Creating Sustainability in Central Courtyard Houses in Desert Regions of Iran

Mansour Nikpour, Shahrzad Shamsolmaali, Hamzeh Dehghani and Mohd Zin Kandar

***Abstract*—**Nowadays, most of houses were designed and constructed without enough respect to the both environmental and spiritual aspects of human being's life. As there is a close relation between human and nature, Iranian traditional architects have brought natural elements such as (water, soil, wind and light) the residential spaces as much as possible through designing central courtyard in houses. In this paper natural elements which are exist in central courtyard were investigated through observation and previous studies. Presence of each elements and then the role and importance of each elements and its effect on creating sustainability were clarified. The result of this research demonstrated that presence of natural elements with designing central courtyard help architect to create convenience condition for users environmentally and spiritually with respect to the hard climatic condition of desert area. Central courtyard and proper utilization of natural elements could be as useful strategies to comply the purpose of sustainable architecture for further designing.

***Keywords*—**Traditional house, Central Courtyard, Natural elements, Desert

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I. Introduction

HOT-DRY Climate consist of the most parts of the central Iranian plateau , receives almost no rain for at least six month of the year, therefore it is very dry and hot. In this climate the summer is very hot – arid and the winter is very cold and hard. In this area, sky in the most of months of year is without cloud and the weather hasn't any humidity. Thus temperature is very variety in the past has presented a series of logical solutions for human comfort. A principle for the existence of building is the need for better environmental conditions. Early men built houses to keep out the elements – rain, wind, sun and snow. Their purpose was to produce an environment favorable to their comfort and even to their survival [1].

This attribute draw a connection between the architecture and the climate and demonstrates a physical and architectural characteristic in a particular region.

Urban texture in this climate has these factors:

1-Urban texture is very concentrative.

2- City spaces are surrounded completely.

3- Narrow alley without any regulation. Sometimes covered by arch.

4- Building attach to each other (wall to wall).

5-Building have been located for using sunray and wind (figure 1).

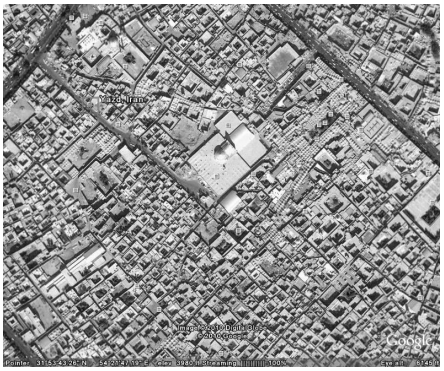

Fig. 1 Yazd city context in hot and dry region of Iran

Main characteristics of building form in central plateau region are:

1-Buildings have central yard, all space are opened toward to the central yard

2-Buildings have underground, and wind tower

3-Floor of yard and floor of ground floor is made lower than floor of alley.

4-Rooms have high height

5-Roof is made of arch and dome (figure 2) [2].

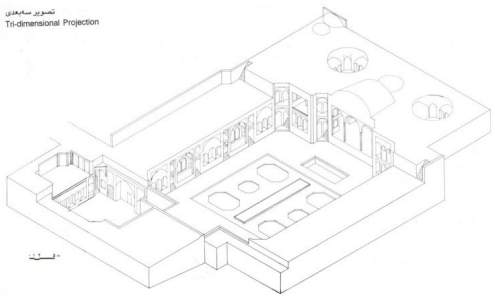

Fig. 2 perspective of Iranian traditional houses

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Mansour Nikpour is with the Architecture Department, Islamic Azad University, Bam Branch, Iran; (e-mail: mnik56@ gmail.com).

Shahrzad Shamsolmaali, is with the Young Researcher Club, Islamic Azad University, Bam Branch, Iran; (e-mail: shshams66@yahoo.com).

Hamzeh Dehghani,is with the Civil Engineering Department, Islamic Azad University, Bam Branch, Iran; (e-mail: hdehghani@iaubam.ac.ir).

Mohd Zin Kandar is with the architecture Department, Faculty Built Environment,Universiti Teknologi Malaysia, Malaysia; (e-mail: drzin2000@yahoo.com).

The traditional Iranian house is the combination of several different open and closed spaces that were designed to adapt the nature and life space together. This combination, by concentrating on the spatial figures and the ability of movement and circulation, tried to create a useful space for users [3].

