BADGIR: DESIGNE WITH NATURE, A TRADITIONAL ARCHITECTURAL AND CLIMATE ELEMENT IN HOT DRY REGION OF IRAN

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ABSTRACT

Performance and energy consumption in buildings are considered to be the most important factor in climate. Today energy consumption reduction requirement is purpose of climatic sensitivity depending on the use of natural resources and promoting comfort in life, healthy and sustainable living spaces, and sustainable building design. Nowadays sustainable design and construction strategies have great importance. Wind, as the source of renewable energy, is the vital factor in climate studies. Wind is the most significant factor used by architects in building design in order to natural ventilation. Badgir -Wind catcher or Wind tower- is a wind dependent and wind driven architectural element, as component of Eco Architecture is depending on natural, climatic phenomena and renewable energy sources. The operating system of badgir depends on the air convection and evaporation. The most important function of the Badgir is cooling the building interior with natural methods without consuming energy in hot, dry or humid areas. The most effective role of Badgir is the reduction of heat and adjustment of temperature of inner life spaces on the basis of comfort with the help of natural convection currents of clean air ventilation.

Keywords: Badgir, traditional architecture, climate responsive design, design strategies, Iran hot-dry region

1. INTRODUCTION

Performance and energy consumption in buildings are considered to be the most important factor in climate. Today energy consumption reduction requirement is purpose of climatic sensitivity depending on the use of natural resources and promoting comfort in life, healthy and sustainable living spaces, and sustainable building design. Nowadays sustainable design and construction strategies have great

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importance. According to some, sustainable methods as the driving force of past are exhibited a variety of different ways and sometimes these ways that are not possible at present. From Vitruvius until today, in spite of the developments in technology and materials observed, the type of problems, designing methods and the structure of measures taken have not changed. In addition, these developments have some negative effects since the emergence of modern methods causes the discharge of old ones. For these reasons, the process of creating a comprehensive approach is discussed. In other words, the climate-responsive selection of materials, design and construction techniques should be assessed jointly for the smooth operation of the final product throughout the service life. How the traditional architecture, topographic and climatic conditions in central and warm regions of Iran, and regional and cultural situation of people living there influence the sustainable design and construction strategies should be carefully reviewed. The main aim of this study is analyzing function of Badgir as component of Eco Architectural element in order to traditional house ventilation that depend on a renewable energy sources like wind works without consuming energy in hot, dry and humid regions of Iran.

2. TRADITIONAL BAGDIR

Wind, as the source of renewable energy, is the vital factors of climate studies. Wind is the most significant factor used by architects in building design with the purpose of creating a comfortable inner space in hot regions. In addition to its aesthetic and ornamental appearance for the building, the most important function of the presence of Badgir is cooling interior spaces of building with natural methods without consuming energy in hot, dry or humid areas. The most effective role of Badgir is the reduction of heat and adjustment of temperature of inner life spaces on the basis of comfort with the help of natural convection currents of clean air ventilation.

Badgir is a wind dependent and wind driven architectural element. “Bad” means wind and “Gir” means exposed in Persian Language (Wind Catcher). The widespread use of Badgir is observed in various forms due to climate-related reasons in different regions of Southern and Central Parts of Iran’s ancient architecture; the main structure in all forms depends on the air, the direction and the altitude of prevailing wind. Constant seasonal and daily winds are characteristic of Iran’s desert (Kavir) regions and therefore, badgirs are constructed in the direction of prevailing winds. The operating system of badgir depends on the air convection and evaporation. For this reason, the sides and upper parts of badgir are constructed open to let the air flow in. While the upper channel of badgir is constructed closed towards sky, the lower part of it in the building is constructed open. With the intention of steering the wind more effectively in the building, the inner of the badgir channal is divided into four, six, and eight sections with mud-brick in numerous forms. This process provides a more effective circulation of air in inner spaces (Fig. 1).

