

Review of Effective Factors on Creating Sustainable Architecture in Hot and Arid Regions

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Abstract—Disregarding the excessive consumption of energy to provide comfort in the residential units, especially in hot and arid areas, is one of the problems of residential complexes in Iran. Although a lot of researches have been done in this field, the inattention to this matter not only causes energy crisis in the future but makes the residential complexes as one of the main environmental polluter resources. The traditional architects of Iran have provided comfort by applying simple and available techniques especially by considering the hard conditions of hot and arid areas, and minimize the use of fossil fuels in the residential areas. Therefore at the first of this research there is a review on the regional specifics and climatic properties of hot and arid areas; then through the observation and former researches the specifics and strategies of architecture of residential areas are discussed and reviewed from the viewpoint of providing comfort conditions by minimizing amount of fossil energy. Therefore, the effect of each feature in reducing the energy consumption could be evident. As a result, the possibility of creating sustainable residential areas is provided in the future by applying the traditional architecture strategies.

Keywords- *Sustainable Architecture, Residential Areas, Comfort Conditions, Architectural Techniques*

I. INTRODUCTION

In discussion of sustainable development followed by sustainable architecture, it has been evident that each building has to be related to its bed and the natural environment around. However, it has been highly problematic that how to develop this relation and the related strategies. It is a point which has been used by Iranian in traditional collections with a special talent for years. Besides, conducting special technologies and regulations, they optimized the use of the available energies

and natural resources including the sun and the wind which are compatible with the climate, whereas today it has been forgotten and extinct due to people negligence. These strategies are effective not only in environmental dimensions but also in other sustainable social and economical dimensions. [1]

Tropical climate features are as follows:

- Hot and dry weather in the summer and cold and dry weather in the winter
- Very low rainfall
- Little humidity
- A high amount of difference between the day and night temperatures
- Dusty wind in the desert and the desert edges [2]

This climate consists of semitropical areas which has a dry weather for the reason of emigrant winds which move from the South West and the North West to the tropical areas. These winds lose their humidity during passing from the continents. Moreover, in the semitropical areas where the air pressure is high, as the weather moves from higher to lower parts of the atmosphere, it gets hot and dry. In designing the building, the dryness of the weather in these regions along with other features has to be taken into account, in order to realize human comfort. The direct sunshine intensity in these regions is such that it produces 700 to 800 kcal/hm² energy in the horizontal surfaces. This intensity gets more by increasing the reflected radiation from barren surfaces of the lands. Meanwhile, sky in these regions is usually cloudless, whereas in the afternoon; fog, storm and dust are raised due to hot weather and movement of the weather layers which are near to the earth. Moreover, low humidity and cloudless sky lead to high variations of temperature in these regions. The summer

daytime temperature reaches to 40° to 50° c, while the nighttime temperature reaches to 15° to 20°c. The central plateau which is the largest region in Iran is surrounded by high ruggedness with dry weather along with harsh and cold winters and hot and dry summers. [3]

In a large country like Iran with different climates, the traditional architects suggested some reasonable solutions for human comfort. One of the necessary principles for life and sustainable buildings is its adaptation to the environmental conditions. The first men made their houses in order to protect themselves from the rain, wind, sun and snow. Their purpose was to protect themselves and create a comfortable place to survive [4].

Therefore, the architectural characteristics of buildings make a relationship between architecture and climate and show that each region's physical and architectural features are defined based on specific climate. This paper investigated the architecture and urbanization in the hot and arid area. [4]

II. METHODOLOGY

This paper attempted to investigate the Iranian traditional housing environments and the role of effective factors on making comfortable situations along with the minimum energy consumption including the way of locating housing environments toward each other (city texture). Moreover, it reveals the direction, the general form and sample of buildings, components, materials, joints, dimensions and proportions in order to create sustainable housing environments due to designing and performing the traditional architects' strategies.

