

Sustainability Analyses of Passive Cooling Systems in Iranian Traditional Buildings approaching Wind-Catchers

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Abstract: Badghirs (Wind-catchers) are often related to halls, pools and basements. They cause the air to circulate in the building. They also relate with the moisturizing elements such as: pool, and compensate the shortage of ground moisture and therefore provide a fresh and suitable place for living during the hot and intolerable summer for the residents and people.

Wind-catchers, as its name denotes, are architectural parts of hot & dry regions that use the wind as an environmentally friendly energy to moderate temperature to the comfort level. Wind-catchers are the vertical elements that can be seen in the cities and after the Minarets of the mosques; they were defining horizon line of old cities. The wind-catcher operates according to wind condition and sun radiation in this region. In ancient times, traditional buildings in arid-dry regions, wind-catcher worked naturally like modern air conditioning system. A wind-catcher is like a chimney whose end is in the underground room and the top is a net over a specific height on the roof and were built at the entrance of the house over underground water reservoirs or ponds built inside the house. The dry and warm wind would pass over a pond with fountain gets cool and wet through evaporation.

Keywords: Wind-catcher, Sustainability, Passive Cooling, Traditional Architecture

1 Introduction:

Badghir (Wind-catcher) is a sustainable element of Iranian traditional buildings in hot & dry regions of Iran considered as a passive ventilation method in architecture for cooling houses built in these areas. In addition to their height (as wind-catchers built very tall) the wind-catchers are also considered as a symbol of towns centered in the desert. In those houses, the wind-catcher is usually constructed in southern side of the court-yard.

2 Wind-Catcher And Its Functions

Wind-catcher is a vertical element which is like a chimney whose end is in the underground and the top is net over a specific height on the roof and were built at the entrance of the house over underground water reservoirs or ponds built inside the house. The dry and warm wind will pass over a pond with a fountain and gets cool

and wet through evaporation. The wind-catcher with one face open at the top, this open side faces the prevailing wind, thus catching it and conducts it down the tower.

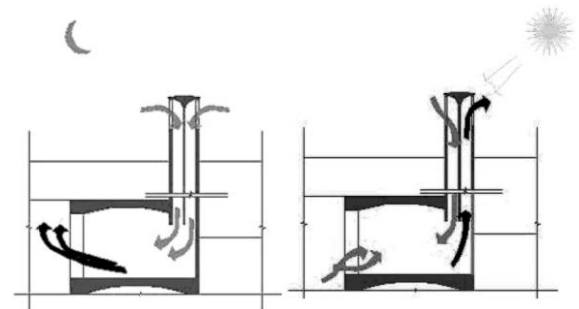


Fig.1: Wind-catcher function during day and night time

The pressure differential between two open faces causes air to be drawn down into duct and after bumping against upper ceiling of the wind-catcher it flows from vertical element which is like a chimney into pond and by coming into

contact with water surface it gives its warmth to water and is cooled by evaporation and thus cooling the building interior in natural a manner (like wind-catcher of Dowlatabad Garden in Yazd).

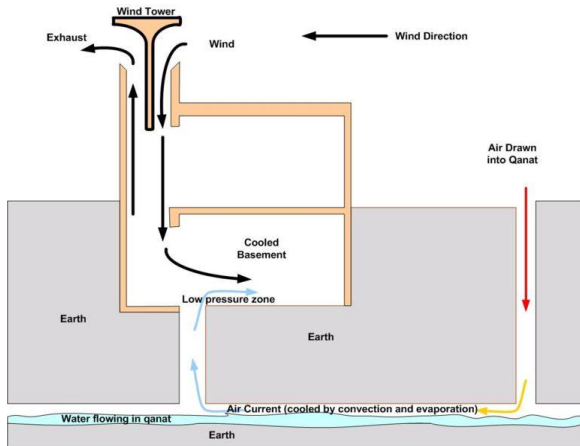


Fig.2: Wind-catcher function

It is worth mentioning that in humid areas the wind passes only through dried duct (like wind-catchers in southern ports) and cooling the building interior. Meanwhile, by planting trees and plants in the courtyard the humidity remains among plants and while the wind is blowing, this humidity helps to cool the air [1].

