the wind catcher acts in the contrary to a chimney. In other words, the upper parts of it have been cooled during the previous night and upon contacting the walls of the wind catcher, the warm air cools down and moves towards the bottom and eventually circulates into the house and exits from doors and windows. The flow of air at daytime accelerates the ventilation process" (Taleghani et al, 2010).



Fig .11. Wind speed variation at different months in Kashan
(Source:Gorji Mahlabani, et al, 2011)

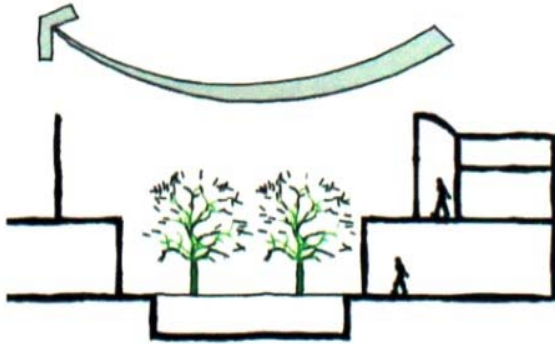


Fig .12.lack of access of undesirable winds to the inner space
(Source: Mahmoud Kelaie. 2008)



Fig.13. Appropriate air circulation in the courtyard
(Source: Mahmoud Kelaieh. 2008)

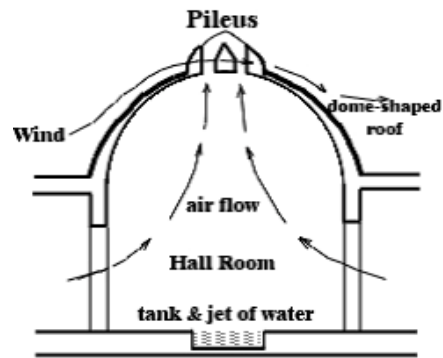


Fig. 14.Schematic section of wind catcher of Boroujerdies' house
(Source:Taleghani, et al, 2010)

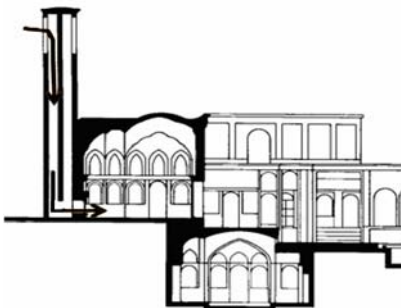


Fig .15.Wind catcher's section
(Source :The Authors)

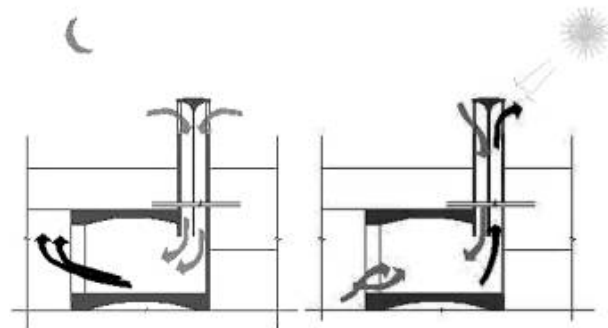


Fig.16.Wind catcher's role in day and night
(Source: Taleghani, et al, 2010)

3.1.4 Water

The high number of sunny hours and intense radiation in Kashan, lead to a compact and dense urban fabric. The distribution of seasonal precipitation of nearest synoptic station to Kashan shows more or less this result: "24.9% of the rainfall in spring, 7.8% in summer, 19.9% in fall and 47.2% in winter" (Mahmoud Kelaieh, 2008) which is allows level of rainfall. The distribution of rainfall during a year in Kashan is not uniform. The average annual rainfall is low and half of it occurs during a few successive days. Therefore, buildings not only should have appropriate insulation but also certain response to direct rainwater from

theroof. Since the junction of wall and roof can be the beginning of erosion because of rainfall, this place usually Has been covered with various types of Rokhbam, which is the last edge of building's roof that protects the common border of façade and roof.Its form depends on rainfall amount, wind speed and construction materials of the building. The relative humidity in Kashan in different seasons is low and during cool days is more than hot days. Pool, garden, and vegetation in the yard can improve relative humidity by increasing moisture. Vegetation and water raise humidity because of evaporation by the sun and

therefore they make the courtyard cooler. In addition, trees and vegetation in the yard make shadows and prevent the entry of solar radiation and heat into the rooms during summer. The rooms' openings are located only in to the internal courtyard that causes better natural air movement



Fig.17.The effects of tree inside the yard
(Source: UN, 1971 in Tavassoli, 1981)

and protection against sandstorms. The windows ratio is very low and they almost embed in the upper side of walls to enhance the warm air removal process from inside rooms. Moreover, the all parapet was used both to make the yard deeper and make shadows on the roof.



