



# Performance evaluation and design guidelines for stratum ventilation

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## ABSTRACT

This paper evaluates the performance of stratum ventilation systems for small to medium individual offices, open offices, classrooms, and retail shops operated under elevated room temperatures according to governmental guidelines. With proper design, stratum ventilation can maintain a thermally comfortable environment that has a horizontal airflow at head level, a small and reverse temperature gradient between the head and foot levels, and a high air distribution performance index.

Because the supply air enters the breathing zone directly, the supply air path is shortened. Therefore, the mean age of air is younger, the ventilation effectiveness is higher and indoor air quality is better in the breathing zone. This air distribution method uses the cooling effects of both temperature and velocity of the supply air. Therefore, for a specific application, stratum ventilation needs smaller capacity. This leads to smaller system size, space occupation, initial cost and energy consumption.

This paper presents guidelines for designing stratum ventilation.

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## 1. Introduction

Guidelines for various elevated room temperatures in summer have been issued by several governments in East Asia [1–6]. The new ASHRAE Standard 55-2010 offers new provisions that allow increased air movement to broadly offset the need to cool the air in warm conditions [7]. To accommodate the elevated room temperatures, stratum ventilation was proposed for small to medium rooms [8,9]. Stratum ventilation was found to achieve good thermal comfort measured by PMV and PPD [10]. Experimental and numerical investigations demonstrated the flow pattern formed by stratum ventilation was able to provide good IAQ in the breathing zone [11]. The particle concentrations under stratum ventilation of the entire room, and of the breathing zone in particular, are less than those under displacement ventilation [12]. The thermal neutral temperature under stratum ventilation was found to be approximately 2.5 °C higher than that under mixing ventilation and 2.0 °C higher than that under displacement ventilation respectively [13]. An extensive experimental investigation found that: (1) the CO<sub>2</sub> concentration in the occupied zone is typically lower than that in the upper zone; and (2) in the occupied zone, the air speed generally increases with height whereas the temperature gradient is reverse with the lowest value at the head level. The cooling effect

(temperature and air movement) of the conditioned airflow is also strongest at the head level [14].

Yuan et al. (1999) presented a set of comprehensive guidelines for designing displacement ventilation in the United States [15]. However, there are no relevant design guidelines for stratum ventilation. The performance of stratum ventilation is not familiar to design engineers. Therefore, in this study, the performance of stratum ventilation for offices, classrooms and retail shops is evaluated. The guidelines for designing stratum ventilation are presented.

## 2. Cases studied

The present investigation studied stratum ventilation systems for three building types: offices (consisting individual offices and open offices), classrooms, and retail shops. Fig. 1 illustrates a typical configuration for each of the building types. In order to obtain sufficient information to evaluate the performance of stratum ventilation, a CFD program used to collect 600 pairs of air temperature and velocity for 280 data points under different internal and boundary conditions. Amid the 280 data points, 73 are of the classroom, 121 are of the offices and 86 are of the retail shop. The thermal and flow conditions for the cases are summarized in a companion paper [16]. These thermal and flow boundary conditions cover a wide range of Hong Kong buildings:

- 10 ACH ≤ ventilation rate ≤ 28 ACH
- 55 W/m<sup>2</sup> ≤ Q<sub>t</sub>/A ≤ 180 W/m<sup>2</sup>

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