

Increasing of Energy Efficiency based on Persian Ancient Architectural Patterns in Desert Regions (Case Study Of Traditional Houses In Kashan)

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Abstract—In general architecture means the art of creating the space. Comprehensive and complete body which is created by a creative and purposeful thought to respond the human needs. Professionally, architecture is the art of designing and comprehensive planning of physical spaces that is created for human's productivity. The purpose of architectural design is to respond the human needs which is appeared in physical frame. Human in response to his needs is always looking to achieve comfort. Throughout history of human civilization this relative comfort has been inspired by nature and assimilating the facility and natural achievement in the format of artifact patterns base on the nature, so that it is achieved in this comfort level and invention of these factors. All physical factors like regional, social and economical factors are made available to human in order to achieve a specific goal and are made to gain an ideal architecture to respond the functional needs and consider the aesthetics and elemental principles and pay attention to residents' comfort. In this study the Persian architecture with exploiting and transforming the energies into the requisite energies of architecture spaces and importing fuel products, utilities, etc, in order to achieve a relative comfort level will be investigated. In this paper the study of structural and physical specialties of traditional houses in desert regions and Central Plateau of Iran gave us this opportunity to being more familiar with important specialties of energy productivity in architecture body of traditional houses in these regions specially traditional houses of Kashan and in order to use these principles to create modern architectures in these regions.

Keywords—architecture principles, stable architecture, management, energy productivity, body, energy

I. INTRODUCTION

THE present-day humankind in order to fulfill his individual and social needs suffer from numerous challenges that each of them implies costs. In other words, productivity means optimizing and replacing the sources and other facility with traditional and incompetent behaviors. Designing of practical and administrative solutions for effectiveness and productivity of limited sources and replacement of stable sources is one of the productivity's definitions. Better and more complete use of work, energy, human resources, capital, processes, structures in different times that causes deletion or reduce of losses due to energy, forces, etc, is called productivity.

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In the not too distant past, scientists and experts believe that energy doesn't have any roles in comprehensive and wide development and progress but over a short time they came to believe that resources have influence on increase and development of one or more energy resources and limitation of these resources and energy shortage in the world became a threat to our industrial and developed communities. Costliness and high economical value of energy and crises due to these factors caused the scientists and economists to think about proposing management solutions and suitable productivity of energy and by the arisen threats they follow the opportunities to achieve the solutions and replacing the stable energies.

In first step, using other countries' experiences and analyzing the traditional solutions of countries which owned history and civilization became the preface of this movement's beginning for the developed countries. According to the regional and climatic limitations which were available in desert regions like water resources, achieving the agreeable comfort level in rough and hard environment, and presence of similar climates, study and experience of architecture and architectural patterns of desert was started.

Iran is a vast country with 1,648,000 km² width is located in the southwest of the ancient continent of Asia. Iran is one of few countries that during its life history has uniquely represented a kind of architectural pure culture to the architecture history of the world. The cultural and geographical important specialties of this country cause to make high diversity in architecture patterns but in all created types and works of this country there are five principles that all architects of Iran in all architectural periods were committed to these principles.

People oriented: means to respect human relations and not hire human to serve beside the foreign architecture but to achieve peace besides the architecture and inside the architecture space. This peace is a divine manifestation and a divine tradition that is hidden in Persian architecture.

Avoidance of vanity: is the other Persian architecture principle that we use suitably its architecture components and all its facility and no part of architecture is useless and confirms Persian architectural purity.

Self-sufficiency: Persian architecture is defined as a regularity and simplicity in architecture spaces. Regularity changed from simplicity into complexity and crystallizes Persian architectural art.

Architecture structure: is beside architecture components and while completing it adds Strength and stability to the architectural body and accounted a part of the architecture.

Introversion: safety in architecture space beside self-sufficiency defines architecture accordance with environment and using the nature in architecture is the other architecture principle.

