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An analytical and numerical study of solar chimney use for room natural ventilation

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Abstract

The solar chimney concept used for improving room natural ventilation was analytically and numerically studied. The study considered some geometrical parameters such as chimney inlet size and width, which are believed to have a significant effect on space ventilation. The numerical analysis was intended to predict the flow pattern in the room as well as in the chimney. This would help optimizing design parameters. The results were compared with available published experimental and theoretical data. There was an acceptable trend match between the present analytical results and the published data for the room air change per hour, ACH. Further, it was noticed that the chimney width has a more significant effect on ACH compared to the chimney inlet size. The results showed that the absorber average temperature could be correlated to the intensity as: ($T_w = 3.51I^{0.461}$) with an accepted range of approximation error. In addition the average air exit velocity was found to vary with the intensity as ($v_{ex} = 0.013I^{0.4}$).

Keywords: Solar chimney; Natural ventilation; ACH; CFD

1. Introduction

Efficient air ventilation and thermal comfort are of great importance in rural areas and hot climate conditions. Ventilation is the intentional supply of fresh outdoor air to a space to dilute and remove indoor air contaminants. Ventilation, whether naturally or mechanically, is a very urgent need in many residential and industrial zones. Natural ventilation occurs due to two causes: aeromotive or wind driving force, or buoyancy driving force (stack effect) due to temperature difference between indoor and outdoor air temperatures. A significant temperature difference should be existed for the thermal driving force or stack effect to be appreciated. Use of solar energy can create such a large temperature difference, and hence improve the stack effect for space natural ventilation.

The solar chimney is an effective practical way to enhance space natural ventilation. In most tropical countries, where it is almost very difficult for the majority to have an air conditioner, people rely on natural ventilation, instead, to achieve comfort through opening windows. However, in some climates, where the wind effect is not significant, just opening windows cannot effectively move the air inside the space to help diluting contaminants, odors, and satisfying the comfort feeling. This is due to the small pressure difference between the indoor and outdoor air. The solar chimney design and construction allow storing an amount of solar energy into a surface, then releasing this energy to an adjacent column of air raising its temperature, and accordingly it flows upward entraining an outdoor fresh air into the space. This will create an air breeze inside the space. The main driving force in moving the air upward in the chimney is the buoyancy force due to the absorbed energy.

Generally, solar energy with high intensity is available in the Middle East countries. Egypt in general and upper-Egypt in particular, has rich sunny and clear skies. These conditions encourage adopting such a concept to enhance building natural ventilation and save energy. Hence this was the motivation behind the present study.

2. Previous studies

The solar chimney is an attractive idea for many researchers in different fields. Some previous studies have been seen in the literature that investigates the use of solar chimney, with different configurations, in ventilation improvement. Some

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