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The Effect of Tower Height in Square Plan Wind catcher on its Thermal Behavior

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Abstract: Wind catchers/towers systems were employed in buildings in the Middle East for many centuries and they are known by different names in different parts of the region .They were constructed, traditionally, from wood-reinforced masonry with openings at the height of 2 to 20m above the building roof. Taller towers capture winds at higher speeds and with less dust. Their application in the hot arid region of the Middle East is to provide natural ventilation/passive cooling and hence thermal comfort, exploiting, particularly, night-time ventilation strategy. They can be beautiful objects, feasible architectural features and are inherently durable. This paper provides a categorization of wind-catchers in Yazd based on their attributes and parameters and stipulates on the best wind catcher plan geometry and height for reducing the indoor temperature experiment are conducted using 3-D computational fluid dynamics (CFD) simulations to compare indoor air temperature in different square wind catchers with different height.

Key words: Wind Catcher, wind catcher geometry, Wind catcher's height, fluent software.

INTRODUCTION

Buildings in hot and humid climates have been traditionally cooled by ventilation. Wind catcher or what is called *badgir* in Persian language has been employed in arid central regions of Iran and the neighboring countries to provide natural ventilation and passive cooling. In these regions due to the hot summer time, the buildings have these special architectural features and components in order to protect the occupants from the harsh outdoor temperature. The function of the *badgir* in these regions is to capture wind from external air stream and induce it into the building and courtyard in order to cool the occupant directly by increasing the convective and evaporative heat transfer from the body surface. It cools the occupant indirectly by removing heat stored in the building structure. When wind is blowing over the tower and the building it severs, a wind pressure develops on various apertures. Air enters from the windward openings, with positive wind pressure coefficient, and leaves the leeward openings, with negative or lower values of the pressure coefficients (Pirnia 1971).

Shapes, heights and internal structures of Badgir s were not only influential to the volumetric air delivery and cooling capacity of the building, but were an indication of dignity, wealth and social position of the house owners. Wind catchers are designed to capture and drive air flow through their top opening, which usually faces the prevailing wind. During daytime, the operation mechanism of the wind catcher is dependent on the wind effect due to the air pressure difference across the inlet and outlet.

The catcher traps and channels down air at a higher velocity and lower pressure than the ambient air. This is known as the Venturi effect. It is also possible to use evaporative cooling to cool the air. During night time, the relatively lower outdoor air temperature helps to cool the building. If there is no wind, then the heat released by the wind catcher heat up the air inside it and drives it outside the building. This is effective when the diurnal variation in ambient temperature is high.

Previous Work:

Karakatsanis *et al*. (1986) determined wind pressure coefficients at various openings of a square wind catcher by testing a scale model of the building in a boundary layer wind tunnel. The tests were conducted on an isolated tower, the tower and the adjoining house, and the tower and the house surrounded by a courtyard. Using measured pressure coefficients natural ventilation through the building was estimated analytically. Elmualim and Awbi (2002) carried out experimental investigations and computational fluid dynamics (CFD) simulations to evaluate the performance of square and circular section wind catchers. The

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achieved results showed that the efficiency of the four-sided wind catcher is much higher than that of the circular one for the same wind speed. They claimed that the sharp edges of the square wind catcher create a large region of flow separation and a higher pressure difference across the device. Montazeri and Azizian (2008) evaluated the performance of a one-sided wind catcher using experimental wind tunnel and smoke visualization testing. The induced airflow rate into the test room and the pressure coefficients around all surfaces of its channel were measured for different values of approaching air incident angles. Neglecting the dependence of discharge coefficient on the flow direction, natural ventilation performance of one-sided wind catcher was estimated using a non-dimensional analytical model. Liu and Mak (2007) used CFD technique to examine the performance of a 500 mm square section wind catcher which demonstrated good correlation with Elmualim and Awbi's (2002) data, although this is limited to the overall ventilation rates. Elmualim (2005) studied a similar wind catcher device, including dampers, diffuser, and a heat source to assess the ventilation capabilities of the device. The results yielded a good correlation between the numerical simulation and experimental measurements. Hughes and Ghani (2009) used CFD to calculate net flow rates through a 1000 mm square wind catcher. They concluded that the CFD results show good correlation, and the grid adoption technique is a well-recognized practice for achieving reliable result.

Methodology:

Experimental studies of wind catcher systems for all different type of wind catcher are obviously costly and impossible. The assessment of the performance of wind catcher systems using computational fluid dynamics (CFD) is very important for both design and improvement of the systems.

CFD has recently been widely used to study airflow in and around buildings (Liu Li, M. Mak, 2007) since it can provide detailed airflow velocity distribution and thermal conditions. For most applications of ventilation and turbulence flow, the results have been approved to be useful and reasonably accurate. CFD has therefore become a reliable tool for air flow analysis in buildings. In this paper, three-dimensional models of a wind catcher system with H blade form have simulate built and their performance under different height has been studied and compared.