3. BADGIR FUNCTION

The method of operation of badgir is as follows: when the wind blows, air goes through the openings of badgir into the building, it creates a pressure at the back of doors and windows existing in building and this action allows the circulation of air. Generally, this type of pressure pattern constitutes in all badgirs: air goes in to the channel from the upper openings of badgir with the effect of a high pressure coefficient (positive) and goes out from the openings in the back of the doors, windows in the building with (negative) low pressure coefficient. The most effective cause of the air flow during the night time is the storage of cold air at walls of badgir channel, the low temperature of air and radiation of the heat to the sky (Fig. 2). The water resources are scarce and very limited in desert regions of Iran and in order to access the water, the water channel "Qanat" -traditional underground water channel- is constructed under the ground. In order to increase the function of badgir. Qanats are located underground, under the badgir channel inside the houses, meets the water needs of houses as well as cool the houses using the coldness of water with evaporation system (Fig. 3).
The air in badgir, running over the very cold water of reservoir and air, leaves its heat and cools down. A pond is built under badgir channel in the building without qanat and the pond water cools and moisturizes air which comes from channel. Badgir working in the evaporation system are usually built in very hot and dry regions. The function of badgir in Dolat Abad Pavilion sited inside the garden in Yazd city (17. century) is in this style. The Dolat Abad Badgir, which has roughly 34 m height (33.80 m) from earth level, is the world's highest badgir and 2/3 length of the badgir channel is out of the building. In front of the pavilion was built a large pool. Plants in the garden and water humid direct the air flow to badgir which has octagonal shape (Fig. 4 and 5).
Function of badgir in a windless environment: at the night times, badgirs get the cold air from outside of windows such as a ventilator, cold air warms up absorbing the heat of the building and the heat of walls of badgir and finally goes out from the upper openings badgir. At the day time, badgir channel function on the contrary of night time, in other words, the hot air of day time cools down absorbing the coldness of walls of badgir channel that preserved during the night and subsequently goes out from doors and windows. The amount of energy stored in badgir channel is limited since it has slight specific heat and mass. For these reasons, natural draft of air from outside of the building to inside which is called as "Chimney Effect" is likely only in the early hours of the day and without wind, badgirs have no significant function (Fig. 6).

3.1. Elements of Badgir

Elements of badgir are effective in its final formation. A badgir in order from downward to upward is formed from the following parts: 1- Pillar, channel or body (chimney), 2- Opening, 3-Blades, 4- Roof.

1. Pillar, channel or body (chimney):
The shape of the badgir's pillar is in the shape of cube, prism and its frame is square frame, rectangular, hexagonal, and octagonal. Wood is used with a view to increase the durability structure of the tall badgirs and a skeleton is designed in the structure. The function of it is same as the modern concrete building armature and it has been used with the aim of reinforcing the building. Head parts of the wood remains out of badgir structure and it is used as second skeleton for the future repair and maintenance of the badgir another time (Fig. 7).

2. Opening:
While openings are positioned at the head part of badgir, blades are located at the rear side of badgir. The common types of geometrical shapes of openings are elongated, vertical and horizontal, rectangular and squareb (Fig. 8).

3. Blades:
Blades are designed in several shapes depending on the plan of badgir. In a square plan, blades such as the shapes of X, H and are cruciform made of hexagonal and octagonal plan's diameters. Blades are grouped in two parts: main blades and side blades. Main blades which have the biggest role in the functioning of badgir are invisible from outside. The main blades which can start 1.5-2.2 m height earth level in badgir could reach up until the ceiling of badgir. In contrast, side blades which is positioned in the middle of the main blades has minor role, provide an aesthetic appearance beautifying the outer appearance of badgir. This issue is one of the characteristics of the Iran architecture. The facade and the structure of building are constructed jointly, not independently (Fig. 9).

4. Roof:
In order to strengthen the resistance of the badgir roof in case of severe storms, the roof is built in form of mound.

4. BADGIR FUNCTIONAL CATEGORIZATION

Functional categorization of badgirs, depending on wind direction, are made with respect to openings in different fronts. By way of direction of openings badgir are classified single, double, triple, and four-sided (Fig. 10).

1. The one-sided badgirs are built by the direction of mountains. In regions close Kavir severe seasonal sand storms occurs and Black Wind blow. In order to block the entrance of dust and sand, all directions that are against the wind are sealed off completely and by keeping open only one direction one-sided badgir is constructed. This type of badgir is built in cities like Meybod, Ardakan, Mahan and Bam. Badgirs are constructed in one sided and seaward in cities such as Bandar Abbas in the Persian Gulf coast and they direct humid breeze of the sea into the building.

2. Generally the water-reservoirs in Yazd have two sided badgirs. The number of this type badgirs are very limited. For example, the ratio of this sort of badgirs in the city of Yazd is only 5%.

3. This kind of badgirs are not so usual, but the badgir of the former military post in old Bam city (Ark-e-Bam) is being made in three sided (Fig. 11).

4. The most common types of badgirs are four sided ones and 96% of the water-reservoirs and houses in Yazd have four sided badgirs. This kind badgirs are made of both square and rectangular plans. The rectangular forms are made specially the big face is towards the appropriate wind.

