Energy for Sustainable Development 39 (2017) 21–28

Contents lists available at ScienceDirect

Energy for Sustainable Development

Experimental investigation of a modular wind tower in hot and dry regions

S. M.R.Khani [a], M.N. Bahadori [b], A.R. Dehghani-Sanij [c,*]

[a] Department of Building, Civil and Environmental Engineering, Concordia University, Montreal, QC H3G 1M8, Canada
[b] School of Mechanical Engineering, Sharif University of Technology, Tehran, Iran
[c] Department of Mechanical Engineering, Memorial University of Newfoundland, St. John's, NL A1B 3X5, Canada

ARTICLE INFO

Article history:
Received 8 December 2016
Revised 9 March 2017
Accepted 9 March 2017
Available online xxxx

Keywords:
Natural ventilation
Wind tower
Thermal comfort

ABSTRACT

Passive cooling systems such as wind towers or wind catchers can create thermal comfort for building residents in hot and dry regions. This paper introduces an experimental study of a modular design of wind tower called the modular wind tower with wetted surfaces. Air temperature, relative humidity (RH) and airflow velocity parameters were measured at different times and at points when the velocity of the ambient air was zero. The results show that the modular wind tower can decrease the air temperature by an average of 10 °C and increase the relative humidity of airflow in a building by approximately 36% on average. Additionally, the wind tower can create the airflow velocity entering the building up to around 1.8 m/s. Furthermore, the obtained data from the measurements illustrate that the conditions of indoor air improve to the thermal comfort conditions.

Introduction

Using air conditioning systems to create ventilation and thermal comfort in buildings is an essential need during the warm months in hot and dry regions. People who are living in these regions have employed different passive cooling systems for centuries to provide natural ventilation and cooling, such as wind towers, domed roofs and courtyards. Traditional and conventional wind towers or wind catchers with different forms and structures are still used in Egypt and in some countries of the Middle East. These wind towers, with different cross sections, can be classified into four distinct types: one-sided, two-sided, four-, six-, and eight-sided, and cylindrical shapes.

Traditional and conventional wind towers have several limitations. Some of these restrictions are as follows (Bahadori, 1985; Bahadori and Dehghani-Sanij, 2014; Dehghani-Sanij et al., 2015):

- Small birds, insects, and dust enter through air openings;
- The head of wind towers is fixed and often cannot capture the maximum wind speed;
- Excluding one-sided wind towers, part of the air caught by the wind tower is lost through other openings and never enters the building;
- The value of coolness that can be stored in the mass of a traditional wind tower is commonly restricted, and may not be adequate to meet the cooling needs of the building on hot days during the warm months. In addition, the exposed surface area of the energy storing material may not be sufficient to allow a high rate of heat exchange;
- There is high erosion due to rain, wind and sun;
- In regions with a very low wind speed, the efficiency of wind towers is negligible.

To achieve higher performance and increase thermal comfort in buildings using wind towers, some researchers proposed new designs of wind towers to be used in hot and dry or windy regions (Bahadori, 1977, 1978, 1981, 1985, 1988, 1994; Bahadori and Dehghani-Sanij, 2014; Bahadori and Pakzad, 2002; Bahadori et al., 2008; Elzaidabi, 2008; Erell et al., 2008; Goudarzi et al., 2013; Issa and Chang, 2012; Karakasanis et al., 1984, 1986; M.R.Khani, 2013; Pearlmutter et al., 1996, 2008; Soutullo et al., 2011a, 2011b, 2012). Bahadori (1985) suggested two new designs of wind towers for hot and dry regions called "wind tower with wetted surfaces" and "wind tower with wetted columns". The performance of these wind towers was investigated experimentally, theoretically and numerically by Bahadori (1977, 1978, 1981, 1985, 1988, 1994), Bahadori and Pakzad (2002), Bahadori et al. (2008). The results show that both of these modern wind towers can decrease the temperature of the air entering a building and provide thermal comfort for inhabitants. However, a wind tower with wetted surfaces has a better performance overall than a wind tower with wetted columns in low wind speed regions.

* Corresponding author.
E-mail address: adehghani@mun.ca (A.R. Dehghani-Sanij).

http://dx.doi.org/10.1016/j.esd.2017.03.003
0973-0826/

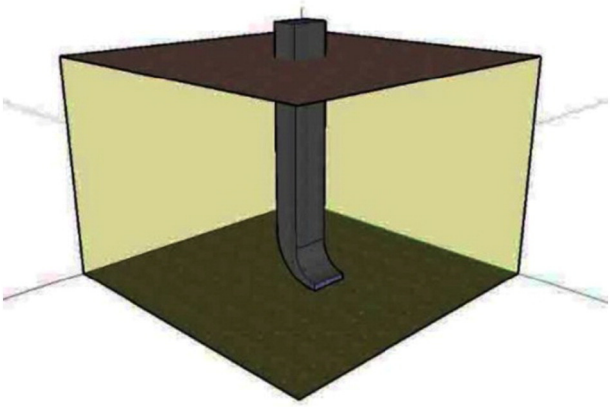

Fig. 1. A schematic of the modular wind tower column.