Findding and Discussion

A. City Texture

Climate is the most important factor which has been affected on city morphology and Iranian traditional architecture in the hot and arid area. Therefore, the city and the country texture forms have been significant in adaptation to natural factors which have been used in unpleasant climate of these regions. These features include:

High concentrated city and country texture

Completely surrounded environments

The way of building placing based on the sun and wind directions

Narrow alleys which were sometimes covered by arches

In this climate, the traditional cities constructions and textures have been compact and concentrated while the houses walls are connected and their borders are not detectable. Therefore, the external surfaces of each building have been reached to a minimum extent, due to the houses concentrated buildings which lead to saving their required energy for a long time. Generally, there is no non- surrounded city environment in these regions, since it is not possible to protect a non-surrounded environment in an unpleasant climate (figure 1)



Figure 1: The compact and concentrated city constructions in hot and dry climate

The narrow alleys with relatively long walls run in a broken line. One reason of making these narrow alleys has been to make better climate situations in the alleys. Therefore, the long walls next to the alleys have been definitely effective on making shadows against sunshine as well as protecting the alleys against the desert winds. Besides, one advantage in these regions is meandering alleys, since in the direct and wide roads, the desert winds can blow strongly and ruined everything. The city construction has been designed in a way that arteries are in the direction of a pleasant wind and they are closed in direction of an unpleasant wind and sandstorm. [2]

B. The Building Form

Since the temperature variations is so high and the humidity is less than what is essential for human comfort and as sunshine creates a very hot environment in the summer and dusty desert winds disturb people comfort in most of the days in these regions, therefore, the building form is designed and constructed in order to confront the mentioned factors. [2] These buildings are built based on four seasons' features, while four or two sides of the building are considered to choose the building direction for "summer-sitting" and "winter-sitting". [5]

In fact, this daily environment change is a kind of climate-local adaptation. It should be mentioned that in houses with central yard there is a kind of yearly environmental change, therefore, the northern part is called winter- sitting and the southern part is called summer- sitting and the house people move to different part of the house in different seasons in order to adopt to the climate. These houses environment consists of the rooms, semi-open porch, windbreak and basement. [4]

The main part of the summer-sitting includes the porch, the protrusions with walls around two sides, is wide, semi-open and high which is located among the rooms and control the sunshine. [6] Making higher porch leads to ventilation and wind blowing in the basements under the porch and in the rooms around in hot summer days. [5]

Porch: protrusion with walls around two sides or the semi-open environments with columns next to the rooms Besides,

having a pool at the center of the room causes a cool and humid climate with reflected pictures in water and this place is called “hozkhane”. [7]

The windbreak is directly related to the porch and to the room next to the porch and it is used for different purposes from morning to the noon, but in the afternoon the basement is used and finally the roof with a cooler weather is used for sleeping on [4](figure 2)



Figure2: Kashan, a big porch and windbreak in the southern front

C. The Internal Buildings with a Central Yard

From morphological points of views, there are two types of houses with the central yard in the hot and dry climate. Types one is for the rich and type two is for the middle class and the poor. Type one consists of very big houses with two central yards, the internal yard which is bigger and it is considered for close relatives (Maharem) is called “andarooni” and the second yard which is smaller is allocated for serving the guests and it is called “birooni” [4].

Therefore, these climate traditional buildings have central yards with the rooms around the yard which are used according to the season. Hence, the northern part of the yard where the sun shines and it is warmer is winter- sitting and all the residents chores are done here. However, in the summer the southern part of the yard which is located in the shadow is cooler and it is called Nessar and the basement namely Sardsab is located in this part of the house and in hot days people move there.

