Study of Wind Catchers with square plan: Influence of physical parameters

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ABSTRACT

This paper is a synopsis of the results of a research on the wind catcher, the cooling systems in traditional Iranian architecture which used in cities with hot-dry and hot-humid climates. This review demonstrates wind towers' characteristics with emphasis on their morphology. Different ratios between different elements of wind catcher such as its plan's length to width, its tower height to shelf height can be fundamental information in the design of wind catcher as a sustainable element on building. This paper is evaluate the performance of square wind catchers in order to find the most efficient form of square wind catcher in decreasing the indoor air temperature which is square wind catcher with plus blade form. Experimental results are evaluated by numerical method conducted by Fluent.

***Keywords* - Wind Catcher, Natural Cooling System, Wind catcher's Blade, Square plan, Fluent**

I. INTRODUCTION

Environmental and natural phenomena play a critical role in laying the region's interrelated cultural, economic and social infrastructures. Traditional 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 the past, without modern facilities, it was only the intelligent architecture of the buildings that enabled people to tolerate the hot summer. A cross sectional view of wind tower is shown in figure 1.. It is seen in settlements in hot, hot-dry and hot-humid climates. They look like big chimneys in the sky line of ancient cities of Iran. They are vertical shafts with vents on top to lead desired wind to the interior spaces and provide thermal comfort. This architectural element shows the compatibility of architectural design with natural environment. It conserves energy and functions on the basis of sustainability principles [1].

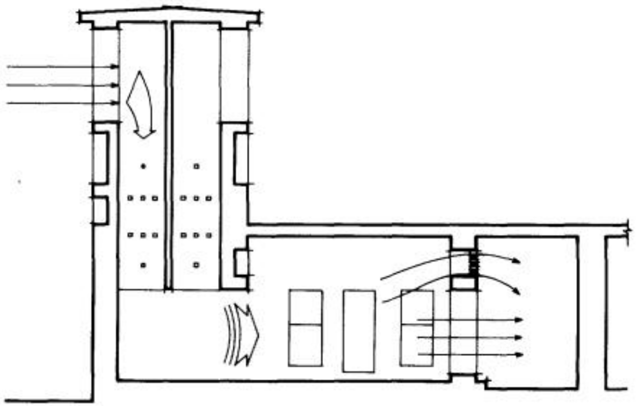

Fig. 1 Cross section of wind catcher

II. ORIENTATION AND FUNCTION OF WIND CATCHER

The orientation of wind tower generally means the positions of the wind tower flank based on the four main geographical directions. It is determined in view of function, use of wind power and the desired direction in which the wind blows. One-directional wind towers can be found in Meibod and they are positioned to face the desired wind. In some cases one directional wind tower acts as air suctioning mechanism with turned its back away from wind direction creating negative pressure which allows warm air of interior to flow out from the house. Desirable wind currents in Yazd blow from the north-west, therefore the long sides of wind towers are oriented north-west for maximum usage of the wind to provide cooling for buildings. In coastal regions like Bandar Lengeh, wind towers have an east-west orientation due to sea breezes and desirable winds that flow during daytime and nighttimes from that direction. Wind towers are also built with a four-directional orientation in order to use all of the desirable winds from north to south and from east to west. Orientations of the wind towers are based on the direction of the main desired wind.

A Wind tower is a formal structural element in Iranian architecture that is used to convey the wind current to the interior spaces of buildings in order to provide thermal comfort for occupants. In Iranian architecture a wind tower is a combination of inlet and outlet openings. A tunnel connected to wind tower provides cool air for building while also serving as a conduit through which the stuffiness within building is conveyed out through wind tower's shaft. There were wind towers in Bam which were destroyed by earthquakes and weren't directly connected to

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the living hall. They were built away from the house and an additional underground tunnel links the base of the wind tower to the basement.

