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An Experimental Investigation on the Square Steel Solar Chimney for Building Ventilation Application

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Abstract

Ventilation is significant to indoor air quality and human comfort in building. By increasing the air velocity, occupant would be satisfied with the thermal comfort at slightly higher temperature than the conditioned space. In present paper, the chimney made by a steel plate with 1 mm thick and 3 meter high, the square duct, where the outer surface is painted in black, is constructed and experimented. The air flow velocity was measured by the hotwire anemometer at the outlet and inlet of the chimney. The outdoor tests were carried out under the real climate condition where the solar radiation was varied throughout the day. It was found that the solar irradiation has influenced the performance of the chimney according to the temperature difference that caused the buoyancy force. The temperature difference and air velocity in the square steel chimney is presented. The experimental results show that the air temperature inside the chimney near the black surface is the highest then gradually decreases to the far distance from the black surface. It is found that the air temperature difference in the horizontal plane across the width of the chimney is up to 7 ^{o}C while the air temperature difference in the vertical direction is at 1.4 ^{o}C. As a result, the air flow near black surface of 0.26 m/s is measured. This can be used for the building ventilation even at the low height chimney.

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Keywords: Solar chimney; Air velocity; Temperature; Outdoor; Testing

1. Introduction

Building ventilation is significant to the reduction of energy consumption; especially in the case of tropical climate countries where the high energy demand comes from air conditioning systems. The study shows a feasibility of using solar chimneys even with humid climate like Hong Kong. In mild climate, this technique has been used not

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only for wood fire to warm the house in winter but also to heating the building by putting on the double layer of the façade. The first one has been well known of it utilization for centuries; although, the number of it has reduced dramatically due to modern house design, the change of way of living and other things such as deforestation, smoke from the burning wood and so on. The second technique, double façade, has commonly seen in new building construction after several research studies. This requires extra area to the building space for air ventilation which some location can be costly. Recently, many researchers are interested in using various type and design of solar chimney for building ventilation. Furthermore, the solar chimney has more advantage in terms of economic but the limitation on the degree of flow velocity and thermal extraction would need to be considered and carefully design for large building application. Otherwise, the application on small or residential building as an example would simply reach satisfaction. Many studies have been done on the different designs of solar chimney some operate as cavity in building [1], chimney technique with roof and wall for the air flow channel to pull indoor air to outdoor for house ventilation [2], influential design parameters to the performance of solar chimney [3] and so on. Literature of the study is summarized in following section.

Ratios of gap to height of solar chimney were studied in the laboratory to learn how this parameter affects the ventilation flow rate [3]. The chimney model was fixed on the height of 2 meter and the width of 2 meter but varied on the gap, from one heated wall to another wall, with the distance from 0.4 m to 1.2 m. In this experiment a wall was heated and received the heat flux between 200 and 400 W/m^2. Experimental results showed that temperature was reduced from highest at the heated wall to the lowest at the far distance near another wall but slightly increase from the lowest value at the opposite wall of the heated wall. An air velocity increases when the gap distance increased and the optimum found at 1 m which was at the ratio of gap to height of 0.5. Another model of solar chimney is with glass cover where the glass pane allowed solar radiation to go through the air gap into the absorber sheet on the wall in an opposite side. In other words, the hollow rectangular chimney has three walls and one glass cover wall or some case smaller as the size of window which opposites the attached absorber wall while another two walls are at the rear. The study on solar chimney for 3 story building model found that combined solar chimney, on the South wall, with three inlets from each floor and one outlet at the top provided higher reduction of the room temperature than separated solar chimney of 1 m high as the same to the height of one floor [4]. The application of chimney cavity, similar to the double wall, where an internal wall has a passage to chimney for a room air to be withdrawn through the cavity between the two walls for ventilation study by heated the internal surface of the two walls to allow convection heat transfer from the heated wall to the air inside the cavity [1]. It was found that the size of the room whether the width, the length or the height has miniature effect on the air flow rate as of 0.137 m^3/s. Since this study used electrical heaters to heat the internal surface of the chimney cavity bring up the buoyant flow thus the higher temperature material will be beneficial to the performance.

There are several researches on the solar chimney with the glass cover. The simple construction with no glass has small number of research study. Considering on its economic and simple construction, the square chimney has been investigated for its thermal feasibility performance.

Nomenclature

A	cross sectional area [m^2]
c_f	specific heat of air [J/kg.K]
L	stack height [=3 m]
$\dot{m}$	mass flow rate [kg/s]
q	heat gain by air stream [w/m^2]
T_{fo}	outlet air temperature in flow channel [K]
T_{fi}	inlet air temperature in flow channel [K]
$T_{fo,top,avg}$	average outlet air temperature in flow channel at the top [K]
$T_{fi,bot,avg}$	average inlet air temperature in flow channel at the bottom [K]
v	velocity [m/s]
W	width of air channel [=0.4 m]
ρ	density [kg/m^3]
ΔT_s	stack temperature difference [K]