In the hot and dry climate, the central yard is regarded as a central association and a social center with environmental functions. It is located at the center of the building where the pool and garden increase the house humidity. In most of the houses, there is a big wooden bed in the yard where its gardens are watered in the afternoon and the yard is sprinkled and the house residents sit together, eat together on this bed and spend their time in the cool yard and sometimes they sleep on the same bed. [2]

In the land with different dimensions, the central yard is designed narrow and stretched in order to provide the required shadows for the long hot summer days. However, its width should be in a form to be able to get the sun shines in the winter. The central yard provides security and privacy along with comfort for the house residents. Besides, there are some gardens with different flowers and trees in the central yard and shallow pools and pond that provide beauty, shadow, relatively humidity and feeling relaxed for the people and finally yard is regarded as a natural cooler in these houses. In Yazd and other

cities in central plateau of Iran, in a front part of the yard where the maximum shadow is found, an open porch is designed which is directly or indirectly related to the windbreak. The big rooms are located behind the porch and the small ones are designed in two or three sides of the yard(figure 3).



Figure3. Yazd, the central yards and the internalization

The yard floor is tiled by the square-form bricks namely; “Farshi” where is cleaned by watering and sweeping which make the environment cool.

In the nighttime, the bulky walls mass and the yard floor lose the sunshine longitudinal waves and it gets cold, therefore coldness stays in the floor and walls surfaces until tomorrow. In this method, the walls mass and the yard floor act as coldness reservoir. However, it should be noted that the yard has to have proper dimensions and a proper shadow giving due to two reasons; first, the yard weather gets cold in contact with the around surfaces; second, the yard weather gets cold through losing the heat from the surfaces by radioactivity [4](figure 4).



Figure4: Yazd, the central yard and the role of the pond in increasing the humidity

D. Ceilings

Generally, the form of ceilings in the internal and central yard houses is archaic along with small life-saver walls a little higher than human observation. These life-saver walls which are surrounded around the roof are not designed just for providing privacy and security for people sleeping and sitting at night, but for protecting the building bodies from the direct sunshine during the day. Besides, it should be mentioned that the ceilings are in expose of the sunshine and the warmth more than the walls. The archaic form of the ceiling covering in this climate is due to both constructive and termophysical

reasons. Semicircular form of an arch has a convex and uneven surface which modifies the sunshine in different directions and in different times of the day through its semicircular surface and leads to reduction of the ceiling temperature. Angles of refraction of the sunshine to the archaic ceilings are different in different points as a part of this surface stays in the shadow during the morning and the evening. Therefore, the semicircular form is appropriate for releasing and exiting the sunshine and waves at night and makes it cooler. In the buildings where the heavy materials have been used, transferring and conducting the heat is done slowly and the daily thermal condition is kept balanced while it reduces the heat variations the same as a thermal accumulator.

In 1964, the Cairo constructing research center compared the thermal comfort in two different buildings; one with brick walls and 50 cm thickness along with dome and arch in the ceilings and the other with panels of prefabricated concrete walls and ceilings. According to results of this experiment, the former's temperature stays in the comfort region while the latter temperature in the internal environments is even higher than the temperature in the external environments [4](figure 5,6)

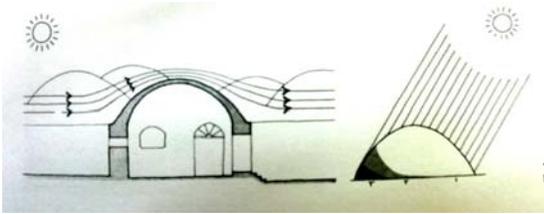


Figure 5: The dome roof against climatic factors, the sunshine reflection and the temperature reduction

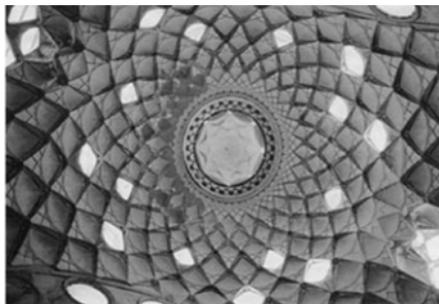


Figure6: The openings in the dome roofs for cooling and ventilating

On the other hand, the opening on top of the dome acts as a vitalization and a light while through which the taken heat in daytime exits quickly. [8]

E. Walls

The thick and brick made walls with average thickness of 1 m. are assumed as a significant element in local houses of the dry and hot climate. The main advantage of these thick walls is

the mentioned thermal feature. However, brick is not a proper thermal insulation, but it can save the heat and slowly transfer it to the internal environment of the building. In all of these materials, there is a delay time factor which is the delay between an attraction force and the heat saving in one side of the wall and the heat releasing in its other side.