One of Iranian people's beliefs is valuing private life and its sanctity; this fact has made Iran architecture, to some extent, introverted. Introversion is a concept which has existed in Iran architecture as a principle and is observable in various forms. In the warm and dry climate of Iran, this Introversion has shown itself in terms of central courtyard.

The traditional architecture of Iran has formed based on courtyard. This greenery and courtyard represents the life existence and is a sample of life and growing. In Dehkhoda Dictionary, courtyard means a campus or any wall-surrounded space of a house [4]

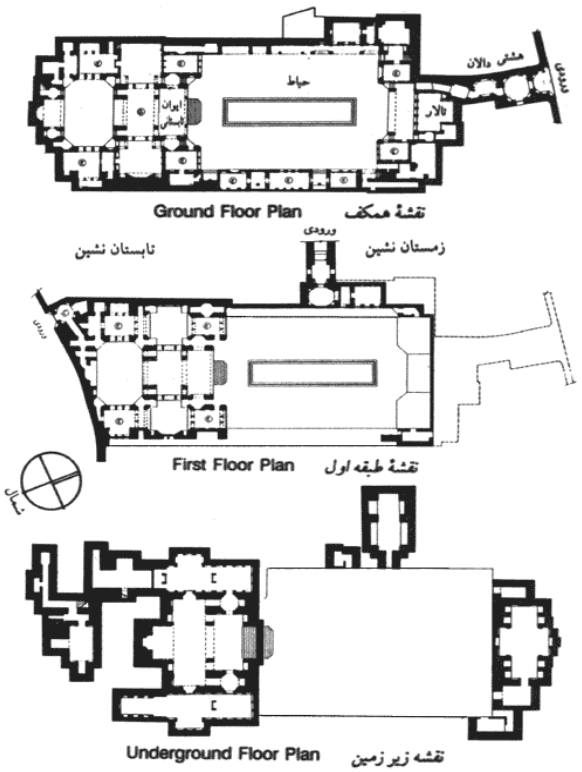

Fig. 3 Typical Plans of traditional Iranian houses

In the desert houses, courtyard is the center and heart of the building. Iranian architecture has given an artistic response to the nature and climate, and has considered the individual's convenience in all periods. In this architecture, courtyard is a central core, a space with an independent, central, internal and open geometric design. This space exhibits the existence all-reflecting mirror through reflecting the blue color of sky in itself (figure 3,4)[5].

Human being is considered to be a symbol of god, and everything is considered to be the symbol of another thing to him and is valuable. Human being lives on the ground, his shelter, and he is center of everything on the earth, because he

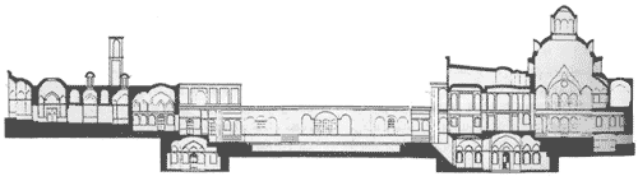

Fig. 4 Section of traditional Iranian houses

is God's symbol. Human has used his around environment which is a symbol of God for him, and has applied it in his architecture so that this nature may lead him to the God. Thinking about nature, its components and elements, and the rules and regulations governing the existence system, is one of the most issues that the Iranian culture relies on it. Thus, respecting the nature has deep roots in culture, and coordination of human being, architecture and nature is completely obvious in the traditional architecture. Iranian people were never willing to cut their relationship with the nature, and have always considered a special value for the nature. According to Zoaros "I believe in a religion in which people respect to the waters, plants and nature". Also, in the glorious Koran, it's frequently referred to plant, light and nature components and they are considered as the heaven symbols. This fact results in the all-dimensional existence of nature in the traditional architecture. Semi-open-semi-close spaces are located next to each other in a hierarchical manner; in a way that it seems that they respect and protect the God's blessings.

Existence of water and light elements in the central courtyard causes that Izadmehr and Anahita Goddess appear in terms of water and light respectively, and spaces frameworks of Iran may be the mixture site of these two Gods, and also they indicate time passage. Considering Koran verses, it can be concluded that the divine Heaven consists of four symbolic gardens with four springs from which four streams flow; they are symbols of the four world's elements: water, soil, wind and light. Human being tries to build a heaven on the ground; therefore, architecture is not in conflict with the natural phenomena.

