Investigation of the Middle East Windcatchers and (Comparison between Windcatchers in Iran and Egypt in Terms of Components)

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ABSTRACT: This paper investigates the function of windcatchers in dry regions in Middle East and compares them in different fields in two areas including Yazd-Iran, and Egypt. The study examines windcatchers in these areas in terms of cooling system and forms, with different plans, forms, constituent components and decorations.Reassessment of windcatchers in these areas can shed light on these differences. Survey was carried out by systematic comparison sampling. Comparison of windcatcher components and performance in two areas of the Middle East can result in a comprehensive understanding of the differences in these two areas. However, to keep factors affecting windcatcher components constant, two windcatchers in two similar regions are investigated.Case comparison between windcatchers in Iran and Egypt in terms of the constituent components can be informative about the windcatcher architecture in two regions with similar climates and different cultures and can give us general knowledge of the issue. Findings of the research have shown that windcatchers have formed a cooling system in the Middle East traditional buildings and their primary function is conditioning using the wind renewable energy. The cooling system works in two ways: through displacement and displacement and evaporation. The latter has been particularly used for hot and dry climate. In hot and arid regions of the Middle East, the windcatcher shapes were determined according to the prevailing wind direction.

Keywords: *Windcatcher, Windcatcher performance, Middle East windcatchers,Yazd, Egypt*

INTRODUCTION

Windcatcher is known as a traditional conditioning element with the function of "Catching the Wind", as the name suggests. Indeed, here favorable wind is intended; therefore, the unfavorable wind should be prevented through an informed architectural design. This has been prevalent in the Middle East because of hot weather in this area. Each region in the Middle East has built windcatchers according to its prevalent weather. Therefore, those in Iran, Egypt, Iraq, and Pakistanare different. The next factor that affects the windcatcher architecture type is that of components, dimensions and proportions of windcatchers. Column, opening, blades and roof are components of a windcatcher. The conditions affecting the shape of windcatcher dictates two kinds of windcatcher performance: 1) conditioning the air of indoors in the absence of wind and 2) taking and transferring prevailing airflow inside the building to cool it. This is done in presence of wind. In the former, windcatcher absorbs heat by the walls and duct during daytime and in the latter, windcatcher traps the prevailing airflow.

MATERIALS AND METHOD

In this study, Iranian and Egyptian windcatchers from two cities with different climates and their components are compared.Since the two windcatchers under study are in hot and dry regions, the comparison can focus on variance in components. Different types of Iranian windcatcherscan be classified according to their inner blade arrangements and also the number of openings. Typically, the Malqaf direction is towards the prevailing wind. As Egyptian windcatcher is usually one-sided, the inlets sensitive to the prevailing wind are more common. The probability distribution of wind speed and direction at the site is very important to maximize the natural airflow. Egyptian windcatchers' columns are built in favorable

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ventilation spaces. Generally, the Malqaf column is square or rectangular. The column shape is not visible from outside the building, because the dominant airflow occurs at low altitude. Questions that arise here are: "What is the difference between Malqaf and Iranian windcatcher in hot and dry areas in terms of their components?", "What is the Malqaf structure?", and "Why were windcatchers in Egypt built this way?" The diversity of windcatchers in the Middle East is surprising given the fact that their functions are based on a common element, i.e. wind. Investigation of this issue is necessary since despite similar function of windcatchers in hot and dry areas of Iran and Egypt, they were built in two different forms. The objective of this study is to investigate windcatcher structure in dry climates of Iran and Egypt, and to examine cases from windcatchers in Cairo and Yazd. Through the observation of differences in the two samples, a general conclusion will come.

In this part, general windcatcher function will be reviewed to be known how windcatcher components work.

Description of theWindcatcher System

The buildings with only one window opening usually have poor ventilation because it is difficult for wind to change its direction to enter the interiors of the buildings, especially when the window opening is small. The windcatcher is designed for solving this problem (as shown in Fig.1(a) and (b)). It can change the direction of wind and channel the fresh air into rooms (Fig. 2). Generally, the windcatchers are installed on the roof of a building in order to increase the outdoor-indoor pressure gradient and velocity gradient, and to provide more fresh air into rooms. In order to induce more air into the interiors when the wind direction varies, the stack of the windcatcher is usually divided into two halves or four segments.