II. MATERIALS AND METHODS:

* *Architecture specialties and principles of houses in desert regions:*

The texture of each city is a dynamic and living composition of elements and spaces in city and their placement toward each other and because of their effectiveness from various factors especially environmental one, it has logical diversity with environment. The texture of traditional cities in desert regions with centralized structures and homogeneous integrated and compressed texture shows close correlation. We can indicate four benefits of this kind of texture:

1. Ease of movement and access.
2. Possibility of creation climatic comfort conditions and suitable energy productivity in all seasons.
3. Reduction the severe effect of hot and annoying winds and penetration of dust into the texture.
4. City security and controlling the principles in the texture.

In city textures the internal open spaces reduce to a minimum and this is distributed in the texture by interpreting the open patterns and forms the private open spaces (yards) with proportional distribution inside the texture.

In continuous texture by forming private open spaces and interior yards all adjacent spaces achieve their requisite light and view through this space. Overall, we can indicate six specialties for the principles in residential texture in desert regions.

1. texture continuity
2. proportion between spaces' dimension and their function
3. being enclosed by open spaces
4. introversion
5. unity regardless of multiplicity and multiplicity regardless of unity
6. combination and cohesive and harmonious intermixture of spaces

In designing a building plan in traditional texture of desert regions, activities and condition of spaces' placement is considered in accord with sun path according to spaces inside the house, and spaces are divided purposely in order to save energy and in the first step they are divided into two main areas, 1- cold area 2-hot area. Architecture components and architectural physical structure of Persian houses according to its culture consists of two parts, inside and outside. The general components of these two parts are as follows:

- [1] entrance: be comprised of platform, door and entrance
- [2] vestibule: space divided between several residential units (divided spaces for neighbors) is defined as pre-entrance into the house or adjacent spaces

- [3] corridor: is a path toward the interior part of the house
- [4] porch: semi-open space for sequence competition of open and close spaces
- [5] yard: a central open space with an artificial nature (pool of water, trees) represents itself as a main structure of a house
- [6] rooms: all spaces around the yard located according to the residents' needs
- [7] kitchen: modern kitchen located in interior part with and a Functional characteristics is needed
- [8] services: WC (toilets), storehouse, pen, etc, generally located in the interior part of the house
- [9] cellars - basements: in order to achieve ground-water (ducts, shallow wells) seen in most residential houses
- [10] vent: used as an especial phenomenon in traditional architecture in desert regions in order to ventilate the interior space

* *The energy productivity in traditional houses*

The Architects in desert regions in order to achieve a suitable space with an appropriate comfort level based on the environmental conditions and climate found several solutions for energy productivity in traditional houses. These solutions are categorized bellow:

1. Texture density: a mass of texture for controlling energy according to especial climate of desert regions
2. House orientation: for radiation of sunlight and Qibla (the direction that should be faced when a Muslim prays during Salah). Each side of the house is suitable for a especial season and it should be designed according to the residents' needs with climatic features
3. Using colors in order to coordinate with the climatic conditions (the role of ornamentation in traditional architecture of desert)
4. Used materials and exploiting the properties of energy control - materials like lime, soil, sand, plaster, brick, adobe, and traditional mortars made with domestic materials
5. (Using measures and innovations like making air holes between the ceiling and the walls in order to alleviate the construction and making thermal insulation and increasing the thickness of exterior walls to control and transmit the temperature)
6. Controlling the size of openings and their location according to sunlight direction, wind direction in different seasons and making shading surfaces
7. Exploiting the structural patterns correspond with climate (brick and adobe with low resistance) and making stable structural shapes with making arch and making domes with two and three surfaces in order to reduce the height and recede air volume to control and heat and chill the air (like winter hall of Mosque of Esfahan (Beyt-o-sheta) and dome of Goharshad Mosque and Yaghoob Leys Tomb.

8. Accentuate the yard in order to plant the trees and greenery and their location and increase the environmental humidity by making a pool in the yard
9. Making a cavity for garden (sunken garden): Going into the ground to control the temperature and save from undesirable air flows and stiff winds full of dust

III. RESULTS AND DISCUSSION:

Because of Iran's width and area and because it has diverse climates, it is a country with various architectural patterns that attracts the experts' attention. Hot and dry district of Iran includes most of surface of Iran that enables different solutions to compete with climatic conditions dominated in the environment in architectural body of these regions.

