

# Productivity and Energy Management in Desert Urban

Masoud Nasri, Rahele Hekmatpanah

**Abstract**—Growing world population has fundamental impacts and often catastrophic on natural habitat. The immethodical consumption of energy, destruction of the forests and extinction of plant and animal species are the consequence of this experience. Urban sustainability and sustainable urban development, that is so spoken these days, should be considered as a strategy, goal and policy, beyond just considering environmental issues and protection. The desert's climate has made a bunch of problems for its residents. Very hot and dry climate in summers of the Iranian desert areas, when there was no access to modern energy source and mechanical cooling systems in the past, made Iranian architects to design a natural ventilation system in their buildings. The structure, like a tower going upward the roof, besides its ornamental application and giving a beautiful view to the building, was used as a spontaneous ventilation system. In this paper, it has been tried to name the problems of the area and its inconvenience, then some answers has pointed out in order to solve the problems and as an alternative solution BADGIR (wind-catcher) has been introduced as a solution knowing that it has been playing a major role in dealing with the problems.

**Keywords**—Productivity, Sustainable development, hot arid zones, climate design, BADGIR (wind-catcher)

## I. INTRODUCTION

MANY of scientists believe that uncontrolled population growth and as the result urbanization leads to excessive and irresponsible use of fossil energy causing the gradual warming of the Earth; and jeopardizing cities with irrecoverable damage to the global environment [3]. Some amount of the fossil energy is wasted due to non-standard models of buildings which lead to waste of energy and pollute the environment simply because they are incompatible with the climatic condition of the region. This issue has made researcher to seek for the other kinds of energy (clean or renewable energy) as an alternative for the fossil energies [6]. Nowadays it seems that the concept of sustainable development is compatible with the goals and objectives of the modern architecture and urbanism and can be considered as one of the main factors to approach sustainability. Along with global science progress, architecture has been developing and benefiting from new ideas for novel designs and modern technologies in constructions. Application of different devices to provide a reliable and comfortable household is a good example of such progress in architecture; devices which

despite their high energy, use and reduce the natural energy and pollute the environment and they have not been able to provide the predetermined goals Wind-catchers (a traditional Iranian architecture to create natural ventilation), as one of unique architectures purposefully directing wind in different ways, have been used by skillful Iranian architecture for centuries. It is obvious that this issue demands more time to indicate all kinds of wind-catchers and their applications. However, reconsidering this issue would be a major step towards retrieving the native and original values of this country as well as a new start on its implementation of this architectural element on modern design and architecture.

Wind-catcher is one of the elements which after its introduction, considered as a symbol of desert architecture, the wind-catcher besides its application has richen the desert architecture and specifically considered as the main ventilation system of the building using the natural energies. Iranians despite the limitations of that era had overcome the harsh climate situation with their creativity and inventions and had brought comfort for the residents. It seems integration of old Iranian creativity and modern techniques would lead us to better and more comfort outcome, which nowadays Iranian architecture lacks it.

Wind-catchers are the respiratory system of a house and are considered as a proof of applicability of using clean energy. A wind-catcher provides air flow contact situation with humidifier elements in the building e.g. pool, garden and trees in order to compensate the shortage of humid condition inside; while flowing inside the building it provides a cool and graceful condition in hot seasons. Wind-catchers has been designed and built considering local climatic condition such as elevation and direction of the winds in the region. Wind-catchers has been used in different residential, religious and service buildings and the remains still stand in hot and dry regions of Iran in central and southern cities like Yazd, Esfahan, Kashan, Boushehr, Gheshm Island, etc.

## II. METHODOLOGY

### *Climate Elements*

Thermal balance between body and surrounding temperature is an important human's health and comfort factor. The climate elements include sunlight, air temperature, humidity and airflow and considered as effective factors in desert architecture [4]. A large part of Iran suffers from hot and dry climate, with low rainfall along with sand storms and hot sunshine. Besides, the big difference of day and night temperature and spreading sand and dust by winds, for such regions with low rainfall, makes it more difficult to get along with the climatic conditions.

