Wind Catchers and Energy Efficiency in Buildings[1]

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Abstract: *This study is based on traditional ventilation methods. Since wind energy, one of the renewable energy resources, has long been used in settlement designs and practices, it is examined as the most important goal of the study. Architect Arastu (in 4th century BC) and Roman Architect Vitrivius (in 1st century BC) first dwelled upon wind energy management in urban design and architecture in historical period. It is intended to evaluate Wind Catcher as a cooling system and as the most important natural ventilation method of buildings. Thus, wind catcher is commonly seen in local architecture of Iran where there is a hot, arid and humid climate. Cities that have been designed for centuries according to climate conditions and weather conditions in hot-arid and hot-humid regions of Iran are taken as examples. Traditional Iranian architecture is directly affected from sun, wind, humidity, cold, hot air and all other weather conditions in various regions.*

Keywords: *Interior ventilation, natural ventilation, wind energy, wind catcher*

Rüzgar Tutucular ve Binalardaki Enerji Verimliliği

Özet: *Bu çalışma geleneksel havalandırma yöntemleri üzerinedir. Rüzgar enerjisi yenilenebilir enerji kaynaklarından biri olduğundan beri yerleşim tasarımı ve uygulamalarında kullanılmaktadır. Bu çalışmanın amacıda bu konu üzerinedir. Tarihsel süreçte ilk olarak Mimar Arastu'nun ve Romalı mimar Vitrivius'un kentsel tasarım ve mimarlıkta rüzgar enerji yönetimi konuları üzerinde durdukları görülmüştür. Rüzgar tutucular soğutma sistemleri olmalarının yanı sıra binalar için en önemli doğal havalandırma araçlarıdır. Bu nedenle rüzgar tutucular sıcak, kurak ve nemli iklimlerin olduğu İran' ın yerel mimarisinde çokca görülür. Yüzyıllardır İran'ın sıcak-kurak ve sıcak-nemli bölgelerindeki iklim ve hava durumlarına göre tasarlanan şehirler örnek olarak ele alınabilir. Geleneksel İran mimarisi farklı bölgelerdeki güneş, rüzgar, soğuk, sıcak hava ve diğer bütün hava koşullarından doğrudan etkilenmektedir.*

Anahtar Kelimeler: *İç mekan aydınlatma, doğal aydınlatma, rüzgar enerjisi, rüzgar tutucu*

1. INTRODUCTION

Annual average rate of global wind energy use in recent years is reported to be around 30% [1]. It is also a natural energy resource with the highest global consumption. Thus, total global capacity of wind power reached to 24,000 MW in 2001. Wind power consumption may substantially decrease carbon dioxide production since it protects the environment and prevents green gas emissions. Another striking point is low initial investment cost of wind energy among renewable energy types. A considerable drop may be seen in costs with expanding technology, increasing number of turbines and elimination of restrictions on

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wind energy use. Electricity power generated from fossil fuels is cheaper than electricity power generated by wind turbines.

A major part of total global energy consumption results from building heating and cooling. The application of optimum and effective methods, minimum use of global fossil fuel reserves and maximum use of renewable energy have drawn attention of architects and engineers in recent years.

This study aims at increasing natural ventilation efficiency, eliminating previous restrictions and contributing to the re-use of wind catcher as the most prominent natural ventilation method. The first part of study gives the definition of ventilation and explains natural ventilation methods and the second part explains the definition, function and performance of wind catcher.

2. VENTILATION

Fresh air inflow from outside to inside by using different tools and various methods in order to change air in a confined space is ventilation. It seems possible to replace stale air with fresh air in a confined space in order to maintain health conditions of interiors not only through mechanic ventilation systems but also with traditional methods. However, ventilation provides an instable protection against toxic gases, vapour and smoke. On the other hand, an effective ventilation method provides means for people to inhale fresh air without being subject to any discomfort. *Natural ventilation* that enables fresh air inflow from outside to inside generally without using air conditioner, cooler or other mechanical devices plays a prominent role in energy savings and protection of human health [3]. Another noteworthy point is *passive cooling* concept that provides heat comfort conditions in buildings without using industrial methods. For example, building windows at various sizes instead of using mechanic ventilation devices indoors.

