Building and Environment 46 (2011) 2520–2528

Contents lists available at ScienceDirect

Building and Environment

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

Thermal conditioning for urban outdoor spaces through the use of evaporative wind towers

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ARTICLE INFO

Article history:
Received 28 March 2011
Received in revised form
31 May 2011
Accepted 3 June 2011

Keywords:
Evaporative systems
Wind tower
Solar fraction
Thermal outdoor comfort
Urban open spaces

ABSTRACT

The aim of this paper is to study the thermal comfort levels achieved in open spaces by means of evaporative wind towers. These systems have been installed in an urban area characterized by its hot and dry summer climate. Conventional wind tower designs for enclosed and semi-enclosed spaces have been adapted for this new installation. These systems are usually composed of a few number of wind towers, this one however is composed by a group of sixteen, increasing the total dimensions of the installation. To integrate this construction into the urban public area, it was built in a circular arrangement, creating an activity and meeting point for pedestrians. This passive system was monitored during the summer of 2008. Measurements of temperature, solar radiation, humidity and wind speed were analyzed. During the analyzed period, the average cooling efficiency of the system varied from 38% at the exit of the tower, to 32% at 1 m high. At this last position, the average exceeds the wet bulb temperature up to 8 °C with an increase of moisture around 27%. The shading effect produced by the global installation itself has been modeled theoretically to evaluate the incident solar radiation at the pedestrian area. Two indices have been applied to predict the perception of heat and cold in the south pedestrian zone: Heat index and TS index. In this position, both variables approached the thermal sensation to the comfort levels by the use of these passive strategies when ambient conditions are hot and dry.

1. Introduction

The use of bioclimatic techniques in the design and construction of buildings is an effective way to reduce their energy demands. These passives strategies make use of the renewable sources available in each location to condition the building. A traditional technique, known as wind tower, is employed to produce passive natural ventilation to increase the thermal comfort conditions. Its operation is based on air movements due to the pressure differences. This difference is caused either by the movement of wind or by the effects of negative buoyancy created by the stratification of the air. To increase and guarantee the wind speed inside the tower a fan is included, providing enough airflow to ensure the correct performance of the system. In hot and dry climates, where temperatures are high and the relative humidity is low during the summer period, the potential of wind towers could be increased by the use of evaporative systems. These towers reduce the temperature by water injection, increasing the moisture content of the air.

Initial studies were focused on the reduction of energy consumption by using these passive techniques to guarantee summer thermal comfort in buildings. Bahadori [1] published one of the first studies on this subject introducing two new designs of wind tower that avoid most of the disadvantages of conventional Baud-Geers. Moody et al. [2] analyzed the possibility of replacing conventional evaporative coolers with evaporative wind towers, in areas without an electricity grid. A few years later, Givoni [3] completed a mathematical-experimental study on the same building designed by Cunningham and Thompson [4]. The main results show a strong dependency between wet-bulb depression, wind speed and temperature of the solar chimney. Later on, Givoni [5] estimated the temperatures inside lightweight residential buildings and the equation that characterizes the efficiency of the system. Recently, a new mathematical model of thermal performance considering the heat and mass transfer balance was developed by Bouchahm et al. [6]. The height of wetted column and the size of conduits partition inside the tower were determined as two important factors of the wind tower configuration.

In the recent years, the use of evaporative wind towers to cool open or semi-open public spaces are growing. This is highlight by the studies performed at the Universal Exposition of Seville in 1992 by

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doi:10.1016/j.buildenv.2011.06.003

the University of Seville and CIEMAT [7]. These evaporative wind towers, evaluated in real conditions of use, were built to increase the comfort levels at the public avenues and inside the pavilions. Most of the issues encountered were produced by the loss of system efficiency over time. Other projects that analyze the thermal behavior of these structures as cooling passive techniques in open or semi-open spaces, was carried out by the Center for Desert Architecture and Urban Planning, Ben-Gurion University of the Negev, Israel [8]. Continuing on this line, an evaporative wind tower was built in the Negev Sde Boquer which was evaluated experimentally. In this study two different cases were analyzed, considering the wind tower with and without the evaporative systems [9]. However, only a few complex installations composed by several evaporative wind towers operating together have been analyzed.

