

# Impact of Openings' Number and Outdoor Flow Direction on the Indoor Vertical Flow Velocity in Wind Catchers

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**Abstract-** It has been proved that the behaviors of both single and multi-pressure types of traditional wind catchers are related to the conditions of lower openings. But still the quantity and the quality of such relation is not recognized. So, this paper aims to indicate the impact of varieties in changing the conditions of such openings and the outdoor wind direction on the velocity of indoor flow in both types of traditional wind catchers. Therefore both types of traditional wind catchers simulated using models in CFD. In this research variations of different border conditions such as lower space without and with opening have been simulated. Also, in case of outdoor wind direction, different angles including 0°, 45°, 90°, 135° and 180° tested. Results of this research showed that in different conditions, the multi-pressure traditional wind catchers show more stable indoor flow, more predictable behavior and finally more efficiency; compared to the single pressure traditional wind catchers.

**Keywords-** Wind catchers; natural ventilation; CFD; Iranian traditional architecture.

## 1. Introduction

Natural ventilation was provided for centuries in traditional architecture of the Middle East and Central Asia by wind catchers. Wind catcher is called Baud-Geer in Iran, Iraq and Afghanistan, Backhor (wind scope) in Pakistan and Malkaf in Egypt. [1] Some sources have estimated wind catcher background in hot and dry areas such as Iran 3000 BC [2] And other sources have identified 4000 BC. [3] Wind catcher main task is to provide ventilation and cooling interior space by using the natural flow of wind. The wind catcher classified based on their internal pressure are divided into two categories Single pressure type and Multi pressure type. When the internal pressure of the wind catcher is either positive or negative; wind catcher is Single pressure. Therefore, the relationship between wind direction and entrance of cage, Wind catcher at any moment may act either as Badkhan(wind tower) (When the entrance is located behind the wind and internal wind catcher pressure is negative) or Badkhor(When the entrance is facing the wind and internal Wind catcher pressure is positive). There are no internal divider blades in these type columns and according to the external column can be estimated channel proportions. But in Multi pressure type; there are separator blades into the wind catcher external column. Also with each wind blowing, different pressures are created around the wind catcher cage that directly impacts on the internal pressure of wind catcher internal columns. [4] Thus is created simultaneously a set of positive pressure (wind

scope) and a set of negative pressure (wind tower) inside the wind catcher channels. [5] In channel of this type are very different from of internal divider blades and according to the external column cannot be estimated internal channels proportions.

About studies in the field of wind catcher can say: Bahadorynejad in 1978 introduced different methods of evaporative cooling in Iranian traditional architecture and determine an equation to calculate the wind pressure coefficient at the mouth of the wind catcher cage. [6] In 1985 he first proposed change Multi pressure type to Single pressure type and effective use of the evaporative cooling potential and wind flow. [7] Cunningham and Thompson (1986) presented a model which it had combined to Single pressure type (single negative pressure) with the solar chimney (single positive pressure). [8] Using data obtained from these studies; Givoni be expressed in 1993 Single pressure type performance is a function of difference between dry and wet temperature (WBT, DBT), wind catcher details and thermal behavior of lateral space of wind catcher. [9] Pearlmutter et al. played on indoor courtyard a Single pressure type wind catcher and its behavior were investigated in the density of moist air. They declared, is created weak downward flow of natural convection that is dependent on the droplet diameter and Timeframe in which the water droplet is located within the flow. [10] Afterwards major studies conducted in various conditions of wind flow and evaporation conditions.

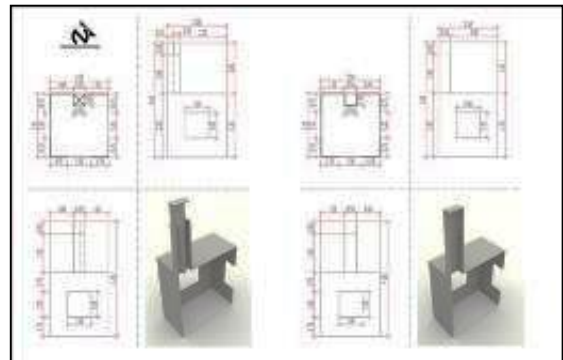
[11,13] then in 2006 Elmualim performed numerical study based on CFD on the performance of Multi pressure type and to compare its results with the experimental model. During these studies it was shown that wind catcher efficiency is totally dependent on wind speed. Moreover it was shown that the binding dampers on the cage openings are weaker flow rate. [4 and 14] In 2009 Benjamin and Ray performed quality assessment of the efficiency of Multi pressure type by using the semi-empirical model. In this study was to investigate the effect of buoyancy force and changes wind speed and direction of the room with no opening and opening. The results showed that; buoyancy force is important in low speed wind flow. [15] In 2008 a new sample was introduced Single pressure type of wind catcher which it's aerodynamic behavior that will create better and more appropriate evaporation conditions. [16] In the same year Pearlmutter et al. began to study different methods of spraying water into the same wind catcher. [17] Montazeri in 2011 performed experimental and numerical (CFD) studies on different cylindrical cage of multi pressure type (2, 3, 4, 6 and 12 sided), which investigated the hydrodynamic behavior of them and showed that with increasing the number of channels, decreases the efficiency of wind catcher. [18]