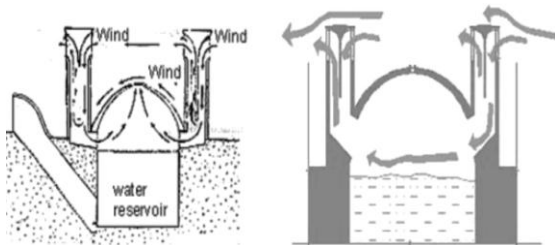


Fig.3: Wind-catcher function

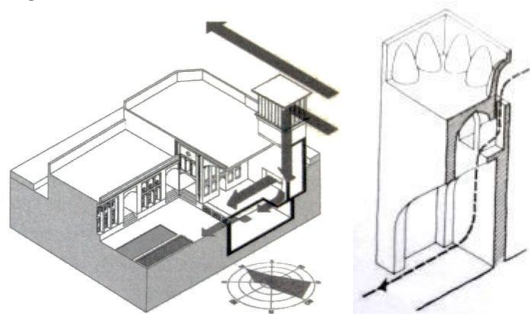


Fig.4: 3D section of wind-catcher function

Wind-catcher direction is built against the air current to current to collect the optimal air

circulation of the area. For example, in Ardakan the wind-catcher is built in a northerly direction in order to conduct northern air inside the home. The main function of the wind-catcher is summarized in two parts: one is to deliver fresh and pleasant air to a building interior and secondly to sending the hot and polluted air out it works like a ventilation and a sucked machine. In order to control the wind, on the path of some of wind-catchers that lead to a basement or a cellar, the bear walls in form of two small shelves with two oblique coat -were made with a wooden entrance door. In winter, entrance door is closed due to cut off interior and exterior space of the room.

3 Wind-Catcher Elements:

A wind-catcher is formed of some parts: roof, shelf, stalk, blade and chimney.

3.1 Roof

In different shapes: A) Flat roof wind-chatcher, B) Sloped roof wind catcher, C- Curved roof wind-catcher

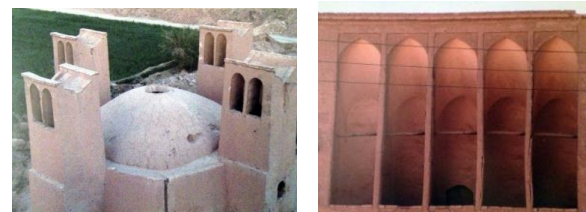


Fig.5: Sloped roof in Yazd (left) and Curved roof (right) of wind-catcher in Ardakan, Iran

3.2 Shelf

The head of the wind-catcher is the shelf which includes the blades and the air passing channel.

3.3Stalk

That part of the wind-catcher which is located between shelf and the room is called the "stalk"; the higher the wind-catcher, the taller its stalk is.

3.4 Blades

Elements consisted of mud-brick and brick that divides shelf into smaller ducts.

3.5 Chimney

It is a vertical element which is usually rectangular cube and sometimes in pyramid form in order to transfer air circulation vertically.

3.6 Symbol Functioning

Two types of wind-catchers are usually recognized: functional wind-catchers and symbolic ones.

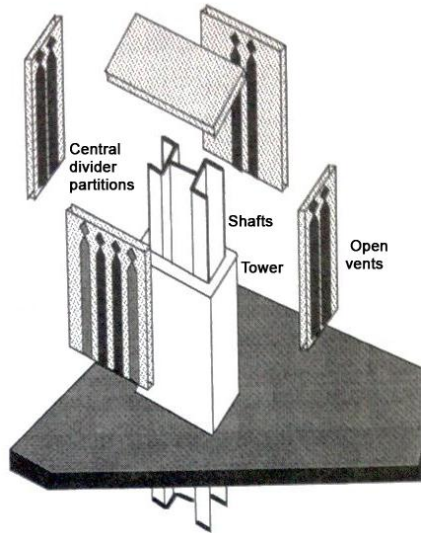


Fig.6: Wind-catcher elements

4 Main Material of Wind-catcher Structures

Main materials of wind-catcher are mud-brick or brick together with plaster of clay and straw but material of wind-catcher structure is usually mud-brick, brick, clay, plaster and wood planks. These hanks have high resistance against termites and they are used for providing tensile force of the wind-catcher. These hanks tie the structure to each other and wood bars ends are put out of structure to create trellis or ladder for constructing the upper of wind-catcher or for doing later repairs and cleaning [2].

5 Kinds of Wind-Catchers

There are different types of wind-catcher as follows: one-sided, two-sided, three-sided, four sided, hexahedral, and octahedral, Khishkhan and Chopoghi (pipe like wind-catcher).

