International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization on TPE (IOTPE)

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

March 2011 | Issue 6 | Volume 3 | Number 1 | Pages 84-91

TRADITIONAL SUSTAINABLE SOLUTIONS IN IRANIAN DESERT ARCHITECTURE TO SOLVE THE ENERGY PROBLEM

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Abstract - The sustainable architecture that advances to a point in order to be allowed to reach its aims and goals deems necessary the design off any building with the least adverse effect on environment as well as design consistent with nature. Thus by considering the traditional Iranian architecture, it is observed that Iranian architectural characteristics conform to the rules of sustainable architecture; and can obtain sustainability in modern architecture by being reveled by certain features of traditional Iranian one. This paper concentrates on the results sustainability caused by climatic elements in Iranian traditional architecture in Hot-Arid regions. In a vast country such as Iran, with different climatic zone, traditional builders have presented a series of logical solutions human comfort. The aim of this research is to demonstrate traditional architecture in Hot-Arid climate of Iran as a sample of sustainable architecture. Traditional architecture of Iran is perceived sustainable for having sustainable features. It is able to response to environmental problems from a long period. Its features are based on climatic factors as well as local construction materials of Hot-Arid regions. Iranian's Hot-Arid zones architecture contains numerous unique features which comprehend aesthetic necessities and ecological capacity. Admittedly, this kind of architecture not only exploits the natural resources but also increase its spirit. As a result its techniques comprehend many latest concepts in sustainable architecture. Result of this paper; show that considering the experience in traditional architecture of hot-aired regions, it is possible to create an environmental and sustainable architecture.

Keywords: Sustainable architecture, Iranian traditional architecture, Hot-Arid zone architecture, Environmental architecture, Energy.

I. INTRODUCTION

Plateau plains, which are considered as the outstanding district of Iran, are located mainly in central and eastern parts of country. Being the biggest region and surrounded by high rough nesses the central plateau of Iran (Falat-e-Marakazi) has a dry climate. The two regions of Dasht-e-Kvir and Kavir-e-Lout occupying one seventh of Iranian area- are located in the center of Iran, which is totally barren with a very little rain. High temperature in days of hot seasons, so much difference between day and night, extreme radiation of sun light, and relative dryness of atmosphere are considered as climatic specifications of salt desert areas. The air temperature of different domains of these regions depends on geographical situation, sea level altitude and wind direction. The habitable states of these regions are scattered with different distances from each other and are in the term of condensed and centralized or concentrated.

Thus, being in a harmonic architecture with the regions, the old habitable states and cities have been serving both as a residential complex and as an answer for material, spiritual and cultural needs of indigenous people. Beyond any doubt making use of intelligent will-power a natural gifts has lead to a constant life with the least damage to balanced order of region's nature.

II. CLIMATIC CONDITIONS

Hard and cold winters, warm and dry summers, very low rate of rain, air humidity, herbal cover, so much difference between day and night temperature and in salt desert and salt-desert border regions, the dusty winds are the outstanding climatic specifications in this region.

III. MORPHOLOGY AND URBAN TEXTURE

The villages and cities of hot-arid regions can be compared to cactus bushes or desert plants. Because the life spaces of these regions consisted of urban spaces, pathways, yards and buildings are completely protected against undesirable winds and at the same time desirable winds and sun radiation are used with special arrangements. The urban texture is condensed and compressed to each other in these regions. Houses have merged or combined walls and the border between them cannot be identified. The compression and combination of buildings has leaded the external surface of each building to the least and as a result each home can conserve the needed energy inside of it for a long time. It is also an answer for the crowdedness.

The narrow serrated lanes which sometimes have high walls and are roofed by arches cast a shadow on the surrounding houses and control the wind speed of Kavir. The structure of city is planned in a way, which arteries are open in the direction of desirable winds and closed in the direction of undesirable winds and sand storms.

Urban texture is harmonised with conditions of life and natural factors and uses these factors in the very unsuitable climate of this city. The important aspects of in urban texture are as follows:
- Very dense texture (Figure 1).
- Urban spaces are completely surrounded.
- Narrow, irregular and sometimes covered Alleys.
- Buildings are connected together.
- Buildings shaped by sun and wind direction.

Figure 1. Yazd urban texture

This city is very similar to a cactus in the desert; it has a very hard skin and is completely closed. Consequently people run their lives inside this skin. All the spaces are well protected against dusty winds and they are shaped to use cool wind in the summer and sun in winter. The urban texture is dense and alleys with tall walls and zigzag form in plan do not let the wind blow easily. Some of the alleys are just wide enough for two people to pass so as to produce more shading.