Hogs et al, (2012) introduced the background of conducted studies on complementary trend of wind catcher's commercial type [19]. Within the same year, Abouseba conducted studies on recognizing the behavior of the performance of traditional wind catchers and determined the preferred type by using simulation method. in these studies, the performance of traditional multiple – pressure wind catchers' were investigated in multi – floor buildings and, ultimately, pressure separating two – floor cage was used as a strategy to establish pressure stability in wind catcher networks [20]. These studies show that far less attention has been on building openings on the wind catcher behavior. In this paper, we simulate single and multi-pressure types of traditional wind catchers and have create all wind catcher conditions possible for the lower space through changing the number and location of openings.

## 2. Modeling

### 1.1. CFD models properties

The dynamic performance of wind catchers can be simulated by means of CFD model. Before using the commercial package of CFD offered in the Fluent Software, a model of the intended volume has to be designed and networked in other software, and for this purpose we used Gambit software. Therefore, in the first stage two volumes with the same conditions were constructed in the Gambit software which is shown in Fig 1 in detail.



**Fig. 1.** Details of CFD model traditional wind catchers

According to this Fig. the dimensions, the height of the channel, and the height of the cage are respectively  $0/5 * 0/5$ ,  $1/5$ , and  $0/5$ . The right image shows a single-pressure wind catcher whose channel doesn't contain any internal blade and the left image shows a multiple-pressure wind catcher which has the internal space of its column divided by two crossing blades into four parts. It should be mentioned here that there are many different plans for traditional multiple-pressure wind catchers, but in order to obtain the kind of results which allow comparison between the two types of wind catcher, a simple model with crossing blades has been used. Moreover, the height of the wind catcher's column is determined in proportion with the dimensions of the plan; however, basically the height of the wind catcher's column is determined by the level of favorable winds and as at this stage of the study the fluid is single-phase and no moisture is injected into it, the temperature fall resulting from momentum transfer between water and air phases doesn't occur.

Therefore, the height of the channel is not increased excessively. In most spaces leading to the wind catcher, the internal blades of the wind catcher stretch down to a height equal to the height of an average man to foster surface evaporation by increasing pressure in the outlet as well as to cause a pleasant flow in a lower level. Therefore, as a more complex performance is created in the bottom side of the wind catcher the internal blades of the wind catcher are stretched down up to the height of the ceiling. On the other hand, in most of similar studies the same technique is employed. Another important point which should be mentioned here is the construction of three openings in the eastern, southern, and western fronts of the model. Mainly in traditional buildings will be opening in along the yard and the wind catcher but in order to generalize to different spaces and determine wind catcher's disadvantages in different situations, we used two additional openings in the eastern and western fronts.

After building the model volume in a range close to 320,000 faces; Volumes were meshed using networks Tet / Hybrid and over 150,000 cells was created which in order to increase model accuracy, the number of cells increase with approaching the important areas. Meanwhile is according to the simple geometry of the wind catcher channel and lower channel space and also having highly important the flow treatment in this area; Therefore, in order to regulate the flow treatment and the reduction cell model, this area were meshed using networks Hex / Wedge. After building and meshing the

model, boundary conditions were determined according to Fig. 2.

Secondly, Model built read in FLUENT software (Fluent 6.3) and solution conditions were defined as follows:

- 1- Solver: Pressure Based
- 2- Space: 3D
- 3- Formulation: Implicit
- 4- Time: Steady
- 5- Operating Pressure: 101325 Pa
- 6- Pressure-Velocity Coupling: SIMPLE
- 7- Velocity inlet: 3.00 m/s

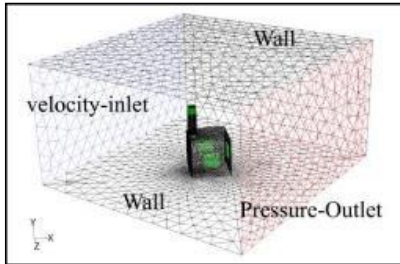


Fig. 2. CFD model boundary conditions

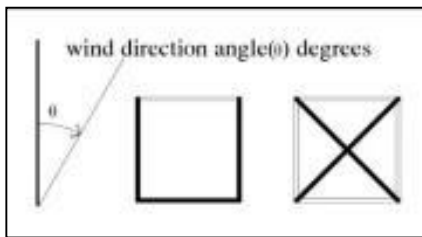


Fig. 3. Air current angle in proportion to the Wind catcher's cage.

The air current angle in proportion to the wind catcher's cage is shown in Fig. 3. According to previous studies and simulations of natural flow, Viscose Model was used the standard k-epsilon model. Continuity, Momentum, k and epsilon equations were governing on the flow. Following two criteria were measured to determine the validity of data.

**Wall Yplus:** Because turbulent flows are strongly affected by the wall, therefore it is necessary to evaluate the sensitivity of mesh near the wall through measurements criteria  $Y^+$ . Usually when the k-epsilon model is used, the mesh near the wall must be arranged so that should be provided  $Y^+ > 30$  or  $Y^+ < 5$ .

