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Passive thermal performance increase in cisterns

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Abstract
Cisterns are ancient building having two main tasks. First task is storing water in raining seasons for using in dry seasons and the second task is decreasing water temperature, which happens because of the air flow above water surface and evaporating water. It can be stated that by increasing fluid flow above the surface, evaporating increase so increasing in heat transfer happens and decreasing of water temperature is the result. This paper has investigated fluid flow around and inside cisterns with FLUENT software results.
Increasing in air flow demand to the cistern is the primary purpose of this study, by changing main parameters of cistern geometry like increasing or decreasing of doom hale diameter, inlet and outlet of wind catcher, elevation of wind catcher and also wind speed. This study introduces the best geometry for cisterns according to maximum air flow demand and minimum volume. Considering that, there is a direct relation between heat transfer and airflow rate in cisterns, so in this study, the influence of mentioned parameters are investigated to reach optimum design for the best performance of cisterns.

Keywords: Cistern; Air flow; Optimization; Geometry; Thermal performance.

1. Introduction

In the past, the use of doomed roofs was conventional for normal homes, And also for large special building like cisterns. The use of doomed roof in addition to improve art aspects in architecture, also adds thermal aspects to the buildings, which are located in hot climates.
In fact, by locating a hole at the top of the doom, the negative pressure occurred because of increasing velocity above the doom leads to intake airflow to the cistern. The flow can play an important role in heat transfer form doom walls to out flow, so this process can cool internal walls and improve passive thermal comfort, indoor, and decease indoor temperate in cisterns in hot climates [1].
Bahadori [2] introduced the important role of doomed roofs in natural ventilation and also in decreasing temperature in cisterns, in hot seasons, attached to the important role of wind catchers. But this study does not involve changing in cisterns geometry. And also changing in other parameters like wind speed. The study sticks only to a real constructed geometry, the study does not involving changing in other parameters like wind speed and outside air temperature, also Bahadori [3] had study on cisterns in 1988 but it only considered water reservoir and does not involve air flow or geometry changing.
Regarding to airflow regime over domed roofs, Yaghoubi [4] conducted some tests on simple models of domed-roof houses in a wind tunnel in two-dimension and low speed. Results illustrated in this research included higher wind speed over the roof and longer open whirl region for domed roofs than flatted ones. In addition, in a newer research [5], studied wind flow around domed roofs in different widths of

building using numerical solution. They put forward higher pressure difference around domed roofs as a privilege factor for buildings with these kinds of roofs than those with flatted ones regard to natural and forced convectional heat transfer [5]. This research could be enumerated as a prologue in studying various geometries in Iranian traditional architecture. Continuing the research, Hadavand [6] investigated wind flow around bowed and flatted roofs using numerical solution. However, all of these studies were limited to investigation and comparison of domed roof with flatted roof, and there were never a specific research on identifying desirable geometry and finding parameters affecting on increasing heat efficiency of cistern complex. Exploring cistern efficiency was conducted only in an experimental, analytical research during 2009-2011 [7, 8] in which calculations performed only considering cistern storage and not making changes in geometry .

According to this fact that because of pressure difference between cistern's inputs and outputs, a stream of airflow out of cistern is sucked inside it, there are several factors including hole diameter of dome, opening size of cistern's wind catcher, height of cistern's wind catcher, and speed of free airflow influencing on increase or decrease of pressure difference between cistern inputs and outputs. Making changes in the parameters, we attempted to find optimum geometry and importance of each mentioned parameter in this research.

2. CFD modelling

In this research using FLUENT software, a two-wind catcher cistern, Abar-Kooh's cistern whose scheme is shown in Figure 1, has been modelled, and using that, inside and outside flows of cistern have been analysed. Then, by making change in parameters affecting on increasing amount of cistern's input airflow, calculations have been repeated and compared with each other.

Figure 1. Two-wind catcher cistern (Abar-Kooh's cistern)

Among effective variables, we can point out wind speed in the region. It is also possible to find optimum sizes by making changes in geometric characteristics such as wind catcher's height, diameter of dome's top hole, size of wind catcher's opening, and repeating calculations, optimum sizes can be identified .