Fig .18. The impact of long parapet
(Source: UN, 1971 in Tavassoli, 1981)

3.1.5 Structure and technique

Because of Iran's geographical situation, many cities are endangering with earthquake. Kashan is a seismic city in Iran, in which severe earthquakes occurred and some of them have been recorded up to 7.5 degrees on the Richter scale. Certainly, buildings that survived for decades, has technical properties to remain durable

Against earthquakes. In order to maximize continuity of the walls, consecutive rows of adobes engaged together. Using the wooden bar was a mechanism to control walls stretch. These bars integrated walls together and let to distribute tension forces evenly. (Figure19).

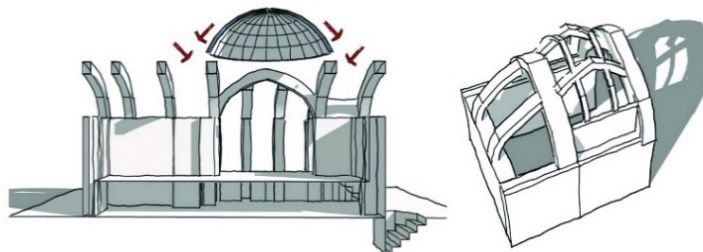


Fig .19. 3dimensional display of hall and eivan
(Source: Students' Album, 2009)

The most important advantage of the adobe is the good integration with mortar that makes building homogeneous. Therefore, the building would resist against the earthquake's forces even more than brick buildings. Because of the alliance of adobes, this building can be much better resist against horizontal forces and lateral movements of the earth. The roof of Broujerdi's house constructed with arch and dome due to construction's restrictions. This system not only reflected the large portion of sunlight and decreased the required cooling load of the building during

summer, but also was the best structural system at its construction period in Iran. Using this system, the backside of dome receives less heat and when the sun moves, the front side receives less amount of heat. Therefore, it reduces the temperature of beneath space of the dome. In sum, all analyzed parameters about the Broujerdi's house explain the vernacular strategies which are consonant with the sustainable approach. Table 1 shows the buildings features as the response to its climatic condition that made this house climatically efficient and durable during decades.

Table 1

Shows the buildings features, which made Boroujerdis' house durable during decades.

Building Features	The appropriate orientation to the Sun
	Summer residence on southern side and winter settlement on northern side
	The use of clay, adobe, and brick
	Summer residents with high height and low windows
	The use of wind catcher
	The placement of gardens and pool (full and empty spaces)
	The use of wood in construction beams
	Use the arch and dome
Result	Large amount of light and heat in the winter and good shading in summer
	appropriate use of solar energy in different seasons
	Locally available materials with high thermal capacity for thermal lag
	Decreasing heat inside during the day
	Benefit from wind blow in the summer and dam in the winter
	Create indoor air circulation, increase natural ventilation
	durable against tension of the earthquake
	Efficient system based on vernacular materials- Inherent resistance

(Source: The Authors)

3.2. Hot- humid climate

Case study: Doraghi House- Shushtar

Iran Doraghi house was built in 1811 in the city of Shushtar in Khuzestan province (Mirzaee, et al, 2011). Shushtar (latitude 32.24 and 32.03) is located in hot-humid climate zone. Due to the high heat and the humidity in this region, the most critical period of the year is during the summer. In July, minimum relative humidity is 4 % and the maximum temperature is 49 degrees. The house has 2 yards that support "andaruni" and "biruni" concept. The East side of the building is biruni and the West side is andaruni. Similar to many other houses in Shushtar and

Dezful, this building has a Shovadan^{vii} and a main floor residence which is above the ground. In order to reach the comfort zone in various seasons, this building benefits from different levels below and above ground. At the higher level, there is upper ground level which is the main part of living. Below it, underground level is located in 1.5 meters below ground. (Figure 20-23). Shovadan at a lower elevation of this level (up to about 8 to 9 meters underground), makes it possible to live against unfavorable climatic conditions. It decreases the heat exchange by walls and makes it possible to settle during hot days as a cooler space. Shovadan construction was common from Safavid historic period, more than about two hundred years ago" (Mirzaee, et al, 2011).

