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

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

December 2013 | Issue 17 | Volume 5 | Number 4 | Pages 124-129

IMPROVE VENTILATION BY WIND TOWER (BADGIR) MODIFIED IN IRANIAN HOT AND ARID REGION

B. Ahmadkhani Maleki

Seraj Higher Education Institute, Tabriz, Iran, bahramahmadkhani@ymail.com

Abstract- A Badgir is a traditional element of Iranian architecture used since centuries to create a natural ventilation in the buildings. Conventional and the modern versions of wind towers can be incorporated aesthetically into the designs of modern buildings in the hot-arid regions of the Iran and other areas of the world with similar climate, to provide summer thermal comfort with little or no use of electricity. In the present study, an attempt is made to study the cooling performance of a wind tower in a hot and dry region, Yazd, in Iran. On this basis the use of two kinds of Wind-Catchers, one with a wet able (soak able) column and the other with wet able surfaces (chaffs) resolves a large amount of traditional wind-catchers problems. The results indicate that the evaporative cooling is very effective in a hot and dry region. The temperature decreases considerably, if wind towers are equipped with water vaporization system.

Keywords: Badgir, Wind Tower, Hot and Dry Region Architecture, Natural Ventilation, Optimization.

I. INTRODUCTION

Environmental and natural phenomena play a very significant role in laying the region's interrelated cultural, economic, and social infrastructures. The buildings in the Iranian desert regions are constructed according to the specific climatic conditions and differ with those built in other climates. Due to lack of access to modern heating and cooling equipment in ancient times the architects were obliged to rely on natural energies to render the inside condition of the buildings pleasant. In past without modern facilities, it was only the intelligent architecture of the buildings that enabled people to tolerate the hot summer. The ventilation structures called Badgirs were the most important means by which the interior was cooled. The wind-catcher operates according to the condition of the wind and sun radiation in the region. In ancient times and in traditional buildings in arid and dry regions the air trap functioned like the present modern air conditioning system. Wind-catcher is like a chimney whose end is in the underground and the top is set over a specific height on roof and were built at entrance of the house over underground water reservoirs or ponds built inside house. Dry and warm wind will pass over a pond with a fountain gets cool and wet through evaporation.

The Badgir's material again plays another role. Due to high fluctuation of temperature differences between day and night in this climate and nighttime coldness, Badgir that is made with mud-brick, gets cool by radiation and convection. The system works, when there is no wind, but when wind is blowing this system does not have problems. Because during the day, if there is wind, then cool air flows faster and at night, with wind, it may absorb the heat of the walls, because the night wind is cool enough.

Nowadays due to the increased use of fossil and electrical fuels, the natural environment is in danger of high amounts of pollution. Hence, by creating natural ventilation with wind-catchers, we may save a significant amount of energy. Due to global converse of sustainable architecture, the use of patio energy and natural ventilation recognizing wind-catchers as a traditional Persian Architecture element seems convenient [1]. Unfortunately, because of vast amount of subjects about wind-catchers we are not able to conclude them all in one paper. The article follows new designs to produce natural ventilation and cooler air with minimum amount of energy by developing traditional wind-catchers.

II. TRADITIONAL WIND-CATCHERS

The wind-catcher has been used in Iran since early times, it is one to the special masterpieces of Iran's architecture and it is also the signs of predecessor's intelligence in agreement with the climate, you can consider it the most specific examples of clean energy. The most number of wind-catchers are in Iran, these wind-catchers are made in two areas: the hot and humid area in south (such as Lenghe Port) and the hot and dry area of central plateau (such as Yazd, Iran in Figure 1).

Traditional wind-catchers are slim elevated 4, 6 and 8 sided tower like structures which are placed on top of buildings and next to Ab-Anbars domes. The Ab-Anbar is a traditional reservoir or cistern of drinking water in Persian antiquity. The Persian phrase literally translates as "water reservoir". In Iran's desert regions, wind-catchers are used to ventilate Ab-Anbars, building interiors and basements. Since Iran's desert regions have predetermined season winds and daily breezes, wind-catchers are built in the direction of the most pleasurable and strongest winds [2].