In Fig. 4, red line shows the rate of  $Y^+$  in the center of the inner blade of wind catcher, which shows the range  $45 < Y^+ < 251$  in height 2.5-4.5 m. Due to the lack of wall at a height less than 2.5 m, has a zero rate of  $Y^+$ . The black line shows  $Y^+$  rate on the vertical wall along the north and wind catcher, which it is zero due to absence of cage wall in the range 4.0-4.5 m and at other altitudes, has been providing the range  $33 < Y^+ < 216$ .

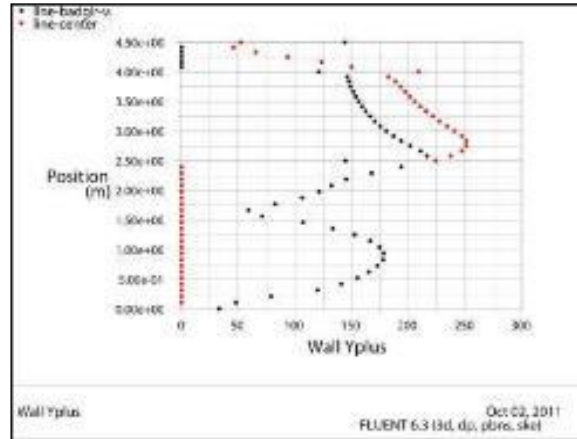


Fig. 4.  $Y^+$  chart near the outer wind catcher wall and the inner blade center

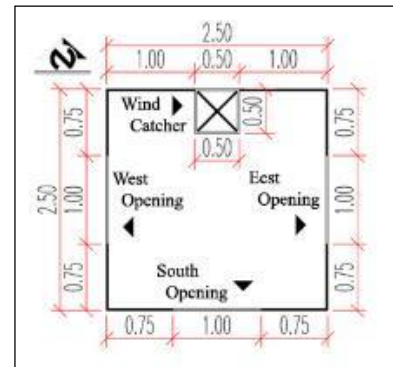
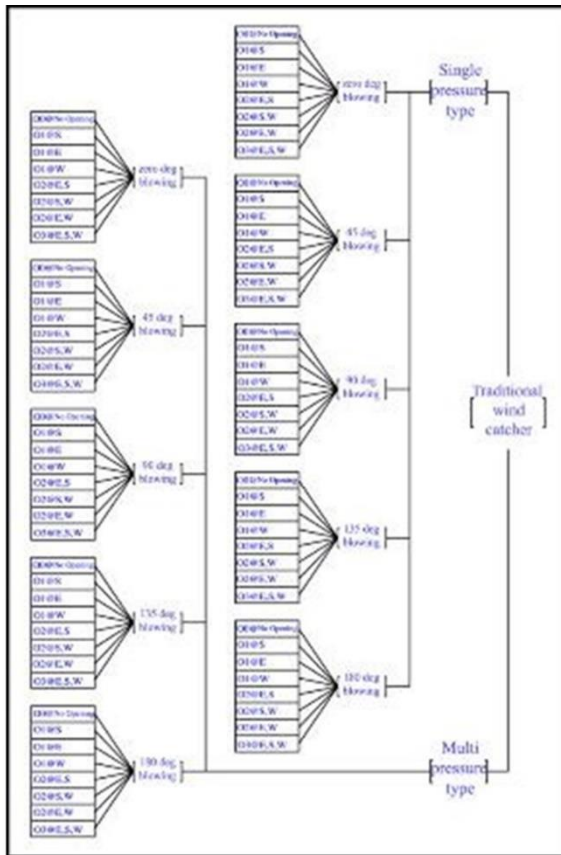


Fig. 5. Place the wind catcher channel and the lower space openings

**Flux Reports:** In this model the mass flow rate is reported as follows:

Mass Flow Rate (kg / s)	
Flow Outlet	-440.99994
Flow Inlet	441.00001
Difference	0.00007

Given the above report, the balance Difference the flow rate is very low. Thus the model seems to be necessary conditions for the flow simulation.



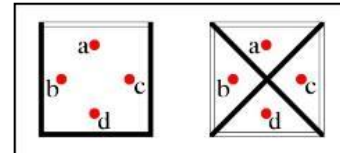
**Fig. 6.** Simulation models with different position openings, different blowing wind direction and both types of wind catchers

Also, in order to create all the conditions that may occur to lower space wind catcher; Openings boundary conditions have changed from Wall to Interior and created the following situations.

1. Building without opening (O0@ No Opening)
2. Building with a single southern opening (O1@ S)
3. Building with a single eastern opening (O1@ E)
4. Building with a single western opening (O1@ W)
5. Building with both eastern and southern openings (O2@ E, S)
6. Building with both southern and western openings (O2@ S, W)
7. Building with both eastern and western openings (O2@ E, W)
8. Building with three eastern, southern and western openings (O3@ E, S and W)

The following diagram comes that Indicating both types of the wind catcher, blowing from different directions and different positions of the lower space. (Fig. 6)

According to this diagram, a high volume of data has been created which it are very time consuming to analyze each of them (For more information, see the source [19]) Thus we compared only the average speed and total speed. The charts show an average speed along the four lines a, b, c, d, where it has been shown in Fig. 7.



