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A new modern Design of four-sided Windcatcher for Natural Ventilation in Residential Building in Saudi Arabia

Ali Alzaed[1] and Ashraf Balabel[2]

[1] *Faculty of Engineering, Taif University, Al-Haweiah, Taif, Saudi Arabia.*

[2] *Faculty of Engineering, Taif University, Al-Haweiah, Taif, Saudi Arabia.*

Abstract

Wind towers can be considered as the optimum solution for energy saving and obtaining the thermal comfort in arid and windy regions in Saudi Arabia. In the present paper, a new modern design for four-sided wind catcher is introduced. The proposed wind catcher can be made from appropriate material and inserted on the top section of the wind towers. The proposed wind catcher can face the prevailing wind from all directions without any rotating parts. Thus enables catching the wind and providing continuous air flow inside the wind tower. The modern design developed for the wind catcher prevents the mixing of the wind received from all directions and brings it down the wind tower into the interior of the building to maintain natural ventilation of the building interior. The internal design of the proposed wind catcher is based on changing the indoor air flow dynamics and characteristics to obtain the best fluid dynamics conditions at the exit section of the wind catcher. The proposed modern design can increase the overall efficiency of the wind towers used for passive cooling systems in residential buildings.

Keywords: Energy saving; Fluid dynamics; Natural ventilation; Thermal comfort; Wind catcher.

INTRODUCTION

Saving energy consumption in the Residential Buildings in Saudi Arabia is most important challenge during the recent decades. The huge consumption of energy in the building sector either for cooling or warming is making the architects to develop new design in order to obtain low energy consumption in different climates. One of the most important topics to achieve thermal comfort especially in countries with hot climate such as Saudi Arabia is the passive ventilation through wind towers [1].

The traditional architecture systems in most of countries are based on wind towers used for passive and low energy cooling systems. The wind towers are similar to vertical chimney with appropriate vents on the top section that called wind catcher. The design of the wind catcher has essentially the function of collecting the desired wind and leading it to the interior spaces for thermal comfort purposes. The wind catcher can be one-/two- or four-sided design to obtain high performance of the wind towers. In order to improve the efficiency of the wind catchers different external as well as internal prospective models are illustrated [2, 3, 4].

In the areas where wind speed is low, wind towers with wetted surfaces can be used in order to increase the performance of the wind tower and to make the incoming air much cooler. This design can use the evaporated cooling potential to lead much cooler air to the interior spaces and provide thermal comfort [5, 6]. Different designs have been proposed for the so-called wetted towers and their performance was estimated [7]. Alternative, a solar chimney or one-sided wind tower can be installed in another part of the building in the opposite direction [8].

Moreover, the previous investigations have considered the effect of the number of sides in the wind tower as well as the cross section shape of it [9]. Nearly all wind towers in hot and humid areas are the four-sided type.

More recently, an increased attention has been given to the influence of different wind catcher's plan geometry on the indoor air temperature. Such investigations are carried out either experimentally in a wind tunnel or numerically using 3-D computational fluid dynamics (CFD) methods, for more details one can see the cited articles [10-12] for experimental works and articles [13-15] for numerical studies.

Computational Fluid Dynamics (CFD) and heat transfer is a well-known technique that can be applied effectively in the industrial design. In such technique, the governing differential equations of a flow system and thermal system are known in the form of Navier–Stokes equations, thermal energy equation are solved with some numerical algorithms by applying appropriate boundary conditions for the case under consideration. Recently, CFD plays an increasingly important role in different research fields, especially for building design. The information provided by CFD can be used for analysis of the impact of building exhausts to the environment, to predict smoke and fire risks in buildings, to quantify indoor environment quality, and to design natural ventilation systems, etc. This gives rise to a new research field known as Computational Fluid Dynamics for Architectural Engineering (ARCH-CFD).

Different recently papers present disciplinary research initiative aiming to make CFD much more accessible to the architecture community. The most particular interest was in the incorporation of CFD into the early stages of architectural design.
Many critical decisions, including those pertaining to building performance, were made during these stages, and it is believe that access to wind/airflow information during these stages would help architects make responsible design decisions. As a first step, a passive cooling system should be designed where wind/airflow was a driving factor for geometry generation.

Consequently, in the present paper, a new and modern wind catcher design is introduced. The proposed design has several advantages over the previous designs found in the literature from the practical as well as dynamics points of view.