Figure 1. A wind catcher in a house in Yazd, Iran [6]

The top of wind-catchers are opened and extended in one, two, four, six or eight directions. They cover the top of the aperture but leave it open to the building or the Ab-Anbar underneath. They divide the wind-catchers column's interior into 4, 6, or 8 diagonal brick partitions in a way that from whichever direction wind blows down, in the opposite direction wind is sucked out. This process ventilates the air within the building or Ab-Anbar, (Figure 2).

Figure 2. Ab-Anbar or "water reservoir"

The working process of a wind-catcher is much alike to modern water coolers. When a breeze enters a wind-catcher it is channeled to above a pool. After being exposed to water and evaporation (a heat absorbing process) which results in a cool breeze it is directed to the summer rooms.

III. WIND-CATCHER'S DIVERSITY

Wind-catchers are divided into different classes according to their external form. The simplest of them being the one-directional. In this type to be safe from storms and heavy winds, wind-catchers are built in the direction of the most agreeable wind and are closed off in all the other directions [3].

The second kind is the two-directional type that has two opposite sides with high slim windows and no barrier. The third kind is the four-directional wind-catchers which is built in a more absolute and complex way than the other kinds, (Figure 3). These types are usually divided by brick, wood or plaster partitions. In some cases beautiful large pools were placed under the channels, so the pool's water would absorb the heat and dust of the incoming wind to produce cool clean air in the summers [4].

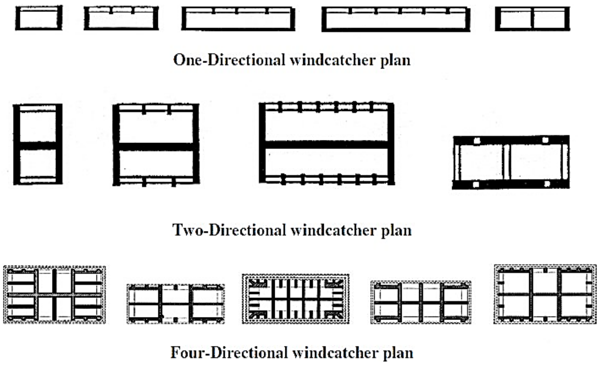

Figure 3. Wind-catcher's diversity plans [3]

In Yazd, Iran and some other central regions of Iran, multi-directional (eight and sometimes even circular) wind-catchers are common. The cause of this fourth type is because it can draw agreeable and pleasant winds from almost any direction and channel it into the building. The Fifth kind of wind-catchers is the pipe like type. In this type instead of the usual cube like external form, we see a few elbow like pipe. The channels and vents in this type are similar to the multi-directional kind. The last stage of wind-catchers evolution is the two-story wind-catchers. To build this kind of wind-catchers first you have to build a large tower with apertures and ordinary partitions on four sides. Then independently from each side, bring the middle of it to a higher level.

The result is a slim wind-catcher placed in the middle of a large fat one in which the thinner one is 1-2 meters higher. If any of the central wind-catchers partitions fell apart then the large four-sided one would still be secure and vice versa (Figure 4).

Figure 4. Wind-catcher diversity in Iran [6]

IV. PERFORM AND SOME POINTS IN WIND-CATCHERS DESIGNING

A wind-catcher is a device with 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 making comfort.

There are actually two kinds of main functions about wind-catchers:

A. Function According to Principle of Traction of Opening Facing of Wind and Suction of Openings Back Against of Wind

The way a wind-catcher works is mainly based on taking the fresh air into the building and sending the hot and polluted air out or the suction functions. Perhaps it is not so necessary to explain that when the wind hits against the walls of internal blades of the wind-catcher it necessarily falls down. However, it is necessary to refer to this point that the other holes of the wind-catcher turning back to the wind direction, gives the hot and polluted air into the wind and so works like a ventilation and a sucked machine (Figure 5).