Most people generally prefer natural ventilation rather than complex mechanic ventilation since it is easy to apply. Some measures need to be taken for proper natural ventilation of environments and interiors that have different functions. Natural ventilation is more effective in rooms that do not have large sizes. Natural ventilation is not considered appropriate for interiors such as kitchens that need special ventilation. It is suggested to build windows as high as possible in order to prevent discomforting air flows and enable outflow of heated and rising air. Air flow generally results from pressure differences from direct wind direction and reserve wind direction. Thus, some conditions should be considered during the construction phase of buildings in order to be able to benefit from this advantage [2].

2.1. Natural Ventilation Methods

The following methods are used for natural ventilation function according to different conditions.

Shadowing

Creating elements or areas such as porticos or eaves against extreme heating throughout the day. Thus, proper natural ventilation may be provided by benefiting from the temperature differences between direct sunlight and shadows. For example, SABAT element used in cities which are shaped by traditional Iranian architectural methods (Figure1) [4].

Figure 1. SABAT used in hot-arid cities of Iran [4].

Directing breeze

During the construction phase: Taking measures such as leaning buildings toward wind flow direction and building opposite windows for producing effective air flow. For example, designing long and narrow streets.

Preventing discomforting wind flow

Planting dense green fields for decreasing severe flow and creating an effective scene.

Making air humid

Designing pools in buildings for making the breeze cool and humid for human health and heat comfort.

Use of dome forms

Roofs that are built in the form of dome always direct the breeze inwards. Since solar radiation is not the same in different parts of roofs, temperature differences occur and thus, air flow occurs.

Use of materials with high thermal capacity

Hot air insulation properties of conventional materials such as bricks or cobs are suggested.

Building thermal (solar) chimneys

An outlet chimney is built in hot regions for facilitating interior ventilation and thus, ensuring outflow of hot air.

Using yards

Yards create air with low temperature and high humidity due to their climatic behaviours and since they have dense green fields and water pool.

2. WIND CATCHER

Wind catcher, designed according to wind flow rate and direction, is suggested as the most natural ventilation method (Figure 2). After hot wind hits the wall within the wind catcher, it is directed downwards and it draws cool air, which is cooled through the pool in the garden, with vacuum to the living environment and thus, cools the room [5]. Hot wind only passes through dry corridors in regions with high humidity rate, i.e. it is directed inwards without using the pool. Wind catcher is shaped by conventional material such as brick, adobe, mud, plaster and wood. Thus, wind catcher, which can adapt to all climatic conditions in terms of construction and cost, is designed in various forms in different geographical regions as the most prominent element of traditional cities.

Figure 2. Traditional wind catchers in the city of Yazd in Iran [3]

2.1. Wind Catchers Types

Wind catchers are classified into different types according to their view.

Type 1/ One Sided Wind-Catcher

It is designed as unidirectional as the simplest type of wind catchers (Figure 3, 4). It is the generally preferred type for interior ventilation in terms of cost although it is built in the roof in a very small size and in the simplest manner like chimney flue. In this method, wind catcher should be built only according to proper breeze and cool air flow in order to prevent possible damages from severe hurricanes and storms and should be closed in other wings. Single-duct wind catchers may sometimes be in the reverse direction of discomforting and severe winds. Only 3% of the wind towers in Yazd were unidirectional [6].

Figure 3. View of wind catcher type 1: one sided;
right picture: A view of a one-sided wind tower in Ardakan city, Yazd province, Iran [7]

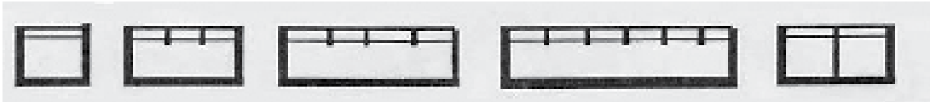

Figure 4. Plan of wind catcher type 1: one sided [8,9].