FUNCTION OF WINDCATCHER

It is well known that wind catcher operate based on two different methods as explained in the following: The first method is based on leading the air directly into buildings by pressure differential. It depends on the air velocity to provide ventilation effects. In the second method, lower air pressure on the windward side of the wind catchers is created when wind blows over the wind catchers. As the air pressure inside the building is higher than the outside, the tendency of higher pressure air traveling to the lower pressure region causes the air to be drawn upwards.

REVIEW OF DIFFERENT SHAPES OF WINDCATCHER

In the following section, different shapes of wind catcher are presented. Some of these shapes are relatively old, the others can be considered are relatively new. The aim of this illustration is to show how the external shape of the wind catcher is developed form ancient ages to the new ones.

A. Ancient wind catchers with different configurations

In Ancient Egypt, the wind catchers are known in traditional Egyptian architecture as demonstrated in Wind catchers on the Pharonic house of Neb- Ammun [17]. A small wind catchers is called a shish-khan can be found in traditional Persian architecture in different cities in Iran [18].

The wind catchers were known in traditional Egyptian architecture in Ancient Egypt as demonstrated in Wind catchers on the Pharonic house of Neb- Ammun, Egypt. It was revived in Neo-Islamic architecture as the works of modern architectural design belongs to Hassan Fathy. In Egypt, the wind catchers are known as *Malqaf*.
Ancient Iran can be also considered as the origin of the wind catchers in the world besides to those of ancient Egypt. Some questions were tried to be solved in previous articles such as the identity and origin of wind catcher, the construction technology and its types.

Figure 1 : The one-sided wind tower of a house inAl-Jawhara in Cairo, [16].

Figure 2 : Several wind-catchers with different configurations, (a) four-sided wind-catcher with flat roof (Yazd), (b) octahedral-sided wind-catcher with flat roof (Yazd), (c) one-sided wind catcher with steep roof (Ardakan), (d) two-sided wind catcher with curved roof (Mehriz) [3].

Figure 3 : Several ancient wind catchers with different configurations [4].

B. Modern wind catchers with different configurations

In the present section, some modern configurations for wind catchers are presented. Most of these models are developed and presented in the previous literature. However, these models were not applied actually in buildings. Some of the literatures were interested in performing experimental measurements or numeral simulations using CFD software. The aim of such investigations is to reach the optimum design of the wind catchers. Some of these treatments are presented in the following.

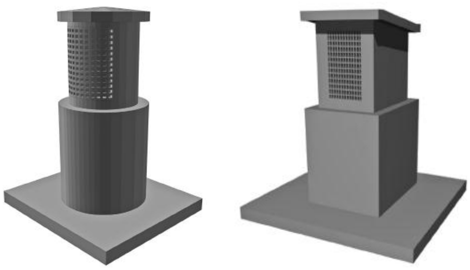

Figure 4 : Modern design of wind catchers [2].

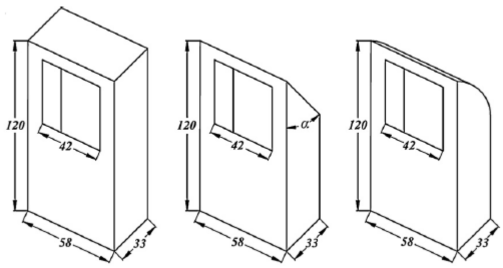

Figure 5 : Modern design of wind catchers with different roof geometry [3].