The function of this kind of a wind-catcher is actually performed according to this fact that when the wind hits an obstacle, and since the density of the air is thick on the side of the wind direction, so in this direction there is a positive pressure, but a negative pressure on the other side. Therefore, when the ventilation is open on the sided of the wind there will be a positive pressure to a negative pressure. In the wind-catchers, according to this principal, the opening facing the wind takes the air into the porch and the air in the porch with its negative pressure on the opening back of the wind is drawn out. Sometimes according to the superficial evaporation, the wind-catcher supplies the necessary moisture by conveying the wind over the weather and the cold-storage [5].

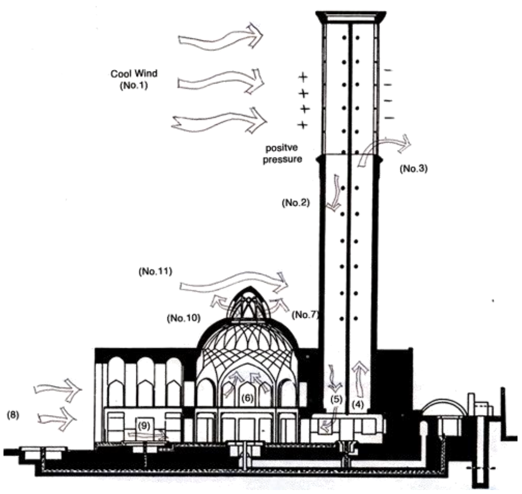

Figure 5. Baghe-E-Dolatabad wind-catcher Section [6]

B. Function According to Temperature Difference

However, it seems that there is a little attention of technicians about the function of a wind-catcher regarding the temperature difference. In fact, when there is not a windy blast sensibly, the wind-catcher acts according to the following action. During the day, since the sun hits on the southern face of the wind catcher, the air heats in the southern face of the wind catcher, and goes up. This air taken above through the inner air of the porch is compensated and in fact, it makes a kind of proportional vacuum inside the porch, and takes the cool air of the inner court into itself, so the existing air in the northern opening is pulled down too. During the night, it becomes cold outside, and the cold air moves down.

This air is saved by the heat and becomes warm on parapets and then goes up. This circle continues till the temperature of the walls and outside temperature become equal. However, before it usually arrives at this situation, the night ends and once again, the wind-catcher acts its function as mentioned above. In general, in most time, wind-catcher does as we explained it, in order to the traction, suction, and the effect of temperature difference (Figure 6).

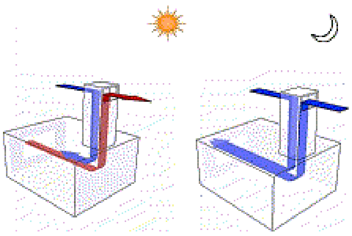

Figure 6. The function according to temperature difference [7]

V. TRADITIONAL WIND-CATCHERS SETBACKS

Wind-catchers, which are used to create pleasant temperatures, are part of the representative architecture in dry and warm areas in Iran. In a sentence, we can define a wind-catcher as a traditional structure for natural ventilation and sustainable air-conditioning. Traditional wind-catchers have been designed and built with the technology and materials of their own time therefore they have the following fault which can be improved with modern technology:

1. Dust, Insects, and occasionally small birds enter the building.
2. A fraction of the entering wind exits from the opposite and other apertures before going down the wind column. This problem is not seen in one-directional wind-catchers.
3. Due to the mass and heat capacity of the materials that used in wind-catchers the amount of cooling energy stored in the wind-catchers mass is relatively small. This amount of energy is unable to suffice the cryogenic needs of a hot day, or the surfaces exposed to air might not be enough for high amounts of heat transfer.
4. Even in buildings with basements after exposing wind to wet surfaces they fail to meet full potential of evaporative cooling. In warm and dry areas, evaporative cooling is an extremely useful process for creating agreeable temperatures.
5. Wind-catchers have no use in areas with weak and slow winds.