II. Research Methodology

This research is carried out through observation and studying the previous researches, and studies the role of nature elements (water, soil, wind and light) in the central courtyard of the houses in Iran warm and dry regions. To do this, some houses with central courtyard, garden hole water pool and wind tower were investigated, which meet physical and spiritual needs of their residents by applying water, wind and sun energy. Therefore the effect of natural elements, in the central courtyard of traditional houses, on providing mental and physical convenience conditions for the residents was clarified.

III. FINDDING AND DISCUSSION

Principles in designing Iranian traditional houses are to adapt with climatic condition and fulfill the cultural and physical requirements. Due to hard climatic condition of desert region of central part of Iran such as unnecessary solar radiation and high temperature in summer, high differences between temperatures in the days and nights, low humidity, sandy wind, adaptation of the houses with climate has become one of critical issues in designing. Therefore traditional architects have utilized simple passive strategies to provide convenience condition in houses [6].

Iranian people have considered a special value for the four elements since long time age; in a way that these elements were sometimes considered as a tribe's symbol. Islam religion has a complete and comprehensive perspective towards all the above-mentioned issues, and considers the nature as a sign of God's wisdom [5].

As God created human being on the earth as his power representative on the earth, the first sign of this power appeared in the first man-made buildings. In order to construct these buildings, human being used the most primary material that is water and soil; and in fact, two elements out of the four holy elements form the creating art on the ground. Wind and fire also contributed in completing this house and did the final works of the human's shelter and dwelling

In the following, four main nature elements (water, soil, wind and light) were investigated and their characteristics and their role in the central courtyard were studied.

A. Water

Water is the clearest symbol of life, and its plenty indicates the abundance of productivity and God's blessing. It's because of the purity and clearness of water that it has been considered holy in the Iranians' religious beliefs since long times ago, as in the (worship of sun), Zoroastrian and Islam religions it has been referred to its value and people are ordered not to waste it away. God has used different symbolic aspects of water for guiding and leading the human beings [7].

Desert has always implied the meaning of dryness and lack of water has been always considered as the main life-giving element in the architecture. Water appearance in Iran architecture can be studied in two pre-Islam and post-Islam periods. In the pre-Islam period, architecture used to approach towards water, relax next to it and notify its existence without having any negative effect on the nature. In these times water had a more abstract role. Some temples were formed next to water completely respectful to it. After Islam, architectures, knowing water physical regulations, behavior, ant its role and relation with human being, brought water into the architecture, in a way that unity and centralization of architecture may be formed in the water.

In hot, arid climates, the water in central courtyard acts as a decorate. Water can not only reflect architecture and multiply the decorative features; it was used as a strategy to show the visual axes and providing a microclimate [8].

Courtyard is an appropriate place for connection of human being and the nature elements including water. In cases that the current water of subterranean canal is not flowing deep under the ground, another pattern shall be appeared. This pattern is the pool at the center of the courtyard. Human being places pool in the middle of the houses; it is symbol of the Heaven on the earth. The still and stagnant water in this pool reflects the sky and it's a place where the depths and beauties of the infinite sky are displayed on the ground. The still and resting water omits the boundary between the sky and ground. The reflective silence and the still gathering of water in these pools have ambiguous secrets, as a pensive and reflecting spirit has penetrated in them from the nature(figure 5) [9].

Fig.5 A view of traditional Iranian houses

Most fountains and pools are located at a part of the courtyard where the existing constructions may be reflected inside them and in this way the dimensions may be doubled. In the case of traditional houses, pools were made proportional with the dimensions of the courtyard. Pools in the traditional houses had various shapes and forms; sometimes they were six-sided and sometimes twelve-sided, but most of the times they were rectangular. Pools were often constructed along one of the main axis of the house, in a way that the length of the pool is located along the length of the house [10].

