Renewable and Sustainable Energy Reviews 42 (2015) 182–195

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A new design of wind tower for passive ventilation in buildings to reduce energy consumption in windy regions

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ARTICLE INFO

Article history:
Received 7 June 2014
Received in revised form
8 August 2014
Accepted 5 October 2014
Available online 24 October 2014

Keywords:
Passive cooling system
Wind tower
Thermal comfort
Energy
Solar chimney

ABSTRACT

In today's world, the significance of energy and energy conservation is a common knowledge. Wind towers can save the electrical energy used to provide thermal comfort during the warm months of the year, especially during the peak hours. In this paper, we propose a new design for wind towers. The proposed wind towers are installed on top of the buildings, in the direction of the maximum wind speed in the region. If the desired wind speed is accessible in several directions, additional wind towers can be installed in several positions. The proposed wind tower can also rotate and set itself in the direction of the maximum wind speed. In the regions where the wind speed is low, to improve the efficiency of the system a solar chimney or a one-sided wind tower can be installed in another part of the building in the opposite direction. Using transparent materials in the manufacturing of the proposed wind towers improves the use of natural light inside the building. The major advantage of wind towers is that they are passive systems requiring no energy for operation. Also, wind towers reduce electrical energy consumption and environmental pollution.

Contents

1. Introduction

Wind towers or wind catchers are small towers installed on top of buildings. Wind towers have different shapes and structures. For centuries wind towers have been used for ventilation and cooling of buildings in the hot and arid or humid areas [1]. Wind towers are still used in some areas of Middle East and Egypt (Figs. 1 and 2). By leading the outside air into the building, wind towers serve as a natural ventilation system for workplaces and houses.

Bahadori is a pioneer in research on wind towers who has worked on wind towers' operation and efficiency for almost 40 years [1,3–13]. He introduced two new designs of wind towers: the wind towers with wetted columns, and the wind towers with wetted surfaces. Wind towers with wetted columns consist of

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http://dx.doi.org/10.1016/j.rser.2014.10.018
1364-0321/

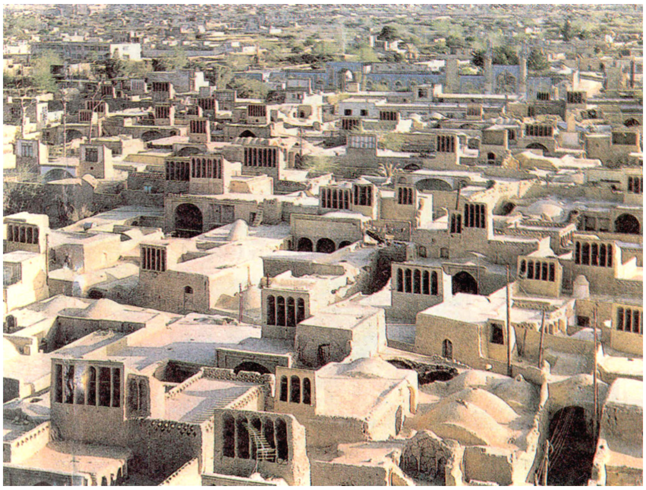

Fig. 1. The view of one-sided wind towers in Meybod city, Yazd province, Iran [1].

Fig. 2. The one-sided wind tower of a house in Al-Jawhara in Cairo, Egypt [1,2].

unglazed ceramic conduits stacked lengthwise on top of one another or thick dampers. Water is uniformly sprayed on the surface of the column, dampening the entire column. The excessive water leaving the column is collected in a sump located at the bottom of the wind tower and can be reused using a pump (Fig. 3). This way, the proposed design can utilize the evaporative cooling potential to deliver much cooler air to the building [1,6,7].

In the areas where wind speed is low, wind towers with wetted surfaces can be used. The surface of the wind tower consists of a series of straws or cellulose called pads commonly used in evaporative coolers (Fig. 4). These pads are placed at the apertures on top of the wind tower and are kept wet by spraying water on them. The air passing through these pads is evaporatively cooled and therefore its density is increased. Since the cooler air is heavier than the ambient air, there will be a downward circulation of the air [1,6,7]. In Fig. 4, wind tower is combined with an air heater or solar chimney [1,8]. In this design, the airflow conducted outside through doors and windows of the rooms and solar chimney. In winter, when wind towers are not operating (i.e., dampers D2, D3 and D4 are closed), the solar chimney can naturally warm the room [1,8].

Bahadori et al. [13–19] examined the new designs of wind towers theoretically and experimentally and compared their performance with that of the conventional wind towers. Results showed that both new designs performed better than the conventional wind towers. The evaporative coolers currently used in the hot and arid regions can be easily replaced by the new designs of wind towers, bringing significant saving in the electrical energy during the warm months.

The influence of wind speed and direction on the ventilation capacity of one-sided wind towers was investigated both experimentally and theoretically [20]. A wind tunnel was used to obtain the experimental results. The roof of one-sided wind towers used during the experiment was flat, inclined or curved. Results showed that the internal pressure field and induced airflow rate inside the wind towers were strongly influenced by the geometry of the wind tower's roof and wind direction. Also, the results of theoretical and experimental methods were very close. These results help improve the design of one-sided wind towers [20]. In another study, the smoke visualization method was used to obtain empirical results for the main flow characteristics around and inside different types of one-sided wind towers [21]. Using this method, the operation of these types of wind towers was analyzed. Results showed that the wind tower with curved roof had better performance than other types of wind towers.

Montazeri et al. [22] numerically, analytically, and experimentally investigated the operation of a two-sided wind tower. A wind tunnel was used to measure the experimental results. The model wind tower was connected to a model house. In the investigation of experimental and numerical model, the pressure coefficient distribution and airflow pattern around and through the wind tower at various wind angles were evaluated. Results demonstrated that the maximum performance is obtained at 90° angle. Also, numerical and analytical modeling results were in good agreement with the experimental results. These results help improve the design of two-sided wind towers.

Zarandi [23] investigated the thermal behavior of conventional wind towers in Yazd, a city in the middle of Iran popular for its conventional wind towers. He analytically and numerically studied 53 conventional wind towers with optimum operation and recorded their specifications. Results illustrated the formal characteristics of wind towers with optimum performance. The information obtained from their study helps designing new structures with better performance. Yavarinasab and Mirkhalili [24] examined the optimum relationship among the length, width, and height of wind towers. They obtained the linear regression equation due to relationship between coefficients. The equation can be used to obtain the optimum model.

Ghadiri et al. [25] numerically investigated the performance of square wind towers with different dimensions in hot and arid regions. They introduced wind towers as a green ventilation system capable of increasing the air quality inside buildings with minimum energy consumption. In another study, Ghadiri et al. [26] examined the effect of traditional wind towers' geometry on the internal thermal behavior of a building. They used FLUENT software for simulation of two different square wind towers. Results of their studies help the researchers to better understand how the traditional wind towers work.

Dehnavi et al. [27] studied the effect of physical properties of square wind towers (such as length to width ratio and height to air openings height ratio) on their performance and found the optimum characteristics of square wind towers for best performance. Their results also show a good agreement between the numerical