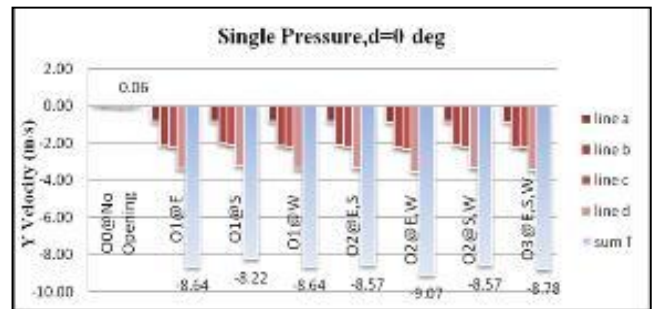
**Fig. 7.** Place along the lines is determined by the average speed

**4. Analyzed the effect of changing the number and location of openings on the Y Velocity within the channel in blowing wind for single pressure wind catcher**

**4.1. At zero degree**

Fig. 8 shows the flow angle of zero degrees to the single pressure type. According to this chart it can be said in general in all positions except in the without opening condition (O0@ No Opening) there has been relatively stable behavior. So that in all conditions except O0@ No Opening condition, the difference between minimum and maximum total speed is 0.85 m/s, but in all conditions, including without opening condition, this undulation is 9.01 m/s.

It can be concluded that in zero-degree blowing, the single pressure type is affiliated with the opening in the lower space but the number and placement of it has not a significant impact on the behavior of wind catcher. This could be due to the lack of opening on the northern side, which it is reduces the direct effect of external flow on the internal flow. However, the eastern and western openings (which suck out the inside flow), had more impact than the southern opening, because the maximum speed is caused by in O2 @ E, W condition and the lowest in O1 @ S condition. Total speed rate of O3 @ E, S, and W condition is reduced to the O2 @ E, W condition; the southern opening has a detrimental effect on wind catcher's behavior.



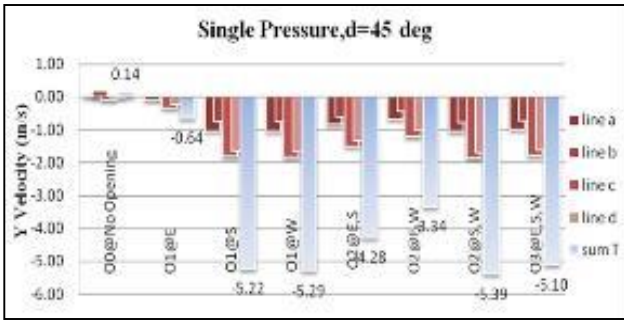
**Fig. 8.** Mean velocities within the channel of single pressure type of zero degree blowing in various openings conditions.

**4.2. At 45 degree**

According to Fig. 9, is characterized by the blowing 45 degrees such as blowing zero degree, remove the opening from the lower space causing internal wind catcher's speeds are less severe. The O1 @ E condition has emerged a large drop in speed which can cause it to be in the outside barrier in front of the opening of the exit internal flow. Therefore, in this blowing, openness has put the eastern opening a detrimental effect on the velocities within the channel. The O2 @ S, W condition is created the maximum speed because the external flow has not only prevented from leaving internal flow, but also is sucked out external flow. Interestingly, that has



occurred in O2 @ E, W condition, despite created two openings, the speed is reduced. Because of this, the flow entering through the eastern opening and wind catcher and it exiting through a single western opening which it has created high condensation on the interior.

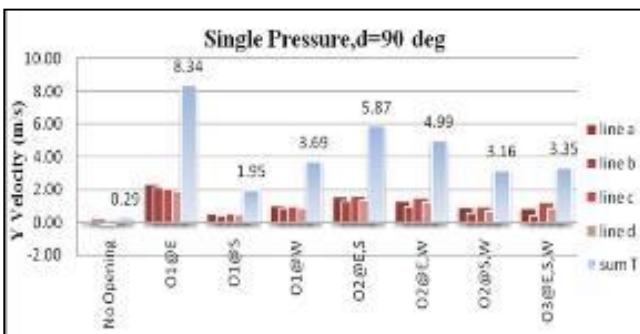


**Fig. 9.** Mean velocities within the channel of single pressure type of 45 degree blowing in various openings conditions

Thus, in general, like blowing zero degree, existence opening in the lower space is necessary but here, opening against the wind has a detrimental effect on the internal flow channel and opening back the wind has a beneficial effect on the internal flow channel; Therefore, increasing the number of openings behind the wind and closing opening against the wind, the highest speed is achieved.