Also these pools often had a low depth, so that they may be extended and their water surface may be in-creased. Reflecting a swelling and effective image from the main porch (veranda) and porch, pools of-ten occupy the biggest central part of the courtyard. In some cases, pools divide the direct route to the main porch (porch) of the construction into two indirect lateral and side routs, in a novel and respectful manner. In the warm climates, pools were often made in two sections and were located in the coming and going passage, so that the wind passing above the water of these pools may provide a cool and desired weather for the residents in the warm summer days. The sonic and aquatic properties of the water are other positive and effective aspects of pools. A fluid like water has the ability to reduce a remarkable amount of sonic energy in its fluctuations; and in fact the existence of water in the pool acts as a hidden barrier and blocking against the sound passing inside and out-side the house. Water sound has been always desired for Iranian people. The magic power of water mostly presents itself through its view and sound. This is why often

there are some fountains in the rectangular pools from which waterfalls naturally due to the water level difference, and presents a desired view and sound that brings happiness and joy. Water drops falling was al-ways indicator of some angles playing with each other [5].

B. Soil

Human's body, nature and mould are naturally from soil, and they shall return to soil. Architecture anatomy is raised out of soil and it shall return to it as well. This homogeneity results in the compatibility of soil architecture with human's nature. Islamic city rises gradually out of soil and uses natural recourses as much as possible; but when it is empty and evacuated it would return to the spoil gradually.

All nature is indicator of the wise creator and the earth and skies have been created for human being according to this viewpoint. The earth is a place for remembering God's power. It is a holy place on which the superior creatures, for whom the skies have been created, bows down. For this reason in the Islamic architecture ground and carpet are holy, but this sanctity is not because of neighboring with human's essence rather than soil.

After water, soil is the most important element in forming the personality of this architecture. Floor, wall, ceiling, far and close view and all architecture elements are made from the soil. Soil appears in the foundation in the shape of concrete, in walls and arcs in the shape of mud, mortar and stratum, in the court-yard wall in the shape of coating, cob and clay-and-straw mortar. Everything is a form of soil, as a component of the desert lands where there is nothing but soil, and in fact, different and various forms of soil. In fact, if water is the language grammar of this architecture, soil is its accent (figure 6) [11].

Fig. 6 Materials of traditional Iranian houses

Traditional architecture mixes the soil with love, as the God created Human being.

Traditional architecture learns philosophy from the Wise Architect and applies it in its task. Thus, the main materials used in the construction of the central courtyards of Iran houses are proper soil, mud, Adobe brick and brick that are proper for constructing thick and huge walls. These materials have high heat-strength and thermal-capacity, and they can attract sunlight through their outer surface. By attracting the sunlight, they prevent increasing the temperature in the inner spaces, and store this heat so that they can transfer it to the environment during the night when the environment temperature decreases.

Also, soil is used in the garden pit. Garden pit used to be constructed in the center of the central courtyard and go down into the ground equal to one floor. In the garden pit the excavated soil was used for making Adobe brick and constructing the building. Also this pit used to provide the possibility of reaching the water of the subterranean canal.

All materials which have been used in construction of Iranian houses such as adobe, brick, gypsum and wood are derived from natural materials therefore everything in Iranian houses can create close relation between habitants and houses.

C. Wind

Wind is the clearest symbol of the ether, a carrier for light, and indicator of heat and moisture properties. The air flow gives the things lightness, softness and ability to rise. Wind is warm but not dry and its wet quality gives it expansion and dissolution properties. Wind is the clearest symbol of air in the nature. This element is symbol of human being's invocations of God, speeches and blessings. Plentiful shapes of roof spaces, wind towers and wind catchers are the constructive shapes that are related to the wind that is the air layer movement [12].

Wind is among those natural phenomena that thinking about it and the role it plays in continuing the nature and human life, can remind those principles and values which are the requirements of a spiritual and meaningful life. The importance of air flow and movement in the residential spaces has been considered in the Islamic training, to that extent that limiting the air of the neighbor's residential space by constructing a high building is considered as spoiling the neighbor's right.

Wind, as the third fundamental concept, has imposed influence on this architecture deeply. In the desert lands, after water, wind shapes the soil. Natural air-condition and applying non-mechanical cooling have had a special place in Iranian architecture. Wind tower as an index of Iranian architecture has an undeniable worldwide fame in this case. The existence of this element is a sample of Iranian architect's effort for utilizing natural gifts.