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Hence architects in order to provide comfortable and graceful place to live have considered the fact that less contact with climatic factors, provides better situation.

#### Wind-catcher

Wind-catchers have been used in Iran for centuries, and regarding the region they have been differently designed based on the elevation and direction of the wind. Wind-catchers mainly work based on the fact that the wall against the wind is cooled off and the natural ventilation is done by the pressure differences inside and outside the building, high air pressure then is sucked in, and low air pressure and warm air comes out. This phenomenon happens through an opening opposed to the wind direction (Badgir) sucking the wind inside, and the other opening on the other side (Badkhan) which make a funnel for warmed air to flow out. Hence the cool air goes inside through Badgirs and choky and warm air flows out. Wind-catchers, in Iran, are designed to cool off the building based on either, convection, evaporation or both. Two examples of the cooling system are the wind-catcher of the Dolatabad Garden and a destroyed wind-catcher in Bam (destroyed in Bam earthquake, 2003). In the first one, the air goes inside and flows over a small pool with a fountain (see figure 1) and then to the rooms. In the latter one, the system had been strengthened by construction the wind-catcher 50 meters away from the main building [1]. The system is actually made of the wind-catcher, an underground tunnel, and a garden over the tunnel. The tunnel cools off by watering the garden, and the flowing air through the tunnel therefore is cooled off and directed to the main building.

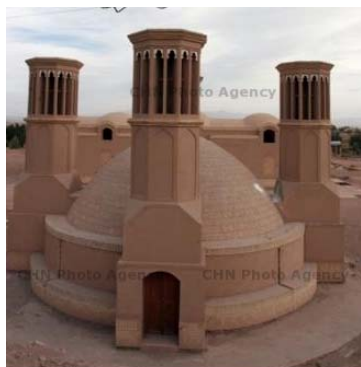


Fig. 1 Dolatabad Wind-catcher, Yazd

#### Types of wind-catcher

Wind-catchers in terms of external shape are several categories. One face wind-catchers are the simplest kind. They are small and are built over an opening on the roof. The face is toward the pleasant breeze and cold wind and the other sides are closed (see fig. 2).

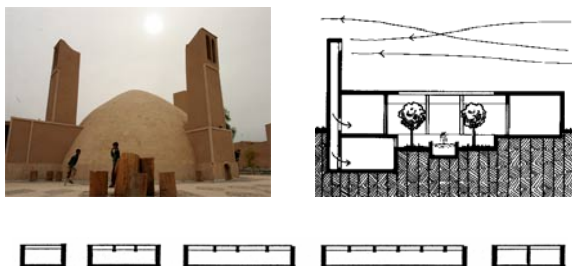


Fig. 2 One Face Wind-catcher Plan

This kind is mainly build to protect the building from the heavy storms and it is mostly seen in Systan and some part of Bam. The second type is two faces wind-catchers. The openings, in this type, are in two opposite side and built by long and narrow windows. It can be found in Sirjan and hardly in Kerman (see fig. 3).

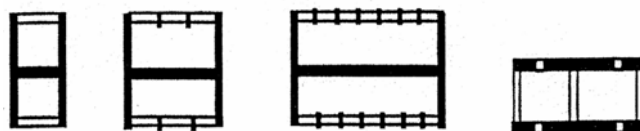


Fig. 3 Two Face Wind-catcher Plan

The third type, trihedral, is very rarely used. The forth type is tetragonal wind-catcher (see fig. 4). The design of this kind is more complete than those of the others. Inside channels, are made of small rows of bricks or plaster divided into several parts. In some cases, at the bottom there is big and beautiful pool to decrease the temperature and absorb dust, and therefore provide a graceful condition for settlers. In places with access to Qantas, the design could benefit from Qantas as well. This type mainly was built in Yazd, Kerman, Boushehr, etc.