A. Very Dense Texture

As you can see in the accompanying photos, Yazd has connected buildings and covered bazaars. So that in a total overview you can see it as a single roof with holes (courtyards), and some alleys cut in this roof. Monochrome color and the same material insure this feeling. This worked as a protection against both natural harsh and enemies who attacked the city in days gone by.

B. Urban Spaces Are Completely Surrounded

All the public and private spaces are surrounded with tall walls and they have internal courtyards to decrease the effect of hot and sandy winds.

C. Narrow, Irregular and Some Covered Alleys

To provide shade and protect from hot sun and dusty winds, the alleys are not straight with tall walls and roofs in some parts.

D. Buildings Are Connected Together

To achieve minimum absorption of solar energy by outdoor walls all the buildings about each other.

E. Buildings Are Shaped by Sun and Wind Direction

The main axis of all court yards is toward south-west. With this order they use the winter sun fully on two sides of the courtyard and they use the wind.

IV. BUILDING ELEMENTS IN HOT-ARID REGION

A. Introversion (Darungharaei) and Court Yard

Being considered as the focal point, court yard is a social space with an environmental function. The lengthened and narrow form of this court yard, casts enough and needed shadow for this space during summer days. Commonly there is a Godal Baghcheh or below ground court yard, with different kinds of flowers and trees and also a shallow pond or to produce fresh and cool place for inhabitants. Net counting the beauty it provides, by shading and increasing relative humidity it helps the comfort condition of yard and is one of the major elements of natural cooling system of the house. All openings and room entrances ends are the connecting space between all parts of house. On the one hand as the heat capacity of air is very low the court yard very soon adapts the temperature of surrounding environment (Figure 2).

Figure 2. A house in Yazd

B. Roof

The domes, which were used as covering roof for mosques, water reservoirs and Bazar (shopping center), are another type of roof in hot and dry regions. In addition to structured reasons, the dome shape roofing of buildings in this region has some thermo-physical reasons as well. Due to having convex and unbalanced surface the impact angle of sunbeam on dome and arched roof is different from one point to an-other, and a part of it always remains in shade during morning and afternoon times, for this reason the curved shape is suitable for releasing and emitting sunbeams and waves during night and it helps to the night cooling. If the flat roofs are used in hot and dry regions it is usually paved with square shape bricks called paved bricks. These bricks receive the most radiations of sun. Early morning it starts to increase and late afternoon it decreases gradually. This action causes the change in sun radiation intensity and radiation angle (Figure 3).

Figure 3. The domes roof

C. Wall

Being considered as an important element in regional house of hot and dry climate, the huge walls have approximately thickness of about one meter. These walls lose the heat through transferring and radiation during night and its temperature remains in low and average degree during the day, thus, it provides enough comfort for residents.

D. Windows

Generally in hot and dry regions windows are small and are located in the upper parts of walls just near the ceiling. Although external walls do not have so many windows there are so many of them on the yard facing internal walls. Passing ventilation is done by these windows. Wind catcher also helps to the internal ventilation (Figure 4).

Figure 4. Hot-dry regions house windows

E. Wind-catcher

By the help of experience, the people living in these regions have noticed that the intolerable hotness of desert regions is because of land reflection, which excessively makes some maters of hot and brand air in the lower thin layer of land for this reason they have improvised a high air vent with at most 8 wings, for their houses, which is called Badgir or wind- catcher (Figure 5).

Figure 5. A wind-catcher

Wind catcher is one of the other elements of hot and dry architecture which is used for cooling and ventilation of internal spaces. Wind-catcher is as constant complex which acts both by sucking and pulling. The basis of action is that wind blowing is used to suck the cold air to the inside of building and the reaction of it is used for sending out the hot and pollutant air from inside the building. Once the wind come in contact with walls of internal wings of wind-catcher inevitably it descends and enters the building space, on the other hand the holes or vents of wind-catcher on the opposite side of wind blowing to the sucking and give the hot and pollutant air of building to the wind (Figure 6).

Figure 6. Abanbar wind catcher

F. Material

The common material for constructing huge wall in hot and dry regions includes mud, mudbrick, stone, brick, mortar, lime and wood. The thermo-physical specifications of these materials are the important factors in hot and dry regions. These materials have thermal resistance, high heat capacity and they absorb the sun radiation by their external surfaces. The microscopic and many pores of the mentioned material, which are filled with air, change them to a material similar to thermal insulator (Figure 7).