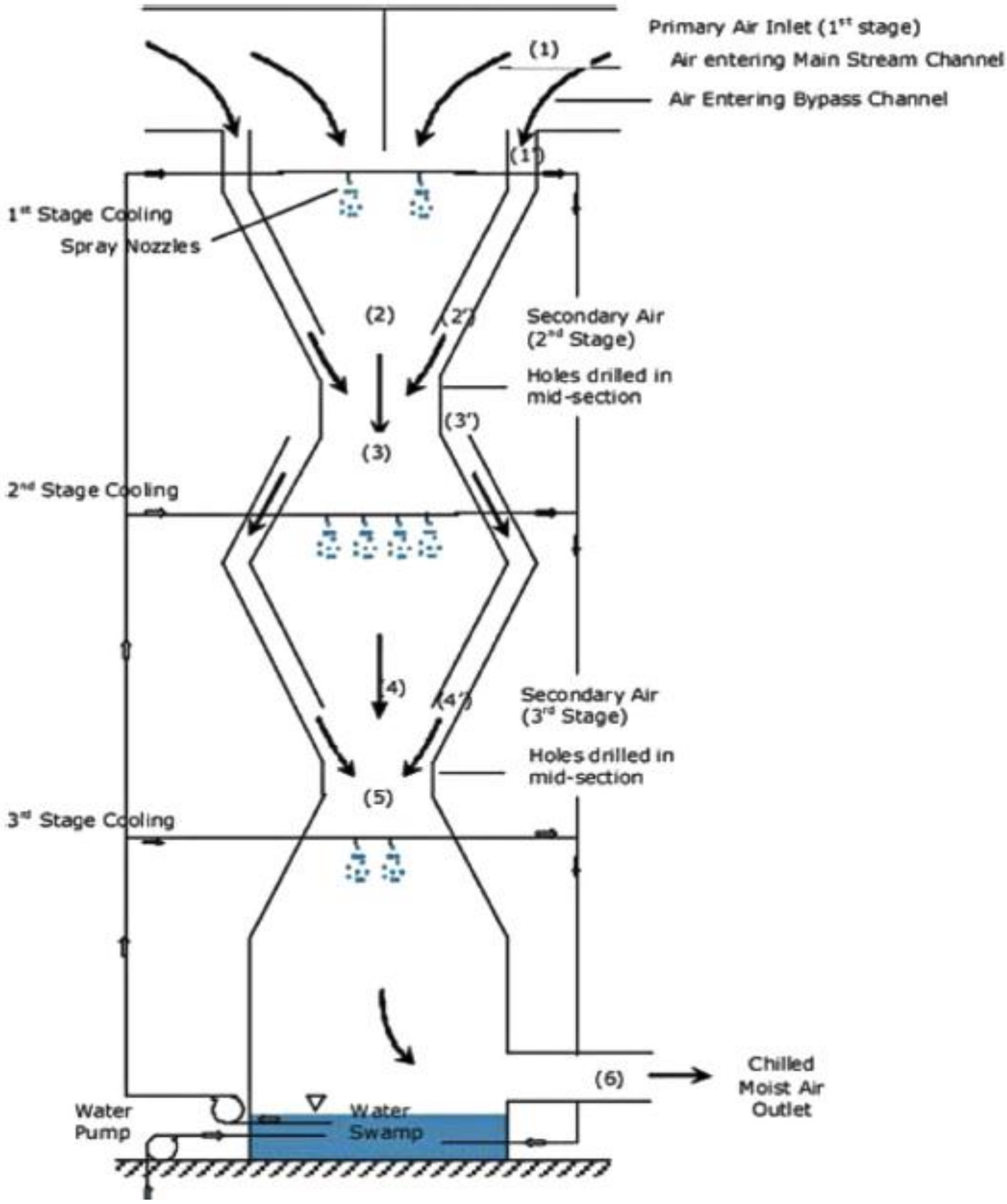

Figure 6 : Three stages wind tower with modern design of wind catchers [2].

THE PROPOSED MODEL OF WIND CATCHER

The proposed model of wind catcher, as shown in Fig. 7, is designed to overcome the limitations of conventional and traditional wind catchers and improve its performance. It is aimed to be installed in the inside of the modern minaret design. It is well known that minaret has not been utilized as a wind catcher before. In more recent article, a conceptual model for multifunctional application of sustainable minarets to improve the comfort of the prayers inside the mosques has been presented

[19]. Using the proposed model of the wind catcher inside the minaret design presented in [19] will lead to electrical energy saving by reducing the number of air condition units required inside mosques.

Four proposed models are collected together inside the four-sided wind tower to receive the prevailing wind from all directions with any speed and without any rotating parts, as shown in Fig. 8. This can remove the limitations of other previous wind catchers and improve the ventilation efficiency; see for more details [2].