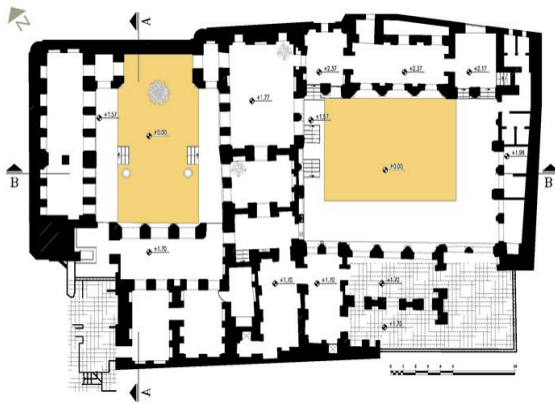


Fig. 20. Underground floor plan
(Source: Mirzaei et al, 2011)



Fig. 21. Upper ground floor plan
(Source: Mirzaei et al, 2011)

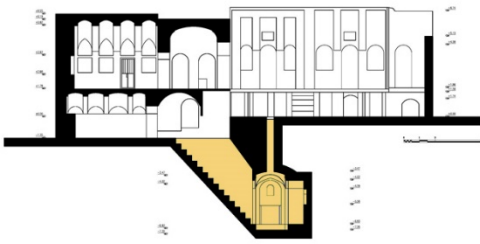


Fig. 22. Section B-B
(Source: Mirzaei et al, 2011)

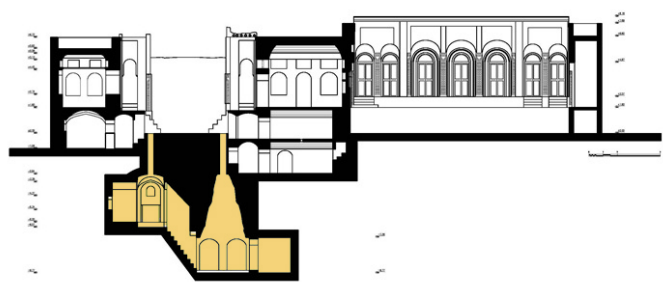


Fig. 23. Section A-A
(Source: Mirzaei et al, 2011)

3.2.1 Building orientation

Douragh houses location is rotated toward the north around 45 degrees. Although accurate studies are needed to determine Ron in Khuzestan (Pirnia, 2005, 156) but it seems that most buildings near the Douraghi house situated in 'RIGHT' Ron direction^{viii}. After 3D modeling of Douraghi house by Ecotect Analysis software (latitude and longitude as input data), incident light and shadowing sides in the summer and winter solstices were calculated.

Figures 26-27 show that the main façade is located in the shadow in the summer solstice. At the winter solstice, it seems that the building does not get much light directly and building receives more of their heat through the roof. Because of hot-humid climate condition of Shush tar, shading in summer is more important than receiving heat during winter. All of these facts prove the appropriate orientation of building towards the sun.



Fig. 24. Building's orientation
(Source: wikimania.org (edited))

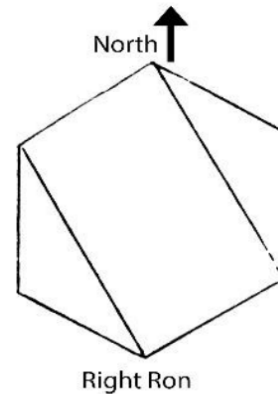


Fig. 25. Shushtar's ron
(Source: Pirnia, 2005, 172)

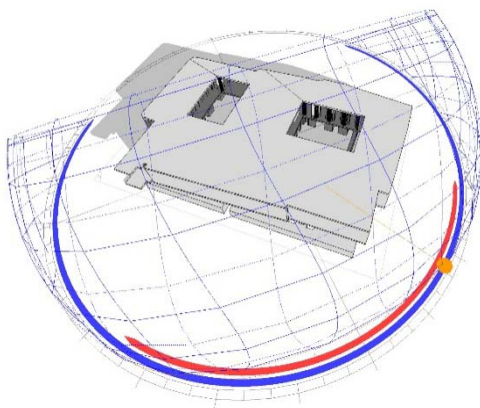


Fig. 26. Shadow pattern in 21 June
(Source: The Authors)

