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Experimental and numerical study on natural ventilation performance of various multi-opening wind catchers

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ABSTRACT

Wind catcher as a natural ventilation system is increasingly used in modern buildings to minimize the consumption of non-renewable energy and reduce the harmful emissions. Height, cross section of the air passages and also place and the number of openings are the main factors which affect the ventilation performance of a wind catcher structure. In this study, experimental wind tunnel, smoke visualization testing and computational fluid dynamic (CFD) modeling were conducted to investigate ventilation performance of wind catchers with different number of openings to find how the number of opening affects hydrodynamic behavior of wind catchers. To achieve this particular aim, five cylindrical models with same cross section areas and same heights were employed. The cross sections of all these wind catchers were divided internally into various segments to get two-sided, three-sided, four-sided, six-sided and twelve-sided wind catchers. The experimental investigations were conducted in an open circuit subsonic wind tunnel. For all these five shapes, the ventilated air flow rate into the test room was measured at different air incident angles. Numerical solutions were used for all these five configurations to validate the proposed measuring techniques and the corresponding wind tunnel results. The results show that the number of openings is a main factor in performance of wind catcher systems. It also shows that the sensitivity of the performance of different wind catchers related to the wind angle decreases by increasing the number of openings. Moreover, comparing with a circular wind catcher a rectangular system provides a higher efficiency.

1. Introduction

A way to design a building with comfortable internal conditions is to observe natural ventilation principles. This leads to less energy consumption and release of harmful emissions to the space around. Innovative natural ventilation techniques such as a wind catcher system have facilitated the effective use of natural ventilation in a wide range of buildings in order to increase the ventilation rate. Wind catchers were employed in buildings in the hot arid regions of Iran and the countries of the Persian Gulf for many centuries and they are known by different names in different parts of the region [1–3]. This structure extracts and supplies air into the buildings using ventilation principles of passive stack and wind tower, respectively. It cools the inside occupant directly by increasing the convective and evaporative heat transfer from the inner part surfaces and indirectly by removing the stored heat inside the building structure [2]. The wind catcher systems come in various configurations to suit various building type and requirements such as the incorporation of solar panel (solar chimney) and light pipes to boost stack effect [4,5].

By using of fluid mechanics principles it can be estimated that height, cross section of the air passages, placement and the number of openings as well as placement of the wind catcher with respect to the structure it cools greatly affect performance of wind catchers. Several academic studies have been reported in the field of natural ventilation in which the hydrodynamic performance of different wind catcher systems is investigated [1–5,7–15]. In almost all these works a four-sided wind catcher attached to an enclosed room has been used. In these types of wind catcher systems the two ventilation principles of wind tower and passive stack are combined in one design around a stack and the cross section is divided into four quadrants, which allows fresh air to enter as well as stale or used air to escape through the remaining quadrants. In other words, the outdoor fresh air flow may be directed into the building via external openings facing wind, while the indoor stale air may be extracted through other external openings at the leeward side due to negative wind pressure [6]. These types of wind catchers attend with some problems. Short circuiting is the most influencing factor in

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