Wind towers are considered to be the breath system of the town that are mostly observed in the residential and old places. In his thesis, "Mohamadkarim Pir-nia", the architect and researcher from Yazd, considers the wind towers and wind catchers as "the lungs of a desert town". Wind towers are components of the Iranian architecture in the warm and human and warm and dry climates that can be seen in the Iranian architecture face in vertical element. These element lead a desired wind to the inner spaces of the construction through their vertical pores, and apply the stable energy of the

environment by connecting the architecture to its around environment and entering a dynamic and environment-based flow into the construction.

Natural ventilation has become an attractive technique and important method for reducing energy consumption and cost. This environmental techniques also helps traditional architect to provide acceptable indoor environmental quality and maintain a healthy, comfortable, and productive indoor climate without using mechanical ventilation[13].

Wind catchers have been used in the hot arid regions of Iran and the countries of the Persian Gulf as a natural ventilation and passive cooling techniques for providing convienience condition in spaces especially in houses[1,14,15]. The wind towers act as a device for natural ventilation in living spaces due to current wind [16]. The wind catcher system captures wind from external current wind and transfer it into the building in order to cool the inside occupant directly by increasing the evaporative heat transfer from the inner part surfaces. It causes providing cool environment in the interior spaces indirectly by removing the remained heat inside the building physics. [17].

Wind catcher is normally a tall structure with the height between 5 and 33 m mounted on the roof of a building. The design of these systems has been traditionally based on the personal experience of traditional architects. Cross-section of the air passages, placement and the number of openings as well as placement of the tower with respect to the structure is important to have a good performance [18].

They are vertical shafts with vents on top to lead desired wind to the interior spaces and provide thermal comfort. This architectural element shows the compatibility of architectural design with natural environment.

Wind tower shows the harmony of human built environment with nature. Wind tower is a key element in traditional architecture of Iran. It is seen in settlements in hot, hot-dry and hot-humid climates. They also effect on the sky line of traditional cities of Iran. Traditional building techniques were normally well adapted to the climate.

Wind is one of the important elements that can effect on climate. It has an effective role in creating comfort in hot region. That's why the wind provides a difference in pressure on the exterior walls that has an effect on the natural ventilation and interior air temperature of a building.

For traditional architects, the wind is an important factor in the design of a building. They consider the wind's effect on the thermal comfort through convection or ventilation and the penetration of air in interior spaces.

This wind tower catches cool winds at a higher level, in all directions, and leads them into the interior spaces. The dry and warm wind will pass over a pool gets cool and wet through evaporation. Then the cool and wet air flows in the room. There is an increase in air pressure to inward so the wind tower will catch the desired air and leads to the interior spaces therefore it causes ventilating of the interior spaces.(figure 7) [19].

A Shabestan is an underground space that can be usually found in traditional architecture of houses, and other spaces in Iran. These spaces were usually used during summers and could be ventilated by wind catchers .

A shabestan can be cooled using a qanat in conjunction with a wind tower. A wind tower is a chimney-like structure positioned above the house; the one of its four openings opposite the wind direction is opened to move air out of the house. Incoming air is pulled from a qanat below the house. The air flow across the vertical shaft opening creates a lower pressure and pulls cool air up from the qanat tunnel below the house. Therefore Shabestan can effect on convenience condition in Iranian houses.

Wind towers can catch different wind speeds and ventilate the building naturally. They can decrease the input airflow temperature and acts as a classical ventilator. Especially, the first type makes high temperature difference between ventilated environment and outside which is suitable for the warm days in the summer.

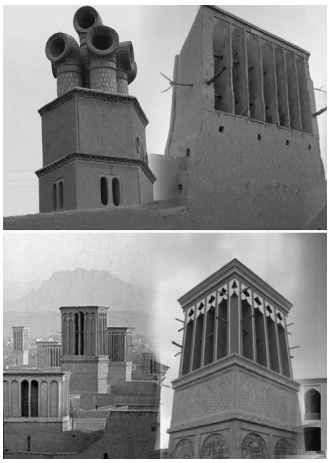

Fig. 7 Different types of Wind catchers in Iranian traditional houses

Wind towers are small towers with square, rectangular or triangle sectional shapes. They have been used for the building air conditioning in different regions of Iran since very old times. Due to the blowing effect of wind, air comes down from channels that are at the top of wind tower to its column. It finally transfers the heat to the internal surfaces of its walls as it comes into the building. Various perfect wind tower types can be found in some cities of Iran e.g. Yazd, Kashan, Tabas, etc. Design of wind towers depends on the shape of building, speed and direction of wind, height of wind tower, air passing section and wind tower location. The most important advantage of wind towers is the air conditioning and air cooling without any use of electrical energy. Wind tower plays the role of blowing and sucking at different air speeds. They cause the air conditioning of internal spaces of building [20].