In the first phase, this cistern (two- wind catcher cistern of Abar-Kooh) was analysed by real world values, and numerical solution was run for the geometry and dominant wind conditions (5 m/s). Figure 2 shows speed contour in solution domain.

In the current paper, the first wind catcher is the one in the windward, and the second wind catcher is located in path of the first wind catcher wake.

To approach real world conditions in numerical solution, grid study have been carried out whose results are shown in Figure 3. Adequate number of grid has been attained using this figure.

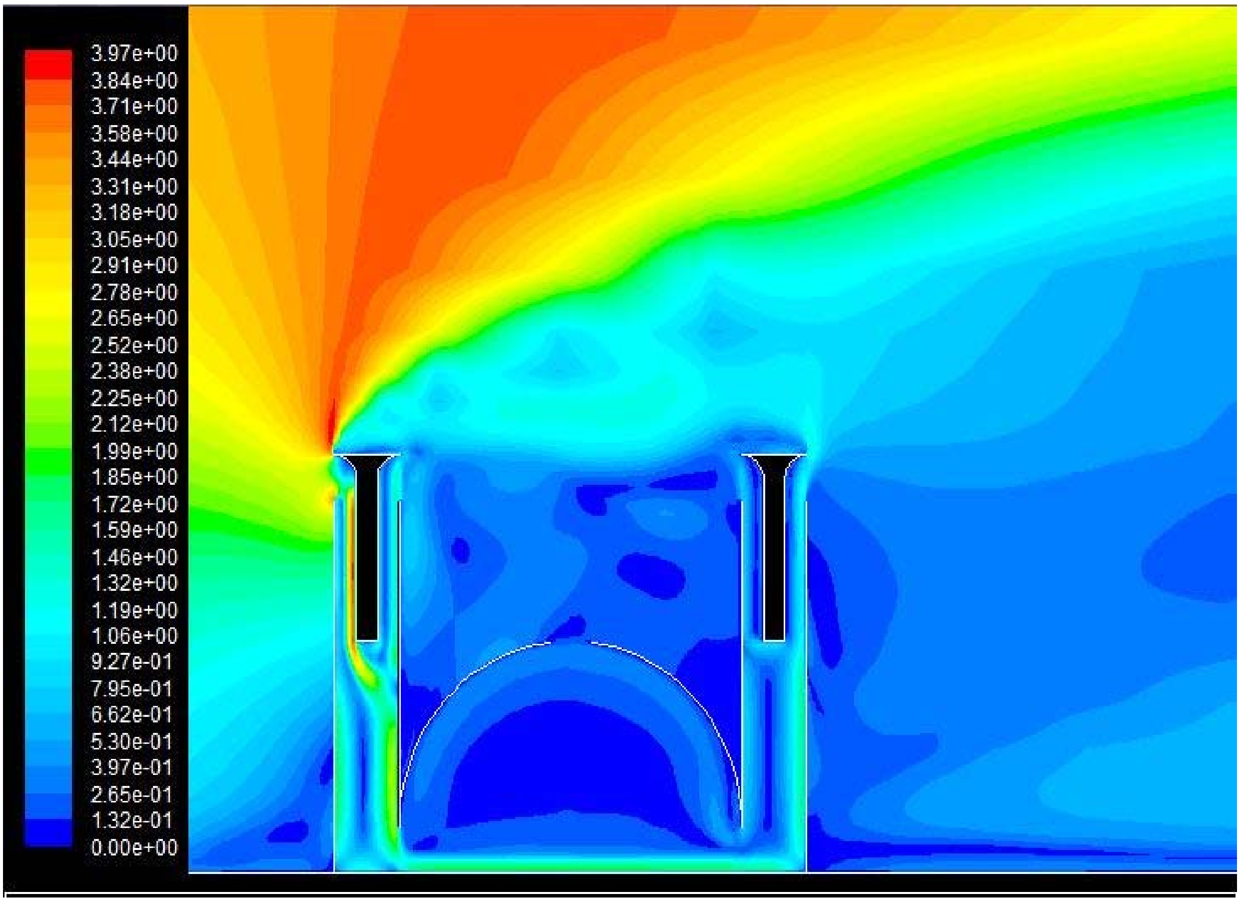

Figure 1. Velocity [m/s] contour in cistern

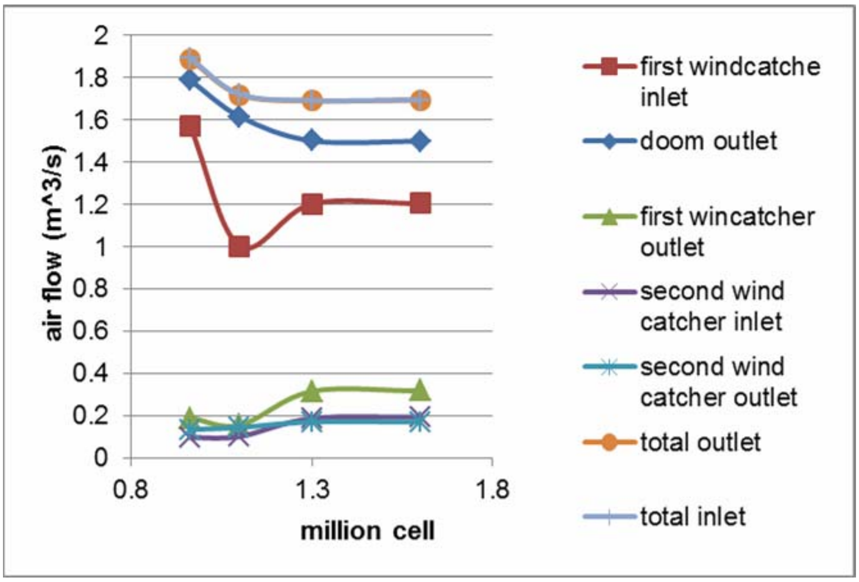

Figure 3. Grid study in numerical solution

3. Results