Study of housing architectural patterns is one the most considerable usages in accord with human and house indicates that the housing physical structure in these regions is the best solution to compete with climatic conditions which is completed during different periods.

Kashan is one of the historical cities beside the central desert of Iran is one of the regions in which we can find precious works that in the hot and dry climate created a paradise in the heart of the desert. Exploiting the solutions and being accord with nature and controlling the environmental factors that cause these solutions and creating unique works in this region.

Kashan city is one the oldest cities of Iran and is the second big city of Esfahan having great historical and natural attractions made this city one of the biggest and the most interesting poles of Persian architecture. This city with a surface round 5000 km² located in 27 and 51 East and 59 and 33 North and has diverse weather and in most of the time of the year the weather is hot and dry. Located this city in the wide desert differentiates its environmental patterns and architectural body and civil body from other parts of Iran.

Kashan from old centuries with 7000 year antiquity was a place for different people to live and included silk civilization. Kashan in different historical periods was a prosperous and affluent city that caused to make a traditional and stable texture. In this texture we can see the formation of valuable houses that in this paper some of them will be analyzed.

* *The house of Boroujerdi in Kashan - Qajar Period*

The house of Boroujerdi in Kashan was made in 1292 Hijri by Mr. Ali Maryam during 18 years. This house is located in Soltan Amir Ahmad Kashan quarter in Alavi Street and because the owner of this house, Mr. Haj Seyed Hassan Natanzi imported commodity and goods from Boroujed it was reputed as the house of Bouroujerdi.

This house includes the interior and exterior parts. On arrival to this house the entrance vestibule is located and there is also entrance to the interior part of the house. After passing the corridor relatively long and steep we arrive to the main yard of the house that has a big vestibule in north and we can see the main view of the room with 5 doors (guest room) there. And in two sides of this house the bedrooms are located which have enough light and more heat in cold weather. In northeast side there are rooms and covert vestibules and there

are stairs in front of each vestibule enable us to go to the cellars. These cellars by means of vents in hot season changed it into suitable place to live. In south side of this house there is the main covert saloon and because of its unique vent it was accounted one of the architectural masterpiece of this house and in the center of the house there is a yard with pool and nice arboriculture which contains all spaces around the house.

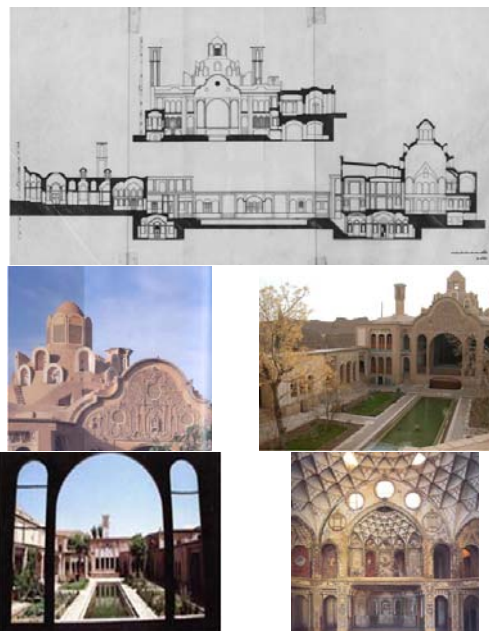


Fig. 1 several views of Boroujerdi house in Kashan

* *The house of Tabatabaei in Kashan - Qajarid Period*

This house is located in the central historical part of the Kashan and near the house of Boroujerdi in Alavi Street besides the monument of Emamzade Soltan Amir Mohamamd. This house was constructed in 1250 Ah with 4730 m² area. This house has 4 yards that its central yard belongs to the exterior part and 2 yards belong to the interior part and 1 yard belongs to the crew.

The exterior part of this house consists of 5 simple doors in the center and 2 yards on both sides and there are cellars with vents. In the yard the northwest side is bigger and has more rooms and there is a separate drawing room. In the underground of this house we can see that despite the presence of vent, the fornicated arches, double walls and roofs, rocky pool in the cellar and a drop of 7 to 10 meters from alley to pool's surface, in hot season the temperature difference is between 15 to 20 degrees.