The wind catchers of Yazd are higher than the other cities of Iran. It dominates the sky line of the city. The usual height of Yazd wind catcher is 5 meter from the roof and the highest is 33 meter from ground. The height of the Yazd wind catchers are between 1.5 m to 26.5 m based on Roaf investigations. If we supposed "high tower" for wind catcher with more than 3 meters height from the roof and "short tower" for the one which is less than 3 meter, then 88.76% of Yazd wind catcher can be considered high. Table1 shows the height of Yazd wind catchers among 53 wind catchers investigated.

Table 1: Wind catcher height in Yazd

height	number	percentage
H > 3	6	11.4%
3>h>5	18	34%
5>h>8	20	37.6%
H < 8	9	17%

The height of the simulated wind catchers are chosen based on the maximum and minimum height of the Yazd square wind catchers.

The ratio between width and length of the wind catcher connected room varies From 1-1, 1- 1.2, 1- 1.3 and 1 - 1.5. The ratio 1 to 1.5 is chosen for the simulation as a large module. This room connected to the wind catcher has a 0.7m by 1.5m window in the south east elevation.

Mathematical Model Setup:

a. Geometry:

As shown in Fig.1 that a three dimensional square wind catcher models each the dimension of 150cm by 150cm with height varies From 3.5, 4.5, 5.5, 6.5, 7.5, 8.5, 9.5 and 10.5 connected to 6m by 4m. The wind speed is 5 m/s and out door temperature is 37 degrees Celsius which is smaller to the average temperature of Yazd during hot summer days. The only parameter which is allowed to change is the high of the wind catcher to find out the best height for reducing the indoor temperature for room with H from wind catcher plan.

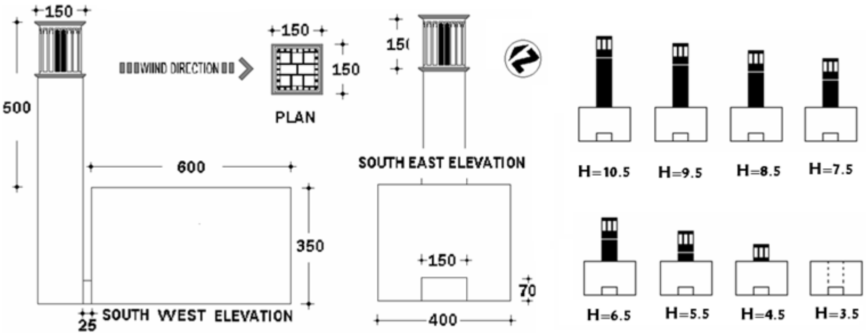

Fig. 1: Dimension of conventional wind catcher with H blade.

b. Numerical Grids:

This series of experiment were carried out using CFD technique. A commercial CFD package called FLUENT, which has been applied to various research works and found to be reliable [8], is adopted in this study to measure the indoor air temperature .The standard (two-equation) k–e turbulence model was adopted. The total number of grids in all simulation models is all around 30,000 and the maximum and minimum grid volume is about 2.8×10^{-3} and 3.3×10^{-5} m3, respectively. Unstructured grid was used for all simulation models (as shown in Fig. 2).

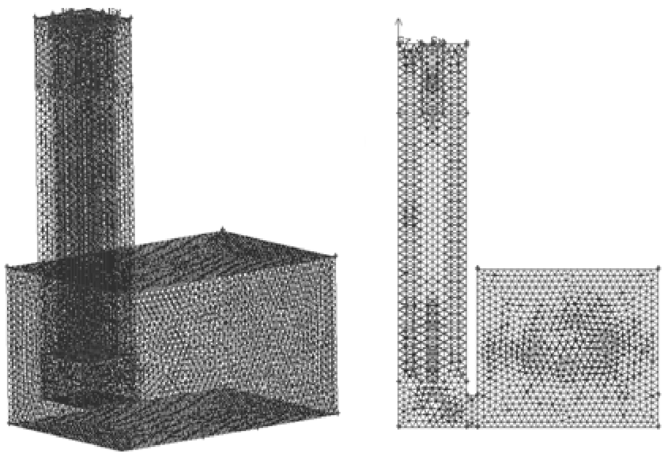

Fig. 2: Geometrical model by Gambit.

Results and Analysis:

Temperature contour of each model are shown in figure 3 which indicates how the air temperature change through the channel and room. The graph in Fig. 4 and 5 show that with wind catcher height less than 6m from ground the indoor temperature decrease steadily and it is begun to level out when the wind catcher height is more than 6m. Therefore there is no difference in indoor temperature when we increase wind catcher height has reached 6m and beyond in room which has no water pond inside for evaporation cooling. These conventional wind catchers cooled the air while the air pass through the wind catchers walls which lose the heat through transferring and radiation during night and its temperature remains in low and average level during the day, thus, providing enough comfort for residents.

Conclusion:

The wind catcher is an intelligent exploitation of wind energy which makes possible in door thermal comfort in hot region. The major advantage of the wind towers is that they are passive systems, requiring no energy for their operation. Thermal behaviour of H form wind catcher with different height between 3.5 to 10.5 are investigated by means of CFD simulation and the results show that increasing height of the wind catcher has effect on its thermal behaviour and the height of 6m is determined to be the best height for conventional wind catcher with no water pond inside for evaporation cooling.