In most wind towers, especially the four sided types, the tower is divided by partitions. One of the shafts operates all the time to receive the breeze and the other three shafts work as outlet air passages. They convey the stuffiness out of the living space through the "flue" (chimney) effect. The chimney effect is based on the principle that the air density increases with the increase in temperature. The difference in temperature between the interior and exterior parts of a building creates different pressures and result in air currents. The average relative humidity or moisture in hot and dry regions is low and it is necessary to introduce humidity within wind tower's system through evaporative cooling. The air current which enters the wind tower is first passed over a stone pond and fountain, thereby bringing humidity to the interior spaces of building.

In some places, mats or thorns are placed within the wind tower and poured with water to increase humidity which helps cool the air flow. The hot weather in Yazd has the potential effect of causing water to evaporate easily to develop cooling in the living spaces and relative humidity in the air, thereby reducing the heat and dryness. It is clear that there is usually high humidity in hot and humid regions because of their vicinity to the sea. In these regions, wind towers reduce the temperature of the surrounding only through the movement of the air they facilitate, not through increased humidity. The level of humidity in this region is already high and an increase of humidity would create uncomfortable living condition. A wind tower in a hot and dry region brings about comfort by evaporation and air motion but a wind catcher in a hot humid region only moves the air and conveys the wind into spaces. Different function and shapes of wind towers were designed for different climates [2].

III. Criteria in Wind Catchers Performance and Design

A wind-catcher is an effective cooling device and constant structure in Iran architecture. It leads desirable wind through the inner part of the building to facilitate thermal comfort. There are actually two main principles in wind-catchers functioning:

1. The principle of traction for opening facing the wind and suction for openings facing away from the wind.

Wind-catcher serve dual functions; bringing fresh air inside building and sending hot and polluted air outside through' a suction process." When the wind hits against the walls of internal blades of the wind-catcher, airflow is brought inside the building. Inversely, when the wind-catcher's hole is turned away from the wind direction, the hot and polluted air will be sucked and released into the wind outside thus functioning as a ventilation or suction machine.

When the wind hits an obstacle, the density of the air is thick on the side of the wind direction, so in this direction there is a positive pressure, at the same time a negative pressure is created on the other side. Based on this principal, wind-catcher's opening which faces the wind, takes in the air while its opening facing away from the wind direction will draw out air (Fig. 2).

2. The temperature difference

It seems little attention has been given to the technicalities and roles of temperature difference in wind-catchers. Wind-catcher's functioning relies on temperature difference when there is no sensible wind available.
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 (Fig. 3).

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. But before it usually arrives at this situation the night ends and once again the wind-catcher acts its function as mentioned above [3].

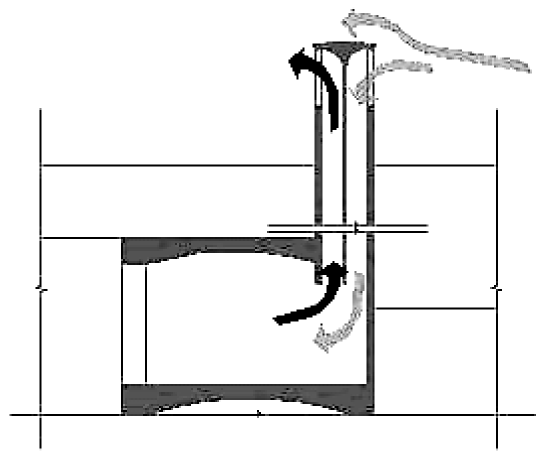

Fig. 2 traction and suction in wind-catcher.

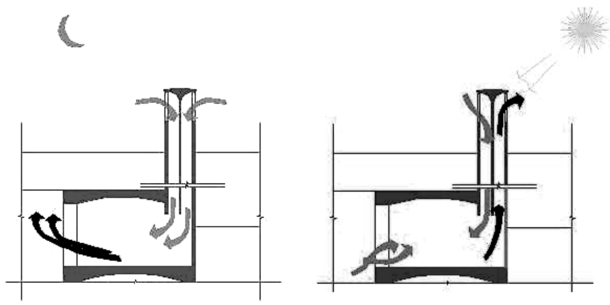

Fig. 3 Wind-catcher function during the day and night

IV. Categories or Types of Wind Catchers Based on Orientations

Wind catchers in Yazd are categorized into five groups by roof, based on their direction.