In the exterior part there is a big saloon in the center and the double and reticulate colorful sash windows are one of the features of this space.

The crew yard consists of crew rooms, kitchen, stall and various warehouses and in this part two aqueducts named Dolatabad and Nasrabad passed and provided the water house, and one of this house's cellars adjoining these aqueducts was located at a depth of 10 meters from the alley's surface.

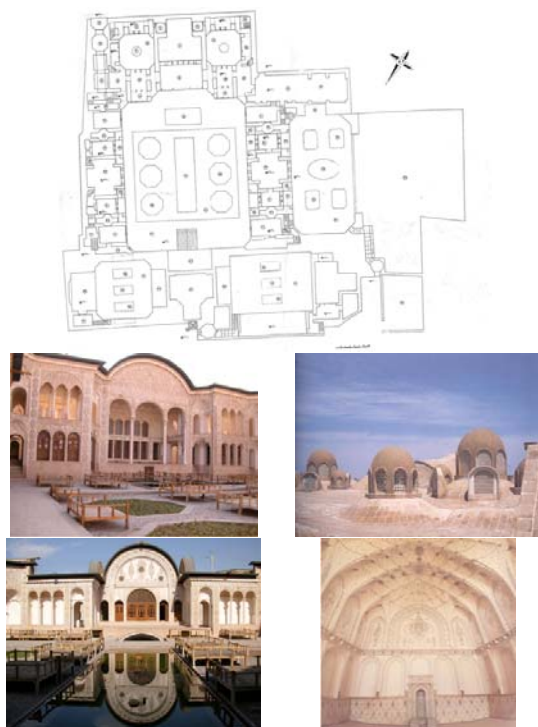


Fig. 2 several views of Tabatabaei house in Kashan

** The house of Ameri in Kashan - Zandiyan - Qajarid Period*

The Ameri House in Alavi street with area of about 7,000 m² has 7 yards and 85 rooms is one the biggest houses in historical city of Kashan. This house was made in Zandiyan period and in Qajarid period was developed by Saham-o-Saltane Ameri. One the traditional and skilled architects of Kashan believed that purdah in architecture is one of the specialties in historical houses of Kashan specially the house of Ameri. Long walls, the entrance porch, sinuous vestibules, being exterior and interior of the yards are the features of the purdah and reverence in the house of Ameri. Introversion and intricateness of 7 unique yards of this house, walls with solidity and simplicity made of thatch (plaster of clay and straw) represents grandeur and glory of architecture in this house. Humanitarianism and pleasantness of the architecture in this house, existence of the rocky seats on both sides of the entrance, human proportions of spaces and care about human presence in all individual parts of the spaces are the features of this house. Settlement of the porches in every yard of this house, unique vents, drop from house floor to adjacent passages, cellars with comfortable living conditions and exploiting the domestic materials and special structures and architecture are the features of this house.



Fig. 3 several views of Ameri house in Kashan

** The house of Abbāsīd*

The house of Abbāsīd was made as a complex in connection with each other in Alavi Street and in Soltan Amir Ahmad quarter in Kashan and in terms of architecture it has harmonious proportions and in terms of decoration it is very rich and also in terms of architectural relations it is valuable. The buildings of this complex made in a manner that is coincided completely with the climatic conditions of Kashan and in terms of culture it is important very much and I dare say that the aforesaid complex especially the house of Abbāsīd is typically unique. The aforesaid complex was made by grandfather of Seyed Mohammad Alavi Boroujerdi (around 53 years after the tremendous earthquake of Kashan in 1192 AH) around the year 1245 AH. A few years later after construction, Haj Mohammad Ebrahim, a tile merchant, father of Ayat-o-allah Seyed Mohammad Alavi Boroujerdi developed this complex.

