Wind, windward and Architecture (Create Natural Ventilation in Buildings by Wind from the Perspective of Iranian Traditional Architecture and Contemporary Architecture)

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INTRODUCTION

Studies conducted in the United States specified that with using housing and energy doctor (HED) programs, we can save 160 billion dollars energy in a year. In housing and industry energy program, it is tried to provide necessary skills and strategies which are necessary for heating and spontaneous cooling instead of using methods and industries which are costly. Spontaneous evaporative cooling in the wind catchers which were used in Iran, was as downward air flow cooling. In this traditional method, the outside air enters from entrance part of wind catcher and pass through porous jars filled with water. This causes evaporation and reduces the temperature. Compared with air conditioning, benefits of building cooling with this method, the non-use of forces, considerable saving in energy and saving in repair and maintenance cost. Today, due to increasing energy consumption in the world and due to the lack of fossil fuel resources, and severe environmental pollution caused by combustion, the necessity of using renewable energy to reduce consumption of fossil fuels has increased. One way to reduce the consumption of fossil fuels is creating the building blocks in the way useslowest energy for heating and cooling [16]. Aristotle four century before BC and Vitruvius, Russian architect, one year before BC, speak about method of using wind in architecture and urbanism. On each hemisphere of the Earth, there are different atmospheric pressure, low pressure and high pressure. According these differences there are some lines that move in different seasons towards one of the poles or the equator.
Regions such as subtropical regions are high pressure and arctic regions are less pressure. Winds are effective in natural ventilation. Pressure differences caused by wind in the external walls cause natural ventilation and the air flow caused by the temperature difference between the levels, the levels of the buildings facing the wind have pressure (positive pressure) on their surfaces. Levels of building with wind at their back have suction (negative pressure) on their surface. It has been shown with minus sign which cause flows between two directions.

2- **Natural ventilation:**

Natural ventilation by using pressure difference that exists around the building, and by wind and depending float forces, the ((chimney effect)) phenomenon takes place. Natural ventilation is based on three climatic phenomena: wind speed, wind direction and temperature difference.

1-2-Wind speed: Wind direction and speed on the building, create a force field around the building. Consequently, vent and wind ages are located to maximize the air pressure differences between the entrance and exit are very important. This increases the efficiency of the ventilation design; because in this case, there is possibility of decreasing opening area. Air conditioning is effective only when the wind speed exceeds 5/2 m/s (19).

2-2-Wind direction: basic element of air passing through a building is wind direction that changes due to daily or seasonal effects.

2-3-difference in temperature: when the temperature increases, air density decreases and consequently the air go upward. Wind tends to apply its force in the same direction as it works to prevent the state that two forces attract each other (4).

3- **How to create natural ventilation in buildings:**

3-1- **The need for natural ventilation in buildings:**

One of the agents assigned to human health and comfort is natural ventilation. This type of ventilation, affect directly cleanliness and air velocity inside the building and indirectly affects the temperature, humidity and internal surfaces. Natural ventilation with replacing air to health, with creating physical comfort for the general welfare, with cooling the material to further cooling the inside hot air, contribute human health(3).

Fig. 1: Building plan ant the effect of wind on it.

3-2- **Natural Ventilations and Ventilator:**

If the building is located in the path of air flow, will cause pressure naturally. When the air molecules are compressed, the pressure increases and when they are apart, reduced. Natural ventilation has been done with utilizing pressure difference created around the building and through the entrance located in areas with positive pressure and by putting a vent in! negative pressure areas. Pressure difference between the entrance and exit points provide the required power for the air to flow through the building (4).

Fig. 2: Create natural ventilation in buildings.
3.3 Replace air (natural ventilation):
Replacing air as natural ventilation of any area should be through its opening areas to the outside of the building, such as windows and doors, hatches, networks and the like. The opening surface of any space to external air must be at least 10 percent of the building space that air replacing is considered. Underground space where natural ventilation is desired may be related with a vertical opening surface and a horizontal opening surface to outside air. In this case, the useful width of the open space which the vertical opening opens from is at least 5/1: equal to the depth of the vertical opening (2).

3.4 Replace the air conditioning:
Building space that is occupied by man should have natural or mechanical air replace. Air Replace on human space considered for following reasons:
1-Supply oxygen for respiration
2-Avoid increasing carbon dioxide, smoke and other harmful gases
3-To avoid Air stagnation
4-prevent moisture condensation. So, get outside air, turn air, discharging air to building spaces with natural and physical features (4).