The proper function of a wind-catcher as a structure or a process for air-conditioning relies on the effect ness in reaching a pleasant and suitable condition. This condition also depends on the temperature and relative humidity. On this basis the use of two kinds of wind-catchers, one with a wet able (soak able) column and the other with wet able surfaces (chaffs) resolves a large amount of traditional wind-catchers problems [6].

VI. WIND-CATCHERS WITH A WET ABLE COLUMN

In wind-catchers that use a wet able column, water is sprayed by a series of fountains from above to a grid of clay tiles or curtain like surfaces installed within the column. The water amounts at the bottom of the column and is circulated to the top again by a pump (Figure 7). In this general design, there have been major advancements in the following parts:

1. The top of the wind-catcher retrieves winds from any direction and channels it down the column without allowing any of the wind to go out from the other aperture.

2. Additional surface for heat transfer, by involving a grid of tiles or curtain like surfaces inside the column we provide more surface for the heat transferring process between air and the column. These grids and curtain like surfaces also offer moist surfaces.
3. It properly uses air's cryogenic potential.

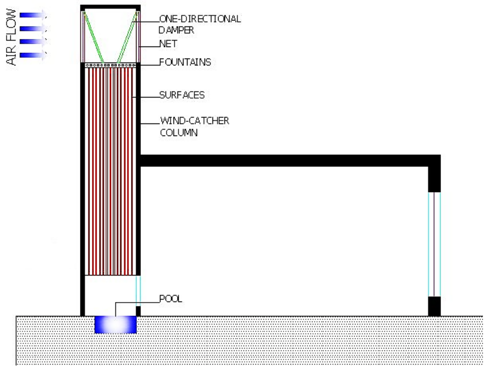

Figure 7. Wind-catchers with a wet able column

VII. WIND-CATCHERS WITH A WET ABLE SURFACE

The structure of this type of wind-catchers is similar to the traditional one but without the slight partitions. In the upper openings of these wind wind-catchers, clay tiles or other soak able surfaces namely "Pad" are installed. Several fountains and a water pump soak the tiles or pads. These kinds of wind-catchers are expected to work well in areas with immobile air, weak and slow wind and for most of the 24 hour day. In this type of wind catcher even without wind after air is exposed to the wet tiles or pads it gets cooler by evaporation and thus results in its density increase (Figure 8).

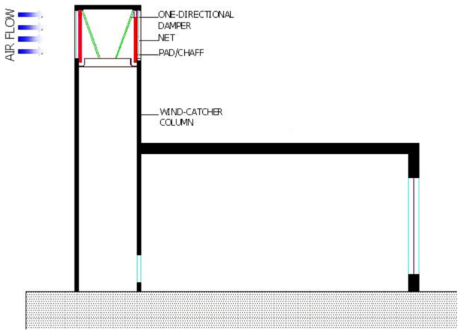

Figure 8. Wind-catchers with a wet able surface

VIII. COMPARING EVAPORATIVE WIND-CATCHERS FUNCTIONALITY

The tested wind-catcher is located In "Golestan Palace" to be found at Ark Square, Tehran, (Figure 9). The name of the building is obtained from its towering wind-catcher. This wind-catcher is the only one decorated with floor tile in Iran. With the help of the central poolroom, the wind-catchers breeze cools the large summer room underneath the wind-catcher Hall. The royal Ganat flows through the central pool room but due to the metro construction it was cut off.

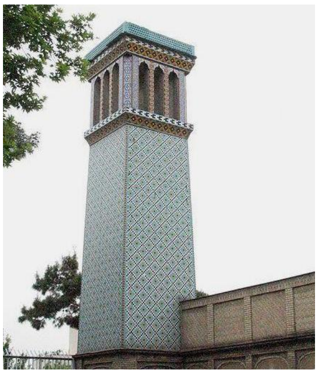

Figure 9. The tested wind-catcher

The wind-catcher is 12 meters high, 2.6 m wide and 2.6 m long. It contains three entry channels. The following is the evaluation of the temperature and cryogenic parameters resulted by the practical measuring of 4 subsequent days in a wind-catcher with a soak able column, and a wind-catcher with soak able surfaces. We placed one of each soak able column and soak able surfaces (chaff) in the side channels, and a soak able surface (pad) in the central channel. And following results are achieved, (Tables 1 and 2, Figures 10 and 11).