Type 2 / Two Sided Wind-Catcher

Bidirectional wind catcher is comprised of two thin and long inlets that rotate in contrast to each other (Figure 5,6). In a survey by Roaf [6], 17% of the towers are of this kind in Yazd and all are found on the ordinary houses.

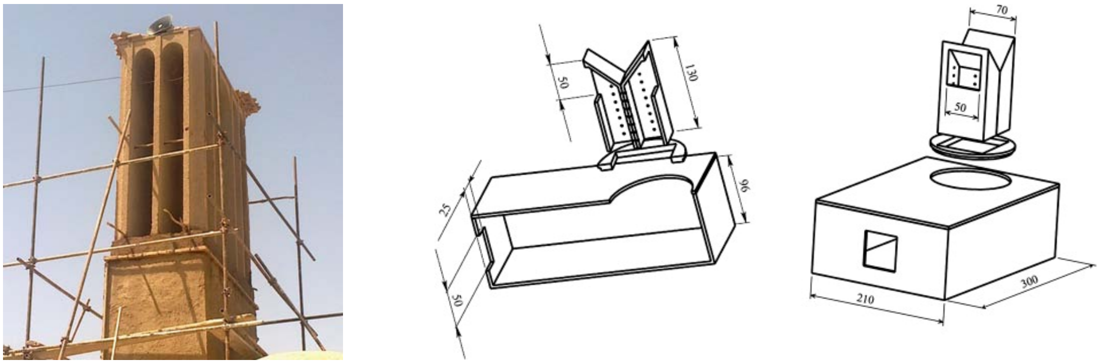

Figure 5. View and dimension of wind catcher type 2: two sided [10]

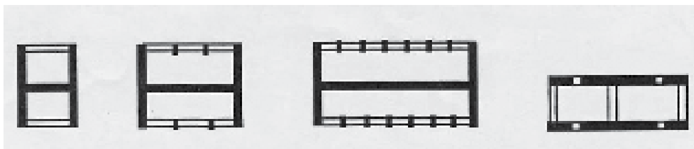

Figure 6. Plan of wind catcher type 2: two sided [8,9]

Type 3 / Three-Sided

This tri-directional type uses air flows from three different sides.

Type 4 / Four-Sided

This quadri-directional type is designed in a more detailed and comprehensive manner than other wind catcher types. Internal ducts are generally separated into different sections with brick, wood or gypsum (Figure 7, 8) [11].

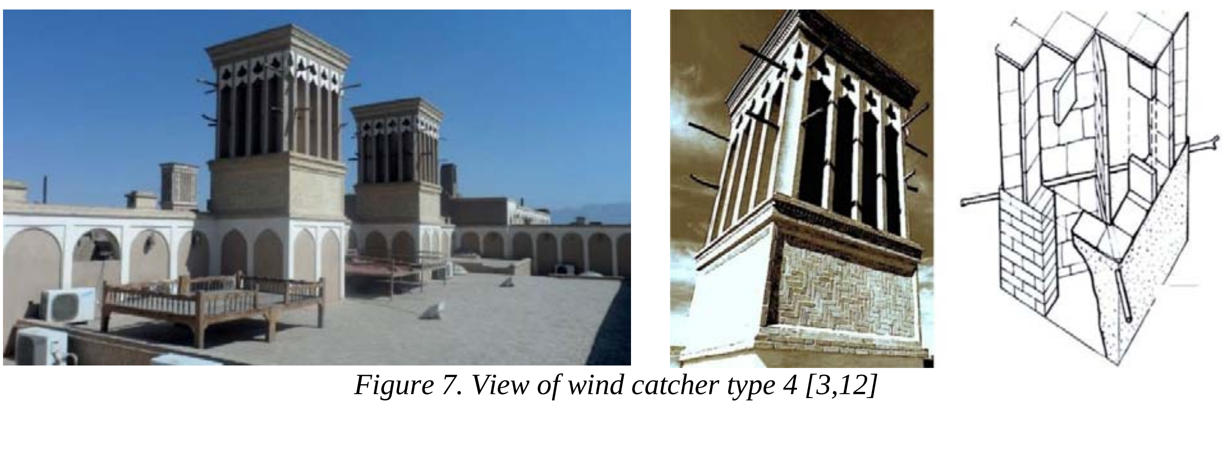

Figure 7. View of wind catcher type 4 [3,12]