4.3. At 90 degree

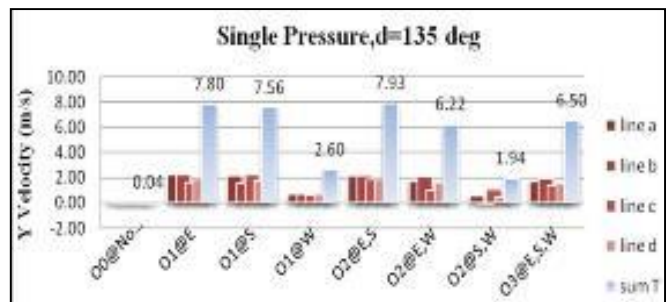
According to Fig. 10, in this blowing, the flow is upward. The O0 @ No Opening condition of this blowing, such as blowing zero and 45 degree, moving flow is completely disrupted, But despite blowing 45 degree, in the condition O1 @ E has created the highest speeds. It seems that flow arrival of a opening and the forced exit of the wind catcher is the main factor to increase flow velocity within the channel. In the earlier blowing, the wind catcher flow was downward, sucking out the flow through the openings were lead to increase the speeds; But in this blowing and other blowing that are caused flow upward into the wind catcher; Flow coming into the space through the openings were lead to increase the speeds. It is predicted, increasing the number of openings behind the wind and reducing the number of openings face the wind, the wind catcher flow speed will decrease. The O2 @ S, W condition is exceptional circumstances because the two openings behind the wind do not suck out the internal flow and external flow has been entered through western opening and it out through the southern opening.



**Fig. 10.** Mean velocities within the channel of single pressure type of 90 degree blowing in various openings conditions

4.4. At 135 degree

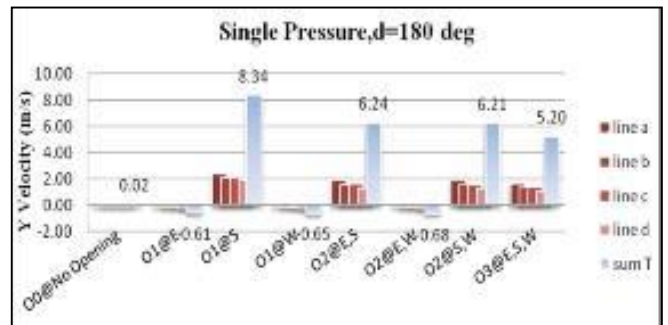
It is also shown in Fig. 11, closing all the openings will result wind catcher performance is impaired. Also, in O1 @ W and O2 @ S, W conditions, the speeds have dropped which it seems that due to negative pressure areas around the western opening. Why in this blowing, the western wall in the negative pressure area and its opening leads flow to outward that has a detrimental effect on the wind catcher velocities. Maximum velocity is created in the O2 @ E, S condition, which both openings were against the wind. Thus, in general, in blowing 135 degrees, the positive pressure regions closer to the end of the wind catcher channel and the negative pressure areas further away from its, the wind catcher speeds is more developed. Therefore, each time increasing the number of openings that face the wind; Positive pressure is closer to the end of the wind catcher and the wind catcher velocities is increased.



**Fig. 11.** Mean velocities within the channel of single pressure type of 135 degree blowing in various openings conditions

4.5. At 180 degree

Changing position openings in this blowing (Fig. 12) unlike other blowing has led to flow upward and downward move into the wind catcher channel. Also again in the O0 @ No Opening condition wind catcher function is impaired.



**Fig. 12.** Mean velocities within the channel of single pressure type of 180 degree blowing in various openings conditions

According to this chart, it is clear that when the opening is placed against the wind; wind catcher flow is moving upward but openings parallel to the wind direction, which causes flow suction to outside; Adverse effects have come on the wind catcher flow speed within the channel. Therefore put opening on the southern side and remove the opening from the lateral side has caused the upward velocity of the wind catcher increases (For example O1 @ S condition) and every time the opposite happened; Not only reduces the upward velocity, But

also it has downward. (For example O2 @ E, W- O1 @ E- O1 @ W conditions)

4.6. Result for single pressure wind catchers

Here can be generally stated that having the opening on the lower space is necessary for single pressure type of wind catcher. To determine the number and placement of openings, it is necessary to be paying attention to the flow direction within the wind catcher and wind direction. So that if the flow direction within the wind catcher is downward; whatever larger positive pressure area is created in front of the cage wind catcher and greater negative pressure areas is created in the front the openings; Increases, flow velocity within the channel of wind catcher.

Thus, Increase the number of openings that are located in the negative pressure area and reducing the number of openings that are located in the positive pressure area; Increases, the wind catcher flow velocity. Also if there are openings in the lower space, which are simultaneously placed on the walls with positive pressure and negative pressure, it will be cause adverse effect on the flow within the channel. Of course if two opening are located in areas with same pressure, but is unbalanced pressure distribution around its; high-pressure area will have adverse effect on the low-pressure area. So the opening that is located in the low-pressure area, will act reverse. Should therefore be balanced pressure distribution around openings otherwise closed the opening in the low pressure area is better than its openness. (Such as O2 @ S, W condition in blowing wind at 90 degrees)

5. Analyzed the effect of changing the number and location of openings on the Y Velocity within the channels in blowing wind of multi pressure wind catchers

5.1. At zero degree

Fig. 13 shows the induced velocities along the four lines (a, b, c, d), total flow velocity of upward and downward and the absolute velocity flow within the channels of the wind catcher. According to this Chart we can say that has happened the flow entry and exit in all conditions even the O0 @ No Opening condition. In all conditions, is an almost constant flow downward along the line A- a channel against the wind - and the main difference is the difference between upward flows. Maximum upward velocity is created in O1 @ S condition and minimum it has been created in O2 @ E, W condition. The upward flow velocity is increased when there are positive pressure areas outside openings and is reduced when negative pressure is created in areas outside openings.