4.1 Windward History
Windward as one of Iranian patents is one of the most unique architectural elements which is used substantially and comply with the environment. The oldest Windward in Iran that virtually remained intact is related to eighth century AD. Many architects to study the design of sustainable architecture and study how wind catchers work travel to Iran (6).

4.2 Wind catchers’ structure:
Wind catcher is an Iranians’ innovative way to create cool air inside the house in warm desert. This air conditioning system, long years from distance days, has made Iranian houses air tolerable. Wind catchers usually are small turrets or regular quadrilateral or polygons. The triangular structure is not found in any of them. Wind catcher is made from the turret which is much higher than elsewhere in the house and formed on the roof. Usually the wind catcher is formed in spring house that is a special part of homes in the dessert. Spring house was a small porch at the end of the summer rooms in each building. Summer rooms are big rooms with many doors. Spring house is between the house yard and summer rooms. Among the space, was a small pond, and the name of this place is because of this pond. Windward are at the top of the pond, but they leading the air flow through the pores to the pond water (14). Native architects build a wind catcher on the roof of the house. With clay or brick built the wind catcher stokehole – rectangular- with square cross section to reach a certain height. Then above the stokehole lay four walls in two woods in cross form. So that both sides of the wood placed at two angle sections. East, West, and South walls have two to five meters height. Then in the North facing Isfahani’ wind make the walls with half of a brick which has six centimeters wide. Heights of these blades are 40 cm higher than the walls and are considered as a carminative, these walls are also useful in terms of architecture. Distance between two blades, which is called vent, is 40 to 60 cm. Number of fountain of each wind catcher is dependent on the width of the room. So that for the room between three and five and seven meters wide, respectively five and seven and eleven vents are used. Sometimes for further cementing the wind catcher, every half of meters put piece of wood in wind catcher walls. Some of them that have more financial resources do tore on wind catchers’ walls. The number of vents in each wind catcher has direct relationship with greatness of the wind catcher. Number of vents in each side of wind catcher is related to wind of that side or in general with wind and air of that region (2).

Fig. 3: Wind catcher mechanism.

4.2.1 One-sided wind catchers:
Cities like Meybod, Ardakan, and Zabul have such wind catchers. In Yazd this types of wind catchers have been seen over water - caches or small Khans.
**4-2-2 Two-sided wind catchers:**

This is a simple kind of wind catchers. In this type the wind catcher channel was hold with a vertical brick blade that has wooden beams and divided it into two parts.

**Fig. 5:** Sample of two-sided wind catchers’ plan in Iran.

**4-2-3 Four-sided wind catchers:**

More than half of Iranian wind catchers are in this way. Local architects called them Yazdi wind catchers. In the south of Iran all wind catchers are like this. Four-sided wind catchers are divided in four channels by some blades. This type of wind catcher guides the wind into by using one channel. Four-sided wind catchers are designed and made with both square plan and rectangular plan. In south of Iran all of four-sided wind catchers are square planed. This kind of wind catchers can be takes into account as a great form of architecture phenomena (6).

**Fig. 6:** Sample of four-sided wind catchers’ plan in Iran.

**4-3 Taking advantages of the natural flow of wind using wind catchers:**

Wind catcher is an Iranian innovative way to create cool air inside the house is warm deserts. This air conditioning system, from long distant days, has made Iranian people living space tolerable. Wind catchers are usually small turrets in four-sided or polygons shapes; the triangular structure is not seen in their structures. Iran’ creative engineers and architects were first group who fought against difficult geographical situations and were able to develop wind catcher, which is a great honor (19). The overall goal of creating a wind catcher is air conditioning and cooling inside a building. Renewable wind energy without using modern energies, are used for adjust temperature. The design of these houses with very beautiful architectural structure made these houses a cool and pleasant place in summer (18). Turret’ of wind catchers height is one of the unknown reasons in wind catchers’ structures (5). Several different factors can cause high height of wind catcher turret structures. One of these factors is that there is a lot of dust on the ground surface. The main reason for this structure is because wind catchers works with wind renewable factor and require more wind, should be built on higher ground. So generally in higher places the weather is pleasant in comparison to surfaces. The air temperature is lower than the ground surface, and there is more wind flow. But higher we go, wind speed increase; so the wind speed on ground surface is zero and it increases in higher places (10).