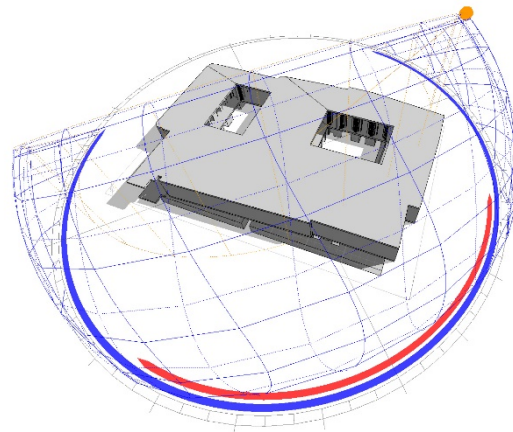


Fig. 27. Shadow pattern in 21 December
(Source: The Authors)

3.2.2. Building materials

Douraghi house was built with brick, mud, adobe, thatch and stone which all are locally available materials. According to the high heat and humidity of Shushtar city, using materials such as wood were preferred but due to the lack of sufficient amount of wood, available materials like brick have been used. Wood just has been used for building structure, doors,

3.2.3 Wind

Climatic data^{ix} shows that general wind direction in shushtar is highly variable in a day and sometimes will change hour by hour. Undesirable winds blow during June, July, and August and cause more heating. A cool

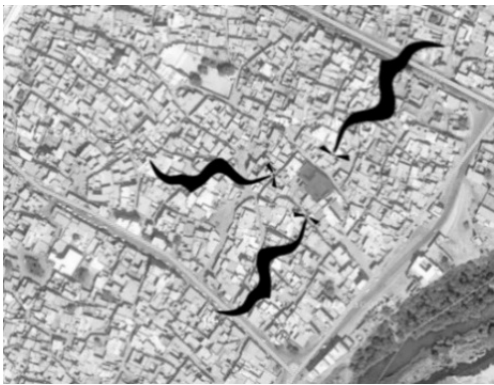


Fig. 28. Major winds of Shushtar
(Source: wikimapia.org (edited))

Reach the human comfort zone. The main residence space is high enough and heat almost situated above the settlement residents and cause better air circulation inside the room. Increasing natural air movement through controlled openings is another common design strategy in this region. Open and semi-open spaces to total mass ratio, as a vernacular architecture strategy, intensify natural ventilation. This solution can be applied in contemporary housing design as a climatic response to improve thermal comfort (Nikghadam, 2013). Doraghi house has two yards which cover more than 15 percent of land area. The checker-patterns semi-open wall helps natural ventilation inside rooms. Furthermore, this pattern supports modesty as a privacy concept (which was very critical in Iranian culture) by defusing view inside rooms. (Figure 29). Northeast windows in Doraghi building is exactly toward the favorable wind. In contrast, the southwest of building is without any opening because of undesirable wind from this side.

and windows. Ubiquitous of Termites in hot and humid areas can be another reason for scarce using of wood. Walls constructed with the stone and has been filled by mud, adobe and brick with the high thermal capacity which makes delay the heat transfer during the night and day. Thatch roofs reflect a portion of the incoming heat to the dome of the sky and reduce heat in underlying space.

breeze blow from the Zagros Mountains in the north and northeast of the city and on the contrary, west, and southwest winds bring dust and toxic material and makes the air warmer.



Fig. 29. Checker pattern in walls
(Source: Mirzaei et al, 2011)

Besides of the openings, the organization of the building responses to the wind. As mentioned before, during very hot days, shovadan has been used as a cooler space. There was an air duct system which conducts cool air from adjacent city's river to the building and conducts it to shovadan. This cool air moves from shovadan to upper levels. However, more studies are required to prove the existence of this system in this building.

3.2.4. Water

Remaining durable during decades, a building should benefit from natural potentials and resist against destructive environmental forces. Precipitation is one of these environmental forces. In Shushtar, most of the water into the yard or inside the alley. Thus, water did not remain on the roof and make no damages. In addition, the roof was restored and modified every precipitation occurs in June and especially in January. Rainwater from the roof has been guided by gutters. These gutters continued on the façade and guided year before the cold season, by rolling the canvas that causes denser thatch.

4. Earthquake

Shushtar is a seismic city, however, due to the rocky base; the earthquake has not damaged this area yet. In Doraghi building, the foundation was built by stone to reduce building subsidence. In addition, the stone reduces the water leakage to the foundation and decrease the risk of corruption. The building structures consisted of beams and load-bearing walls. Wood beams which bear tension forces, stretch along the load-bearing walls and then to the foundation. In this

facades. Moreover, rooms' vaults transmit forces to thick way. All the building works as a unit system which reduce the possible earthquake damages. Analyzed parameters about the Doraghi house disclose the sustainable vernacular strategies which are adopted to the context. Table 2 shows the design and construction strategies of this house which lead to its durability over the time.