5.1 One Sided Wind-Catcher:

The simplest form of wind-catcher is one sided wind-catcher and it is made in very small sizes to resist black winds and heavy storms. They are built on top of roof over a holed chamber facing cold and pleasant winds and the other side is closed. Sometimes one sided wind-catchers are made away from black winds and in fact this type of wind-catcher functions as air ventilator. It comes in smaller sizes in comparison with other kinds and its shape is more primitive in compare with other kinds of wind-catchers. This diagonal passage (seen on top of roof) after connection with vertical duct inside the wall and exit window of the building such as stove is situated in a corner of the room and ventilate the air.

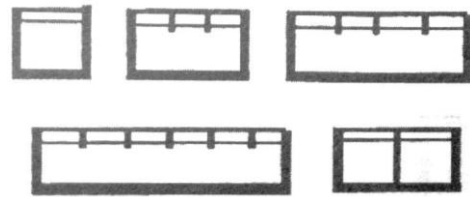


Fig.7: One sided wind-catcher plan

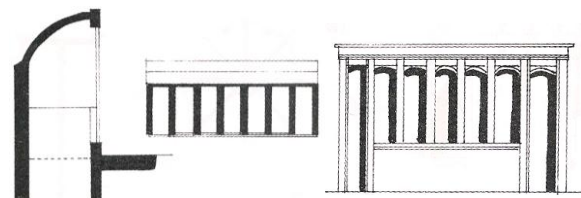


Fig.8: One sided wind-catcher section

5.2 Two Sided Wind-Catcher

This kind of wind-catcher has two sides facing each other and made with vertical and thin windows without frame.

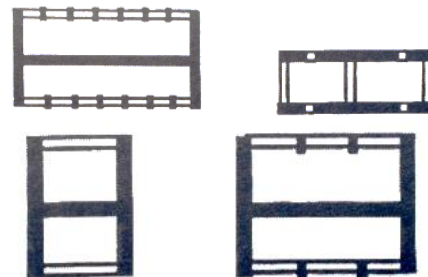


Fig.9: Two sided wind-catcher plan

In building the interior it is seen as one or two openings in niche. This kind of wind-catcher is seen in Sirjan and rarely in Kerman cities, Iran.

5.3 Three-Sided Wind-Catcher

It is of two kinds: joined three-side and disjoined or separated three sides. It can be used in one, two or three sides. This kind of wind-catcher is not so common, but it is used in Tabas, Iran.

5.4 Four-Sided Wind-Catcher

Four-sided wind-catchers are the most current wind-catchers. This kind of wind-catchers is made of both square and rectangular plans. The rectangular forms are usually made in such a way that the big face is towards the appropriate wind. Usually its interior ducts are divided by blades made of brick or wood or plaster [3].

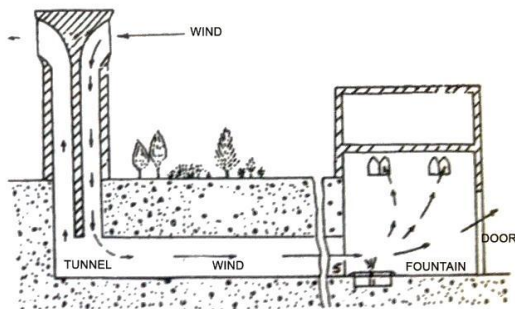


Fig.10: Four side wind-catcher functional section

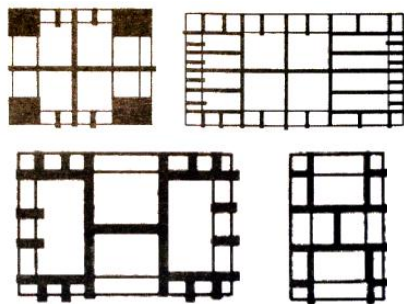


Fig.11: Four sided wind-catcher plan

5.5 The Hexahedral and Octahedral Wind-Catchers

The hexahedral and octahedral wind-catchers can be found in the water-reservoirs of Yazd Shrine, and the octahedral ones can be found in the water-reservoirs of Khanom-Jan in Ezz-Abad Village. These wind-catchers are higher than any other wind-catchers, and they have been designed in the form of octagon, because in this case the form of the wind-catcher has more flexibility against the wind, and also the wind.

Lateral forces decreases against the wind-catcher frame. The reason for designing these kinds of wind-catchers is the existence of favorable winds blowing from any angle and blades can trap the wind and conduct it inwardly.