1. The one directional towers

One directional towers (figure 4) generally face north-west or north. They have a sloping roof and one or two vents only. Otherwise they are commonly described by the direction in which they face such as "Shomali" or north facing. Based on a survey by Roaf [4] 3% of the wind towers in Yazd were unidirectional [5].

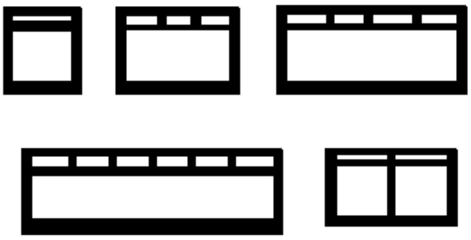

Fig. 4 One directional towers plan

2. The two directional towers

The tower is divided into two shafts by a vertical brick partition as shown in figure 5. It has only two vents. They are often called by direction, such as north-south towers. Roaf's survey indicates that 17% of the towers are of this kind in Yazd and all are found on the ordinary houses.

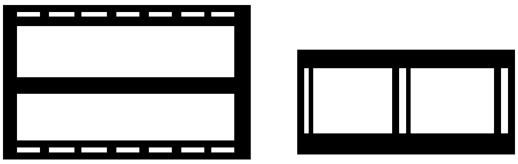

Fig. 5 Two directional towers plan

3. Three-sided wind-catcher

This type of wind-catcher is not usual. A little number of this form can be found in Tabas.

4. The four directional towers

Studies indicate that this is the most popular wind tower. They have four main vertical shafts divided by partitions. More than half of the wind towers in hot and dry region are of this type and they are called Yazdi. Almost all wind towers in hot humid region are the four sided type which is shown in figure 6[6].

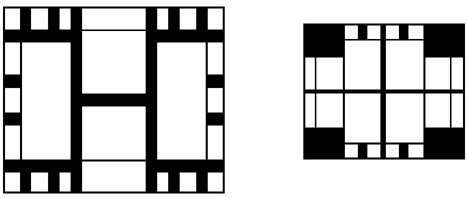

Fig. 6 Four directional towers plan

V. CATEGORIES OR TYPES BASED ON PLAN FORMS

Generally speaking, in Iran wind catchers have been recognized in a variety of forms and plans (figure 7) such as circle, Octagon, polygon, square and oblong. However, no triangular form has yet been recognized or located anywhere in the Middle East. Wind catcher with a circular plan or form is very rare and such type of wind catcher does not exist in Yazd. The square form is the type used in the four directional wind towers in Yazd. The rectangular forms consist of one, two, four directional wind towers. Eight directional wind towers are those with an octagonal plan.