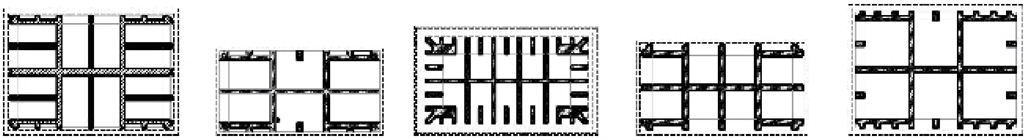

Figure 8. Plan of wind catcher type 4 [13].

Type 5 / The Hexahedral and Octahedral

As a multi-directional wind catcher, it is used in regions where weather conditions allow in terms of climate conditions.

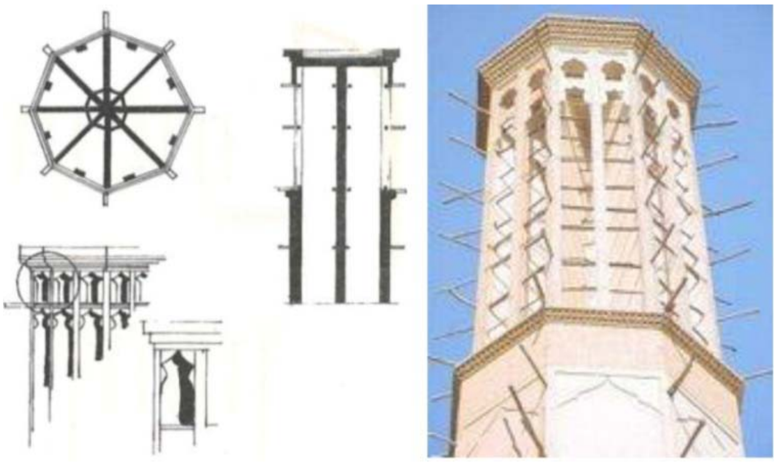

Figure 9. View of wind catcher type 5[9]

Type 6 / Pipe Like (Chopoghi)

Exterior form is designed in cylindrical form and appears as a circular pipe as differently from other types that have cubic shape. However, it is the same with versatile type of internal ducts.

Figure 10. View of wind catcher type 6: pipe like (Chopoghi) [9]

2.2. Function of Wind Catcher

The existence of wind catchers in houses used to represent reputation and welfare of families in terms of traditional life styles. Its size – big or small – was related to economic condition of house owners. Thus, it is possible to determine economic condition and welfare of every family at first sight according to the external form of wind catchers in a city or in any settlement. Wind catcher is the optimum ventilation method for breathing houses (Figure 11) that are located in the core of regions with hot-arid weather conditions such as deserts. It also provides fresh air flow in rooms, basement and all liveable parts of a house. Thus, wind catcher should be directed to optimum air flow for a more effective performance. The basic function of wind catcher is summarized in two parts. Its first function is to direct cold and fresh air to interior spaces and its second function is to discharge stale and hot air to outside with vacuum effect.

