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Experimental and Numerical Studies of Solar Chimney for Ventilation in Low Energy Buildings

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Abstract

As an effective way to protect environment and save energy in buildings, passive ventilation method has generated intense interest for improving indoor thermal environment in recent years. Among these passive ventilation solutions, design of solar chimney in buildings is a promising approach for guiding natural ventilation orderly. Many studies about solar chimneys have mainly focused on achieving a better ventilation performance both experimentally and theoretically in ideal condition, whereas experimental studies are mainly focused on small-sized equipment. This research examines the performance of a full-scale solar chimney in a real building in East-ern China. The measured performance is compared with theoretical calculation and numerical simulation. In a solar chimney of 6.2m length, 2.8m width and 0.35m air gap, the experimental results show that air flow rate of 70.6 m3/h~1887.6 m3/h can be achieved during the daytime in the testing day. Comparing measured value with theoretical value, the flow rate is generally lower than the theoretical value. By data analysis, the suggested discharge coefficient Cd of solar energy in real engineering project is 0.51. With the use of this suggested value, the simulation results show that during the transition seasons (from April to October), solar chimney can be used for saving energy with an energy saving rate around 14.5% in Shanghai. It is shown solar chimney is an effective approach to save energy for residential buildings in transition seasons in hot summer and cold winter area in China.

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Keywords: Solar chimney; Natural ventilation; Field measurement; Simulation

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1. Introduction

Nowadays, referring to the increasing rate of environmental pollution and limitation on fossil fuels, the use of sustainable energies becomes to be inevitable for the world[8].Natural ventilation technology has attracted much attention because it can effectively improve the thermal environment of buildings. Natural ventilation can be generally divided into two types: organized natural ventilation and unorganized natural ventilation. Organized natural ventilation is realized in the form of exhaust equipment in the building channels through which indoor air is discharged to the outside. It can effectively control the air flow. Unorganized ventilation is realized by the means of leaks and cracks in structures (air infiltration), and by airing the room through the open windows and vents. As a kind of organized natural ventilation technology, solar chimney has attracted attention in recent years because of its ability to effectively drive natural ventilation.

The method of using solar radiation to enhance natural ventilation appeared in the 16th century in Italy. It is known as "Scirocco rooms"[11]. In recent years, scholars have made researches on theoretical models, numerical simulation and experiments of solar chimney [13]. On the aspect of theoretical research, Bansal et al. set up a steady-state mathematical of solar chimney in 1993[9]. Anderson et al. used 0.57 as the discharge co-efficient for a sharp-edged opening [6]. Flourentzou et al. [3] discussed the value of velocity coefficient, contraction coefficient, and discharge coefficient by using gas tracer method. The value of discharge coefficient was suggested as 0.6±0.1. Ong established one-dimensional steady state mathematical model to calculate air temperature in the air channel in 2003 [5]. J. Arce used 0.52 as the discharge coefficient for it's closer to the real situation in experiments [9]. On the aspect of experimental investigations, Bouchair obtained an aspect ratio (Height / depth) for the optimal ventilation performance of a solar chimney [1]. Angui Li et al. discussed the temperature and air velocity distribution in a solar chimney based on the research of a vertical solar chimney. It was pointed out that the temperature and velocity boundary layer formed near the heated surface [2]. Chen et al. pointed out that the theoretical result was usually higher than measured value due to underestimation of inlet and outlet losses [5]. At present the calculation of solar chimney's flow rate mainly bases on the ideal experimental situation, while the flow rate may be lower than the existing theoretical model value considering all kinds of resistance in a real building. Based on a real solar chimney in the P+ demonstration building in Changzhou, this article discusses the value of discharge coefficient and simulates the ener-gy-saving efficiency when a solar chimney is used in Shanghai.

2. The Ventilation Effects of the Solar Chimney

2.1. Theoretical model

Figure 1 shows the basic form of the solar chimney discussed here. The solar chimney is consist of a glass plate, a dark heat absorbing plate, a layer of thermal-protective material, a metal support, a metal blind flange, air inlets and air outlets. The ventilating duct is between the glass plate and the heat absorbing plate.

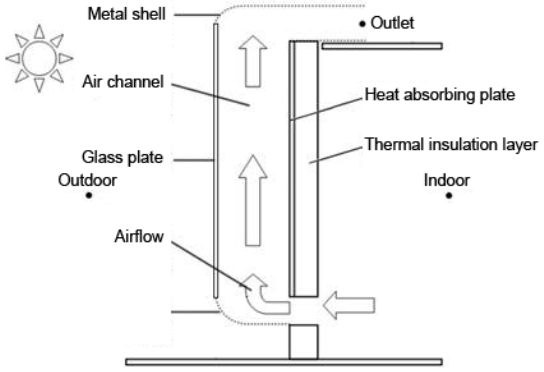

Fig.1. The sketch of a solar chimney