Construction of windcatcher and necessity of enhancing the traditional windcatcher

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1. Introduction

Windcatcher, as its name denotes, is considered as a part of building form customarily constructed in any hot and dry or humid area of Iran. It plays an effective role in modifying heat and adjusting a temperature of interior living spaces in regard to thermal comfort as it uses the convection created by a wind flow and natural pure energy.

Environmentally Sustainable Architecture, also known as "Green Architecture" or "Green Building," is an approach to architectural design that emphasizes the place of buildings within both local ecosystems and the global environment. The windcatcher has been used in Iran since early times, it is one of the special masterpieces of Iran's architecture and it signs the predecessors' intelligence in agreement with the climate, it can be considered as one of the most specific examples of clean energy. The most number of windcatchers are in Iran; these windcatchers are made in two areas: the hot and humid area in the South (such as Lenghe Port) and the hot and dry area of central plateau (such as Yazd) [1].

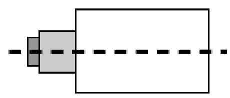
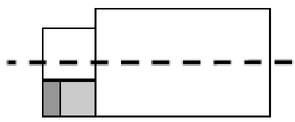
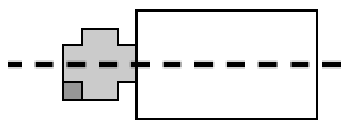
A windcatcher, also often called wind tower, is a device used to deliver fresh outside air to a building interior, and to deliver extract stale air from it. It does not require any human-made energy like electricity. So it is a natural-ventilation device.

In windcatcher the driving forces for the air flow are all natural. They arise from either a blowing wind, or a temperature difference between the building interior and the outside. When windcatcher is placed on the roof of a building, a blowing wind will generate a high pressure on the windward side of the windcatcher, and lower pressures inside the building and on the leeward side of the windcatcher. These pressure differences are often enough to drive the fresh air from the wind into the building, and extract the stale interior air out, through the windcatcher’s openings.

When there is a temperature difference between the building interior and the outside, the windcatcher can also deliver ventilation flow. This is because hot air rises due to changes in buoyancy force on air parcels at different temperatures. In buildings or chimneys, this is called stack effect. This mode of temperature-driven ventilation through a windcatcher is especially effective during summer nights when the outside air is significantly cooler than the air inside, thanks to a much faster cooling rate for the outside air [2].

2. Windcatcher location in plan

Table 1. Three kinds of typology [3]

Type	Description	Model
1	A windcatcher positioned behind the hall on its axis of symmetry. In this type of windcatcher, the axis of symmetry, hall and courtyard extend together.	
2	A windcatcher positioned on a corner of a yard: this type requires that windcatcher is connected to the hall through the medium of an aquarium space but not directly related to it.	
3	A windcatcher positioned on one of northern corner of a hall.	

3. Windcatcher shapes in plan

Shapes of windcatcher is one of the most important factor for the region: any plan shape of windcatcher works different from other. The position of blade makes the shape, and there are two categories of blades: main blades and side blades. The main blades take their rise from a floor at ground reaching 1.5-2.2 m high, continuing to the ceiling of a windcatcher, and contribute to development of smaller ducts. Main blades play operational roles more often and influence the operation of windcatcher. In contrast, side blades are inserted within the input gap of a windcatcher and play lesser roles. These blades add more aesthetic feature to windcatchers rather than anything else.

The blades are made of adobe and brick in the traditional windcatchers.

*A. Windcather with **X**-form blades*

This type of windcather is rarely used in traditional Iranian house. The length of windcatcher of this species is fairly 1/5 times as many as its width (fig. 1).

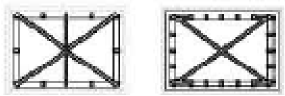


Figure 1. Windcacher with X-form blades [4]

*B. Windcatcher with **+**shaped blades*

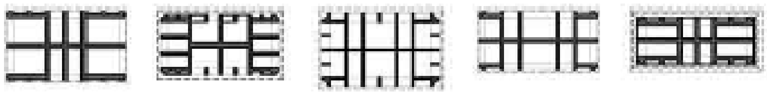


Figure 2. Windcatchers with +form blades [4]

Windcatcher with blades perpendicular to each other and with a +shape is the most dominant windcatcher in traditional houses. The different types of them with various symmetries have been seen in traditional houses .