Apart from these four types of badgirs, there are some exceptional types. For instance, the badgir of "Broojerdi House" built in Kashan in 1813 is one of these exceptions. It is the most perfect example of Iranian architecture as a house. The Badgir that was built in the form of a column adjacent to the hall of "Shah-Neshin" that has a roof closes with a very different dome. The dome was designed with functions of both to receive light and air as a badgir. The inner side surface of the dome is decorated with stucco and color (Fig. 12). The other exception is the one which is designed in pipe form in a house Sirjan city. This badgir inspired by the ship's pipes were built at the beginning of the 20th century (Fig.13).

4.1. Categories Based On Forms of Plans

At the time typology of badger is analyzed, the shape of pillar is seen to be built in the form of square, rectangle and a regular hexagonal, octagonal polygon and rarely in the shape of circle. Since square and octagonal types are able to receive winds blowing from several directions, they are suitable for the regions exposed to light winds from various paths. Rectangular forms are widely used since they increase the entry field of one way blowing wind in hot seasons. Badgirs are not only different in terms of their plan, but also blades located in badgir can vary in form (Fig. 14). They can be in the form of +, H, I, K and X. For instance, the blades of octagonal badgir of the pavilion constructed in the Dolat Abad Garden are in the cross form. Blades divide badgir channel in the small channels to increase air motion according to "Bernoly Effect". Bernoly Effect defines that air rate will be increased when air pass from narrow section. Such an arrangement provides more surface in contact with the flowing air, so that the air can interact thermally with the heat stored in the mass of these blades.

5. STURUCTURE

By means of wood hanks in a horizontal state in the mud bricks function the role of support in badgirs and also increases its resistance against lateral imposed forces (wind) in long heights. These hanks tie the structure to each other and two of wood bars ends are put out of structure to create trellis or ladder for constructing the upper of badgir or for doing later repairs. While the Shurune Wood is used in the desert regions like Yazd, in hot and humid regions like Bandar Lenghe in Persian Gulf coast, the Sandal Wood is used in the structure of bagirs wooden hanks (Fig. 15).

5.1. Material and Colour

One of the design features of Iranian architecture is the harmony of construction materials with regional and local climate, since it shows a good insulation performance with its own heat without consuming energy. General materials used in the structure are mud brick, wood and plaster. The type of wood used must be resistant against moisture, termite and decay. Badgirs in hot and dry regions such as Yazd are built either of brick or mud brick covered with clay and mud plaster (kah-gel). Mud plaster is mixture of soil, water and straw and it reflects the radiation of the sun. After the water evaporates from mud plaster, it leaves empty pit, causes that heat and cool cannot filtrate inners of the soil and mud brick or adobe. At the same time, the straw increases roughness of texture of mud plaster which in turn obstructs sun radiation.

In regions near to Persian Gulf such as the Port Lenghe (very hot and humid) plaster, lime plaster (sarooj) is used for coatings. These plasters are resistant to moisture and due to their white color they fully reflect the sun's rays.

5.2. Section

Since the function of badgir is to get prevailed wind and transfer it to internal spaces, its ratio of length to height and width to length would be of much importance. The ratio of length to width for Yazd badir's is 2 to 1, in Lenghe Port the ratio of length to width is 1 to 1. Channel cross-section of Yazd bagdirs reaches to two spaces: 1. Cellar of underground, 2. summer sitting hall in ground floor but; there is not underground in Lenghe port because of high altitude of water, badgir channel only, will continue until the ground floor.

5.3. Facade and Decorations

Generally, ornamental features are in two types in Iranian architecture and especially in badgirs. Firstly, ornaments are added on badgirs as merely aesthetic reasons. Secondly, the ornaments are on the facade of badgirs as a functional element. For instance in Yazd region's badgirs, stucco are used both ornamental as well as functional in various arches form on the badgirs openings. Each architect used a different type of arch consistent with his personal preference this type of ornamentation was accepted as his signature. However, the mud brick lines and arrays at the top of the badgir that reflects regional and local features of architect visually are simply ornaments of badgir facade (Fig. 16).

5.4. Badgir Floors

In most cases, badgirs are built in single floor. In very rare cases, with the intention of increasing the impact of the wind they can be made of two-floor. This kind of badgirs are constructed large, massive and, in places where the wind direction is locally variable. Only example of this kind two stories badgir in Iran is the one built in a house at Abargou city (Fig. 17).