In the last years, the European Commission within the Life Program has been promoting projects to improve the thermal conditions in open spaces in Mediterranean countries. One of them is 'ECO-Valle Mediterranean Verandahways' project, sponsored by the Empresa Municipal de la Vivienda y Suelo de Madrid [10]. With this goal, Ecosistema Urbano Office Architects [11] has designed and built a bioclimatic boulevard at the New Expansion of Vallecas (Madrid, Spain). This avenue is composed of temporary installations that will be reused in other open spaces once the boulevard has developed its own wooded zone, providing a comfortable area for pedestrians. It is composed of three cylindrical passive systems called 'Air Trees', which were designed with several purposes: increase the comfort levels along the boulevard, increase the use of open spaces during the summer months and drive social sustainability in the zone. Each 'Air Tree' has different configuration and functionality (Fig. 1). The northern one is composed of wind towers with direct evaporative systems installed on the top. The central 'Air Tree' is surrounded by a vegetal envelope that shades the interior area and reduces the ambient temperature thanks to the evapotranspirative process. The third one is covered inside by a screen with a double purpose: to shade the interior of the 'Air Tree' and to be used as a television screen. All the structures are crowned by sixteen units with four photovoltaic panels each; with a power rate of 165 W per module. This photovoltaic installation supplies all the energy requirements and makes the 'Air Trees' independent of the electricity grid. This study is focused on the use of evaporative wind towers as bioclimatic systems to improve the comfort level in open spaces, so the northern 'Air Tree' had been monitored during the summer of 2008.

2. Model descriptions and experimental methodology

The northern 'Air Tree' is a metallic structure with thin cylindrical shell geometry. Sixteen wind towers uniformly distributed

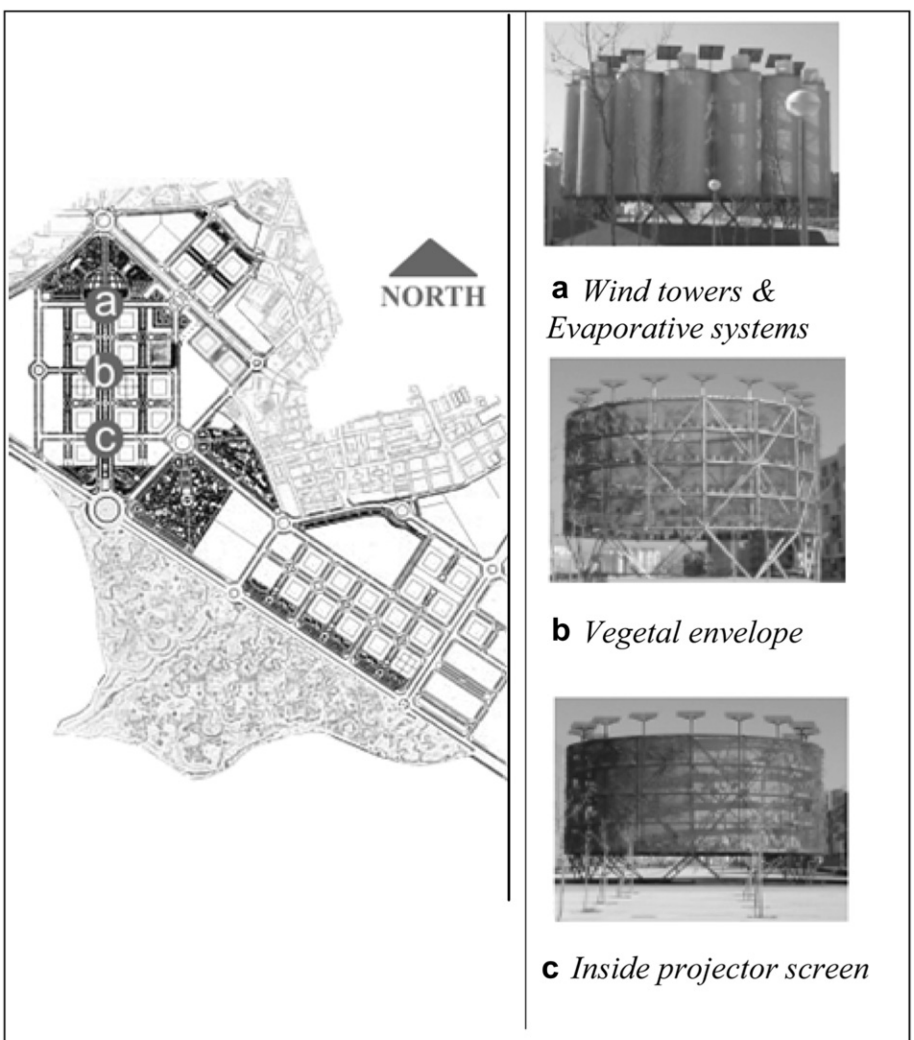

Fig. 1. Main characteristics of the three 'Air Trees' built along the bioclimatic boulevard in Madrid.