Windcatcher is composed of wind-in (inlet) and wind-out (outlet) which are structural elements with inhaling and exhaling architectural functions. Wind-in is the architecture inhale which catches the airflow and leads it down. Wind-out provides airflow exit and is the architecture exhale. The

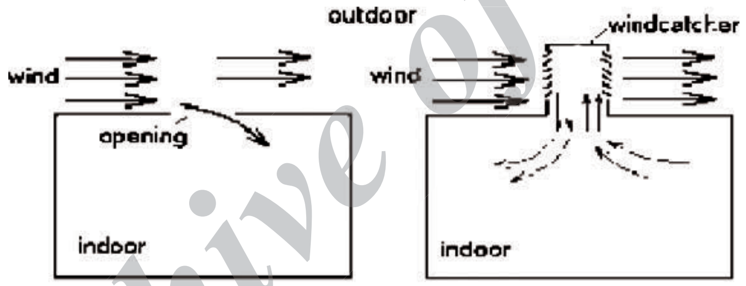

Fig. 1: Comparison of different ventilated rooms. (a) Rooms without windcatcher; (b) Rooms with windcatcher (Source: Li & Mak, 2007)

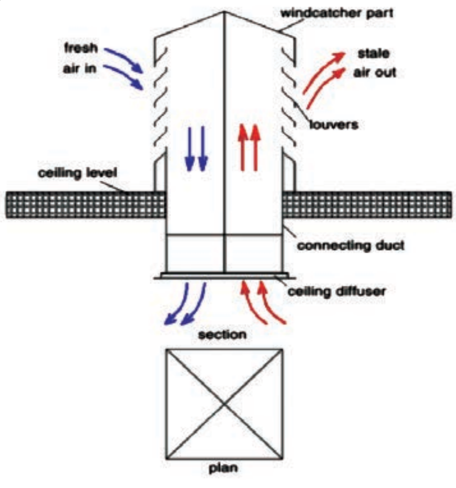

Fig. 2: The structure and principle of the wind-catchersystem (Source: Li & Mak, 2007)

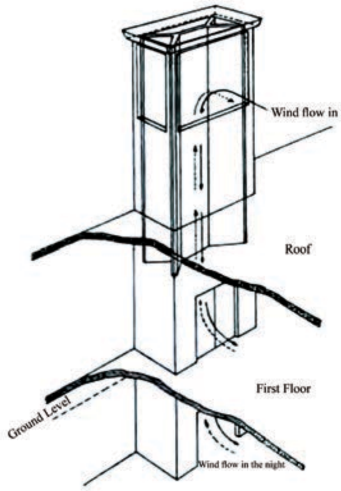

Fig. 3: Section of traditionalwindcatcher, the arrows shows the direction of the wind in day and night (Source: Azarm et al., 2012)

main task of windcatcher can be summarized in two parts: conditioning the indoor air in the absence of wind; and taking and transferring prevailing airflow inside the building to cool it in the presence of wind.

The first function of the windcatcher is air conditioning in the absence of wind where windcatcher absorbs heat by the walls and duct during daytime and releases it during the cool nighttime (Fig. 3) (Azarm et al., 2012).

Fig. 3: Section of traditionalwindcatcher, the arrows shows the direction of the wind in day and night (Azarm et al., 2012)

The next day, in the absence of wind, the outer warm airflow enters the wind and gets cooled by heat exchange with the windcatcher wall and duct which had got cool the night before. The entering airflow circulates through the building and exits from the back entrance of windcatcher and windows. During night, the cool airflow enters the building via the windows and the windcatchers and absorbs heat and takes polluted air out via the back windcatcher openings. In the presence of wind, due to the pressure difference between the windcatcher and windows, airflow enters windcatcher. The incoming air passes over water and gets cool. Then, it circulates in the open space and exits from the doors and windows of the building and the windcatcher back openings (Fig. 4) (Mahmoudi, 2008).