Wind tower influences on creating natural cooling in two ways:

1- Air movement and displacement

2- Evaporative cooling

In an overall classification, air movement and displacement operation of the wind towers can be analyzed in two ways:

1- Leading the wind into the building (when wind blows)

2- Sending the inner air flow out of the building (when wind does not blow)

There are some pores on the top of the wind tower that are mostly made vertical to the prevalent windward. When the wind tower places in the wind direction, the pores that are in the direction of the wind are loaded by the positive pressure and the pore that are at the opposite of the wind direction are loaded by negative pressure.

Air-condition is effective only when the wind speed is more than 2.5 m/s. at night, in the result of air flow inside the wind tower, and the heat reflection of the outer surface of the wind tower to the sky, the wind tower mass is reduced and the wind tower becomes cool. During the day, when the outside air flows into the wind tower, the air cools, due to the heat exchange with the inner surfaces of the wind tower , and enters the neighboring or the beneath building.

When the wind speed is not remarkable, the wind tower natural air-condition takes place according to the chimney (smoke venting) property. In this mood, whole of the wind tower acts as a chimney and when the wind does not flow, the air inside the construction is raised and transferred to the outside of the construction through the wind tower. In this way an air flow is created inside the building, although its intensity is less than the times when the wind flows outside the building.

In warm and dry regions, besides warm weather, dryness and low rate of moisture are among those factors that endanger the thermal convenience. Thus, the wind towers in these regions try to optimize the cooling operation by evaporative cooling. For this reason, they act like water-coolers to some extent. This wind tower operation is not efficient in Iran warm and humid climates.

The evaporation phenomenon takes place in the wind towers when the water surface is under the wind flow. As the water turn from liquid state to gas state, attracts a remarkable rate of heat from it's around environment and in this way it helps to the environment cooling. Generally, in the evaporative cooling systems, water may be sprayed in the air. This kind of evaporative cooling can be observed in terms of some fountains in the pool inside the wind tower room.

Water exists beneath the wind tower in four forms:

1- Placing water pots beneath the wind tower.

2- Preparing and making a pool in the middle of the wind tower room.

3- Connecting the wind tower to the living room through a humid horizontal cannel.

A rare sample of this kind of evaporative operation of wind tower was in Bam. The wind tower was located in a distance from the residential space and connected to the construction by a horizontal canal. This canal was under the courtyard and gardens. Thus it was always wet due to penetrating the water of the gar-dens and plants watering to it. The air flow entering the residential space from the wind tower was remark-ably wet due to passing through this wet underground canal.

4- Connecting the wind tower with the underground water flow through a vertical cannel [21].

D.Daylight

Fire, by its ability of burning, softening and processing, creates coordination in all things. Light and

Warmness are aspects of fire, and they are most important things for the architecture art. In Iran, a country with a severe sunlight, light had been always considered to be the most prominent aspect of the fire [12].

In most of the religions, light is symbol of divine wisdom and source of all purities and doing goods, and human's exiting from darkness of ignorance and entering the knowledge light has been always a final goal. Although shadow and darkness indicate lack of light (this God's great blessing), they are also among God's signs, in a way that the existence of shadow

and using it by animals, plants and human beings is not less important than light, since in the absence of shadow, there is no night and no trees and plants shadow; and no creature can be alive on the ground under permanent light. In addition, the creatures' and objects' shadow is the sign of their humility in front of the Single God; this is symbol of the creatures' divine purity [7].

In addition Light acts as a modifier of other features and models in Traditional architecture. Beauty of architecture can be clarified by proper use of light. It can show architecture, form and pattern quality. Furthermore the appearance of this quality can be changed due to dynamic identity of light in different times. Interaction between light and shade provides a contrast on different surfaces and the texture of each surfaces can be seen clearly [22].