The depth of its canal in linear front is ½ of its latitudinal depth (fig. 2).

*C. Windcatcher with **H**-form blades*

In this type of windcatchers the main blade isolates the duct of it. It is inserted in the center of canal and does not extend to the latitudinal walls of windcatcher. The symmetries of plan approach the square, and plan is not extended with an oblong. The symmetries of plan is 1-1.3 or less.

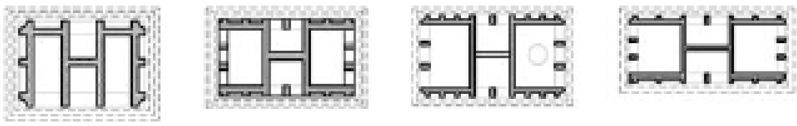


Figure 3. Windcathers with H-form blades [4]

This type of windcatchers with H-form blades is really seldom in traditional houses with windcatchers (fig. 3).

*D. Windcather with **K**-shaped blades*

This species of plan design is a combination of X-blade and +shape blades. It had been rarely seen in traditional houses with windcatcher (fig. 4).

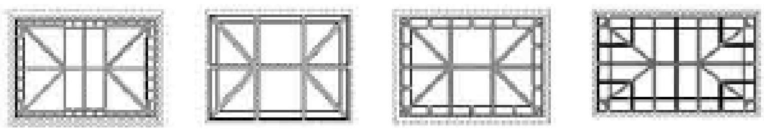


Figure 4. Windcather with K-form blades [4]

*E. Windcatcher with **I**-shaped blades*

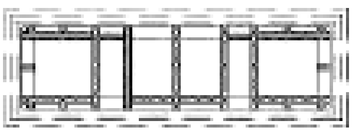


Figure 5. Windcatcher with I-form blades [4]

The main blades are hidden in the latitudinal front of the windcatcher. One closed opening exists on the opposite side of an opened hole to let wind escape. This is the most extended oblong (fig. 5) [4].

4. Material, color and texture of windcatchers

The construction materials used for windcatcher depend on climate. The choice of materials is made to ensure that the windcatcher operates effectively as a passive cooling system. Windcatchers in hot dry regions are built either of mud brick or more commonly of baked brick covered with mud plaster. Mud brick (adobe) passes heat at long time, because soil has got uncompressed volume, and mud is made of water and soil. After evaporating, the empty pit is made. It causes that heat and cool can not arrive in molecules of soil and mud brick or adobe. Mud plaster (kah gel) is mixture of wet earth and fine or chopped coarse straw. These construction materials give the windcatcher a coarse texture. The mud-plaster covering the facade of windcatcherhas has light colour, and this is well for reflects rays.

Windcatchers in hot humid regions are covered with plaster, and this type of covering resists moisture. Vapour in the air in these regions is on the surface with temperature less than dew point in the environment. If there are high penetration on walls and surfaces of building, these drops penetrate in wall for the osmosis pressure or absorption of materials. It causes demolition of surfaces. It pushes salts of materials out of surfaces. The texture of windcatcher is polished with a white colour, which also ensures that the windcatchers do not absorb rays. It provides more operation in climatic function.

Windcatchers trap the desired wind currents and transport them to interior spaces. To fulfil this purpose, a wind tower is designed to raise above the building roof [5].

5. Windcatcher disadvantages

Windcatchers that we used before had lots of disadvantages that made the condition so unwell and uncomfortable in some of traditional houses in Iran in Yazd region that have these windcatchers. Today when CO2 is one of the most concern in the world we have to enhance the windcatcher with new technologies.