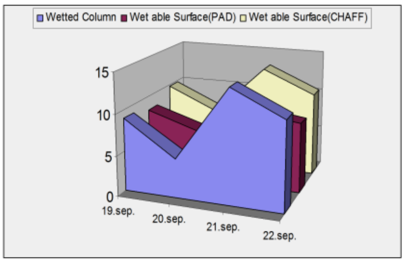

Figure 10. Average cooling production chart (KJ/sec)

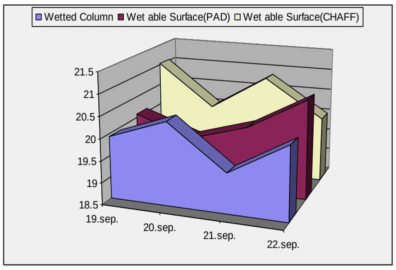

Figure 11. Average temperature range chart

Table 1. Average temperature range

	(℃) T_1 Wetted column	(℃) T_2 Wet able surface (Pad)	(℃) T_3 Wet able surface (Chaff)
19-Sep.	19.94	20.10	21.04
20-Sep.	20.43	19.65	20.05
21-Sep.	19.42	20.05	20.87
22-Sep.	20.20	20.81	20.01

Table 2. Average cooling production

	(KJ/sec) Q_1 Wetted column	(KJ/sec) Q_2 Wet able surface (Pad)	(KJ/sec) Q_3 Wet able surface (Chaff)
19-Sep.	9.01	8.28	9.84
20-Sep.	4.87	6.29	6.99
21-Sep.	14.0	9.45	13.11
22-Sep.	10.92	8.54	10.42

IX. ANALYSIS OF EXPERIMENTAL RESULT

Two modern designs of wind towers are considered which eliminate the traditional wind-catcher disadvantages. One design incorporates one-way dampers in the tower head and a wetted column in the tower. This design, which is particularly suitable in areas with good winds, evaporative cools the hot-dry ambient air before admitting it into the building. The other design incorporates evaporative cooling pads at the tower entrance. This design is particularly suitable in areas with very little or no winds.

The two new designs were one with wetted column, consisting of wetted curtains hung in the tower column, and the other one with wetted surfaces, consisting of wetted evaporative cooling pads mounted at its entrance. The air temperature leaving the wind towers with evaporative cooling provisions were much lower than the air temperature leaving the conventional design, and its relative humidity much higher. The airflow rate was reduced slightly in these new towers.

It was found that the wind tower with wetted column performs better with high wind speeds whereas the tower with wetted surfaces performs better with low wind speeds. It is recommended that these new designs of wind towers should be manufactured in different sizes and incorporated in the designs of new buildings. They can replace the evaporative coolers currently employed in Iran, and other hot arid regions, with considerable saving in electrical energy consumption.

X. WIND-CATCHERS FROM THE FINANCIAL POINT OF VIEW

The main cost for traditional wind-catchers, wet able columns, and wet able surfaces is the same. In the traditional wind-catchers, there are no additional expenses. In wind-catchers with soak able columns, the cost for constructing a tile grid or curtain like surfaces to be installed within the column is considerably high. In wind-catchers with soak able surfaces pads are expensive. However, in wind-catchers with soak able surfaces (chaffs) the expense of straw is significantly lesser than the other two.

XI. CONCLUSIONS

From the societal point of view, in this age of technology and machinery mankind needs designs and equipment that should initially meet our heat and cryogenic necessities and secondly revive our serenity. The use of traditional systems grants us serenity and peacefulness along with comfort. However, even though modern systems provide us with comfort sometimes they strip us from our peace. Old and new technology should bond in way to eliminate the conflicts of human life. Traditional wind-catchers were and are still being used as non-electrical ventilation systems and natural air conditioners in Iran's desert regions. Traditional wind-catchers have a few complications the biggest being the small amount of cryogenically in the wind-catchers' structures mass (Figure 12).