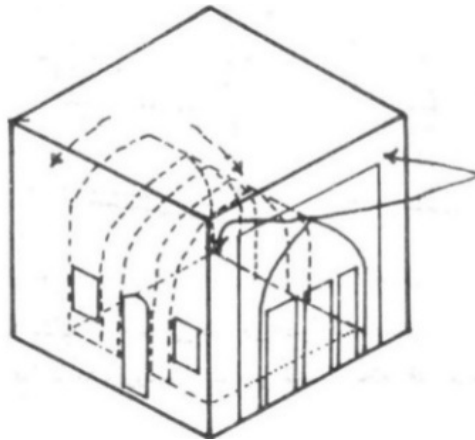


Fig .30. Loading transfer in Vault
(Source: Mirzaei et al, 2011)

Table 2

Shows the critical features of Doraghi house which cause to its durability over the time.

Building Features	Appropriate orientation toward the sun (45 degrees to the North)
	Use of adobe, mud, and brick
	High height rooms with large windows
	Proportion between full and empty spaces
	Use of gutter
	Use of stone in Foundation
	Shadow in summer
Result	Locally available materials with high thermal capacity for thermal lag
	More natural ventilation to remove humidity
	Create internal air circulation and natural air movement
	conduct heavy and sudden rains
	Avoid water leakage through the stone to the foundation and upper floors

(Source: The Authors)

5. Conclusion

To investigate the durability reasons of houses from Qajarian dynasty in Iran, two houses in two different zones (hot-dry and hot-semi humid) was selected as samples. In each, we analyzed five main parameters to assess their response to various environmental factors. The results disclose the sustainable vernacular approach of these traditional houses in hot climate conditions. These houses put into service sun radiation, soil, wind and water. They not only used natural resources to improve human comfort but also resist against unfavorable issues of them. Furthermore, the construction techniques and materials of these buildings make them sustain against earthquake. Designing of these traditional domestic houses reduced

needing for fossil fuels and made less damage to the environment so they are examples of sustainable architecture. Table3 proved that some of the strategies which have been used in these two buildings are quite similar especially their response concept toward building orientation, material, and construction. However, their response especially about removing humidity inside house is different. The result of this research and similar studies can help policy makers to put on board these strategies both for future architecture and urban design policies in order to reduce the building footprint and impact to the environment.

Table 3

Shows the use of natural elements and the seismic resistance of the mentioned historic houses

House name	Borujerdi's House	Douraghi House
Climate	Hot-dry	Hot humid
Building orientation	Appropriate orientation: Shadow on summer residential space - receive solar radiation during winter on residential space	Appropriate orientation: Shadow on residential space during summer (critical season)
Material	Locally available materials: Clay, mud, adobe, bricks with high thermal capacity to thermal lag	Locally available materials: Clay, mud adobe, bricks with high thermal capacity to thermal lag
Wind	Use of the favorable wind through the wind catcher during summer- Block the adverse wind by closing wind catcher during winter	Natural ventilation to remove humidity through large windows- two yards to improve natural air movement and making microclimate
Water	Use of gutter to guide rainwater, use of the pool to increase indoor air circulation and humidity	Use of gutter to guide rainwater
Earthquake (structure)	Use of wood as a tensile structure- arched structures to distribute tensions	The use of wood as a tensile structure, arched structures distribute tensions- using stone in foundation to block humidity

(Source: The Authors)

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ⁱTraditional houses of Iran, usually consist of 3 main parts: “biruni”, “andaruni” and court yard. Biruni was the parts that used more for guests. Andaruni was the main parts of building and the major parts of life were there. Court yard almost was in the center and mostly had trees and water.

ⁱⁱ See the note i

ⁱⁱⁱHasht-o-nim-hasht is octagonal reception hall at the entrance of traditional buildings in Iran. This space not only was designed as a central divider space but also as a cultural buffer zone which separates interior parts from exterior ones.

^{iv}Eivan is one of the most important parts of traditional houses in Iran. This architectural element, which is quite similar to ‘porch’, has been used in houses in different climates especially in hot climates.

^vTo producing adobe, clay with some organic materials like straw has been mixed together and then molded to different sizes. The ordinary size was 20*20*5 cm. Although it was not a proper material against precipitation, but in hot-dry climate it worked very well. This material has not been used in facades mostly.

^{vi}Symgel is a white material that used for covering walls or as underlie for thatch.

^{vii}Shovadan is an underground space that was very common in Shushtar houses.

^{viii} Iran cities have 3 main Rons: Isfahani, Right and Kermani. For more information see Pirnia, 2005, 155.