Figure 7. Material in desert architecture

G. Godal Baghcheh in House Yard

The depth of the yards was more than the normal to have access to Qanat water or subterranean canal of water, which was passing underground of yard, to water garden and below ground court yard. These yards were called Godal Baghcheh or Padiav. By having a cover full of plants and trees and naturally because of evaporation and sudation they are acting as a cool and fresh air generator for the upper yard spaces. The floor of the yard was paved with square bricks called paved bricks, which water and broom were used to clean them and it caused the yard space to become cool.

When a building is constructed without any excavation, the contact surface of it with earth would be equal to its area but once the excavation is done the contact size would be increase. In hot and dry regions to decrease the heat exchange of building with outside air and to provide low-expense and natural cooling and heating, the buildings are constructed in a pile of soil as much as possible (Figure 8).

Figure 8. Godal Baghcheh

H. Planting

In desert regions the rate of planting depends on water amount and way of accessing to it. In hot and dry region the herbal space lots of effects on the small surrounding regions for the following reasons:

1. Decrease of direct radiation of sunbeams and yard space.
2. Shading on ceiling, walls, windows, and yard space.
3. Decrease of dust in the surrounding environment of building.
4. Decrease of undesirable wind speed in building surroundings.
5. Concentration of wind blow and increase of its speed in a desired direction.
6. Increase of humidity in dry regions.
7. Decrease of temperature in building surroundings.

In most of the houses of hot-arid regions of Iran, wind catcher has a direct connection to parch and this space is used for diversity of functions from morning to noon and inhabitants use the underground in the afternoon and roofs at night, which have colder weather, for sleeping. In fact, this act of changing daily space is called local-regional correspondence. It should be said that there is a yearly space in the houses at court yard and for this reason the north part is called winter portion and the south is summer portion. The inhabitants of the house move to northern part in winter and accordingly to the southern part in summer to adapt themselves to regional conditions. Mostly, the height of summer portion is more in these houses thus; the hot weather as ends up and the cooler one replaces it in the lower surfaces. For better air ventilation, wind-catchers and air vents are mostly located in the southern part of building (Figure 9).

Figure 9. Planting in Yazd houses

V. OTHER SUSTAINABLE TRADITIONAL ELEMENTS

A. Qanats

The most important problem in the desert, as we all know, is water. So they had to find a way to bring water to the city, without any kind of modern technology or pumping system. A passive system "Qanat" is used there. A mother-well was dug in a place far from the city where

they could reach to the water table maybe 100 meters underground, they dug other wells to direct water toward the city, with minimum possible gradient. Using the slope of the earth they could bring water close to the surface in the city. It can be seen more clearly in the figure below (Figure 10).

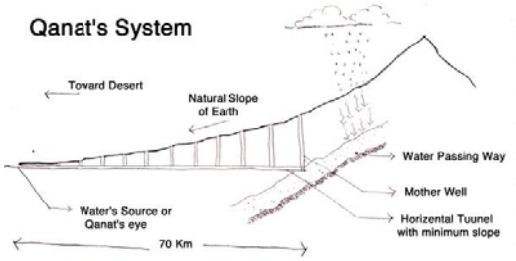

Figure 10. Qanat's system

Due to the shortage of water in the central provinces of Iran, there are thousands of water wells connected together by Qanats. At the present time, although the Qanats have been replaced by the modern deep wells, the agricultural lands of many Iranian cities in the central part of Iran such as Yazd, Kerman, Naein, Kashan, Shiraz, and Isfahan are still benefited from the Qanats. In Yazd, some parts of the city are located on several Qanats and their branches which have provided the lower agricultural farms with an adequate water supply system. It should be noted that these urban facilities are the main water resource for irrigation of the agricultural lands of the city and neighboring areas. Many residential buildings, schools, bazaars, and mosques have also been connected to the network of Qanats by gutters, grooves, rivulets, and ponds. In some cases, people also used to take advantages of the water of Qanats for their personal use such as drinking, cleaning and irrigating their small gardens.