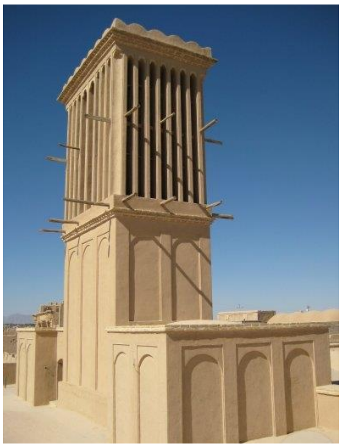

Figure 12. A traditional wind-catcher [8]

By the various methods mentioned above, we are able to improve the cooling evaporation of wind-catchers. As seen in the results of the practical measuring and figure analysis, wind-catchers with wet able columns are more suitable for areas with strong winds (at least 3 m/s) and wind-catchers with wet able surfaces specifically ones with pads have better results in areas with feeble winds.

However, in whole and after examining all the aspects and parameters we conclude that wind-catchers with wet able surfaces (chaffs) have an exceptional outcome and are the cheapest. It also can be used in new buildings in desert regions. In the end, to improve the traditional and new wind-catchers performance we recommend that:

1. In traditional wind-catchers, if we use appropriate materials to cover the inside of the column so it can resist against water and preserve it's humidity it would largely improve its performance.
2. In elevated wind-catchers with soak able surfaces due to the height, the equilibration temperature of the wind flow increases. To prevent this raise we can install curtain like surfaces close to the columns' walls. These wet surfaces will prevent the columns' temperature from affecting the wind.
3. Since water pumps use electrical energy, we can place solar collectors on the exterior walls as well as the roof to generate the required energy.

REFERENCES

[1] A. Mahyari, "Wind-Catchers", Ph.D. Thesis, No. 62, Sydney University, 1997.

[2] M. Mahmoudi, S.M. Mofidi, "Analysis on Typology and Architecture of Wind-Catcher and Finding the Best Type", Honarhaye Ziba Journal, Vol. 36, No. 8, p. 29, pp. 22-23, 2008.

[3] M. Mahmoudi, "Wind Tower as a Natural Cooling System in Iranian Architecture", Passive and Low Energy Cooling in Buildings Conference, Greece, pp. 11-12, 2005.

[4] M.N. Bahadori, "An Improved Design of Wind Towers for Natural Ventilation and Passive Cooling", Solar Energy, Vol. 35, No. 2, pp. 30-41, 2005.

[5] B. Ahmadkhani Maleki, "Traditional Sustainable Solutions in Iranian Desert Architecture to Solve the Energy Problem", International Journal on Technical and

Physical Problems of Engineering (IJTPE), Issue 6, Vol. 3, No. 1, pp. 84-91, March 2011.
[6] B. Ahmadkhani Maleki, "Wind-Catcher - Passive and Low Energy Cooling System in Iranian Vernacular Architecture", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 8, Vol. 8, No. 3, pp. 130-137, September 2011.
[7] B.R. Hughes, "The Development of Commercial Wind Towers for Natural Ventilation", Applied Energy, Vol. 92, pp. 606-627, 2012.
[8] O. Saadatian, "Review of Wind-Catcher Technologies", Renewable and Sustainable Energy Reviews, Issue 3, Vol. 16, pp. 1477-1495, 2012.

BIOGRAPHY

Bahram Ahmadkhani Maleki was born in Tabriz, Iran, 1980. He received the B.Sc. and the M.Sc. degrees from University of Shahid Beheshti, Tehran, Iran. Currently, he is a full time Academic Staff at Seraj Higher Education Institute, Tabriz, Iran. His research interests are in the area of sustainable energy in architecture, green energy, and green architecture. He has published more than 30 papers in international journals and conference proceedings.