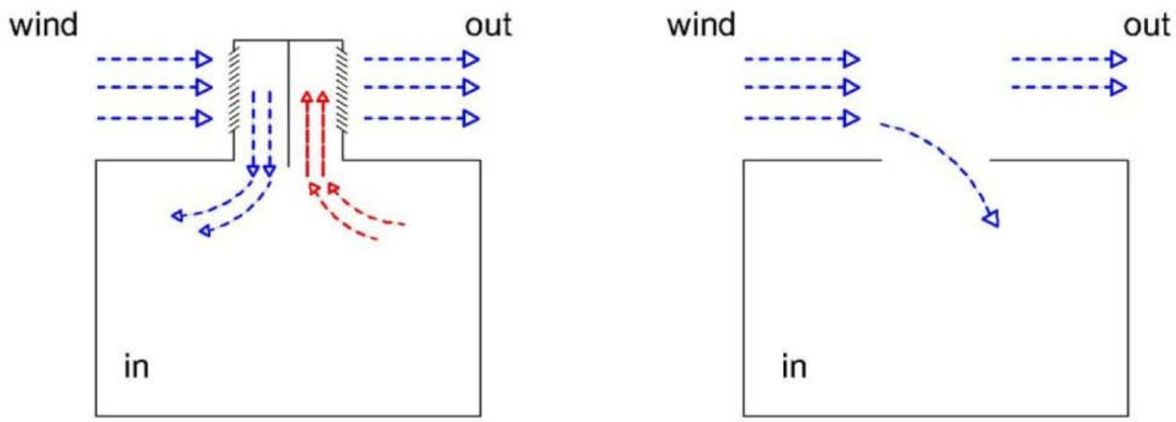

Figure 11. Air flow in a building with and without a wind-catcher edited by Narguess Khatami [14]

2.3. Components of Wind Catcher

A wind catcher is generally composed of five parts, i.e. stem, shelves, blade, opening and roof.

Shelf: It is the top of the wind catchers including blades and air flow ducts.

Stem: Wind catcher has a depth of 1m-2.5m mostly and durable wood should be placed at half meter intervals to make it stronger.
Blade: It is designed as a wind barrier element and has architectural benefits. For example, it is perceived as a component that is influential on frontal view and shape of wind catcher.

Opening: 40cm-60cm space between two blades. The number of openings of wind catcher depends on room width and wind flow intensity but the number is never an even number.

Roof: The upper part of wind catcher is covered with CAPILE or in the form of staircase roof, which helps its performance [15].

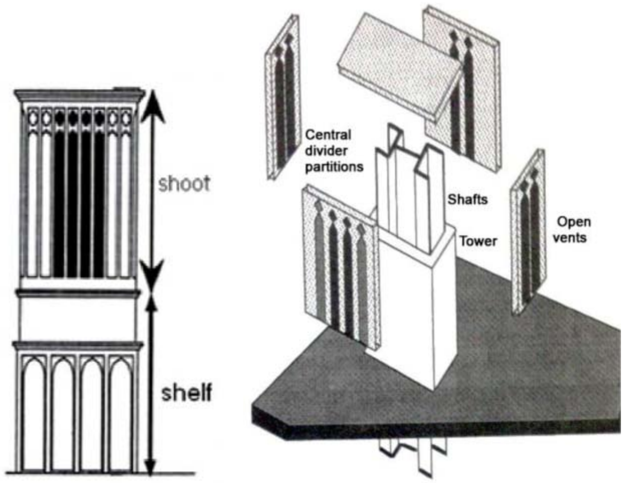

Figure 11. left: Shelf and stem in wind catcher [16]; right: wind-catcher elements [19]

2.4. Performance of Wind Catcher

Two basic operation modes are observed in wind catcher performance although it has various forms for interior ventilation and is used in different climatic regions.

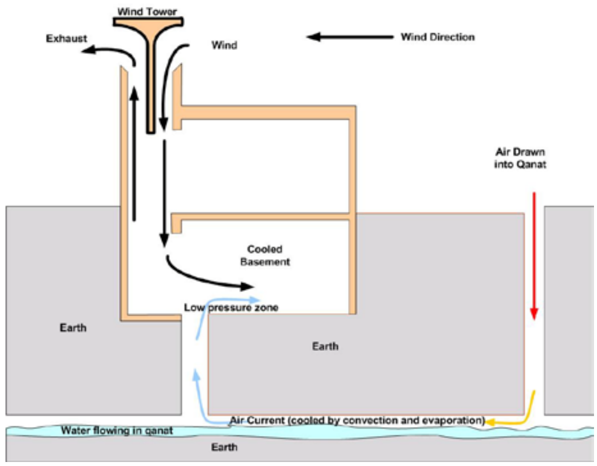

Figure 12. Performance of Wind Catcher [9]