B. Abanbar

An Abanbar is a traditional reservoir of drinking water in Persian antiquity. The Persian phrase literally translates as "water reserve". The architectural elements making up an Abanbar are presented in this article. To withstand the pressure the water exerts on the containers of the storage tank, the storage itself was built below ground level. One important aspect to consider here is their resistance to earthquakes. Many cities in Iran lie in a region that has been struck with massive earthquakes. However, since almost all Abanbars are subterranean structures capped barely above ground level, they inherently possess stable structures (Figure 11).

The construction material used for Abanbars were very tough and extensively used a special mortar called Sarooj made of sand, clay, egg whites, lime, goat hair, and ash in specific proportions, depending on location and climate of the city. This mixture was thought to be completely water impenetrable. The walls of the storage were often 2 meters thick, and special bricks had to be used. These bricks were especially baked for Abanbars and were called Ajor Abanbari. The bottom of the storage tanks were often filled with heavy metals for various structural reasons.

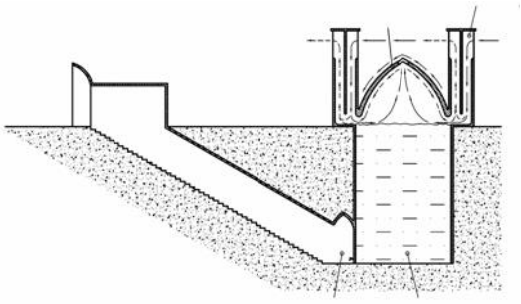

Figure 11. Section from Abanbar

In order to access the water, one would go through the entrance (Sardar) which would always be open, traverse a stairway and reach the bottom where there would be faucets to access the water in the storage. Next to the faucet would be a built-in seat or platform, a water drain for disposing water from the faucet, and ventilation shafts. Depending on where the faucets would be, the water would be colder or warmer. Some storage would have multiple faucets located at intervals along the stairway. Thus nobody had access to the body of water itself, hence minimizing possible contamination. The storage is completely isolated from the outside except for ventilation shafts or wind catchers. To further minimize contamination, the storage tank's interior was scattered with a salty compound that would form a surface on top of the water. The storage tank would then be monitored year round to ensure that the surface had not been disturbed. The water of course would be drawn from the bottom using the Pasheer (Figure 12).

Figure 12. Six wind-catcher Abanbar in Yazd

C. Sabaat

The Sabaats are the linked arches between two walls of an alley which make the hot temperature of the city more tolerable. One of the main intentions behind the construction of Sabaats has also been the creation of a bracing system for the linked structures. These structures have also enriched the sense of neighborhood among the citizens. In fact, these linked arches have been multi-functional structures. Particularly over the long days of the hot summer of Yazd, these structures together with

narrow alleys and tall walls of residential buildings widely create shade and prevent sunlight falling directly on inhabitants who walk through the alleys and also protect them from the cold wind in the winter. In some cases they also function as single rooms over the narrow alleys (Figure 13).

Figure 13. Sabaat

D. Yakhchal

A Yakhchal is an old natural refrigerator. This structure in form of half-sunken dome was used most of the time to store ice, but also sometimes to store food. In Iran the Persian engineers controlled already the technique allowing storing ice in full summer in the desert. The ice was brought surrounding mountains during the winter and was then stored in especially designed and naturally cooled refrigerators, called Yakhchal, which means "storage of ice". This structure was a buried big space (up to 5000 m^3) which had thick walls of at least two meters at the base, made with a special mortar called Sarooj , composed of sand, clay, of egg white, lime, hairs of goat and ashes in specific proportions and which was resistant to the transfers of heat. The Iranians also think that the mixture was completely impermeable.

This space was often connected to a Qanat and had also often a Badgir (turn with wind) which could easily refresh the temperatures during the days of summer. The stored ice was then used to manufacture coolings for the royal court. These structures were built and used especially in Iran. Among those which remain today, many which is those were built hundreds of years ago (Figure 14).

Figure 14. A Yakhchal (Ice-maker)

VI. A TIMELESS WAY OF SUSTAINABLE BUILDING

Sustainability in any urban development is non-damaging to the environment and which contributes to the city's ability to sustain its social and economic structures. According to a accepted definition of sustainable development that is taken from the Brunt land report2, the objectives for an agenda of urban design in a regime of sustainable development would emphasize conservation of both the natural and built environments.

Principals of sustainable urban design would place priority on the adaptation and re-use of existing building, infrastructure and roads, together with the re-use of recycled building mater ials and component. Where new development is necessary, the pattern of such development and its structures should minimize the use of energy consumed in travel between essential activities and also in the operation of the buildings. Sustainable development places a premium on the conservation of natural resources, wildlife and habitat protection. It also assumes high degrees of self-sufficiency at all levels of settlement structure.

