A STUDY ON THE CONTROL STRATEGIES TO IMPROVE INDOOR AIR QUALITY WITH OUTDOOR AIR - DEMONSTRATED BY A BATHROOM DESIGN

Nien-Tzu Chao¹, Che-Ming Chiang², Wen-An Wang² and Po-Cheng Chou²

¹Department of Interior Design, Chung-Yuan Christian University, Taiwan
²Department of Architecture, National Cheng-Kung University, Taiwan

ABSTRACT
Poor indoor air quality caused by poor ventilation was indicated from field measurements in apartments in Taiwan. Four strategies of employing thermal buoyancy effect, dedicated air flow pattern, transom and spatial connection control are proposed to improve indoor air quality by removing indoor pollutants with outdoor air. To prove the concepts, a bathroom design based on the proposed strategies is presented by numerical simulation using a computational fluid dynamics code. Instead of spreading the pollutant, humidity, throughout the whole apartment as an inevitable consequence of the traditional design, the strategies enable the pollutants to be removed effectively from the apartment. The humidity produced in the bathroom is first collected at the upper level by thermal buoyancy effect, then removed through higher outlet to the hallway, finally excavated through transom from the apartment.

INTRODUCTION
There are two goals for ventilation: to provide indoor thermal comfort and to improve indoor air quality. Natural ventilation has long been termed as a useful source to regulate indoor thermal comfort. As control strategies to improve the indoor air quality of residency, natural ventilation has recently been receiving attention (1).

Poor indoor air quality was indicated from field measurements in apartments in Taiwan (2). Poor ventilation is the cause for the poor indoor air quality since the concentrations of the examined indoor pollutants (carbon monoxide, carbon dioxide and humidity) are higher in the indoors than those in the outdoors (1).

To improve indoor air quality with outdoor air, this study proposes strategies based on principles of fluid flow, heat and mass transfer. To demonstrate the feasibility of the concepts, the strategies are then applied to a bathroom design for improving its indoor air quality by effectively removing humidity during taking shower. The bathroom design is conducted by numerical simulation using a computational fluid dynamics (CFD) code.

APPROACH
Strategies

thermal buoyancy effect
Thermal buoyancy effect (3) is generated when heat source present in a relatively cold and still ambient air. There is an upward going air plume produced above the heat source when the cold ambient air is driven by a heat source. If the heat source releases pollutants at the same time, the pollutants will eventually go with the air plume. This effect enables a room to attain higher air quality by removing pollutants effectively with even minimal amount of ventilation rate (4).

dedicated air flow pattern
To remove pollutants effectively from the indoors to the outdoors, possible air flow passages should be identified in an apartment.

387
Transom provides connection between spaces, which makes indoor air move freely in the indoors to minimize potentially stagnant regions.

Spatial connection control
Spatial connection control helps to confine and remove pollutants effectively without spreading them over other spaces.

CFD technique
The simulation of a bathroom design is conducted by CFD evaluation. A commercially available CFD tool, PHOENICS, is employed for this simulation. The applied turbulent model is the renormalization group (RNG) of k-ε model (5) which is the best among the eddy-viscosity models for predicting flow fields with thermal buoyancy phenomenon involved (6).

Demonstration case - bathroom
To examine the validity of the proposed strategies, the ventilation design of a bathroom is performed. The bathroom in an apartment unit which was investigated experimentally (2) on the distribution of pollutants concentrations and environmental parameters, such as temperature, air velocity, humidity and so on. The dimension of the apartment (Fig. 1) is 8.74 m in length, 6.12 m in width and 3 m in height. The size of the bathroom is 2.7 x 4 x 3 (m3).

For most apartments in Taiwan, the bathroom has no openings connected to the outdoors. Due to the absence of exhaustion vent and improper ventilation design, the humidity produced by taking showers is eventually spread throughout the whole apartment unit, which eventually creates problems like condensation and mold. The goal of this design is to remove the humidity (assumed airborne) generated in the bathroom from the apartment unit. The application of the aforementioned strategies to this case is elaborated as follows.

RESULTS
There are two cases (Table 1); each based on one type of proposed air flow pattern (Fig. 2).

<table>
<thead>
<tr>
<th>Proposed air flow pattern</th>
<th>Type A</th>
<th>Type B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Inlet</td>
<td>1</td>
<td>II</td>
</tr>
<tr>
<td>Air change per hour (based on the volume of the bathroom)</td>
<td>4</td>
<td>16</td>
</tr>
</tbody>
</table>

From comparisons between the two cases on the distribution of pollutants (Fig. 3 and 4), we can see that case B (Fig. 4) has lower pollutant concentrations inside and outside the bathroom. For case A, the additional inflow volume from inlet II only cause a wide spread of the pollutants, discharged from the bathroom, throughout the living room and kitchen. The air flow pattern of type B has better performance.

CONCLUSIONS
Four strategies of employing thermal buoyancy effect, dedicated air flow pattern, transom and spatial connection control, are proposed to improve indoor air quality by removing the pollutants produced in the indoors effectively. To prove the concept, a bathroom design based on the proposed strategies is demonstrated. Instead of spreading the humidity throughout the whole apartment unit as an inevitable consequence of the traditional design, implementing the proposed strategies enables the pollutants to be removed effectively from the apartment. The humidity produced in the bathroom is first collected at the upper level by...
thermal buoyancy effect, then removed through higher outlet to the hallway, finally excavated through transom from the apartment. To attain optimum design, more simulation cases with various inflow rates are needed for further examination.

Figure 3. Case A, the distribution of pollutant at $x = 6.12$ m.

Figure 4. Case B, the distribution of pollutant at $x = 6.12$ m.

REFERENCES


