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The characteristics of space cooling load and indoor humidity control for residences in the subtropics

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Abstract

For residential buildings located in the subtropics, it is more challenging and difficult to deal with space latent cooling load than space sensible load, using a room air conditioner (RAC), partly due to hot and humid climates. This paper reports a simulation study on the characteristics of space cooling load and indoor humidity control for residences in the subtropics, using a building energy simulation program. Both the weather conditions and the typical arrangements of high-rise residential blocks in subtropical Hong Kong were used in the simulation study. The simulation results on both the space cooling load characteristics and the hourly application sensible heat ratio (SHR) in the living/dining room and the master bedroom in a selected west-facing apartment under different operating modes of RACs in the summer design day are presented. The problem of indoor humidity control due to the mismatching between an application SHR and an equipment SHR in the two rooms both in the summer design day and during part load operations and the influences of indoor furnishings acting as moisture capacitors on indoor RH level are discussed.

Keywords: Space cooling load; Humidity control; Room air conditioner

1. Introduction

For residential buildings located in the subtropics, because of hot and humid climatic conditions, air conditioning is normally required for up to 7–8 months in a year [1]. Unlike the air conditioning for commercial buildings, residential air conditioning is very often provided by the use of a discrete system, i.e., room air conditioners (RACs) which are generally of direct expansion (DX) type. In the hot and humid subtropics, air conditioning will have to deal with both sensible and latent loads in a space, and in many cases to deal with space latent cooling load using a RAC is more challenging and difficult. This is partly due to the fact that the current trend in designing a RAC is to have a smaller moisture removal capacity, in an attempt to boost energy-efficiency ratings (EER) and coefficient of performance (COP) [2]. The method that has been used to improve efficiency is to increase the surface area of heat exchangers in a RAC. Such a strategy allows a RAC to run at a higher refrigerant temperature in its evaporator and a lower refrigerant temperature in its condenser, resulting in a lower latent capacity of the RAC. This can potentially lead to a situation where a RAC will provide a desired temperature control but not a desired indoor humidity control [3–5]. As a result, very often, a RAC removes space latent cooling load only as a by-product of a cooling process which primarily deals with space sensible load.

Sensible heat ratio (SHR), which is defined as a ratio of sensible cooling load to the total cooling load, is an important parameter in studying both the characteristics of space cooling load occurring in a conditioned space and the ability of cooling and dehumidification for the cooling coil of a RAC. The SHR for an air conditioned

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space is normally called an application SHR and that for an air conditioner an equipment SHR. An equipment SHR is largely a function of the design of a cooling coil while an application SHR depends however mainly on the characteristics of space sensible and latent cooling load [6].

Studies related to the space cooling load characteristics in residential buildings located in hot and humid subtropics have been reported. These included the studies on the effects of both the thermal insulation of external wall or roof and the *U*-value of windows on space cooling load [7–9]. Furthermore, a number of reported studies discussed the control of indoor relative humidity (RH) levels under part load conditions, and briefly mentioned that the mismatching between an equipment SHR and an application SHR can significantly influence the control of indoor RH levels in residences using RACs [3,5,6,10–14]. However, in all previously reported studies, the characteristics of space cooling load and the quantitative analysis for the matching between an equipment SHR and an application SHR and its impacts on indoor humidity control were rarely addressed.

On the other hand, dynamic behaviors of the moisture absorption and desorption between indoor air and the surfaces of indoor moisture capacitors such as indoor furnishings were studied [15–20]. The damping of the fluctuation of indoor RH level due to the presence of indoor furnishings was qualitatively predicted [18,20]. However, in these previously reported studies, no quantitative assessments on how the space latent cooling load due to the presence of indoor furnishings would influence indoor RH level were given.

This paper reports on a simulation study where the characteristics of residential space cooling load and the issues related to indoor humidity control using RACs were investigated and analyzed, using a building energy simulation program currently available in the public domain, EnergyPlus [21]. The weather conditions and the typical arrangements of high-rise residential blocks in the subtropical Hong Kong were used in the simulation study. The detailed descriptions of a typical apartment in a model high-rise residential block, which was used as a platform to perform the simulation study and a number of assumptions used in the simulation, are firstly presented. This is followed by reporting both the detailed analysis of hourly space cooling load characteristics and the hourly application SHRs in both the living/dining room of the apartment at daytime and the master bedroom of the apartment at nighttime, respectively, in the summer design day. Thirdly, the problem of indoor humidity control due to the mismatching between an application SHR and an equipment SHR in the two rooms both in the summer design day and during part load conditions was quantitatively investigated. Finally, the influences of indoor furnishings acting as moisture capacitors on indoor RH levels were also quantitatively studied.

2. Description of the apartment in a model building and the assumptions used in the simulation

A hypothetic 30-story residential block, which was modeled after those widely used in Hong Kong was used as the platform for performing the simulation study. This hypothetic block was used in a previous related simulation study, therefore detailed descriptions of the model block and all the assumptions used in the simulation were previously given [22]. However, for the completeness of this paper, these are repeated here. In addition, unlike in the previously related study, only the apartment facing west, one of a total of eight apartments in a floor, was used in this study. The floor plan of the selected west-facing apartment is shown in Fig. 1.

2.1. Occupancy pattern

In this apartment, there were three bedrooms, one living/dining room, one kitchen and two bathrooms. It was occupied by a four-person family consisting of two working adults and two school children. In this simulation study, it was assumed that the living/dining room was occupied by all family members at daytime; and the master bedroom (i.e., bedroom 1) by the two working adults and the other two smaller bedrooms, each by one of the two school children, respectively, at nighttime.

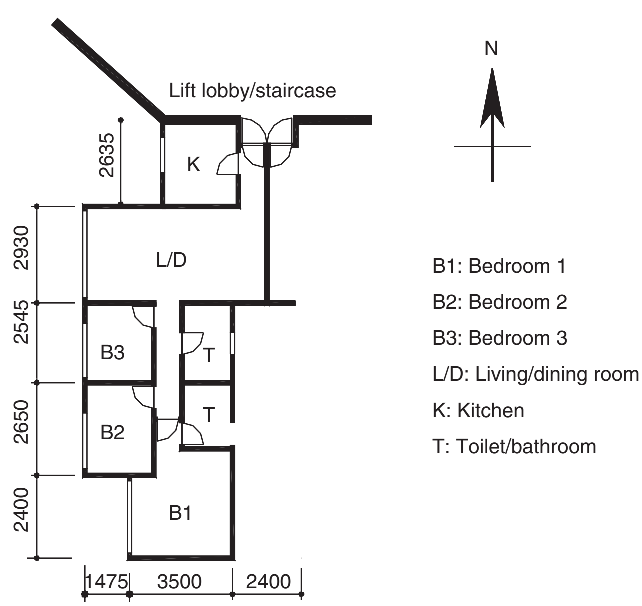

Fig. 1. Floor plan of a west-facing apartment under study in a hypothetic high-rise residential building.