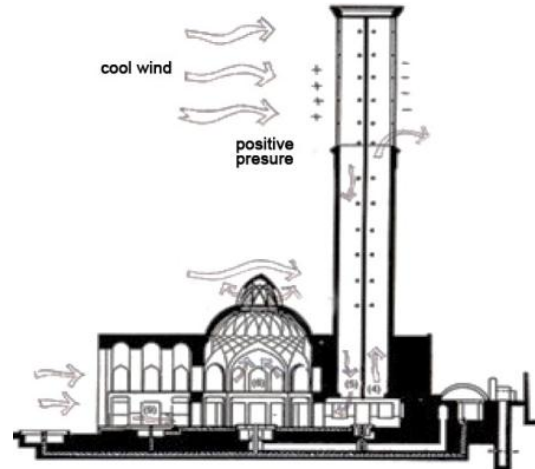


Fig.12: Dowlat abad wind-catcher section

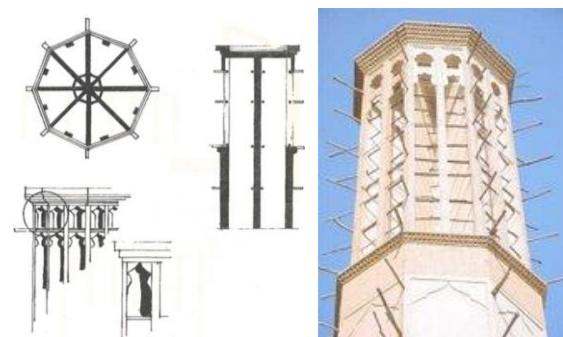


Fig.13: DowlatAbad wind-catcher, Yazd, Iran.

5.6 Pipe Like Wind-Catcher (Chopoghi)

It is the six wind-catchers and it can only be seen in Sirjan in southern Iran. A number of bended pipes are used for its outer size and dimension.



Fig.14: Pipe like wind-catcher(Chopoghi)in Sirjan

5.7 Khishkhan

The other type of wind-catcher is Khishkhan (mud shelves) by putting water soaked mat on it, the cool of the pool house would be increased.

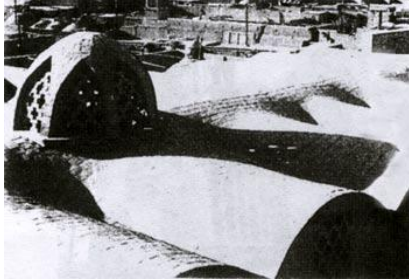


Fig.15: Khishkhan in Yazd, Iran

Here we should mention multifaceted wind-catchers, two-story wind-catchers and hollow wind-catchers. There are some wind-catchers in Shiraz such as Citadel wind-catcher and Karim Khan Zand and Karim Khan Zand water reservoir.

In regions where Howz khaneh (impluvium) (or pool house) could not be made on the ground floor they used to let underground canal to run in the basement and wind-catcher canal running over this water current. These places (cellars) were sitting place of family in summer afternoons in cities such as Yazd, Kerman and Bushehr.

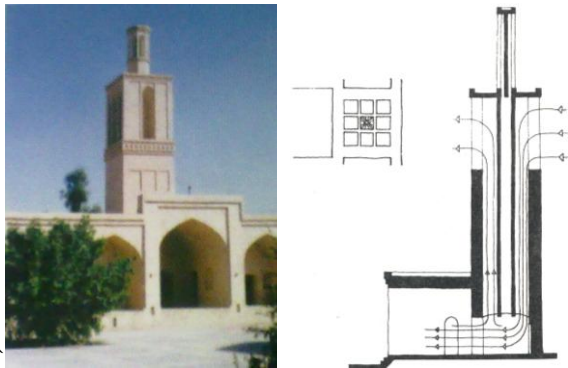


Fig.16: Two-story wind-catcher picture & section

6 Simulated Performance of Wind Catcher's Air Current

With numerical simulation (without considering thermal effects) concerning effect of wind speed, height of inlet canal and also the height of middle blade of the wind-catcher on distribution of speed and pressure over opening side of the wind-catcher and its surrounding residential place, the following results were achieved:

a) A large part of the induced air is provided by a wind-catcher through its opening side facing the wind. Also investigating distribution of the speed in open side away from wind shows that the canal facing away from wind acts as a suction factor for the air and its delivery to residential place. Whirlpools created in the building yard plays a major role in inducing air from the canal facing away from the wind. Also it has been observed that with changes in geometrical coordinates of the wind-catcher in a fixed current scenario, the rate of input of induced air from the canal facing away from the wind shows more sensitivity.