Checking the Windcatcher in Middle East

Before the industrial revolution, residents of hot arid zones were encouraged to figure out natural ways to cool their houses and keep them as comfortable as possible during hot days. In the Middle East, different approaches had been attempted by dwellers according to different cultural and climate conditions (besides material availability)(Fig.5and 6) (Al-Shaali, 2002, 48). By looking at Fig. 5 and 6, it is understood that there are

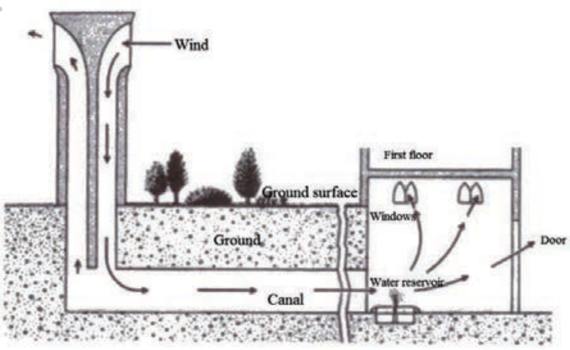

Fig. 4: Section of a wind catcher in Bam-Iran, the function of a windcatcher in blowing of the wind
(Source: Bahadori Nejad& Dehghani,2008, 17)

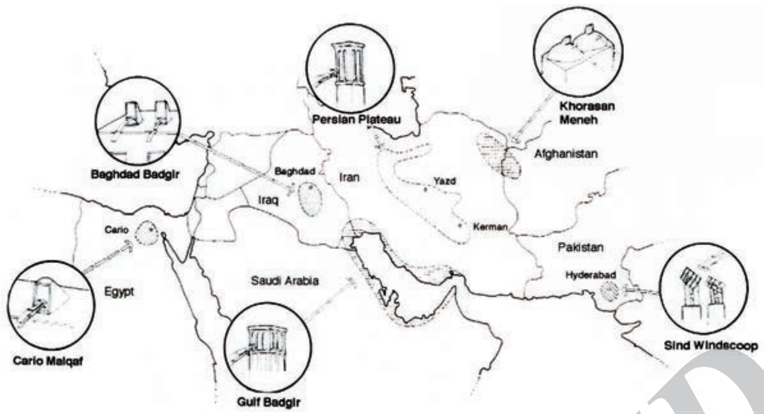

Fig. 5: Wind Catcher in the Middle East
(Source: Al-Shaali, 2002, 48)

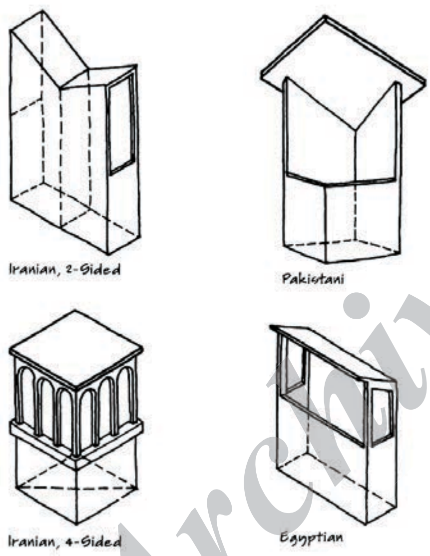

Fig. 6: Wind Catcher in the Middle East
(Source: Al-Shaali, 2002, 48)

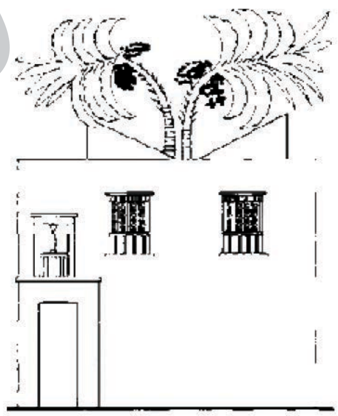

Fig. 7: Malqaf of the Pharaonic, house of Neb-Amun
(Source: El-Shorbagy,2012)

a number of windcatchers in terms of predominant wind and common culture in middle east countries like Iraq, Afghanistan and Iran. Here, Egyptian windcatcher and their function as a subset in middle east windcatchers, will be checked.

Malqaf (Egyptian Windcatcher)

Malqaf or windcatcher is a primary Egyptian vernacular device which leads the wind in to the building. For centuries, Malqaf, as a good solution, was used for natural ventilation (El-Shorbagy, 2012). There are number of architectural elements which help provide cooling in internal spaces, including an inner courtyard, local materials and windcatchers.Throughout history, a windcatcher was introduced as an architectural device, which achieves thermal comfort inside buildings. It is believed that it is a traditional Persian architectural device, which was used for many centuries, but there is evidence that the idea of the windcatcher dates back to the early Pharaonic periods. Examples can be found in the Eighteenth Dynasty houses of Tal Al-Amarna. The Pharaonic house of Neb-Amun (Fig. 7), shows a windcatcher with two openings, one facing windward to capture the cool air and the other facing leeward in order to evacuate the hot air by suction.

