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Experimental investigation of thermal and ventilation performances of stratum ventilation

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A B S T R A C T

Stratum ventilation has been proposed to cope for elevated indoor temperatures. Air speed, temperature and CO_2 concentration of a stratum ventilated office are investigated experimentally. The data obtained under well defined conditions and therefore can be used for validating numerical models. Thermal comfort conditions and ventilation efficiency are studied based on the experimental results of four experimental cases. Thermal comfort indices, i.e. PMV, PPD and PD are calculated from measured data. The values of these indices are found to satisfy the requirements of ISO 7730, CR 1752-1998 and ASHRAE 55-2010. In terms of thermal comfort, the two cases with supply air temperature of 21 °C are found to perform better compared with the two cases with supply air temperature of 19 °C. For all the cases, the ventilation effectiveness is close to 1.5. This ventilation method could therefore be expected to provide indoor air quality in an efficient way.

1. Introduction

Minimizing the energy consumption by air conditioning systems would help to reduce carbon emission. Proactive actions in this regard have been taken by several governments in East Asia. Guidelines of various elevated room temperatures in summer have been issued, e.g. 25.5 °C for Hong Kong [1], 26 °C for the Chinese Mainland [2], 27 °C in the “Office of President” in Taipei [3], 26–28 °C for the Republic of Korea [4], more radically, 28 °C for Japan [5]. Similar trend even occurs in the United States [6]. These administrative measures seem to be in line with the principle of sustainable development. But would such practice deteriorate indoor environmental quality, especially thermal comfort? To answer this question, the new ANSI/ASHRAE Standard 55-2010 renders new provisions that allow elevated air movement to broadly offset the need to cool the air in warm conditions [7]. In revising EN ISO 7730, Olesen adopted Fountain and Arens' (1993) theory that higher air speed was required to offset increased indoor temperature [8,9]. Arens et al. 2009 reported that when the room air temperature above 22.5 °C, there is a small risk of draft and a strong preference for more air movement [10].

To decide suitable ventilation system(s) for the elevated room temperatures, criteria have been set based on the existing literature [11,12]:

1. Comparably higher temperatures and air movements in the occupied zone within the range advised in ANSI/ASHRAE Standard 55-2010 [2], and
2. Horizontal airflow(s) from the side and/or front direction(s) toward the occupant(s).

These performance requirements are difficult to fulfill with a conventional method like mixing ventilation or displacement ventilation [11,12]. Task station ventilation fulfills the requirements, but it is not designed for serving mobile occupants. Also the design, installation and cost of the ductwork, which runs in the occupied zone, limit its application.

In order to cope with the elevated room temperatures, stratum ventilation - was proposed by Lin et al. for small to medium rooms [11,12]. This ventilation method is realized by positioning supply terminal(s) at the side-walls or columns slightly above the height of occupants. Although the supply air temperature for stratum ventilation is higher than that of conventional ventilations, the distance between the occupants and the air terminal is shorter, which results in:

1. Reverse temperature gradient in the occupied zone - the temperature is lower at the head-chest level (the breathing zone) and higher at the ankle level, which effectively cools the occupants' area superficial to their carotid arteries that need cooling most [13–16];

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