6. BADGIR LOCATION IN BUILDING

The forms in which badgirs were set up at the roof of houses varied from region to region, even houses to houses at same region. The most important form is the residential form available in the Iran's desert regional architecture. Generally, residents are built in the form of courtyard called as "Daroungara" in Persian Language. In the courtyard form all of the openings are not in the direction of the outside of the building but they are toward courtyard and the reasons for that are to reduce the entrance of sun light to interiors in warm climate, intensify the degree of shadow, to create micro climate with pool made and plants growth and to ensure the privacy as a culture. The most important places in this system are hall (Shah-Neshin) and position of badger in the building. The main reasons of the differences are diverse location of badgir in the houses and on top of the roofs, spaced used in summer season and their connection form to courtyard. Therefore the locations of badgirs at buildings can be classified in to three groups (Fig. 18).

1. Badgir positioned behind the hall on the axis of symmetry. In this type badgir, the axis of symmetry, hall and courtyard extend together.
2. Badgir positioned at the corner of yard. In this type badgir connection to the hall is possible through the means of a space.
3. Badgir positioned on one of northern corner of a hall.

7. CONCLUSION

Iran's ancient architecture is implemented in hot and dry regions. Badgir (wind-catcher) is an intelligent application that proceeds of exploitation from the wind natural energy, and at last it makes possible the coldness comfort ability in hot regions. Traditional architecture in hot – arid and hot-humid climate of Iran, rely on renewable fuels, It use wind energy for cross ventilation and cooling in the summer. This method is the best example of contemporary architecture which leads the art of architecture to benefit from sustainable, clean and renewable energy sources. In this respect the importance of environmentally responsive architecture will arise.

Sustainable architecture necessities force us to re-think and synchronize traditional methods of construction and use of local-materials. Several propositions are given in this paper for architects and urban designers to consider how to relate energy efficient traditional design strategies and technologies to the design of contemporary architecture.

7.1. Figures

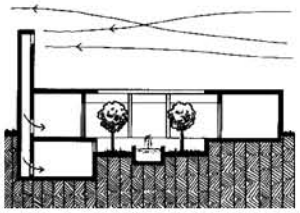

Figure 1. Badgir general function

Figure 2. Air convection in Badgir

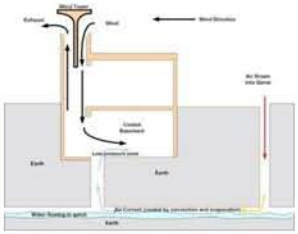

Figure 3. Evaporation system in badgir

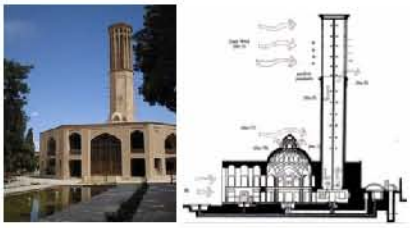

Figure 4 and 5. Dolat Abad Garden's badgir

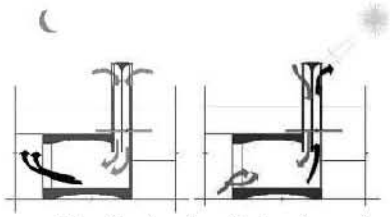

Figure 6. Badgir function during day and night

Figure 7. Outer skeleton of badgir

Figure 8. 3D model of badgir opening and blade

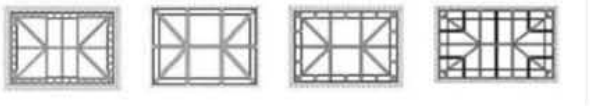

Figure 9. Badgir inner blades in horizontal section

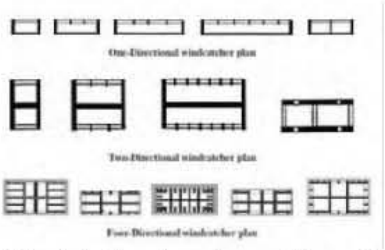

Figure 10. Typical plan of one, two and four sided badgirs

Figure 11. Ark-e-Bam three sided badgir

Figure 12. Broujerdi House badgirs

Figure 13. Sirjan Pipe badgir

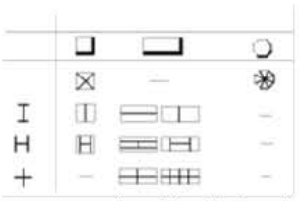

Figure 14. Categories of badgir based on plan

Figure 15. Wooden hank in badgir

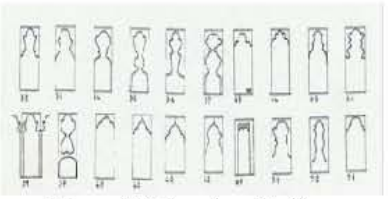

Figure 16. Opening details

Figure 17. Abargou, two stories badgir

Figure 18. Badgir locations in building

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