We do not have to search far for ideas for sustainable building: they are all pervasive in our lost constructional traditions. The solutions to present environmental problems are probably not to be found in the traditions of "great architecture". It is more likely that they will be associated with the everyday buildings that have always formed the greater part of towns and cities." It is the vernacular or 'a Timeless Way of Building' to which the urbanist must turn for inspiration and guidance." The aim of the next chapters is to discover the lessons that can be learned from the timeless ways of building that can be found in the native traditions of the vernacular.

VII. THE PRINCIPLES OF SUSTAINABLE ARCHITECTURE GLEANED FROM VERNACULAR ARCHITECTURE

In the urban scale, the model of this compact city (Yazd) is according to principles of the sustainable urban design. "Certainly the compact city and " densification" of development can achieve reductions in the use of fossil fuels for transport and town heating, reduction too in the use of land and in the cost of urban infrastructure. The organic model for the city is most in tune with the concept of sustainable development when, in particular, it takes on the attributes on nature's ecosystem." According to the urban task force, the sustainable city or more accurately speaking, a city that approximates to a sustainable form-is a compact and flexible structure in which the parts are connected to each other and to the whole, with a clearly articulated public space. At the smaller scale, there are a number of design principles of buildings which is going to be studied and analyzed, here, resulting from this vernacular architecture.

A. Compatibility with Regional Context

The first principle gleaned from a study of the past practice is to relate buildings to the local environment and particularly development to the local environmental

context. In this case study, buildings formed with local climate and the environment, the southern par t contains the living rooms and bedrooms with the main windows maximising the benefit of any sun for the cold winter. In the northern face of the building usually, the summer spaces and wind catcher has been located. It is important to insulate buildings to the highest standards; to reduce the amount of external wall surface; to orientate the building towards the sun; to organize the interior of the buildings compatible to the sun movement and wind direction. Further energy savings can be made by designing the building to work well within the conditions set by the local climate.

The vernacular tradition has much to teach in the art of relating the building to its site. This common-sense approach to the location of a building on its site and the organisation of the building elements to mitigate the adverse effects of a hot summer has valuable lessons for the greening of building design.

B. Using the Local Materials

The second principle is to using of local regional building materials for construction work where possible; it is preferable to use materials requiring low inputs of non-renewable energy in fabrication, transportation to the site and in the construction process itself. Those materials which are labor intensive rather than energy intensive in their extraction, dressing and erection being more environmentally friendly and equitable in terms of the distribution of resources, are more acceptable for purposes of sustainability. The used materials such as clay and mud in this region require only man's efforts to make a structure from them. Most people on this planet live in building made from earth. Building from earth does least damage to the environment: It is close to the building site and so does not involve transport energy costs. Until the later stages of the industrial revolution in the nineteen-century, settlements were constructed largely from building materials obtained close to the site. Moreover, when no longer required, the building decomposes naturally and without pollution, return to the earth from where it comes before. Nevertheless, it can stimulate the imagination as an analogy for sustainable development. The sod or earth roof has a long history reflecting the value of soil and turf as shelter from heat, cold and rain. The earth roof still has great potential in future urban centres of developed world where it forms valuable open space in dense developments; it can improve air quality, modify microclimate, retain rainwater and provide the base for urban agriculture.

C. Reduction the Environmental Damage

The third principle is to mitigate the effects of any environmental damage and to avoid those materials that cause environmental damage. Today, all new buildings cause environmental damage, no matter how carefully they are designed. Much of the atmospheric pollution is caused by the burning of fossil fuels in the creation of energy to support city life. This energy is used in the building of city structures (energy capital); during the lifetime of the structure; and in the transportation of people and goods between and within cities (energy revenue) I t is considered that two types of energy used in the building: energy used to construct the building and energy used to service, operate and maintain the building.

The pollution causing environmental damage can be attributed directly to the building process. "For example, 50 per cent of the world's fossil fuel is directly related to the serving and use of building materials, to transport them to the site, and in their erection as par t of the building."

The building design that is compatible with climate in relation to the sun for absorbing the maximum of heating in winter as well as shadow in the summers and providing coolness and natural ventilation by the wind catchers and making the spaces in the fond of earth, has made the conditions to using the clean energies and to reduce the fossil energy consummation and consequently the environmental damage.