Fig. 4 Tetragonal Wind-catcher

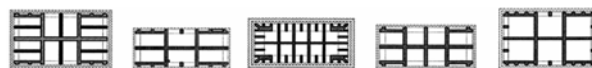


Fig. 5 Tetragonal Wind-catcher Plan

Polygon shape wind-catcher, mostly octagonal shape, were built in Yazd to catch the wind from all sides and pipe shape (Chopoghi) wind-catchers, in which the pipe shape opening were used however the inside design was exactly the same as polygon shape wind-catchers. It is only in Sirjan.



Fig. 6 Pipe Shape Wind-catchers

### III. RESULTS AND DISCUSSIONS

#### Comfort Zone

Human feeling to the surrounding environment would not be only expressed through assessing only one climate element of all; because it is a combination of all elements which provides human physical comfort by affecting him. In different locations and various natural environments, human presented different methods to challenge the nature; and the

very reason is to reach a point in which he feels security and comfort. Each region has specific temperature (dry and wet), relative humidity, absolute pressure, water vapor, which are at their optimum point and by any change on them causes an inconvenience for the persons faced with. To determine whether a region has criteria of a comfort zone, all information and statistics of the region, and then the decision would be made based on the SYCROMETER graph. This method would let us know which factors must be strengthened and which one must be weakened in order for the graph to be inside the zone. For instance in a desert area, low humidity and high dry temperature must be considered reaching comfort zone condition. Most affordable way of dealing with such problems, is to construct compatibly to the climatic condition to make it possible to decrease the inside-buildings' temperature by expending no money and energy.

#### Mechanism and Function of a Wind-catcher

There are two main functions for wind-catchers. Functions are based on pressure and temperature difference.

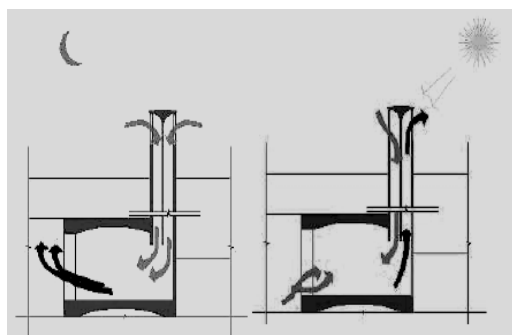


Fig. 7 Different Temperature Mechanism of a Wind-catcher

#### Pressure difference:

Wind-catchers use wind to absorb pleasant air inside and the formed suction to drive warm and polluted air out of buildings. This function is based on the fact that the side faced to the wind has positive pressure while the other side has negative pressure. Thus by having opening in the sides, there would be air flow from positive pressure to the other side, negative pressure. Regarding the fact, in a wind-catcher, the opening toward the wind, sucks in the air and cause formation of negative pressure on the other side which drive out the inside air; by flowing the air over water surface placed in the way, it is possible to maintain the needed humidity as well [2]. For example in India and Egypt this is done by placing pots of water in the way of air flow.

#### Temperature Difference:

Function based on temperature difference is less considered by experts in this field. Wind-catchers function differently and mainly based on temperature difference when there is low or no wind flowing. In days the southern side warms up by solar energy and therefore the southern inside air moves upward while it makes air to flow inward through the northern side of wind-catcher. It also results on formation of such a negative pressure inside and sucks in the cool and pleasant air inside

the yard. At nights, lower temperature outside makes the air to flow inside; it warms up by heated walls inside during day and then moves upward and out of building. This process continues until the temperature of the walls and outside are balanced, and normally the next day starts before this happens (see fig. 7)

#### Effective Factors on Wind-catcher's Function

A wind-catcher is an architecture component of an Iranian house in hot and dry area, a tool to provide thermal comfort for the residents. It is a traditional architecture functioning as an automatic ventilation system; it functions with two mechanisms, air movement and evaporate cooling [5].

Wind-catcher's goal is to provide appropriate temperature and humidity for inside the building. There are main factors affecting the goal. The parameters are categorized as following.