In another investigation, two modern wind towers for use in windy regions were proposed by Dehghani-Sanij et al. (2015). These new designs of wind towers can catch the highest rate of ambient air velocity because the wind tower head can rotate and set itself in the direction of the maximum wind speed. They showed that using a number of the wind towers and a structure called Kolah-Farangi can naturally ventilate a commercial building without using electrical power, because the Kolah-Farangi increases the rate of air conditioning in the building.

The principal objective of this paper is to introduce a modular wind tower for use in hot and dry regions. One of the significant characteristics of the proposed wind tower is its potential for easy construction in a factory. Air temperature, RH and airflow velocity parameters were studied experimentally at various times and points in order to evaluate the performance of the modular wind tower.

The proposed wind tower design

Although wind towers with wetted surfaces remove some of the limitations of the traditional and conventional wind towers, using this technology in new buildings is not easy. M.R.Khani (2013) suggested a type of wind tower to be used and installed easily in modern buildings. The modular wind tower with wetted surfaces was granted as a patent via the Industrial Property General Office of Iran in Aug. 2014 (M.R.Khani et al., 2014). It should be noted that the modular wind tower is indeed a wind tower with wetted surfaces, but its structure is slightly different. The main advantages for using the modular wind tower in new buildings are (M.R.Khani, 2013):

(1) Nowadays, structures and materials of buildings are varied compared to the past when using wind towers was more common;
(2) The proposed wind tower is a passive cooling system that can be easily built in a factory and assembled in buildings;
(3) Installation of this type of wind tower is simple and easy;
(4) The cost of electricity for air conditioning systems is high in hot

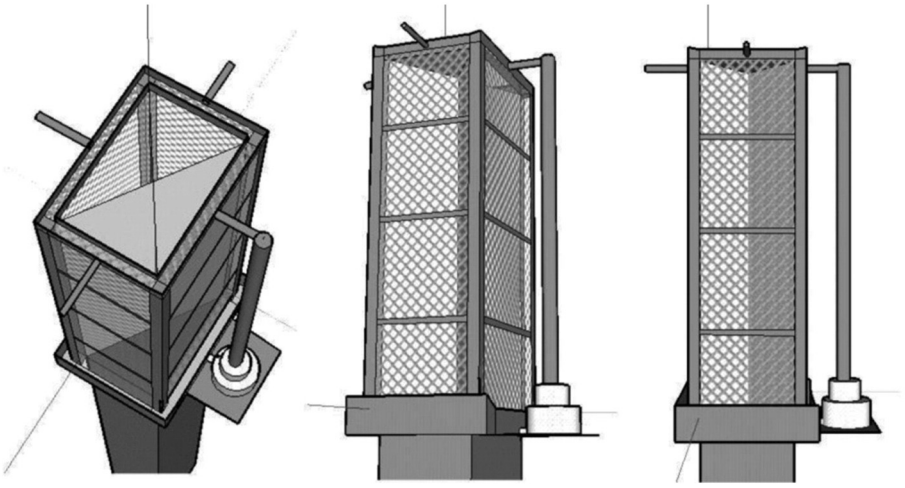

Fig. 2. Schematic representation of the head of the modular wind tower design with wetted surfaces.

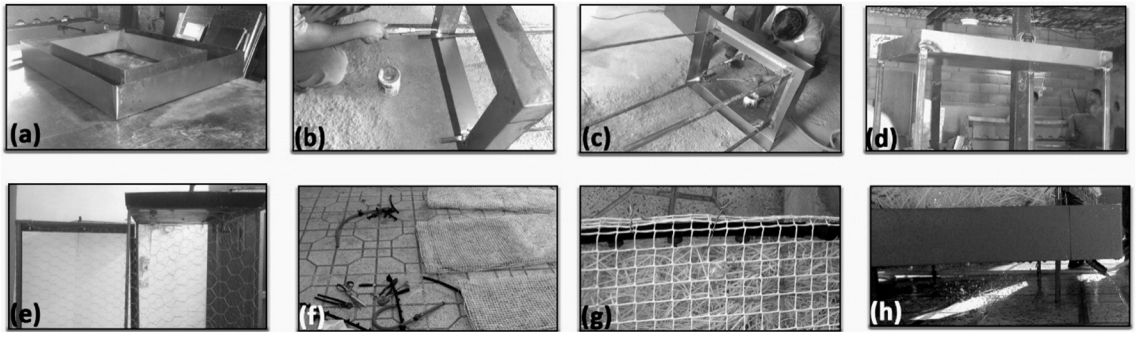

Fig. 3. Construction representation of the head of modular wind tower with wetted surfaces. Note: (a) the bottom of the wind tower head (water collector), (b) legs for connecting wind tower to the column, (c) wind tower's framework, (d) the top of wind tower's head, (e) metal net for hanging straws pads, (f) straw pads and drop irrigation parts, (g) installed drop irrigation pipes in a straw pad, and (h) water collector.