Comparative Analysis of Yazd's - Iranian And EgyptianWindcatchers

Here's a comparison between the components of Persian and Arabic (Egyptian) windcatchers. As the weather conditions need to be identical for the purpose of this study, the comparison was carried out between the windcatchers in hot and dry regions of Iran and Arabic countries (Egypt). Egypt (Cairo) is located at 30.05 degrees North and Iran (Yazd) is located at 31.90 degrees north, indicating similar regions being studied in the two countries.

Below is a review of Cairo climate. Cairo, the capital of Egypt, is in the middle of the northern and southern Egypt. Thus, it has a temperate climate inclined to hot and dry. In addition, Egypt is a desert country. The climate of Egypt indicates desert unfavorable wind that carries dust with it. For natural ventilation in buildings windcatchers are used. Due to unfavorable winds, the windcatchers had to be one-sided and face dominant favorable wind direction. The favorable wind direction is usually north-west. A system should be provided in the windcatchers so that wind is created via evaporation and displacement. However, the prevailing wind direction in Yazd, Iran is North-West and North-East.

Comparison of Yazdianand Egyptian Windcatcher Components

At this stage, the windcatcher elements as factors affecting the windcatcher performance, are examined in Iran and Egypt. Windcatchers are made up of four main sections:

Column (body, stem or channel) which is usually in cubic, rectangular or prism form.

Opening(shelf, stem or spring) which is located at the top of the windcatcher and consists of blades and the airflow pathways. The opening is divided by vertical fin-like blades which increases its strength, has aesthetic functions and prevents the birds from entering it.

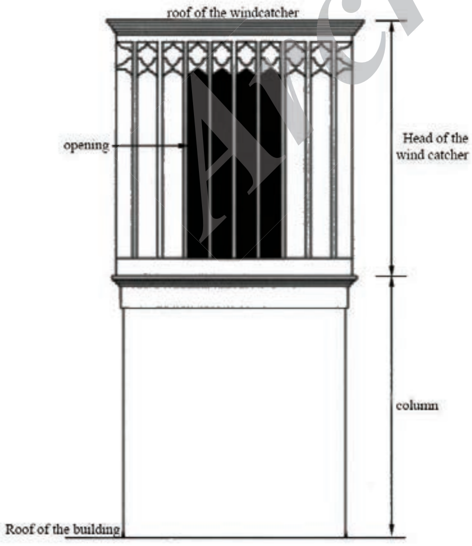

Fig. 8: Components of a windcatcher (Source: Bahadori Nejad & Dehghani, 2008, 247)

Blades: blade is an element composed of clay and brick that divides thewindcatcher channel into few small channels.

Roof which is seen in two form of flat and sloped (Bahadori Nejad & Dehghani, 2008, 246) (Fig. 8).

RESULTS AND DISCUSSION

Based on comparison of the windcatcher components, Yazd windcatchers have all four constituent parts, i.e. column, opening, blades and roof. But Malqaf (Egyptian windcatcher) has opening, blades and roof but not column as seen in Iranian ones (Figs. 9 and 10).

Fig. 9: Yazd's windcatcher
(Source: : KazemiEsfeh, et al., 2012)

Fig.10: Malqaf
(Source: Hooshmand Aini, et al., 2012)

In Iranian windcatcher, the windcatcher height is usually 3 to 5 meters above the ground. The height is created by column. The reason for Yazd's column is that there are winds at high speed and heights in Yazd. In Yazd's windcatchers, there are large distances between the blades. That is because the wind speed is high, and the distances canfacilitate wind entrance. The roof is usually flat and windcatcher is a visible architectural element for the buildings. Yazd's windcatcher is placed diagonally relative to the wind to catch the whole air volume given the variety of wind directions. However, in Malqaf (Egyptian windcatcher) only the opening and the roof are seen and there is no column like that in Yazd's ones. In Malqaf, the windcatcher heights is one story above the roof and only opening is visible. The reason is lower-altitude favorable winds in the area. Also, the distance between blades in Malqaf is very small and imperceptible.This is to prevent unfavorable dusty desert wind from entering the building. The Malqaf roof is sloped the reasons for which are discussed below. Because there is a prevailing wind that blows in one direction, the direction of the opening is towards and in line with this wind without significant angle.