In the basement of this house, on the wall there is an inscription with Sols chirography and on the plasterwork we can recognize the year 1252 AH was engraved. All houses of this complex while having a harmonious and measured correlation, each of them has a separate entrance and their doors are opened into the aforesaid corridors and porches and the house of Abbāsīd has also a separate path in Alavi street that consists of porch transom and entrance corridor to the yard. The house of Abbāsīd was made as a sunken garden to gain access to the desirable water (Narabaa duct) and also utilization of all different parts of the building in all seasons. The upper floor of the building is suitable in winter, the lower floor that has underground water reservoir adjacent the yard and the garden and pool located around it is suitable in summer. The visible views in the yards are topically trimmed and inside the rooms there are suitable decorations based on the their usage generally decorations like trim, mirrors, wooden windows, priceless porcelain, delicate and valuable plaster fretworks, wooden two-leaf doors, valuable sashes.

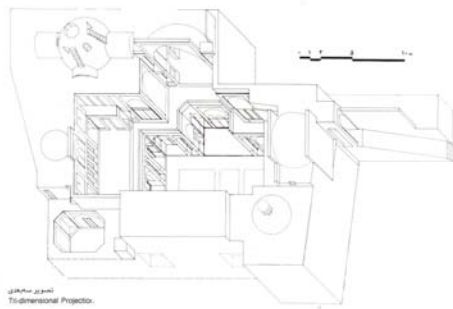


Fig. 4 several views of Abbāsīd house in Kashan

Climatic indices and architectural design in traditional housed of Kashan

Kashan is a city with hot and dry weather and desert climate and in forming the residential texture of this city according to environmental conditions special patterns were used. In this regard to achieve this matter we study a number of environmental parameters in traditional houses of Kashan. Based on studies and recording the data related to the temperature and humidity in the house of Ameri and Tabatabaei and Boroujerdi in Kashan, the following results were obtained:

TABLE I
 TEMPERATURE AVERAGE OF THE YARD AND ROOF IN DIFFERENT SEASONS IN THE HOUSE OF AMERI

month	Farvardin	Ordibehesh t	Khordad	Tir	Mordad	Shahrivar	Mehr	Aban	Azar	Dey	Bahman	Esfand
Temperature inside the yard	10	14	23	31	31.5	30.5	23.5	13	9	4	1	7
Temperature on the roof	30	38	39	45	48	43	38.5	24	18	14	12	19
Temperature inside the basement	13	17	21	23	25	23.5	20	15	10	4	5	8

Based on the provided statistics in table (1) the temperature average of environment in different months in three parts the roof - the yard - and the basement is investigated. The recorded temperature average on the roof in Mordad is 48 °C and in winter it is at least 12 °C. In the same conditions inside the yard the maximum temperature in Mordad is 31.5 °C and the minimum temperature in Bahman is 1° C. Inside the

basement the temperature has small changes, in summer it is 25 °C, in winter it is 4 °C. Based on this statistics on the roof we can see tangible changes in general climatic conditions and by making sunken gardens and central yards and by making shadows on the walls and surfaces we can reduce the temperature and change sunlight conditions without spending energy and by reducing the temperature we can reduce considerably the temperature difference between the rooms and the yards. On the other hand, settlement the building inside the ground causes to control the temperature and reduce the changes during the time of exploiting the space.

TABLE II
 TEMPERATURE COMPARISON BETWEEN THE YARD AND THE ROOMS ADJACENT THE YARD IN THE HOUSE OF AMERI

month	Farvardin	Ordibehesh t	Khordad	Tir	Mordad	Shahrivar	Mehr	Aban	Azar	Dey	Bahman	Esfand
yard	10	14	23	31	31.5	30.5	23.5	13	9	4	1	7
south	17	18	18.5	26	27	25	21	15	13	11.5	9	11
west	21	25	28	32	33	30	23	17	10.5	13	16	18.5
east	18	18.5	19	22	22	21	20	15	12	13	15	17
north	9	15	16	21	23	25	21	17	11	8	7	10

Based on this analysis according to the data from table (2) in comparison between the temperature of the yard and the rooms adjacent the yard based on the geographical directions, the temperature rate shows the considerable change. While in the hottest month of the year the temperature in the yard is around 31 °C, the temperature inside the south room is 25 °C, in west room it is 27 °C and in east room it is 23 °C and in north room it is 22 °C. And in winter while the temperature in the yard is 4 °C, the temperature in south room is 12°C, in west room it is 12 °C, in east room it is 13 °C and in north room it is 8°C. This matter causes to make cold and warm parts in the house and also winter and summer domains in these houses.