One of the purposes of Iranian architecture is to fulfill the basic needs of users. This is a reason that Iranian architecture has great consideration to the people's requirements. Lighting is one of the requirements of users that can penetrate to the building through different strategy in Iranian traditional architecture. Designing central courtyard provide an opportunity to most of spaces in houses to access to daylight as much as possible (figure 8).

In hot and dry climate of Iran, All traditional houses were built with central courtyard and majority of spaces located around this open space. Rectangular Courtyard provided easy accessibility to each space in houses.alo some geometrical rules have been considered in designing. In addition this designing causes all spaces have good day light utilization. This architecture can be nominated as sustainable architecture especially from energetic point of view. All spaces which are close to the courtyard get the day light from central courtyard directly. This space has the most potential to pass the light to

the other spaces. The second layer of spaces also can use natural day light indirectly. If there was a space as a third layer respect to the courtyard, Theses spaces got daylight from apertures on the dome. This strategy was used to provide enough day light in space.

Water in pool acts as a reflector of light and these natural elements reflect the light to the internal spaces of the traditional houses [23].

Fig. 8 Perspective view of Iranian traditional houses

Light, the most non-material, perceptible element of the nature always exists in the Iranian architecture and in fact, it is the sign of the superior world and spiritual space. The traditional architecture observes the light greatly under influence of Islamic thought. Islamic architecture has a special focus on light, especially in Iran. In the desert, due to the sever sun shining and clear air of the high plateau , light-tolerance and need to live in the light-resistant places, have been the in-separable parts of Iranians' lives along the time. Light is the main feature of Iran architecture that is not only a material element but also a symbol of God. Iranian architecture, knowing the importance of the light, tries to bring the light into the close spaces, so that it can lighten the spaces through reflecting the light in the water. As it can be understood from "Lecorbusier's Speeches": architecture is the objects' wise, correct and magnificent play under the light.

Traditional buildings have been shaped based on the natural sources of energy and are designed in a way that they provide maximum light in winter and maxi-mum shadow in summer. In the Iranian houses ,depth of skylight spaces differs in the different directions of the courtyard, and separating summer and winter rooms was playing an important role in coordinating the spaces with the residents' needs during the different seasons of the year. Winter rooms are all spaces built in the northern side of the courtyard in order to use the winter light which shines into the rooms with a sloped angle. On the other hand, the summer rooms are built in the southern direction of the courtyard so that they can be safe from the direct sunlight shining in the summer [24].

IV. Conclusion

The great concepts and symbolism roots are those things that have maintained the desert architecture stable up to this date. Perceptible and astonishing nature has been always the inspiring source for the traditional architects. The central courtyard of traditional houses in Iran warm and dry climate is a symbol of supplying the convenience and designing based on the climatic conditions.

Nature elements (water, wind, sun and soil) have been applied in this pattern in different manners by technology. This indicates the architects' clear understanding of the environmental conditions. Using proper patterns and models in the field of designing (central courtyard) Iranian architects enjoy maximum privileges of the renewable sources and energies. Traditional houses have been built with a full consideration of all the climatic, cultural and social factors, and they have been designed with the aim of utilizing the pure energies and respecting the nature.

Most of traditional buildings have pool and area for growing plants and trees. It causes close relation between habitants and natural elements. Courtyards cause presence of water, wind and sun radiation in the middle of the houses. It creates sense of live in houses. Presences of tree, water, current wind and solar radiation have a lot of beneficial for all spaces around courtyard from different point of views. These elements especially water and trees provide cooler environment with compare to the exterior of houses. Space connection and space distribution can be easily available with using courtyard in designing houses. Presence of wind and sun radiation provides convenience condition in different orientations in different seasons. Wind causes natural ventilation in hot seasons.

Using natural element in traditional architecture shows the compatibility of architectural design with natural environment. It conserves energy and meets the purposes of sustainable architecture. In traditional architecture of Iran, climate, natural elements and renewable energy resources have been used.

Today the designers are looking for different methods to reduce using the renewable sources and developing the natural environment in the residential complexes. One of these methods is modeling the traditional architects' experiences for utilizing natural elements. Central courtyard can be introduced as a sign of sustainable architecture and as a proper pattern for this aim.

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