Checking the Roof Role in Windcatcher Function

Here, there is a comparison between sloped roof windcatcher and flat roof windcatcher. Fig.11shows the pattern of flow inside and around the one-sided windcatcher with flat roof. It is seen that the flow separates at the lower corner of windcatcher inlet opening, resulting formation of a separated flow in the windcatcher channel. The formation of separation zone strongly decreases the effective area of passing flow. In other word, separation zone in the wind-catcher's channel is an inactive area. It is believed that reducing the effects of separation at the entrance region will increase the ventilation capacity of the windcatcher. The flow separation can cause sudden changes in the pressure and velocity distribution (KazemiEsfeh et al., 2012,).

Fig. 12 presents the variations of measured pressure coefficients on the three internal surfaces of windcatcher's channel .As it is shown, on all surfaces and at point 1 (Fig. 2b) the pressure coefficients are in maximum value, but with movement of air stream towards the bottom of the channel, the pressure coefficients decreases, indicating the acceleration of flow (KazemiEsfeh et al., 2012).

The measured pressures coefficients along the left and right internal surface of the channel are almost identical, indicating the flow symmetry for the zero incident angle. In point 4, on all surfaces, the pressure coefficients drop sharply. This point exactly corresponds to the lower edge of the opening where flow separation occurs. At point 6, the pressure coefficient achieves its minimum value. Partial pressure recovery is seen as the flow approaches the exit opening of the windcatcher (KazemiEsfeh et al., 2012).

It is seen that minimum velocity of airflow occurs in the middle of channel, close to the windward face, where the flow separation occurs. Moreover, the maximum airflow velocity occurs in the corners of channel (KazemiEsfeh et al., 2012).

Fig. 13-a shows the visualized flow pattern inside and around the windcatcher with 15 degrees steep roof. It is seen that even with a roof slope of 15 degrees, the size of separation zone and vortices become smaller than windcatcher with flat roof. The steep roof prevents airflow from moving towards the upper half of windcatcher opening and properly guides it into the windcatcher channel. This downward airflow slightly squeezes separation zone and increases the effective flow passage area (KazemiEsfeh et al., 2012).

The same visualized flow patterns are provided in Fig. 13b and c for windcatchers with roof slope of 30 and 45 degrees respectively. It is noticed that by increasing the roof slope, the separation zone size decreases and the effective flow passage

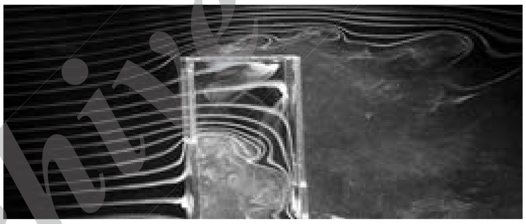

Fig.11: Visualized flow pattern inside and around the one-sided wind-catcher with flat roof
(Source: KazemiEsfeh et al., 2012).

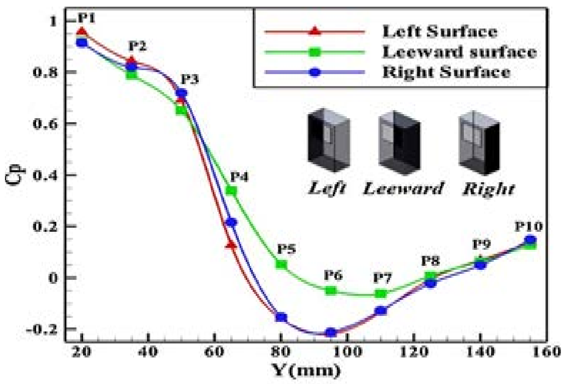

Fig. 12: Pressure coefficients on internal surfaces of the flat roof wind-catcher's channel at zero angle of incident
(Source: KazemiEsfeh et al., 2012)