**Fig. 7:** Dolat-Abad Garden Pavilion’ point of view in Yazd (highest wind catcher).
4-4 Wind catcher mechanism:

Wind catchers long been used in different parts of the world, but their mechanisms are not the same. They are designed due to geography of each region (3). Wind catchers are consists of a high turret and are place in the roof. These turrets are consists of two inlet and output valves. The body of house divided into two parts, including the basement (spring house) and the ground surface. Deep channel been dug before the building is connected to the main channel of aqueduct. With the entry of air into this channel and connection of the air with water in the aqueduct, volatilization takes place. When the air inter into the building through turret entrance, low pressure area is created in underground (spring house), and cool air in the aqueduct channels goes upward, so the indoor air become very nice and pleasant. Finally all the flows that come into the building get out from turret output valves. The mechanism described is quite obvious in the figure below (19).

Fig. 8: The function of wind catcher in air conditioning and reduce the inside temperature.

4-5 Wind catcher Performance:

The main factors that cause the cooling flow inside the Wind catcher are:
1) The pressure difference between the air entrance place and its’ exit place that creates the air flow.
2) Evaporative cooling, which made the air cool.

4-5-1 Evaporative cooling: Since evaporative cooling for large and half open spaces is one of the most efficient methods of cooling the climate in hot and dry places (20). Using it in wind catchers due to create cooling is also common. Evaporative cooling in traditional wind catchers have been reported in two ways:

4-5-1-1 Relationship between residential area near wind catchers with underground water flow.

In other species of evaporative cooling, air that enters from wind catcher and connected to the ground passes out of a well and is connected to the base. The farther the distance from the hot and dry air enter from other well, after passing over the flow of cooling water come out from first well and go into the ground (Figure 9) (7).

Fig. 9: Connection with the aqueduct space.

4-5-1-2 Using of moisture in lateral surfaces of underground spaces related to wind catchers:

For creating evaporative cooling effect in many wind catchers use the moisture of walls and floor of the basement that was related to wind catcher. In this way, the water in the underground aquifers using osmotic effect is close to the surface has been exploitation in order to provide the necessary moisture for evaporative cooling. Considering that, more close to underground waters the soil moisture increases. So some residential areas built underground so the moisture in its walls is combined with the current output of wind catcher and cool air. On the other hand, the temperature of the underground masses is lower than earth surface, so the basement walls temperature is lower than other places in a building (Figure 10)(22).
4.6 Wind catchers as desert breathing:

Exist of wind catchers in each house represents the dignity of its owner. The size of wind catcher is associated with owners’ economic position. When you enter into a desert village with a quick look at wind catchers you can detect the economic position of each household. Wind catcher is considered a good air conditioner for houses in the heart of desert, can cause the air conditioning in rooms, halls or basement. In fact in town and villages in the desert people breathe with wind catchers. This is because in every place, the wind catchers are made in direction which absorbs the most appropriate air flow. For example in Ardakan, to directing north wind into the house, built wind catcher towards north. Therefore back of main wind catcher is built toward open direction (qibla) that has a lot of dust. The main work of wind catcher divided in two parts: 1- Conduct the pleasant weather to the down section, so as soon as the air flow into wind catcher vents, because of special positions of wind catcher vents, wind is drown downward quickly. 2- Warm and polluted air get out from other side of the wind catcher, actually it does the suction work.

4.7 Simulating wind catcher operation:

For the reason of evaluation the efficacy of several parameter like wind velocity, wind catcher height, wet index or water usage and atmosphere condition to wind catcher operation, a software which that describe it’s details here was processed.

Table 1: simulated wind catcher operation input (simulated via writers).

<table>
<thead>
<tr>
<th>Software input</th>
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<tbody>
<tr>
<td>Wind catcher height</td>
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<tr>
<td>Section length</td>
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<tr>
<td>Section width</td>
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<tr>
<td>Wind catcher area under shine</td>
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<tr>
<td>Input dry air temp</td>
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<tr>
<td>Input air relative Wet index</td>
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<tr>
<td>Input air velocity</td>
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<td>Injected water temp</td>
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Table 2: simulated wind catcher operation output.

