Ventilation System

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An additional window frame with a ventilation function is applied to the existing window. Thus, when the window is closed, a cavity, which is created between window frames, serves as an air path for ventilation. The additional frame has the same material and finishing as the existing frame, thereby ensuring design consistency. On the outside, the frame does not show any application of the mechanical system. Another advantage of the proposed system is that, as the width is 65 mm, it occupies as small an area as possible and minimally affects the view from the inside.
Polyvinyl chloride (PVC), a generally used material for windows, is used for the ventilation system, and this system is formed in a "U"-shape consistent with the existing window frame. This system can be attached or detached on the existing window frame and does not generate either a gap or a distance in the process of installation for airtightness. The cavity is 45 mm in width, 20 mm in depth, and 1940 mm in height and serves as an air path connected to the outdoor air intake and the indoor air supply outlet.

Ventilation system window frame carbon dioxide particulate matter

1. Introduction

There has been an increasing interest in the indoor air quality of buildings, as it is closely related to the health of residents. The indoor air quality of houses is affected mainly by pollutants that flow through ventilation and infiltration from the outside as well as those generated indoors. Pollutants generated from indoor building materials and furniture tend to decrease over time [1], and the levels of such pollutants are also being reduced through the current application of environmentally-friendly materials and mandatory measurement of air quality in newly constructed apartment buildings. However, pollutants generated by residents must be continuously managed. The main pollutants include PM, CO_2 generated from breathing, carbon monoxide (CO), and nitrogen oxides (NOx) generated from cooking.

Previous studies have indicated that the concentrations of CO_2 and PM (i.e., PM_{10} and $PM_{2.5}$; PM_{10} is particulate matter 10 micrometers or less in diameter, $PM_{2.5}$ is particulate matter 2.5 micrometers or less in diameter) in houses in Korea tend to exceed both the Korean and international standards for indoor air quality, and that maintenance regarding such pollutants is required. Special attention is needed to examine indoor air quality during the sleep time of a resident, which accounts for one-third of the day [2][3][4][5][6]. Bekö et al. [7] noted that the ventilation rate was likely to be low during the sleep time of residents. Canha et al. [8] also reported that the concentration of pollutants increased during the sleep time of residents. Many studies have been conducted to analyze the relationship between the concentration of pollutants during sleep and the quality of sleep. Some studies found that the work efficiency of residents the next day increased when the concentration of CO_2 in their sleeping areas decreased [9][10][11][12]. Other studies [13] were also conducted to examine the relationship between the level of indoor exposure of residents to PM and the quality of their sleep. As a result, the hypnagogic state of residents during sleep time and their symptoms such as headaches and sore throats after sleep improved when they were less exposed to PM than usual. The results of the aforementioned studies show the importance of ventilation in that the degree of exposure to PM has a significant impact on the human body. Currently, three types of ventilation systems are being applied in residential buildings. The first is a ceiling-type ventilation system. Because the installation of a ventilation system became mandatory in 2006 in a residential area that was permitted for construction and included 100 households or more, ceiling-type ventilation systems, among the mechanical ventilation systems, have been generally applied. Other types of ventilation systems include natural ventilation systems and mechanical ventilation systems, both of which are installed on the envelopes of buildings.

Natural ventilation systems cannot ensure a stable amount of ventilation, because they rely on the difference in pressure between indoor and outdoor areas [14][15]. Moreover, these systems increase indoor cooling and heating loads, because outdoor air at high temperatures during the summer and low temperatures during the winter comes directly inside [16][17]. Some natural ventilation systems are equipped with filters as well as an existing method of window opening and closing, although they do not show a high level of efficiency for preventing PM [18][19][20]. Several studies have proposed natural ventilation systems that can recover heat through double glazing. Specifically, these systems were designed to recover heat lost from the inside to the outside and obtain heat through solar radiation during the daytime using the cavity of double glazing as an air path [21][22][23][24][25][26].

2. Applicable Ventilation Systems

Ceiling-type ventilation systems account for most of the ventilation systems installed in houses. As wall perforation and ceiling construction are required to install ceiling-type ventilation systems, they are applied at once in all the units of buildings during new construction. In these systems, an amount of ventilation of 0.5 air changes per hour is set as a domestic standard for apartments and multi-use facilities. These systems can reduce the cost of air-conditioning and heating through heat recovery and ensure a stable amount of ventilation based on mechanical ventilation. However, they are unlikely to be installed in existing homes and cannot be moved to different places once they are installed. It is also difficult to perform maintenance work for the ducts and filters used in these systems. In addition, economic burdens regarding a great amount of construction costs are expected when they are installed in each household unit of the building [27].

Studies are being conducted to develop mechanical ventilation systems installed on the envelope of a building, which ensures convenient access to solve the aforementioned problems. There is a system that directly installs a ventilation device inside the outer wall, and there is a system that supplies fresh air into the inner space using the outer wall itself as a ventilation air path [28][29][30][31][32]. However, this type of mechanical ventilation system based on the use of the outer wall has disadvantages in that the wall structure must be replaced or perforation must be performed on the existing wall structure. In this regard, studies on mechanical ventilation systems using opening parts are also being performed [33]. This type of mechanical ventilation system can be easily installed in the existing windows in the horizontal or vertical form. Some mechanical ventilation systems using opening parts can also reduce energy consumption through heat exchange. However, when this type of mechanical ventilation system is installed as a separate unit to the opening part, it can lead to problems such as a requirement for a large area, the disturbance of a hypnagogic state, and difficulty in providing an external view owing to the installation of a fan, a heat exchanger, and a flow path.

A newly proposed ventilation system was appropriate to the room of an apartment in which the improvement of indoor air quality was analyzed based on the aforementioned experimental results. This system can be easily applied to existing houses without ventilation systems and utilizes a window cavity, which is created between a new frame and an existing one, as an air path for ventilation. Specifically, insulation materials were used in the cavity of the window frame to prevent condensation. A filter net was also applied on the external sides of the lower parts to control the inflow of PM. The locations of insulation materials were examined based on the heat transfer simulation, and the balance between the actual flow rate and pre-heating temperature was optimized through a CFD simulation analysis. When the ultimate design flow rate of 12.5 CMH was assumed, the indoor heat transfer alone could result in a pre-heating effect of 8.9 °C.

The application of the ventilation system sufficiently enhances the indoor air quality in the small room targeted in this study. Moreover, it is also expected to decrease the concentration of CO_2, which rapidly increases during the sleep time of residents.

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