The main disadvantages of traditional windcatchers are:

- flies, bees and other insect that go through the windcatcher and make the condition uncomfortable;
- the wind speed that sometimes become very slow – the windcatcher does not work in the low speed;
- the height of the windcatcher – the tall windcatchers work better (the higher windcatchers could catch more powerful winds), but it is not possible to make the windcatchers very tall because of the structures and architecture things;
- the humidity – in traditional houses there were some water survivors under the windcatchers and nowadays it is not possible provide these things for a structure. [6]

6. Ways for enhancing windcatchers

One of the ways that we can enhance the windcatcher is to make them taller. In this case it can get more powerful wind, and sometimes when the wind speed in the lower height is good it can come down.

Another way is to use cellulose network in the entrance of windcatcher with water survivor that can increase the humidity of wind, and because of the humidity the temperature decrease.

One of the best ways to enhance the windcatchers and improve them is to assist sun and the energy of sun by stick the solar panel to the top of the windcatchers. It can get energy of sun and can save it. The fan in the windcatcher that feeds from the solar energy starts in the sunny days when the wind comes down. By the moisturizer damper we can control the humidity and by increasing the humidity we can reduce the temperature (fig. 6).

Figure 6. Windcatcher with solar panel [14]

In normal weather it works as usual windcatchers but in the sunny and high temperature the fan should start and then the damper control part should observe the moisture and all these things start automatically with the sensors that are in the system (fig. 7).

Sola boost windcatcher now is the best way for enhancing the traditional windcatchers. The results of some researches about the features of these windcatchers are below.

Air flow rate

There has been a number of scholarly works on the windcatcher as an effective natural-ventilation device. For example, Elmualim [7] made a wind tunnel and computational modelling study of a square windcatcher of dimensions 500×500 mm and 1.5 m length. Measurements from this work have shown a ventilation rate of 74 l/s is achieved at wind speed of 2 m/s blowing perpendicularly to one windcatcher side face, increasing to 101 l/s at 3 m/s wind, and 137 l/s at 5 m/s wind. When wind blows diagonally to a windcatcher face, the corresponding flow rate is reduced to the minimum of 36 l/s at 2 m/s wind, 53 l/s at 3 m/s wind, and 82 l/s at 5 m/s wind, respectively. Very little or no short-circuiting (flow passing directly from one windcatcher’s opening to the other openings without passing through the space to be ventilated) has been observed.

Kirk and Kolokotroni [8] conducted air-exchange tests (using tracer gas decay) during summers 2001 and 2002 on 3 occupied UK buildings fitted with Sola boost windcatcher (as can be recognized by their model names, namely 1200 mm square GRP, 1000 mm square GRP, and 550 mm circular ABS units, respectively). They reported that both wind and stack effects affect air exchange rate through the buildings. Among other work, Su and others [9] investigated a solar-boosted circular windcatcher, using both experiments and computation, while Li and Mak [10] made a computational fluid dynamics (CFD) study.

Indoor temperature and CO2 level

The sola boost windcatcher provides secure night cooling. Kirk [11] conducted tests on council offices in Kings Hill, UK, in summer 2002, and reported that indoor air was cooled by up to 4°C by night cooling, thus allowing for a fresh start to the day, and providing cooled thermal inertia to the building structures. The external temperature was high (31°C), the indoor temperature was still several degrees lower (25 °C on the ground floor, and 28 °C on the first floor). Whereas when the outside temperature was not high (below about 23°C), the indoor temperature was only 3°C to 5°C above it.

Jones and others [12] examined the air quality in 2 classrooms in UK, one fitted with a 800 mm square sola boost windcatcher (the test room), while the other is ventilated by conventional opening windows. Their measurements pertaining to summers (done in May and June 2006) show that the test room was cooler than the control room by an average of about 1.5°C. CO2 level was also lower in the test room, 840 ppm vs 1324 ppm in the May test, and 575 ppmvs 588 in the June test. Night cooling with the windcatcher results in the test room's peak temperature being lower than the external peak temperature by nearly 3°C, namely 27.8°C vs 30.5°C; the corresponding peak temperature in the control room was 28.9°C.

