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Simulation study of an innovative ventilated facade utilizing indoor exhaust air

Lin Liu[a], Zhuang Yu[a], Hui Zhang[a,*]

[a]Architecture and Urban Planning College, Huazhong University of Science and Technology, Wuhan 430074, PR China

Abstract

This paper presents a simulation study on an innovative ventilated façade utilizing indoor exhaust air. A numerical model of the basic ventilated façade module was developed and validated with the experimental data. The study investigated the energy saving of the ventilated façade in the heating and cooling seasons. The effects of the configuration of the materials in the ventilated façade and the impacts of the cavity air flow rate on the thermal performance of the façade were also studied. The results proved the ventilated façade has excellent energy saving performance in comparison with the façade with its cavity closed. The appropriate design of the façade configuration and the cavity air flow rate were also provided.

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Keywords: Ventilated façade, Indoor exhaust air, Energy efficiency, Thermal performance.

1. Introduction

Building energy conservation has become an extremely important issue around the world. The building envelope and the building services system, to a great extent, decide the building energy efficiency. There have been advanced

* Corresponding author. Tel.:+86-18202730506; fax: +86-18202730506.
E-mail address: zhhust@163.com

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facades designed to introduce the air cavity to improve the façade performance, such as double surface façade (DSF) and opaque ventilated façade (OVF). The DSF consists of multiple glazing layers, and the OVF consists of the main wall and an additional cladding which can be added externally or internally. Innovatively utilizing the exhaust air of indoor air conditioning systems to flow through the ventilated façade can improve the facade thermal performance further. Most studied OVF and DSF technologies were applied to public buildings with large and integral facades. The ventilated façade technology has seldom been applied to residential buildings, especially when ventilated with indoor exhaust air, because it is only applicable to buildings with indoor air conditioning systems.

Ventilated facades can adopt different ventilation strategies according to various outdoor environments, and they can be classified as four types, including exhaust air façade (EAF), supply air façade (SAF), outdoor air curtain façade (OAC) and indoor air curtain façade (IAC) [1]. Most studied DSFs were ventilated as OAC in summer, and as SAF in winter, or keep cavity closed in winter. Xu et al. [2] conducted the experiments on the DSF of a two-story house. The results showed that the DSF operated as OAC in summer could achieve 20% of energy saving compared with the single skin façade, and the DSF with cavity closed in winter could achieve 30% of energy saving. Chan et al. [3] used EnergyPlus to study a natural ventilated DSF of an office building. The results showed that the DSF with appropriate configuration could save 26% of the annual cooling energy. The studies focused on OVF are much less than that on DSF. Carla et al. [4] developed a model to simulate an OVF which was naturally ventilated in summer and turned the cavity closed in winter. The OVF could reduce 27.5% of the summer over-heating, and decrease about 37.5% of the wall heat flux in winter. Carla [5] also developed a method based on non-dimensional analysis to study a naturally ventilated OVF. The proposed method is useful to achieve design indications by analysing the OVF with different design parameters. Lopez et al. [6] studied a traditional building retrofitted with external OVF modules, which could preheat the outdoor air for the building in winter. The OVF modules could lead to an energy saving above 70% under some weather conditions in Italy. Some other studies also investigated different design parameters on the façade performance. It has been concluded that increasing the cavity air flow rate can improve the thermal performance of the ventilated façade in the cooling season [4, 7]. Decreasing the cavity inlet temperature can also improve the façade performance significantly in summer [8]. Fantucci et al. [1] proved the excellent thermal performance of the ventilated façade with EAF configuration in winter, and the heat flux through the façade varied from 43% to 68% under different configurations, while for the SAF configuration, the pre-heating efficiency varied from 9% to 20%.

It can be seen that the flow rate and the temperature of the cavity air flow affect the façade performance obviously. Therefore it deserves to utilize indoor exhaust air through the ventilated façade to improve its thermal performance. However, there are limited studies focused on the OVF ventilated with indoor exhaust, especially studying the innovative façade adopted in residential buildings. This paper studies a ventilated façade module with a window in the middle, which makes it applicable to common residential buildings. The façade module extracts the indoor exhaust air mechanically in the cooling and heating seasons to reduce the heat transfer. The study aims at investigating the energy saving of the ventilated façade, and analysing the the effects of the configuration of the materials in the ventilated façade. The impact of the air flow velocity in the cavity was also investigated.

2. The ventilated façade and experimental measurements

The studied façade module belongs to a ventilated facade system implemented in a small building located at Wuhan (latitude 30.57◦ N, longitude 114.30◦ E), China. This area is in the hot-summer and cold-winter zone of china, which needs over 3 months cooling and heating seasons. The building is a two-story small one with the floor area of 194 m^2, and it was constructed in the south–north orientation. Its ventilated façade system is driven mechanically by a dedicated fan, which supplies the indoor exhaust air respectively to the southern and northern façades, and let the air flow through the southern photovoltaic roof and the northern flat roof respectively. The schematic of the whole system is shown in Fig. 1. The south and north ventilated façades of the building consist of 40 mm external polyurethane panel, 60 mm air cavity and 100 mm internal formed concrete wall. The facade can be divided to basic ventilated modules as shown in Fig. 2. In the transition seasons, the ventilated façades can also be driven by the unpowered fans installed on the top of the roofs, which are mainly to increase the efficiency of the photovoltaic panels.