Among discussed variables is effect of wind speed on total flow rate of input air to cistern. Although wind speed is a parameter out of our control, it can be helpful in selecting the location for constructing cistern. Figure 4 shows effect of changes in wind speed on flow rate of air in wind catchers' input and output, output of dome's hole, and total input and output.

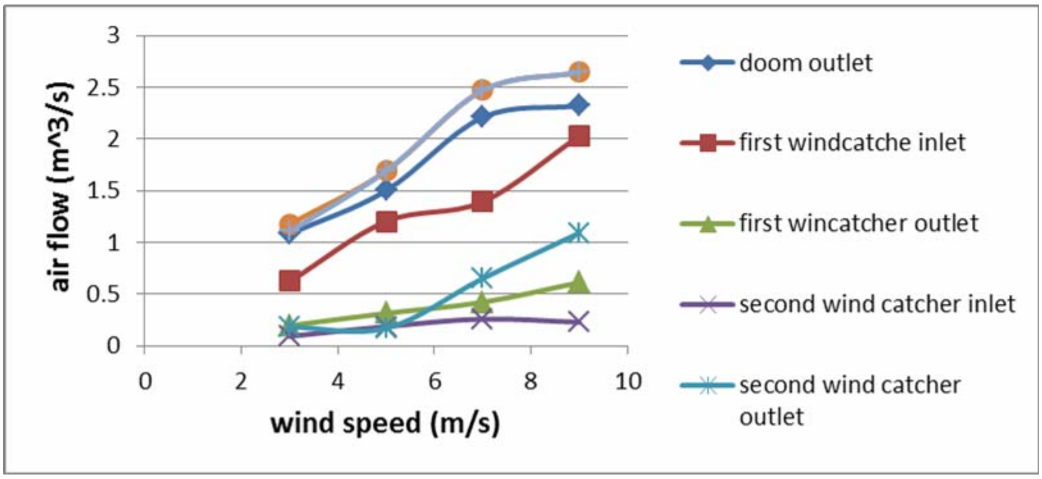

Figure 4. Influence of wind speed on airflow

According to this figure, it can be said, as expected, that flow rate of input air to wind catcher, and consequently, to cistern complex increase with increasing wind speed. Despite of previous suppositions, effect of this enhancement is bounded and after reaching to a certain value, increasing of wind speed will have no significant effect on increasing input flow rate to wind catcher owing to considered geometry. It is due to geometric constraints, and input flow rate to cistern can be increased by changing geometric features. Thus, we examine geometric features.