TABLE III
 HUMIDITY COMPARISON INSIDE THE YARD AND ON THE ROOF

month	Farvardin	Ordibehesh t	Khordad	Tir	Mordad	Shahrivar	Mehr	Aban	Azar	Dey	Bahman	Esfand
Inside the yard	33.3	39	38	37	39	38.1	38.3	32.	33	36	35.1	36
On the roof	23	24.1	18.3	17.1	17	19	20.1	31	30.1	30.2	31.5	32
Basement	33.5	38.5	39	43	41.1	42.2	38.9	21.5	32	32.7	33.1	32.5

Based on the table (3) the humidity average in these three areas, the roof - the yard - and the basement was investigated. The humidity average in the yard in spring due to special climatic conditions and prevailing seasonal precipitation in this region is recorded about %38 and the lowest rate at the

end of the warm season is about %33.1. The existence of water pools and overshadow areas and long walls and being located inside the ground the humidity rate consequent on water evaporation increases so that we can see high rate of humidity in the yards of traditional houses and meanwhile on the roof due to having air flows in different seasons the general humidity rate reduces and drops to %17. According to this statistics the humidity in spaces that is lower from the yard level like cellars and basements reaches to %43 that is almost stable during the year.

As it is mentioned in studied cases, in order to energy productivity in traditional architecture in houses of Kashan, the below cases are inspired by stable architecture principles and Persian architecture and experimental and artistic mechanisms of its architects has been considered.

In designing the house's plan of Kashan and in its traditional textures, physical orientation according to sun path is accomplishes based on the separate spaces inside the house that causes better savings in energy consumption and this orientation divides the house into two cold and hot spaces.

Generally the most thermal wind in summer is on the roof and east and west walls and the walls receive half of the energy in comparison with the roof. And in contrast the south walls receive relatively less heat. Using thick walls with heavy materials, creating entries in the ceiling and afforested entrances and yards with tile flooring and water pools are solutions for good energy productivity in these houses.

In these houses domestic materials like clay and mud with high heat capability are mainly used and also location of these houses inside the ground according to drop from streets and alleys around the house with houses' floor in thermal conditions causes to create a balanced environment in the house. The exterior surface of these houses in passages has most overshadow areas and minimum openings and windows and as far as possible it desires to delete these openings.

Most ceilings of these houses are like arch or dome that generally with methods of building styles toward creation the space insulation in this surface attempted to control and save energy. Also using bright colors on the walls and roofs is the other solutions used in these houses.

Using natural energy of wind in most warm seasons due to temperature difference between night and day in this climate with making vent and its orientation toward the desirable wind guide it toward the cellars and area with high humidity deep in the earth cause to use suitably these spaces in warm seasons.

In brief, introversion and enclosed rooms adjacent the passages, basements, and various cellars, porches, vents, hooked arches with log height, thick walls, low level of spaces from the street's level, orientation of the houses towards Qibla and creating physical spaces the divide between main space and open space and to control and save energy are the features of these houses.

SUGGESTIONS

* The solutions to increase energy productivity in building architecture in desert regions are:

1. Refining the construction techniques and raising the education level of technical manpower and using domestic knowledge of the region
2. Pay attention to the situation of the building establishment according to the city texture, orientation and sunlight and climatic and weather conditions
3. Pay attention to the shape and physical body of the building like mass, length, width, and height of the building
4. Using modern materials in accord with physical and mechanical characteristics of traditional materials and replacing them (thermal insulation materials, etc.)
5. Pay attention to dimension, shape and situation of openings' establishment and defining the overshadow areas (double windows and insulated Frames and special and heat-resistant glasses, etc.
6. Pay attention to type and color of exterior materials according to the texture and climate of the environment

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