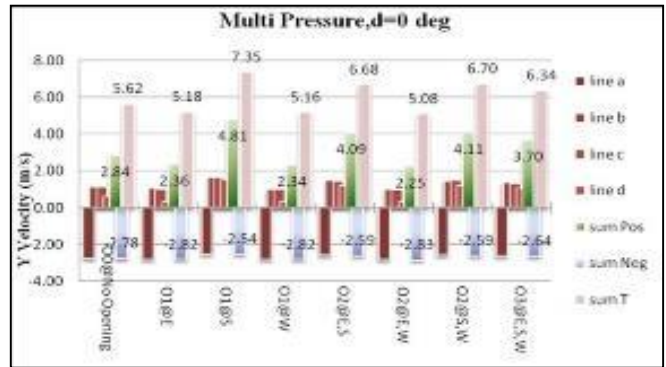


Fig. 13. Mean velocities within the channels of multi pressure type of zero degree blowing in various openings conditions

5.2. At 45 degree

Fig. 14 is a very special and favorable situation, because the absolute value of total flow velocity is almost equal in all conditions while the downward and upward flows velocities are varied. Thus, despite changing conditions, the appropriate balance has been created in the velocity of downward and upward flow because the flow is moving through a separate channel of positive and negative pressure flows in the Multi pressure wind catcher.

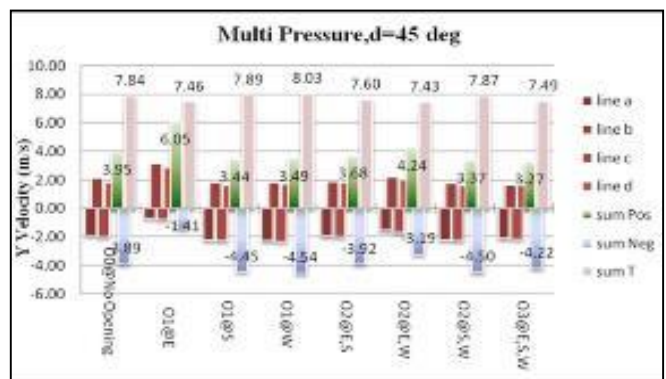


Fig. 14. Mean velocities within the channels of multi pressure type of 45 degree blowing in various openings conditions

This happened to a better balance in the wind blowing of 45 and 135 degrees because the optimum concentration of forces at the end of the wind catcher and the equality of positive and negative pressure channels.

5.3. At 90 degree

According to Fig. 15 can be expressed; in all the conditions of the wind blowing, ventilation is performed in the lower space. But here the difference between minimum and maximum absolute value of total flow velocity increase is relatively large so that it's in O1 @ E condition 10.42 meters per second and in O1 @ S condition has reduced to 5.05 meters per second. Condition O1 @ E, flow is directly into the lower space and has created excessive pressure at the end of the channel in order to wind up, if that is not only increased the flow velocity upward along the three channels a, b, d, It also has a detrimental effect on the downward flow within the channel.

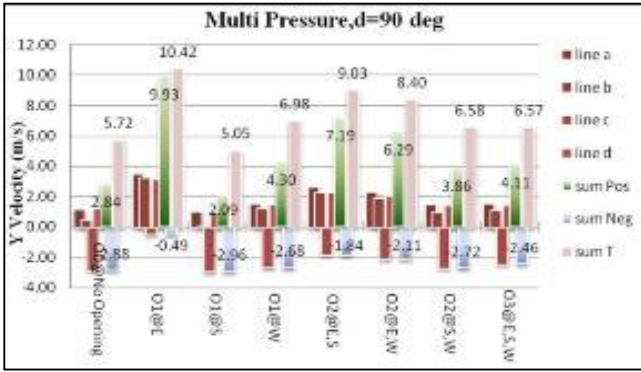


Fig. 15. Mean velocities within the channels of multi pressure type of 90 degree blowing in various openings conditions

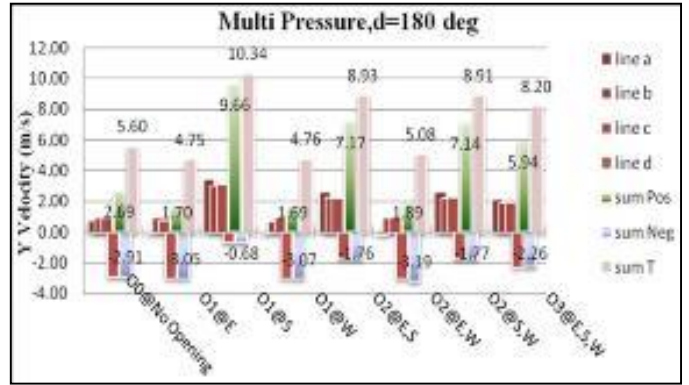


Fig. 17. Mean velocities within the channels of multi pressure type of 180 degree blowing in various openings conditions