Moreover, in the case the wall measured thickness is clear, it can transfer the sunshine for hours after wall heating and also it can naturally keep the heat in its internal part and cause the least temperature variation. Therefore, based on this feature, a building can be designed in a way that it can attract the heat during the day while it can be released as it is required at night.

Another advantage of the thick walls is the amount of the heat they can attract without raising the temperature. The thick walls lose the heat through transferring and radiating during the night and it stays lower than average in daytime. Therefore, when the wall temperature is less than the human skin temperature, the human body will radiate to it, even if the temperature is high.

Thus, the thick walls in the traditional houses of hot and dry climate, provide the most comfort to people through attracted radiation during the day while in the nighttime the required coolness is created through radiation and transference.[4]

F. The openers

Generally, in the hot and dry climate, windows are smalls and located on top of the walls nearly under the ceiling, while the big windows are not used so much due to their heating effect. Hence, if the sun radiation to the internal environment is not prevented by using the shade or considering proper direction of the building, even if the sunshine intrusion is deleted completely or the windows is kept closed, but due to their low thermal resistance and the sunshine intrusion through the opening in the windows it is also regarded as a negative point in energy transferring matter(figure 7).



Figure7: "Oorsi" windows for variety and lighting in the hot and dry climate

Despite of having the external walls which are without windows, but on the external walls toward a humid and cool yard, there are many windows in order to provide a proper environment for people comfort. The passage ventilation is

done by the same windows, while the windbreak can also help to ventilating the internal environment. [4]

G. Windbreak

One of the other elements of the hot and dry architecture is windbreak. Windbreak is regarded as a cooler system which provides proper ventilation by using renewable energy of the wind. [9] Windbreak is a stable collection which can act in both forms of suctioning pushing. The windbreak uses the wind blowing for pushing the cold weather inside the building, while its reaction namely; suction is used to exit the hot and dirty air outside the window. When the wind hits to a block or to the wall of internal blade of the windbreak, it inevitably comes down and entered the internal environment of the building. Meanwhile, other openings of the windbreak which are located behind the direction of the wind run the hot and dirty air in the wind and do the suctioning (figure 8,9).

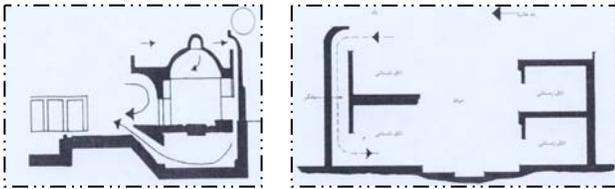


Figure8: A cross section of the windbreak hall



Figure 9: The windbreak and its role in ventilating and cooling the building

H. Materials

Some materials which are used in the thick walls are rocks, brick and mud. The termophysical characteristics of these materials are among the most important factors on the hot and dry climate. These materials have a high thermal resistance and capacity and they can attract the sunshine through the external surfaces. The mentioned significant features are the results of three factors:

1. High sun radiation which leads to increasing attraction of the sun energy through the external surfaces in the buildings of the hot and dry climate.

2. Low stream pressure in this climate increases the temperature to 27° to 28° c just by the least ventilation in hot days. Therefore, the inside temperature kept lower than the outside temperature. Reducing the inside temperature is related to resistance condition of proper heating time which is a combination of two factors of heating resistance and capacity. For example, this phenomenon can be found in Yazd basement where the house residents take a rest in the afternoon.
3. The temperature of the outside in the hot and dry climate along with the best sample of daily ventilation lead to resistance of proper heating in the building and it keeps fix the daily temperature inside the building and keeps it below high temperature of outside.