b) With speed wind higher the performance of the wind-catcher as an air inducing system for natural ventilation improves.

c) Reducing the height of inlet canal has a minor effect on the rate of induced air into the residential space. We reach the conclusion that induced capacity of the wind-catcher is associated with height of air inlet canals and air input increases by increasing the height of the opening sides of the wind-catcher.

d) Reducing the height of middle blade of the wind-catcher causes the speed of the air passing through the residential place and as a result the induced air input increases. The interesting point is the increase of the rate of the inlet air from the canal facing away from the wind as the result of reduction in height of the middle blade of the wind-catcher [4].

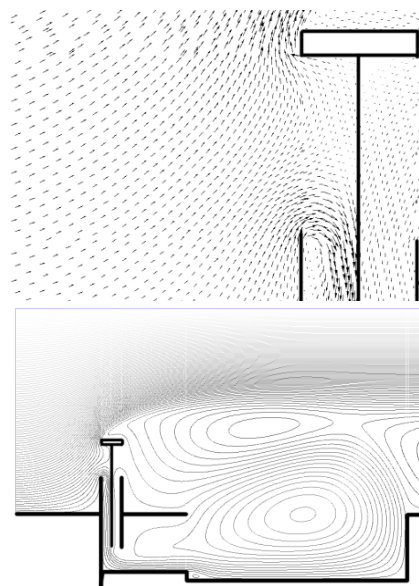


Fig.17: In both pictures wind is 10m/s

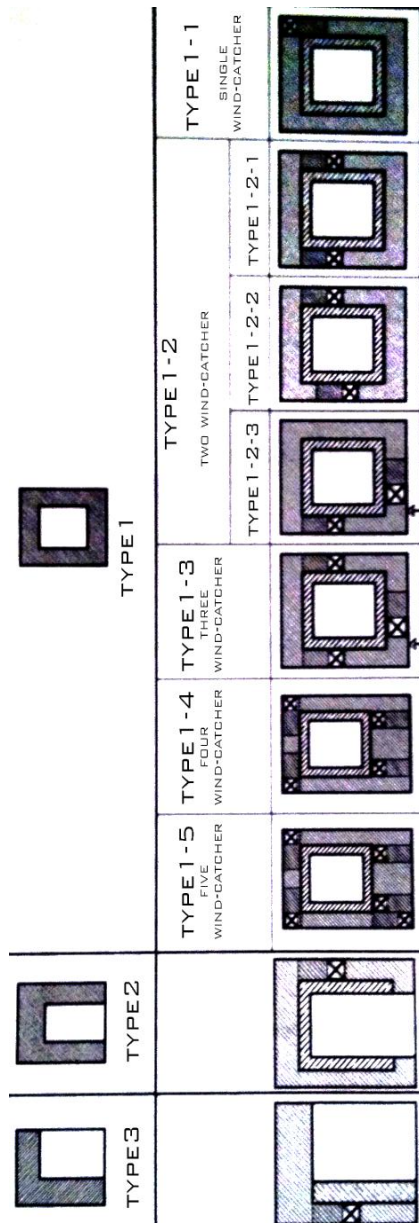


Fig.18:Types of wind-catcher in length port

7 Conclusion

(A wind-catcher is a device with a real/noble form and constant structure in Iran architecture. It leads the suitable wind through the inner part of the building and it is the most effective function in bringing about ease of life.

To encounter unfavorable conditions of the arid climate of the desert in Iran, our ancestors devised such a system to overcome the harsh aspect of nature to make living in the desert tolerable. This architectural element made either

facing good wind or facing away from bad wind used to cool the indoor temperature of the room by directing the wind into the chimney of the wind-catcher and sometimes by passing over underground water canal sometimes by passing over underground water canal.

In the modern era with the advanced constructional technologies and intense urban life it is not possible to use wind-catcher as it was in the past but by learning from architectural ventilation ideas of wind-catcher and by integrating it with modern ideas and contemporary architectural elements we can provide a climatic comfort in terms of building ventilation. It is evident that by examining and investigating unknown technical-engineering aspects of wind-catcher one can revolutionize mechanical air ventilation as used today based on environmental concerns.

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