Wind catcher's height can be mentioned as an effective geometric characteristic. According to results summarized in Figure 5, it is observed that total flow rate of input air to cistern shows a growing trend with height of wind catcher. Nevertheless, this increase is ultimately confined to other geometrics characteristics and the growing trend reduces significantly for wind catchers higher than 3 meters.

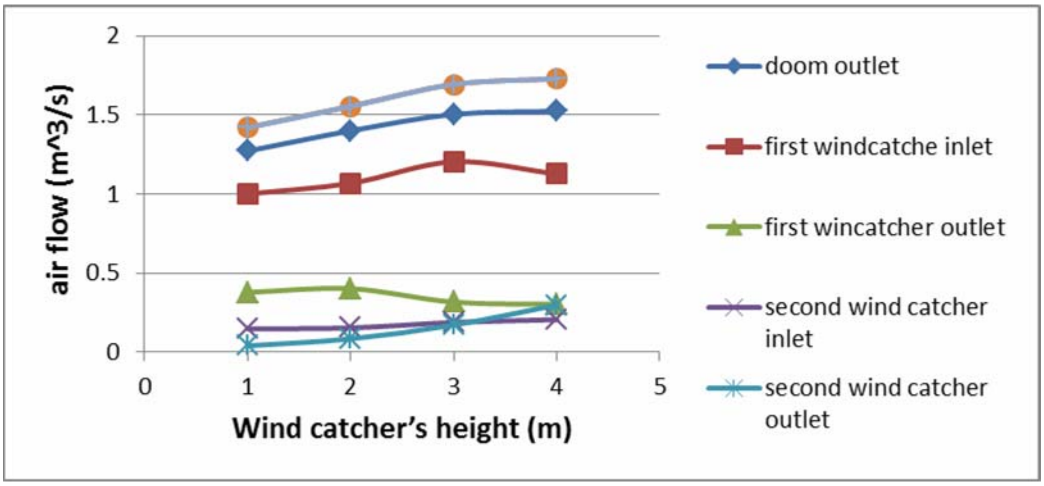

Figure 5. Influence of wind catcher's height on airflow

The other discussed geometric feature is size of wind catcher's opening. Results of iteration of numerical solution for various values of wind catcher's opening are depicted in Figure 6.

As it is clear in the figure, increasing opening of wind catcher's width from 7 cm to 10 cm in the first stage, increase flow rate of total input air by 50%, but beyond that, any increase in size of wind catcher's opening has no effect on enhancing amount of input air to cistern. According to issues rise from widening opening of wind catcher such as possibility of entering birds to the wind catcher and its subsequent problems, it is seen that, again, increasing entrance opening of wind catcher is not proper any more beyond a certain value despite of prior suppositions.

The last studied parameter is diameter of dome's hole. In order to do this, numerical solution is repeated by increasing diameter from 10cm to 20cm; results of the solution are summarized in Figure 7.

Regarding to Figure 7, it is observed that by changing the size of top hole of cistern's dome, input flow rate to cistern has no significant change. This examination is illustrated in Figure 7.