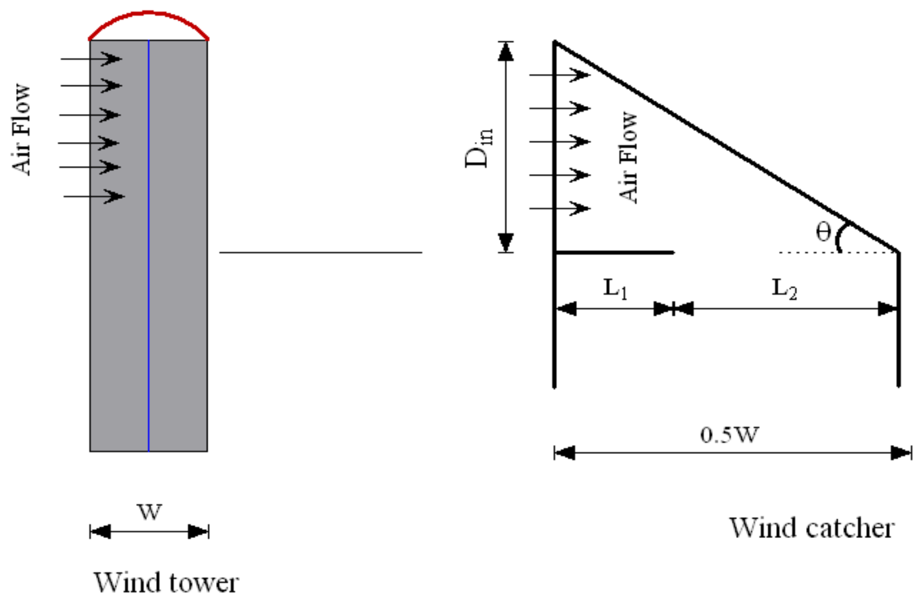

Figure 7 : The proposed wind catcher and its geometrical parameters

The previous figure shows the proposed design of the wind catcher model. The side view of the proposed design indicate the internal configuration of the model which consists of:

1- An inlet section for the air flow rate with width D_{in}.
2- An inclined outlet surface with a defined angle θ.
3- A flat slab with a defined length L_1.
4- An exit section for air outlet with a defined length L_2.

The total width of the model is 0.5w, where w is the width of the wind tower.

The future numerical study of the proposed model using some commercial CF D code should answer the questions about the optimum values of the geometrical dimensions of the model; i.e. D_{in}, L_1, L_2,θ.

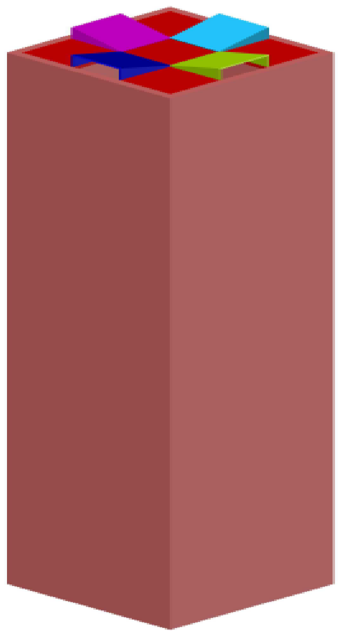

Figure 8 :3D-Plot of the proposed wind catcher

THE INTERNAL DESIGN OF THE PROPOSED WIND CATCHER

The internal design of the proposed wind catcher is made according to the dynamics and wind characteristics at required the exit section of the catcher. The proposed wind catcher has only one opening with width Din, facing and perpendicular to the direction of the incoming wind. It has also a steep roof inclined with an angle θ to the horizontal direction. An extended flat plate with length L1 is connected to the end of the opening section. The rest of the length L2 is opened in the downward direction of the incoming wind.

This internal geometry of the wind catcher can increase, firstly, the velocity of the incoming wind according to the steep roof shape which stands, with the existence of the plate L1, as a convergent section. After the issuing of the incoming air form the opening L2, the area is expanded enabling the pressure to increase. This increase in pressure leads naturally to further movement in the rest of wind tower and makes the distribution of the air in the interior of the building much easier and naturally. These geometrical parameters of the proposed model should be investigated in order to reach to the optimum values of such parameters in relation to the wind tower dimensions. This will be done in our future work using CFD software.

It should be pointed out that the proposed design is based on the author’s experience in the field of the computational fluid dynamics with its application on diffuser performance. The key element of any wind catcher design is the calculation of the pressure coefficient (Cp) at the exit section of the wind catcher and the estimation of the ventilation efficiency of the propose model.