Moreover, using the local materials and no wasting materials by reusing them are reducing the transport between the site and the resource, making the restoration possibility of building help to reduce the environmental pollutions.

D. Reusing and Recycling

The forth principle is to the priority given to the conservation and reuse of buildings, infrastructure and materials and also design buildings for flexibility so that a mix of uses can be accommodated under the same roof and so that floor plans are "robust", in the sense that they can be adapted for different uses during the lifetime of the building. A building, which can be used for many different purposes and is easily adapted to serve many different activities during its lifetime, has a flexibility that reduces the need for demolition and rebuilding to serve changing needs reuse and recycling of building materials and components in the construction of new building and infrastructure was the main tradition of this regional building. Nowadays, the flexibility of ancient buildings has allowed them to be re-used with the different functions such as school, office, restaurant, and hotel in the traditional tissues.

E. The Life Styles

The last subject, which also needs more consideration, is the different ways and styles of living for using the maximum of environment potentially. It seems that the culture particularities according to people's view to the world and their environment characteristics, which help to adapt and respect the nature laws. The most important requirement for life in desert is to have personal particularities in compatibility with natural environment as much as which of social. We can find them clearly in the people everyday life in this region. The first is having the working mentality for to defeat the hard conditions and transforming the environmental limits into possibility. The second is to be sufficient to what the nature gives him though little. The third is forethought, a characteristic imposed by limits of hard

nature for earning one's living that ensure him and future generation without fright of future. These three characters help the person for sustain the life at least in the good conditions. The attempt must continue the generation by generation. This manner helps the people to know better their needs and environmental potentials. Citizen participation in development and the political structures, which sustain it, is clearly an essential requirement of local and regional government in a sustainable world.

VIII. CONCLUSIONS

1. Residential architecture of these regions is an expressive sample of ecological architecture. Old architecture in hot and dry region is in accordance with region and regional factors such as desired and undesired winds, humidity, sun, etc. Planning each of the full and empty spaces like court yard with tall and shading walls, enclosed spaces, porches, rooms in different directions, corner rooms with wind-catcher and pond, basement and roof is for special hours of day and night of cold-average and hot season. And a person can change his/her living space in harmony with regional changes. In addition to this, all traditional buildings of Iran, both in architectural and constructional fields, are planned in a way to have maximum of sun radiation during winter and maximum of shade during summer to use natural ventilation and to provide peace and comfort for the house residents. The houses of court yards with indicators like thick walls, porches, underground, wind catcher, vault and dome, are clear examples of architect understanding of environmental conditions.

2. The urban morphology in hot arid regions is the cause of condensed and concentrated urban texture in which the main arteries are facing the desired wind and opposing undesired one. In hot-arid region architecture of Iran the materials with heat capacity and resistance like mud, mud-brick and brick are used which are very effective in cooling and heating of internal spaces. These materials can be recycled thus, are very effective in the sustainability of Iranian architecture.

3. Traditional architecture of Iran is called Organic architecture and is formed with extreme respect to site and geophysical specifications of earth. It is noticed that houses don't have equal sizes and dimensions and they also don't have a clear geometric form, through the architect tries to solve this geometric disorder in spaces but because of regional reasons court yard has a completely calculated dimensions, or in the planning of cities the lanes and city spaces are meandering and are planned with regard to natural phenomenon's of earth and sit thus, they don't have any geometric order.

4. In this region the creation of court yard in the middle of building and preparing pond and flower-bed increases humidity in building environment and the mud-brick and brick walls, which are made thick, due to heavy weight of arched and dome vaults, acting like a thermal condenser, decrease the variance of temperature during day and night. Finally by making all openings facing to relatively humid space of yard and blocking external walls of building (except entrance door), the internal and external space connection is cut as for as possible and a suitable microclimate is constructed for human comfort in hot arid region.

5. The experiences at the 20th century showed us that we couldn't have the today's cities immediately and with ignoring that has happened in the past. The fact is that the most of modernists forgot by making the no time and no locality spaces. The reactions to modern architecture and modern planning have led to a new appreciation of the traditional city and its urban form. Sustainable development is more likely to occur when local communities take responsibility for their own particular environment, though to take such responsibilities seriously effective power must return to local communities. It is effective public participation that is also the foundation of good urban design. This paper was an essay in trying to regain the values of an architecture well suited to this environment, in not only addressing the hot and are id climate, but more importantly, in developing a language of design appropriate to the way of life in a traditional city.

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BIOGRAPHY

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