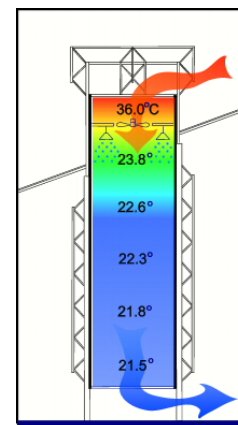


Fig. 8 temperature change in a wind-catcher

#### Effects of Air Mass Flow Rate

Air mass flow rate in a wind-catcher is different during days. The biggest effect is when it causes more evaporation, meaning that it causes more evaporation from the wet surface which itself increases evaporation efficiency along with temperature decline. Air mass flow rate is proportional to wind speed at entrance,

#### Wind Speed Effects

Wind speed is proportional to air mass flow rate. An increase in wind speed or the volume of the air causes less time needed for efficient evaporation and causing evaporation efficiency to decline. However it seems different speeds have different effects on the evaporation efficiency [7].

#### Wind-catcher Cross-Section and Geometry Effects

There are factors affecting evaporation efficiency or functionality for a wind-catcher i.e. input mass flow rate into the building, and wet system. For sure, more air volume, more evaporation rate, and better efficiency thereafter. According to Bernoulli Effect, narrower cross section, more speed and therefore it is possible to speed up the wind by designing the wind-catcher inspired by venture pipes. The best case is when the wind speed is 3-10 m/s and the wind-catcher is one face and positioned toward the wind.

#### Pergola Effects

In all pergola-like buildings, containing a pool, the specific geometry helps air rotation. The formed rotation decreases temperature more and makes it more pleasant, thus implementing such a system makes the function of wind-catchers better.

#### *Wind-catcher Height*

Wind-catcher height extensively affects ventilation process, meaning that higher wind-catchers could catch more powerful winds in higher altitudes and forming more negative pressure. The taller the wind-catcher is, the more pressure difference forms, and it also means more volume of air and as the result better evaporation efficiency.

#### *Bubble Drop Effects*

Wet bubble temperature is always less than that of dry bubble. Less wet bubble drop means less temperature difference between wet and dry drop (relative humidity is higher) and that brings better efficiency for evaporation. Regarding the mentioned fact, the least cooling occurs when air is near saturation mode. Therefore in order to increase cooling efficiency with known height, the output temperature must be kept at dew point.

#### *The Thickness and Geometry of Wet Surface Effects*

Wet surface area is proportional to evaporation rate, meaning more wet surface area, more evaporation and therefore better cooling function for wind-catchers. If cooling and evaporation occurs at the wind-catcher head, air is already cooled off and heavy enough to move faster downward by gravity force. Two kinds of new wind-catchers, could improve the function of common wind-catchers. One wind-catchers with wet columns and the other would be with wet surface tool e.g. chaff.

#### IV. CONCLUSION

Sustainable architecture is a sustainable solution to improve comfort and quality of life. It can be achieved inspiring by traditional architecture; an architecture which reduces the cost of implementation of developed countries' technology and approaches us to the picture of a sustainable architecture. Currently, it is environmental architecture at the center of attention [8]. This architecture concerns the main environmental issues e.g. environmental control by means of natural systems, decreasing energy consumption in the production stages, constructing and using low-consumption devices, using clean and renewable energy, etc. the main challenge is now to get as close as possible to %100 efficiency to bring architecture and nature together and ignore any discussion in which environmental issues are not discussed or considered. Unfortunately, urban modernism and changing in the old believes without wisdom and analysis has been ended to loss of some worthwhile spaces and forgetting about creative techniques. Take advantage of new installation and technology are considered as obvious fact, while it is followed by energy source decline as well as environmental pollution. The best solution to reduce defects is integration of traditional architecture and new features and therefore there would be an opportunity to improve the traditional architecture. It is possible to provide pleasure environmental conditions by means of old architecture patterns, its division of space and

using traditional architecture elements like a wind-catcher. A simpler solution for countries like Iran is combining old and modern technology in creative designs and projects to use the advantage of controlling climatic condition in native architecture.

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