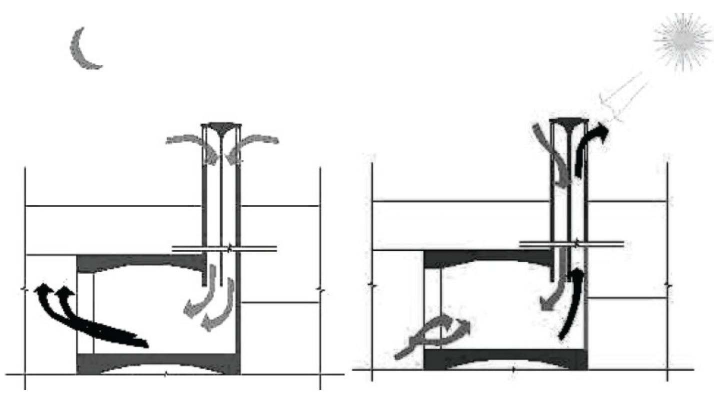

Figure 13. Wind-catcher function during the day and night [17]

Draught and Vacuum of Openings
When wind hits the openings, pressure difference occurs in the other direction since air flows intensively and thus, hot and dry air is directed downwards (draught) and stale air of room is extracted outwards in the opposite direction (vacuum). In the meantime, air cleaned and humidified through pool is directed to interior space.

Temperature Difference
It is the second method for wind catcher performance that draws attention of experts less. In fact, wind catcher operates on the principle of temperature difference when wind does not flow. Air in the stem of wind catcher is heated during the daylight and rises upwards. For compensating this lack of air, stale air from interiors is extracted outwards while cool air of yard is drawn inwards. In the night time when air outside is cold, air is directed downwards and it is heated due to temperature stored in walls. This cycle continues until the temperature of air outside and wall temperature become equal. Since it is not possible to build a pool on the ground floor in some regions, duct water remains on the basement floor and passes through wind catcher's ducts (Figure 14) [11].

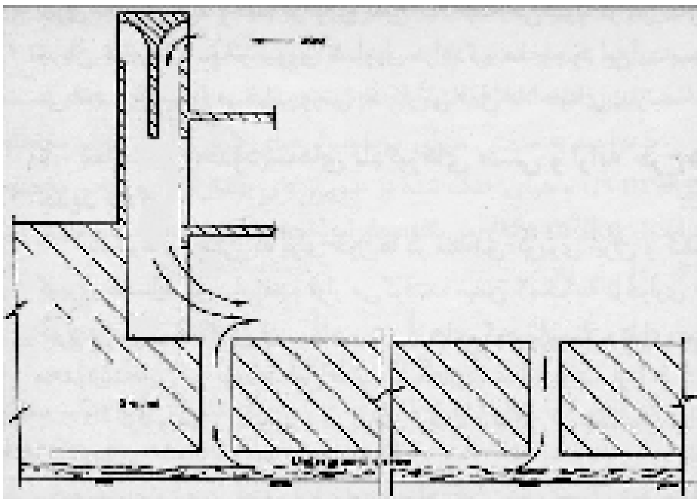

Figure 14. Wind catcher and wing water

3. CONCLUSION
Despite all technological developments, wind catcher is an important factor that completes ventilation system as a component giving an identity to buildings in terms of vernacular architecture and meets cooling requirements of buildings. It also increases energy efficiency due to climatic adaptation and provides cost efficiency since it can be built from recyclable materials. Thus, wind catcher is considered an important object that ensures sustainability of buildings and large-scale cities in dry-hot regions. In conclusion, it is necessary to modernize traditional natural ventilation methods instead of complex technological solutions in order to evaluate the performance of wind catcher. Thus, wind catcher provides heat comfort conditions for a building through natural ventilation depending on different seasons and contributes to human and environmental health. For example, first zero-emission office building (Figure 15).

Figure 15. left: first zero-emission, eco-friendly office;
right: First zero-emission, eco-friendly office A. Wind catcher; ventilation means in summer season.
B. Solar collectors, hot water and power generation means.
C. High amounts of heat insulation [18].

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