Mud: the humid soil which is combined with water and small pieces of straw. It is used for making muddy walls. Low ratio of the heat conduction and dispersion in the mud- brick shows that these materials are regarded better thermal insulation when they are compared with the cooked brick and concrete.

Mud- brick: it is a combination of the soil and sometimes some small pieces of the straw. This combination takes shape in the wooden square-form mould and then it is dried on the land in front of the sun and is used for making thick walls. However, a combination of raw mud- brick and cooked brick has been also common in the building construction. In these regions, there is no other material as resistant as strength of raw mud- brick and mud under the sun radiation against the heat. [4, 11]

Brick: it is the cooked mud- brick which gets smaller due to fire heating. It is used both in the floor and wall making. The central yard floor is often made by the brick as it is relatively cheaper than rocks. The ceilings are made by the brick in order to protect the building against the climatic factors.

Rock: the coarse and big rocks are used in construction as the only available materials in the mountainous and desert regions. Rocks are used in the ponds, pools, stairs, the sidewalk curbs and the yard walls as well as where there is a possibility that breaking and opening are found in the construction.

Plaster: the internal part of the walls and the ceilings are usually plastered, whereas the external part is covered by soil, water and straw pieces which are added for their flexibility and resistance characteristics. Sometimes lime is added for making some parts of buildings that are in danger of destruction in front of the humidity. It makes a coarse surface which is turned to a smooth surface as it is covered by the plaster. The final surface is really interesting, when the small golden pieces of the straw are observed in it[4](figure 10).

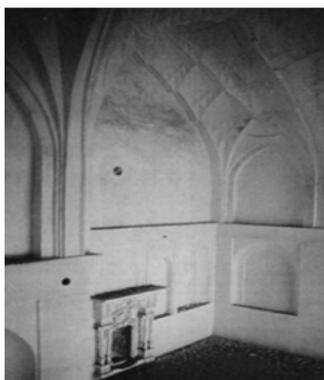


Figure10: The inside environment of the building, incrusting and plastering

I. Paint

The walls and ceiling paint in the hot and dry climate where the sun radiation is higher than it radiation in other regions, it has the highest effects on attracting the sun radiations. Paint plays a significant role in different directions of the building and in different directions of the sunshine to the walls especially to the ceiling where attracts the maximum sun radiations. The temperature difference in a white and in a black ceiling is about 40 K. However, the amount of receiving the heat inside the building is related to termophysical features of the layers, but paint is also a significant factor. Therefore the light paints are used in this climate for the mentioned reasons. [4]

J. Green places and plant covering

The amount of green covering in the desert is related to the amount of water and how to access the water. The green covering around the buildings is really effective on the climate for the following reasons:

1. Reducing the sun radiations properly and their reflection
2. Shading on the ceiling, walls and windows as well as the yard
3. Reducing the dust around the building
4. Reducing the speed of improper wind around the building
5. Focusing the wind and raising its speed in desired direction
6. Increasing the humidity in the hot and dry climate
7. Reducing the temperature around the house

The plant ability in modifying the temperature has been a significant feature for handling the sun energy. A land which is located in the shadow attracts the heat more quickly. The humidity caused by the plant reduces the heat; therefore, coldness stays for a longer time in the green surfaces [4](figure 11).



Figure11: Kashan, the green covering around a building namely, Boroujerdiha house

III. CONCLUSION

The traditional architects of Iran provide residential areas with comfort conditions by applying simple techniques. Using compact plans, minimizing the outer surface against the covered volume, applying materials with good thermal insulation and capacity and minimizing the inner air exchange and natural ventilation are among the techniques that were used by traditional Iranian architects to create comfort conditions and this case was performed with minimum use of fossil energy. Applying nature -returnable materials and minimizing the use of fossil fuels are among the aim points of sustainable architecture. Therefore, the strategies applied in Iranian traditional architecture have a great effect in creating a sustainable architecture. These techniques can also be used in the design of residential complexes in Tropical Areas to minimize the energy consumption for providing comfort conditions. In this case, by taking advantage of these techniques the aim of sustainable architecture is achieved.

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