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A study on the potential of natural ventilation and cooling for large spaces in subtropical climatic regions

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ABSTRACT

The potential of natural ventilation and cooling due to stack effects was investigated for large spaces with high ceilings. Different opening area ratios with respect to floor area were studied. Parameters of stack effects that consider floor heights were analyzed. Performance of natural ventilation was evaluated with cooling effects and indoor air quality for different months of the year. Three cities in northern, middle and southern Taiwan were used to represent typical subtropical weather types. It was found that opening ratio above 0.9% is sufficient to provide fresh air to meet IAQ requirement. Two different temperature control strategies, fixed indoor temperature (FIT) and operative indoor temperature (OIT) were proposed and studied. A sensible cooling potential, f_{pc}, was proposed. Different levels of f_{pc}, namely, strong, medium, weak and not available were used to evaluate the number of days for which natural cooling, hybrid ventilation, mechanical air conditioning are to be applied to satisfy the cooling requirement. The research results presented can be used in the design of openings for large spaces, and also the air-conditioning control strategies for different seasons of the year.

1. Introduction

Natural ventilation has been used as a building ventilation strategy since the ancient time. However, it is sometimes overlooked since the invention of mechanical systems. Modern building designs usually rely less on natural ventilation. Natural ventilation can improve the indoor environment and save energy, therefore can be considered as an important strategy for green buildings in subtropical regions. Subtropical climate exhibits mild winter, and the outdoor temperature is lower than the indoor temperature more than half of the year. In consequence there could be high potential of natural ventilation and cooling in these months of the year. When mechanical cooling is needed to supplement the need of ventilation and cooling, it is called the hybrid system. The hybrid system has recently caught the attention in the green building applications. However, there is still lack of research literature and design technology.

Natural ventilation is a passive system that the performance would rely on the characteristics of the building openings. This study used an analytical approach, in a detail analysis using single cell large space as the building model. The building model was built with two openings, one at the top and the other at the bottom. The performance of natural ventilation due to these openings was studied with respect to the needs of satisfying the requirements of indoor air quality (IAQ) and cooling in different months of the year. Natural cooling intensity in different seasons of the year was studied and analytical parameters were proposed.

Natural ventilation in different levels can provide sufficient fresh air, partly cooling, or sufficient natural cooling. When natural ventilation is insufficient to provide required fresh air or natural cooling, mechanical systems are then required to provide partly the thermal comfort and fresh air [1]. This operation mode of using both natural ventilation and mechanical system has been named the hybrid ventilation or the hybrid system [2–4]. This is a good approach for green buildings that making use of the building openings to save energy and provide better indoor environment [5].

The driving force of natural ventilation comes mainly from the stack effects that due to the temperature difference and also external wind effect [6]. Therefore, natural ventilation is similar to building infiltration in terms of the driving forces [7]. In this study only stack effects were considered so to provide generalized results that can be applicable in similar climates. In principle stack effect is more prominent for taller buildings [8]. Large spaces are typically designed with high ceiling and therefore the stack effect would be larger than residential houses. Therefore under the same temperature conditions, large spaces have greater potential of applying

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