But in the O1 @ S condition; a negative pressure area off the southern opening has to be sucked out the inflow. This suction has caused that the maximum downward velocity occur along a single channel c and minimum upward velocity along the other three channels. Therefore cause of this difference can be expressed in difference between the number of positive and negative pressure channels.

5.4. At 135 degree

Fig. 16 shows a situation similar to Fig. 14, so we avoid the repeated explanations. Although for both the condition has been created in almost identical circumstances surrounding the openings, in this situation, the flow velocity in O1 @ S condition is higher than O1 @ E condition. The reason can be seen along the flow path after crossing the openings to the end of wind catcher channels that it has occurred in O1 @ S condition route more appropriate.

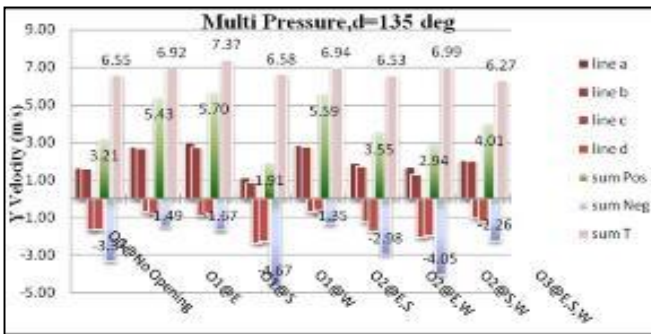


Fig.16. Mean velocities within the channels of multi pressure type of 135 degree blowing in various openings conditions

5.5. At 180 degree

According to Fig. 17, it can be stated that upward velocity has increased when the positive pressure areas are created outside openings it has decreased when the negative pressure areas are created outside openings. However, in all conditions has been in place flow entry and exit.

5.6. Results for multi pressure wind catchers

Totally, the lack of opening in the lower space of multi pressure type of wind catcher does not lead to dysfunction but changing the wind direction is effective on the flow velocity within the wind catcher. Change wind direction has affected on the number of positive and negative pressure channels, so that in wind blowing of zero, 90 and 180 degrees, has created three negative pressure channels and a positive pressure channel, while in the wind blowing of 45 and 135 degrees, has created two positive pressure channels and two negative pressure channels. This proportion has affected on the flows velocities so that in the proportion 3-1 if there is no opening in the lower space, without any external force; flow has been entered only through one channel and it is out of the three channels; Thus the total velocity at three suction channels, is almost equal to the velocity of tail channel. Nevertheless existence an opening in the lower space has caused instability flow velocity within the channels. (Such as O1 @ E and O1 @ S conditions in the wind blowing of 90 degrees) But if the proportion of 2-2; Openings that have been in any situation of lower space will impact (Adverse or beneficial) equally on wind catcher.

6. Conclusion

Possible to compare types of wind catcher is provided in Table 1. Presented in this table is the mean absolute velocity of both types of wind catcher passing through channels, in different wind blowing and in different conditions. Also the difference between the most and least average speed (Max Undulation) and average wind speeds generated in different conditions and in different wind blowing (Total Av) are identified.

According to this table it can be said; most and least velocity in Multi pressure type has been 10.42 and 4.75 m/s (in O1 @ E condition of wind blowing of 90 and 180 degrees) and it's in Single pressure type Has been 9.07 and 0.02 m/s (in O2 @ E, W condition of zero degrees wind blowing and O0 @ No Opening condition of 180 degrees wind blowing). Therefore, the Multi pressure type has been created higher velocities. Max Undulation in Multi pressure type is in the range of 5.59 – 0.60 m/s while this range in Single pressure type is 9.01 – 5.25 m/s.



**Table1.** Mean absolute change flow velocity within the channels of both types of wind catcher in different blowing and various conditions

Type	Wind Direction	O0 @ No Opening								Max Undulation	Total Av
		00deg	010deg	020deg	030deg	045deg	060deg	075deg	090deg		
Multi Pressure	0deg	5.62	5.18	7.35	5.16	5.16	5.08	6.70	6.34	2.27	5.82
	45deg	7.46	7.89	8.03	7.60	7.43	7.87	7.87	7.49	0.69	7.71
	90deg	5.72	10.42	5.05	6.98	9.03	8.40	5.58	6.57	5.37	7.22
	135deg	6.55	6.92	7.37	6.58	6.94	6.53	6.99	6.27	1.19	6.77
	180deg	5.60	4.75	10.34	4.76	8.93	5.08	8.91	8.20	5.58	7.47
	Total Av	6.19	7.83	7.63	6.22	7.50	6.59	7.21	6.97	2.99	6.92
Single Pressure	0deg	0.06	8.64	8.22	8.64	8.57	9.07	8.57	8.78	3.81	7.57
	45deg	0.14	0.64	5.22	5.29	4.28	3.34	5.39	5.10	3.25	3.68
	90deg	0.29	8.34	1.95	3.69	5.87	4.99	3.16	3.35	3.05	3.96
	135deg	0.04	7.80	7.80	2.60	7.93	6.22	1.94	6.50	7.89	8.10
	180deg	0.07	0.61	8.34	0.65	6.24	0.68	6.21	5.20	3.32	3.49
	Total Av	8.11	5.21	6.31	4.17	6.58	4.86	5.85	5.79	7.70	4.76