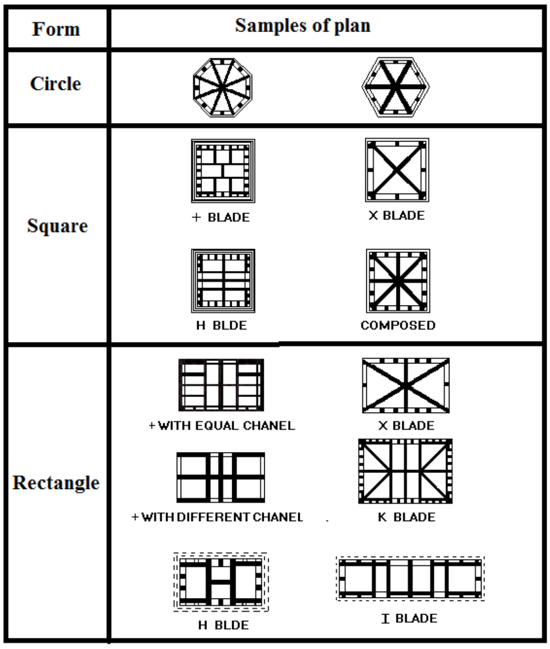

Fig.7 categorization of wind catchers

Partitions are component in wind towers which divide it into several shafts. They are built of mud brick. These partitions form a plane grid of vents ending to a heavy masonry roof on top of the tower. Partitions can be classified into main partition and secondary partitions [7]. Main partitions continue to the centre of the tower, forming a separate shaft behind the vents. These partitions often start between 1.5-2.5 m above the ground floor level. The patterns of the partitions vary from tower to tower, but the most commons are in forms of I, H and diagonal. Secondary partitions remain as wide as the external wall, about 20-25 cm. A shaft can be subdivided by a number additional partitions performing either structural or thermal role. These can separate the tower, respectively into two or four shafts. Partitions divide wind tower into small shafts to increase air motion according to "Bernoly effect". Air flow rate increases when air passes through narrow section [8]. Such an arrangement also provides more surfaces in contact with the flowing air, so that the air can interact thermally with the heat stored in the mass of these partitions. They function as fins of radiator because mud brick partitions give back stored heat during the night and are also good in absorbing heat. Contact between warm wind and mud brick partitions can transfer heat to the partitions, thus wind with less heat will enter the space.

VI. EXPERIMENT

Four square form wind catchers with different blades form including +, x, H and K which are shown in figure 8 as model 1 to 4 were investigated to find out the effect of wind catchers on decreasing the indoor air temperature. The air temperature inside and outside the wind catchers are measured by a thermometer. The dates selected for the experiments is on the 23rd and 24th of July which represent the hottest days in Yazd. In order to comparison all selected wind catchers have almost same specification such as tower height, shelf height, plan dimension and wind catcher room size which is represented in table 1. The only variable in this experiment is the blade form of wind catchers.

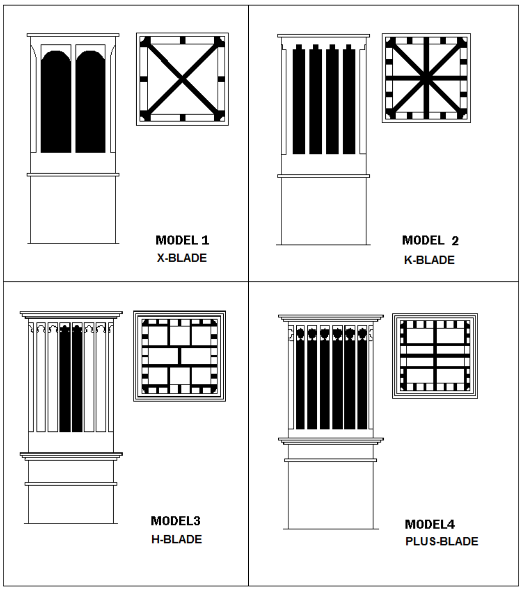

Fig. 8 Plan and elevation of investigated models

Table1. Specification of selected square wind catchers

Type of square wind catcher	Tower height (m)	Wind catcher room (m^2)	Plan dimension (m^2)	Shelf height
X blade	8.50	6×4	1.5× 1.5	1.50
K blade	8.35	6× 4	1.45× 1.45	1.45
H blade	8.42	5.8× 3.9	1.42× 1.42	1.42
+ blade	8.56	6×4	1.5×1.50	1.48

VII. RESULT

Through the chart in figure 9 when the outdoor temperature is maximize around 43ºC on 2:30 pm, the wind catcher room temperature is around 39 ºC in model 1, 38c in model 2 ,38.5 ºC in model 3 and 36 ºC in model 4.hence these kinds of wind catchers can decrease the temperature between 3ºC to 7ºC while outdoor temperature is in the highest level. Outdoor temperature decrease gradually in the afternoon while indoor air temperature decrease 3ºC to 5ºC up to 8pm. After 8 at night, indoor air temperature is 3ºC to 4ºC more than outdoor temperature, which is the time that courtyard air temperature is less than indoor air temperature and indoor thermal comfort could be obtain by opening the windows of room. As we can see through the chart, indoor air temperature in wind catcher room with plus form blade wind catcher is than other samples. As 36 ºC is not an ideal comfort temperature, ancient architects use water pond under the wind catcher for evaporative cooling in order to decrease the indoor air temperature. In order to validate the results numerical method is employed conducting by Fluent 6.3 for X-blade wind catcher which is shown in figure 10. As shown in figure 11, the difference between numerical result and experimental result is 8% which is acceptable.