<table>
<thead>
<tr>
<th>Software output</th>
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<tbody>
<tr>
<td>Wind catcher output air temp</td>
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<tr>
<td>Wind catcher output air relative wet index</td>
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4.7.1 Create a common design group to reduce energy usage:

In process of wind catcher conventional usage method, building was designed owing architectural design. Energy usage reducing model isn’t means that the people accept condition that aren't acceptable in normal. In this way people will be obtain more flexibility against conditional variation. Analyze and evaluation of several variant in building which that some when cause to eliminate some variant, will doing in way of building modeling to separate evaluate and analyze of coefficient of temperature transmissibility trough roof, floor and windows. Study shows that building energy demand will reduce to a considerable extend if evaporative cooling used through wind catcher. [15]

5 State of windows design and positioning to utilizing wind energy for natural ventilation at current architecture

5.1 Window position and that influence on building ventilation condition

The Room Windows location towards wind move direction will be more effective on state of room and building ventilation so that the best and ideal ventilation condition occurred when windows located on both side of building, it means that some of windows locate in face that is toward wind direction and the others located in face that is backward wind direction. In this way building ventilation is at efficiency, usable and ideal condition. [9]

5.1.1 To create maximum flowing in a room, it's not necessary that the windows at face towards and backward wind be across together and orthogonal with wind direction. [4], [21]
5-1-2-Best ventilation occurred when the wind direction.

![Diagram of building plan](reference: redraw via writers)

5-1-3-If windows located in abutting face the best ventilation occurred when the wind direction was orthogonal with windows in face towards wind. [4], (Fig. 12)

![Diagram of wind flow direction](reference: redraw via writers)

5-1-4-The room which contain windows in both face towards and backward wind when the winds blow orthogonal to windows air flow will come in form windows at face towards wind [5] and go out without direction change from windowsto face backward winds seen in figure 13-a in some space of room no air flow occurred. But if windsblow angular to the windows of this room that towards wind we can claim that almost will have air flow in all space at room. In the other word the air flow do ventilation with spiral movement at corners and near the wall of room. [10], (Fig. 13-b).

![Diagram of wind flow state](reference: redraw via writers)

5-1-8-In room that windows located on one face enlarging its dimensions will affect a few on air flow velocity, but if the winds blow angular to this area enlarging windows dimension cause increase air flow velocity and more desirable ventilation will occurred. [4], [20]

Note 5-1-6:In rooms that contain windows in both face towards and backward wind, enlarging windows dimension cause increasing wind velocity and therefore cause desirable ventilation. And if in same room make the dimension of windows backward wind larger than windows towards wind the wind velocity will increase very highly. [17], (Figure 14).

![Diagram of window backward wind](reference: redraw via writers)

Note 5-1-7: Best ventilation will occurs when the direction of air flow and ventilation in building or room change and if the air flow after coming from windows in face towards wind goes out from windows backward wind without direction change the ventilation not much desirable. [21].
5-1-9) In normal condition if room's windows located on one face the ventilation there occurred in poor level.[11] To solve this problem at least two windows locate in same face for room which that the win flow direction be angular to two windows. As shown in figure 15 for reason of amplification air stream most the partition wall will be use. That this parameter summation causes to create two zones of pressure and suction behind windows than air flow and ventilation between two windows of room occurs. [8].

Fig. 15: state of amplification air stream (reference: redraw via writers).

5-1-10-Locate roof opening and windows in suitable positions is effective to increase the ventilation rate in building as much as possible which will not forget in designs. [1]

Conclusions:
Using of new energy such as wind, sun and etc. renewable energies is economical large scale because paid cost for implementing these project will back in future years because of reducing energy usage and reducing usage of fossil fuels. Using of conventional engineering and also design accurate position and dimension of those to ventilation with renewable wind energy cause to economize about 50 than 60 percent at fossil fuels usage. Using these systems has important effect to having a clear environment without pollution. Attend on starting new process to reducing energy usage. We could present the wind catcher such as an important element in usage reduces energy and fossil fuel. Result of using our country conventional systems in USA shown that desirable economize obtain from using spontaneous cooling and heating systems.

REFERENCES
[9] Mahyari, A., 1996. the wind catcher; Ph.Dtheses; Sydney University; Australi, 38.