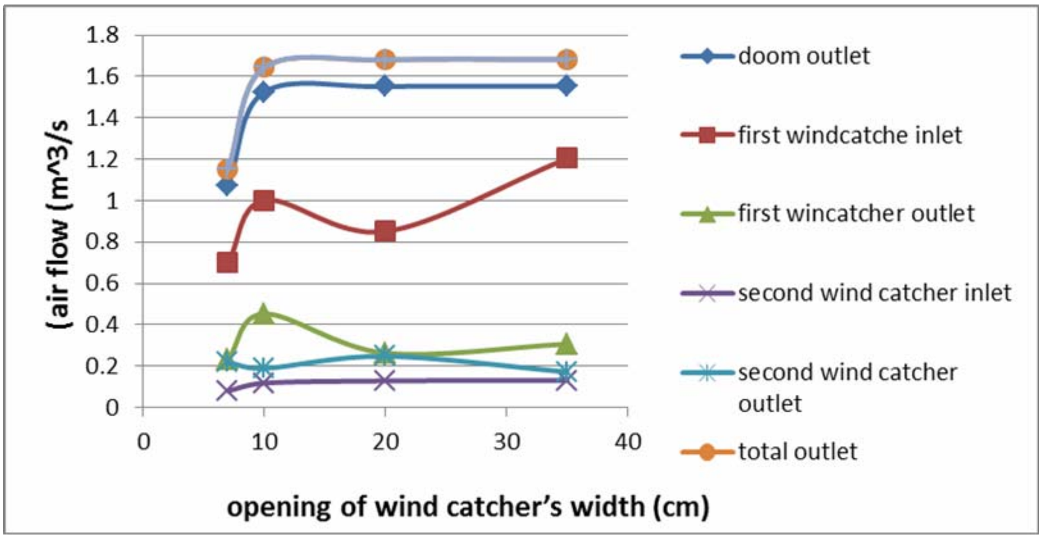

Figure 6. influence of Opening of wind catcher's width on airflow

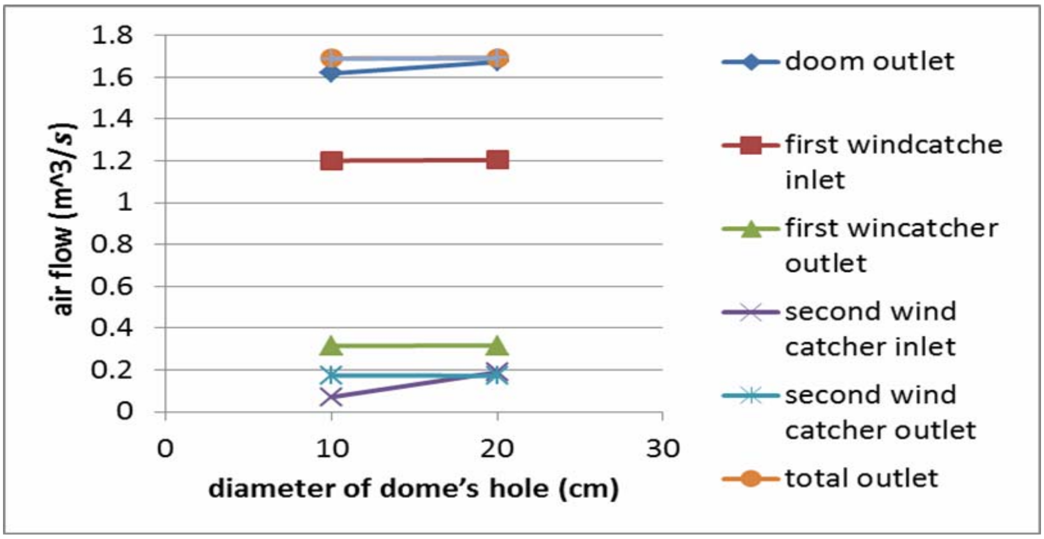

Figure 7. influence of diameter of doom's hole on airflow

4. Conclusion

Since increase of input air flow rate to cistern leads to increase in surface evaporation, and ultimately, increase in heat transfer or, in other words, increase in heat efficiency of cistern, investigations conducted in order to enhance input air's flow rate to cistern can be extended for increasing cistern's heat efficiency.

Therefore, results of this research can be concluded as follow:

- Input flow rate increase with wind speed, but after reaching a certain value, no significant increase in input flow rate to wind catcher is observed with more increase in wind speed. It happens because of geometric limitations.
- Total flow rate of input air to cistern increase with height of wind catcher. Nevertheless, this increase is also restricted to other geometrics features, and after a distinct increase in wind catcher's height, this growing trend is ceased and do not change with more increase in wind catcher's height.
- Fifty percent increase in wind catcher's opening leads to Fifty percent increase in total flow rate of input air to cistern, but more enhancement of wind catcher's opening has no dramatic effect on increasing amount of input air to cistern.

- Changing size of cistern dome's top hole do not influence significantly on flow rate of input air to cistern.

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