Thus in Multi pressure type has created a range of speeds closer together and it has a more stable behavior. The mean velocity at different conditions in Multi pressure type is 2.99 m/s and in Single pressure type is 7.70 m/s; the mean changes and instability is in Single pressure type about 2.5 times Multi pressure type. (Fig. 18)

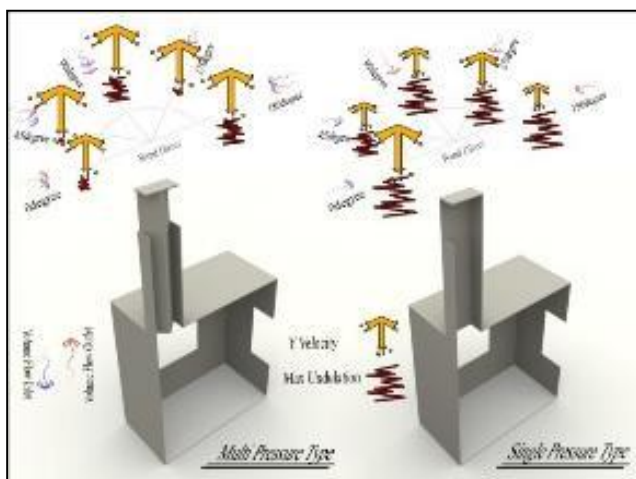


Fig. 18. How to change the Y velocity and the maximum its difference in the various blowing of both types of wind catcher.

Overall we can be studied efficiency of both types of wind catcher in variable conditions through comparison of total average speeds in different blowing and various conditions. This value is in Multi pressure type 6.92 m/s and in Single pressure type 4.76 m/s; As a result the efficiency of Single pressure type was 68% compared to the efficiency of Multi pressure type. Since the results presented in Table 1, including O0 @ No Opening condition and in this condition very low velocities is caused by Single pressure type; it is possible that this ambiguity may be removed O0 @ No Opening condition, it will change the results. Therefore, the results in Table 2 were prepared by removing O0 @ No Opening condition. Max Undulation in this table is remaining in Multi pressure type 2.99 m/s but in Single pressure type declined to 5.14 m/s. Thus eliminating O0 @ No Opening condition, Max Undulation of Single pressure type has decreased, but still is about 1.7 times

higher than Multi pressure type. Also total average speeds in Multi pressure type is 7.02 m/s and its 5.42 m/s in Single pressure type. Although velocity in Single pressure type has grown more than Multi pressure type, however the efficiency of Single pressure type is still about 77% compared to the efficiency of Multi pressure type. In the end, it can be stated that changing conditions; Multi pressure type has supplied low swing speeds and it's the behavior is more stable and more efficiently than Single pressure type.

**Table 2.** Mean absolute change flow velocity within the channels of both types of wind catcher in different blowing and various conditions, regardless of O0 @ No Opening condition.

Type	Wind Direction	O0 @ No Opening								Max Undulation	Total Av
		00deg	010deg	020deg	030deg	045deg	060deg	075deg	090deg		
Multi Pressure	0deg	-	5.18	7.35	5.16	5.16	5.08	6.70	6.34	2.27	5.85
	45deg	-	7.89	8.03	7.60	7.43	7.87	7.87	7.49	0.69	7.74
	90deg	-	10.42	5.05	6.98	9.03	8.40	5.58	6.57	5.37	7.45
	135deg	-	6.92	7.37	6.58	6.94	6.53	6.99	6.27	1.19	6.80
	180deg	-	4.75	10.34	4.76	8.93	5.08	8.91	8.20	5.58	7.38
	Total Av	-	7.03	7.63	6.22	7.50	6.59	7.21	6.97	2.99	7.02
Single Pressure	0deg	-	8.64	8.22	8.64	8.57	9.07	8.57	8.78	0.85	8.64
	45deg	-	0.64	5.22	5.29	4.28	3.34	5.39	5.10	4.71	4.18
	90deg	-	8.34	1.95	3.69	5.87	4.99	3.16	3.35	6.38	4.18
	135deg	-	7.80	7.80	2.60	7.93	6.22	1.94	6.50	8.94	5.83
	180deg	-	0.61	8.34	0.65	6.24	0.68	6.21	5.20	7.73	3.99
	Total Av	-	5.21	6.31	4.17	6.58	4.86	5.85	5.79	5.14	5.12

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