CONCLUSION

In the present paper, a new modern design for the wind catcher used in the passive ventilation of the building interior is presented. The proposed model is suitable for the four-sided wind tower and prevents the mixing of the incoming wind from all directions. Moreover, the proposed model has the advantages that it does not contain any rotating parts and it is simply fixed in the interior of the wind tower. The internal geometry of the proposed wind catcher is based on improving the dynamics and the characteristics of the incoming wind at the exit section. Consequently, the appropriate conditions of velocity and pressure can be obtained. In our future work, a numerical simulation of the internal flow structure inside the proposed model will be carried out using suitable CFD software.

REFERENCES

[1] D. Patel and S. T. Rajan, Design of A Passive and Wind Speed Responsive Wind Catcher for Energy Efficient Buildings, IJIRST –International Journal for Innovative Research in Science & Technology, Volume 1, Issue 8, 2015.

[2] A.R. Dehghani-sanij, M. Soltani, K. Raahemifar, A new design of wind tower for passive ventilation in buildings to reduce energy consumption in windy regions, Renewable and Sustainable Energy Reviews, 42 (2015) 182-195.

[3] M. Kazemi Esfeh, A.A. Dehghan, M. Dehghan Manshadi, S. Mohagheghian, Visualized flow structure around and inside of one-sided wind-catchers, Energy and Buildings 55, 545–552, 2012.

[4] H. Montazeri, F. Montazeri, R. Azizian, S. Mostafavi, Two-sided wind catcher performance evaluation using experimental, numerical and analytical modeling, Renewable Energy, 35, 1424–1435, 2010.

[5] Bahadori, MN. An improved design of wind towers for natural ventilation and passive cooling, Sol Energy;36(2), 119–29, 1985.

[6] Bahadori, MN, Pakzad, AR, Performance evaluation of new designs of wind towers, proceedings of ASME FEDSM02, ASME 2002.

[7] Bahadori, MN, A passive cooling/heating system for hot arid regions, In:13th National passive solar conference, MIT, Cambridge, MA;June20–24, 364–367, 1988.

[8] Nouanegue HF, Alandji LR, Bilgen E. Numerical study of solar-wind tower systems for ventilation of dwellings. Renewable Energy,;33(3), 434–43, 2008.

[9] M. Mahmoudi and S. Mofidi Shemirani, "Analyze on typology and architecture of wind catcher and find the best type," Journal of Honar-haye-ziba, no. 36, pp. 27-36, 2009.

[10] V. Kalantar, Numerical simulation of cooling performance of wind tower (Baud-Geer) in hot and arid region, Journal of Renewable Energy 34 (2009) 246–254.

[11] M.N. Bahadori, M. Mazidi, A.R. Dehghani, Experimental investigation of new designs of wind towers, Journal of Renewable Energy 33 (2008) 2273–2281.

[12] C. Karakatsanis, M.N. Bahadori, B.J. Vickery, Evaluation of pressure coefficients and estimation of airflow rates in buildings employing wind towers, Journal of Solar Energy 37 (1986) 363–374.

[13] L. Li, C.M. Mak, The assessment of the performance of a wind catcher system using computational fluid dynamics, Journal of Building and Environment 42 (2007) 1135–1141.

[14] A.A. Dehghana, M. Kazemi Esfeh, M. Dehghan Manshadi, Natural ventilation characteristics of one-sided wind catchers: experimental and analytical evaluation Energy and Buildings 61 (2013) 366–377.

[15] H. Montazeri, F. Montazeri, R. Azizian, S. Mostafavi, Two-sided Wind Catcher Performance Evaluation Using Experimental, Numerical and Analytical Modeling, Renewable Energy, Volume 35, 1424–1435, 2010.

[16] http://archnet.org/library/dictionary/entry.jsp?entry_id=DIA0483

[17] S. Roaf, Air-conditioning avoidance: lessons from the windcatchers of Iran, International Conference “Passive and Low Energy Cooling 1053 for the Built Environment”, May 2005, Santorini, Greece.

[18] A. A'zami, Badgir in traditional Iranian architecture, International Conference “Passive and Low Energy Cooling 1021 for the Built Environment”, May 2005, Santorini, Greece.

[19] A.Alzaed, Sustainable Minarets: Towards Multifunctional Applications as a New Conceptual Design Model, International Journal of Emerging Research in Management & Technology,4(12), (2015) 18-24