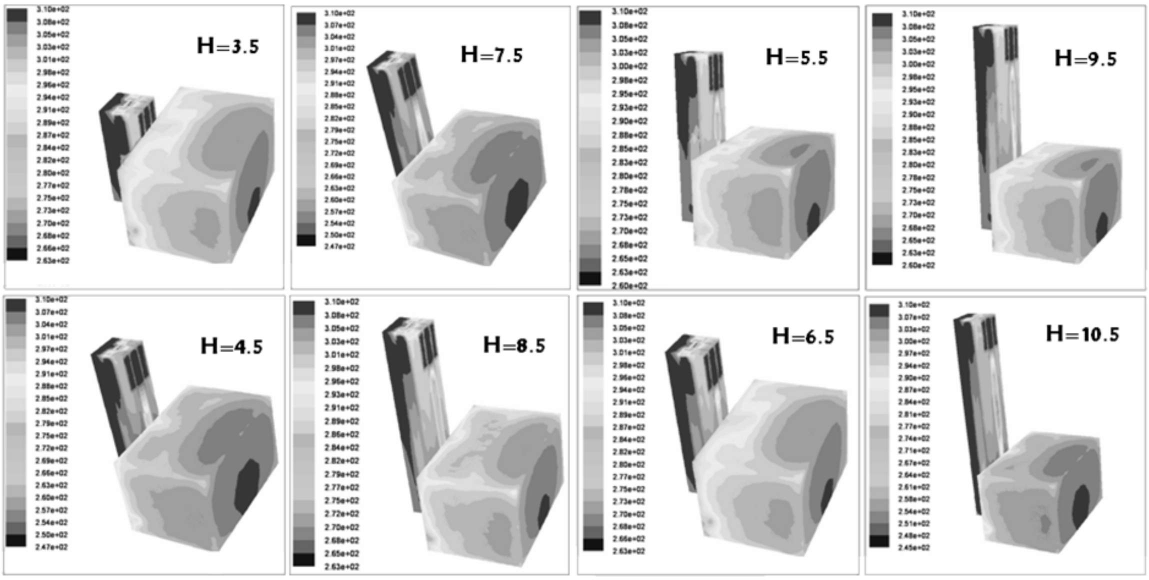

Fig. 3: Temperature contour of wind catchers.

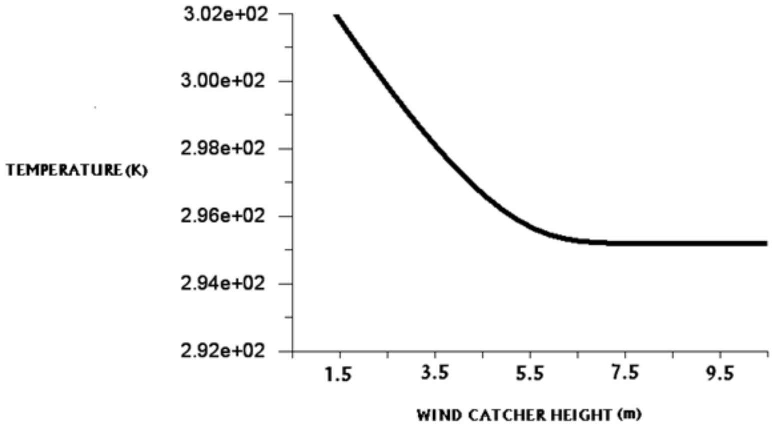

Fig. 4: Variation of indoor temperature with wind catcher height.

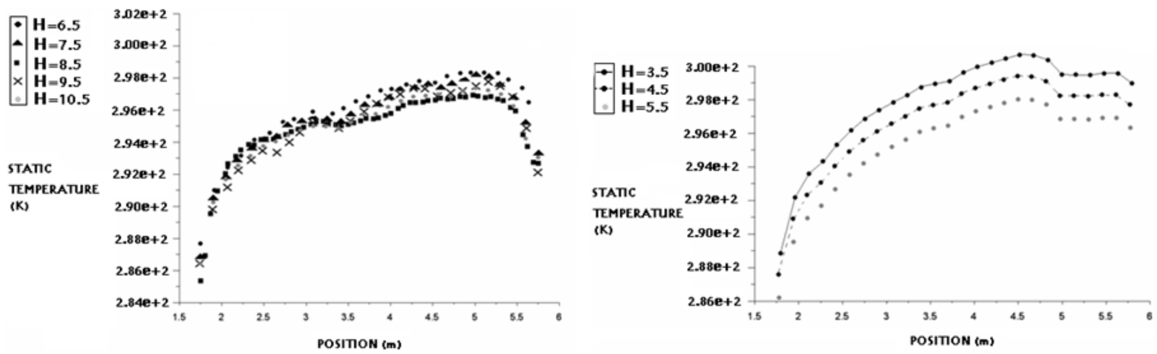

Fig. 5: Variation of indoor temperature with position.

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