In Autumn 2008 tests were conducted at the reception area of the BSRIA building of the Building Services Research and Information Association in Backnell, Berkshire, UK, to assess the performance of a GRP 1200 Sola Boost windcatcher [13]. The building has a particularly high solar gain, and the temperature on its first floor in summer was known to have reached 40°C with an outside air of about 28°C. During the test, which lasted about 7 days, operation of the windcatcher was seen to lower the peak temperature in the building (measured at 5.32 m above the ground floor) from 31.2 °C to 29.5 °C (whereas at 1 m height, temperature was unchanged at 26°C). In particular, operation of the windcatcher had reduced the CO2 level from 1000 ppm to 508 ppm.

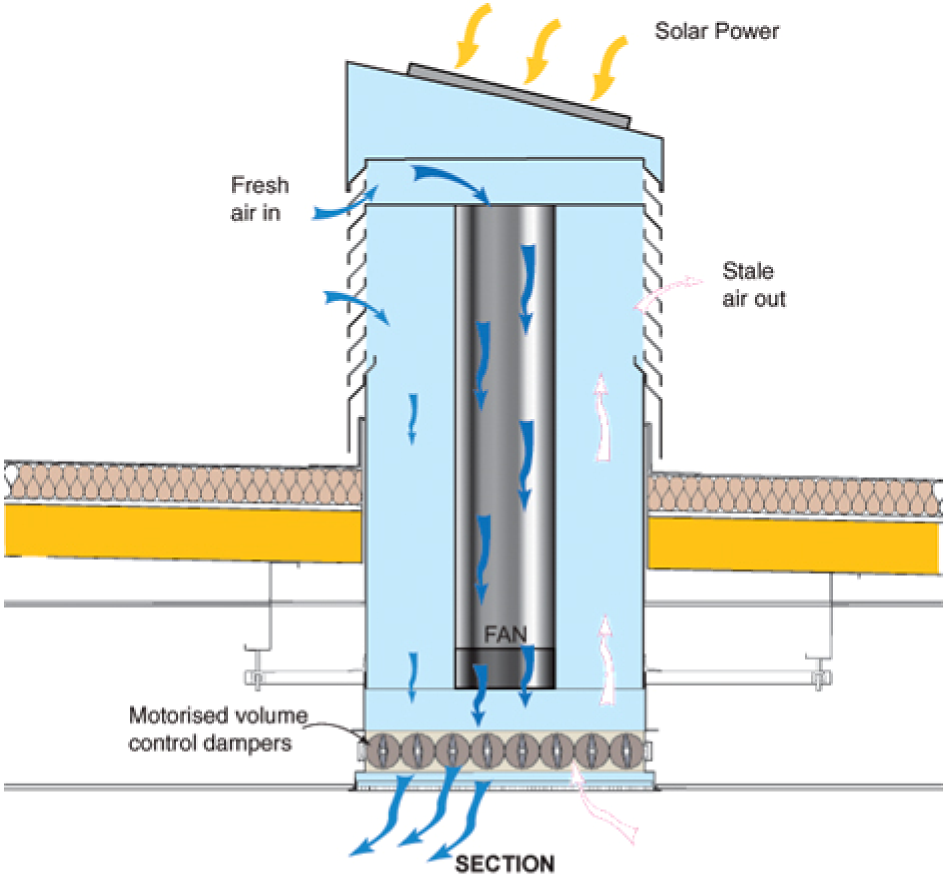


Figure 7. Windcatcher work in sunny days [14]

7. Conclusion

When we know the disadvantages of windcatcher and windcatchers itself completely we can ameliorate these traditional systems of heating and cooling and support the Environmentally Sustainable Architecture. The solar windcatcher that uses both sun energy and wind energy helps us to use lower CO_2.

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Abstract

In the past without modern facilities and modern equipment for cooling and heating, the architect was obliged to use economical engineering systems that rely on natural energy.

This article evaluates one of such economical systems: the windcatcher used in traditional house of Iran. Nowadays the global warming is one of the most concern in the world and the necessity of using the sustainable systems could be a good solution for having a comfort zone with a suitable relative humidity and temperature with lowest fossil fuel consumption.

This research has gathered the information about traditional windcatcher and its modern modifications. The advantages and disadvantages of different windcatcher shapes are analyzed. The methods for enhancing its construction are suggested.

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