VIII. CONCLUSION

The wind catcher is an intelligent exploitation of wind energy which makes possible thermal comfort in hot region. The major advantage of the wind towers is that they are passive systems, requiring no energy for their operation. Wind catchers can be categorized based on the ratios between their different parameters such as height, width, and length as demonstrated in this study. The categorization and performance study of wind-catchers as undertaken in this study are the initial steps towards providing a more comprehensive guide of wind tower designs for passive cooling.

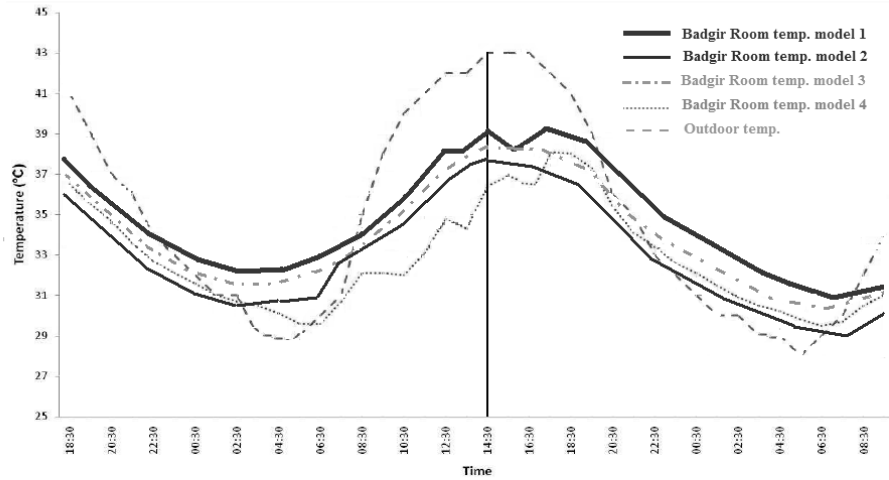

Fig.9 Outdoor and indoor temperature of models

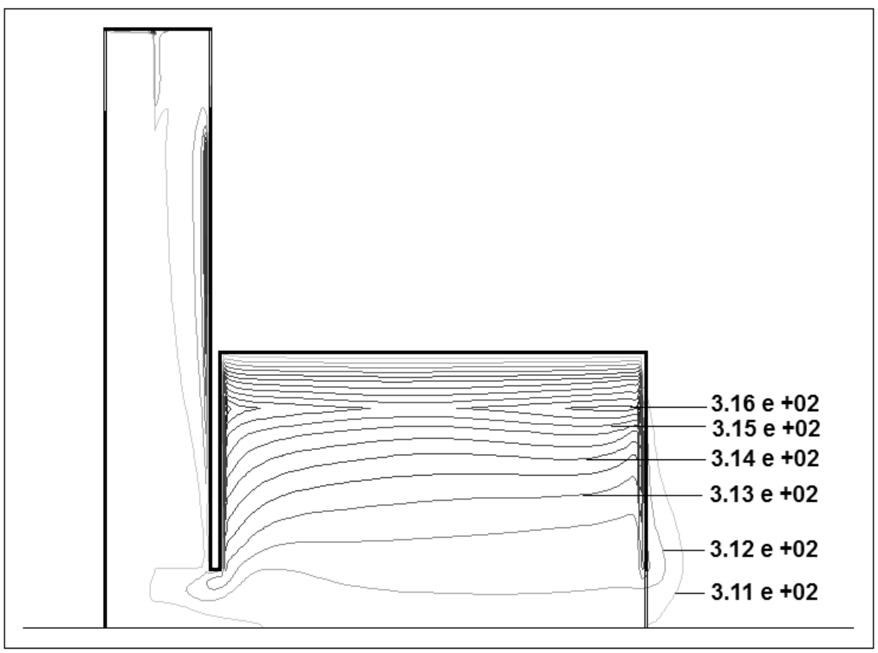

Fig.10 temperature contour of x-blade form wind catcher

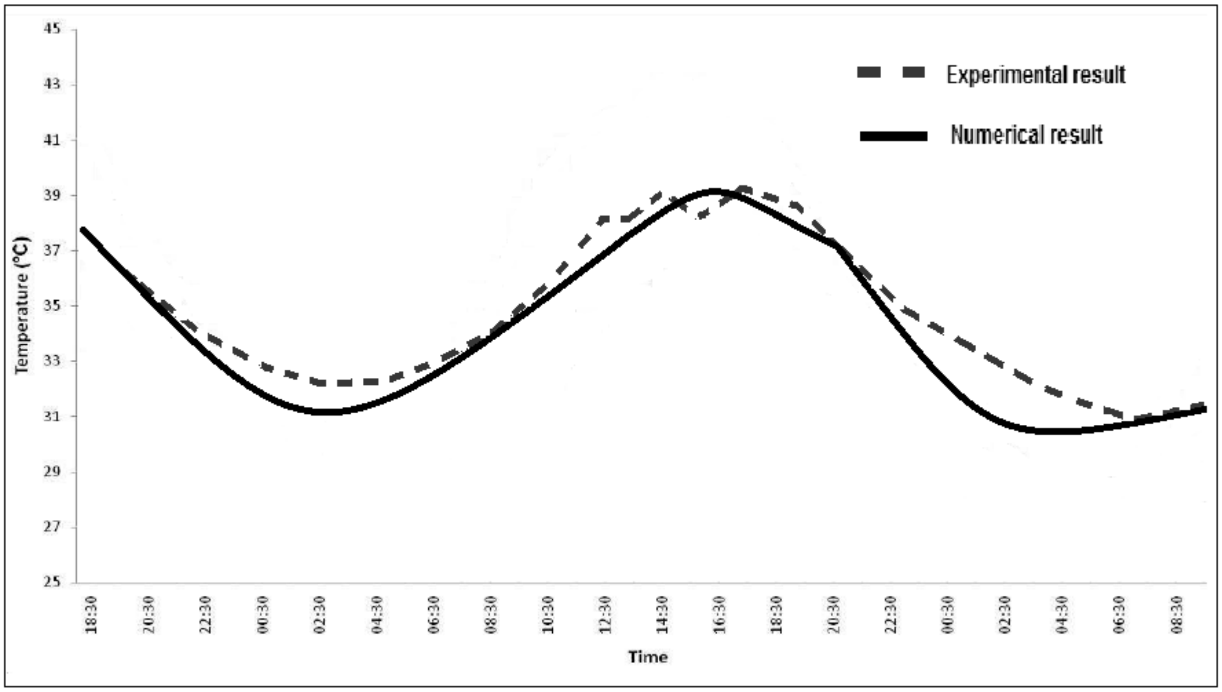

Fig.11 Comparison of numerical and experimental result of x-blade wind catcher

REFERENCES

[1] M.K. Pirnia, Wind catcher, *Journal of Art and Architecture, 10(1),* 1971,30-34

[2] P.Ghaemmaghami, Wind Tower a natural cooling system in Iranian traditional architecture, *1st international conference passive and low energy cooling for the built environment*, Santorini, Greece, 2005, 71-76

[3] A. azami, Badgir in traditional Iranian Architecture, *1st international conference passive and low energy cooling for the built environment*, Santorini, Greece, 2005, 1021-1027

[4] S. Roaf, *The wind catchers of Yazd*, PhD. Thesis, Oxford Polytechnic, 1989

[5] G.H. Memarian, *Residental architecture of Iran* (Soroshe danesh, 1996)

[6] M. Mahmudi, *Badgir, the symbol of Iranian architecture*,(Yazda, 2009)

[7] A. Mahyari, The wind catcher, PhD. Thesis, Sydney university, Australia, 1996

[8] M. Mahmudi, Analysis on Iranian Wind Catcher and its Effect on Natural Ventilation as a solution toward Sustainable Architecture, *World Academy of science, Engineering and technology*, 2009, 574-575.