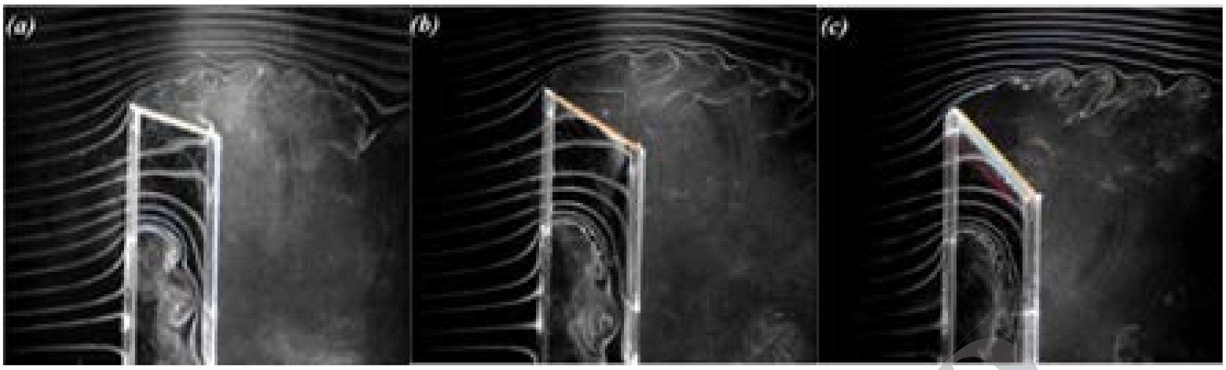

Fig.13: Visualized flow pattern inside and around the one-sided windcatcher with, (a) 15 degrees steep roof, (b) 30 degrees steep roof, (c) 45 degrees steep roof
(Source: KazemiEsfeh et al. 2012)

area increases accordingly. However, increasing of roof slope beyond a certain value may reduce the induced airflow rate. So there may be an optimum angle for roof slope inclination. (KazemiEsfeh et al., 2012). The performance of wind driven natural ventilation is influenced significantly by the boundary conditionsset for the wind. In real conditions, the wind direction is fluctuating constantly, so it is important to consider this fluctuation in experiments and simulations (Ji et al., 2011).

The Reasons for Sloping Roof of Egyptian Windcatchers

If one is asked to provide a general principle based on the above examinations, he can say that in the flat-roof windcatcher, the amount of water entering the bottom of windcatcher and the space being ventilated is less than the one entering sloped-roof windcatcher. If the test results can be generalized and the reason for sloped roof in Egyptian windcatcher is investigated compared to Iranian windcatchers, we can conclude that wind speed in Yazd is high and does not need to be increased. Therefore, since the amount of air entering the space being ventilated is reduced with a flat roof, windcatcher roofs are made in flat form. But, in Egypt due to low wind speed, the windcatcher roofs are sloped so that the amount of air entering the space is increased.

CONCLUSION

Windcatchers are among the traditional natural ventilating elements in the Middle East buildings and their primary functions are different based on climates. Comparison of Iranian (Yazd's) windcatchers with those of Egypt shows that the former have all four constituent parts, i.e. column, opening, blades and roof and all are visible. Iranian windcatcher is built obliquely against the wind. This is because there are different wind directions and this angle is able to get all the prevailing

Table 1: Comparison of Iranian and Egyptian windcatchers in terms of components

Comparison	climatic zone	prevailing favorable wind	Height (meters)	Direction relative to favorable wind	components	Roof type	Distance between entrance blades
Iranian Yazd'sWindcatchers	Hot and dry	North – West, North – East, North	3 to 5 meters from ground level	oblique	all components visible	flat	More than Egyptian Windcatchers
Egyptian Windcatchers	Hot and dry	North-west	One story higher than the roof	In the wind direction	Without column; other component visible	30 degrees sloped	Lower than that of Iranian-Yazd'swindcatchers

wind. Iranian windcatchers have column because there is favorable high speed wind at ground level. In order to catch this favorable wind, the windcatcher height has to be increased via column. In Iran, this height reaches 3-5 meters from ground level. It should be noted that dominant wind direction in Iran is North-West and North-East and North. However, in Egyptian windcatchers, the openings face the dominant wind direction. Egyptian windcatchers don't have columns. This shortens the windcatcher height from ground surface. This is compatible with low-altitude favorable wind. In other words, windcatchers without column can catch low-altitude wind common in Egypt. The windcatcher is one story higher than the roof. It should be noted that the prevailing wind direction is North - West. In Iranian windcatchers, and the distance between entrance blades is more than that in Egyptian windcatchers. This is because dusty weather in Yazd is lower. Iranian Yazd's windcatcher roof is flat, but in Egypt the roof is sloped. This is due to higher wind speed in Yazd which increases airflow inlet. This is compatible with flat roof of windcatchers which allows lower amounts of airflow in. But in Egypt, due to lower wind speed, sloped roof is used to allow higher amounts of airflow in. These are summarized in Table 1.

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