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Development of new indices to assess the contribution of moisture sources to indoor humidity and application to optimization design: Proposal of $CRI_{(H)}$ and a transient simulation for the prediction of indoor humidity

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ABSTRACT

Many indoor and outdoor factors (e.g., the presence of occupants, hot-water supply equipment, the use of hygroscopic materials, and ventilation) contribute to indoor humidity. It is important to investigate and understand the contribution of each factor to indoor humidity and to establish an effective method for the design and control of indoor humidity. In this study, indoor humidity was treated as a linear summation of the contribution of various factors, all of which can cause an increase or decrease in indoor humidity. New indices for assessing the contribution of factors to the humidity distribution in a room are proposed as Contribution Ratios of Humidity ($CRI_{(H)}$) 1, 2, and 3 which can be calculated based on Computational Fluid Dynamics (CFD) simulations. Furthermore, a transient simulation based on $CRI_{(H)}1$ and the Contribution Ratio of Indoor Climate ($CRI_{(C)}$) was developed to predict the indoor humidity distribution. A 100-day transient analysis was performed in a living room in which moisture-buffering materials were used. The simulation results were compared with those from a well-mixed zonal model and a CFD transient analysis to confirm the effectiveness of the approach. The analysis provided the three-dimensional spatial distribution of indoor humidity and temperature with good prediction accuracy. The calculation time was approximately equal to that of the well-mixed zonal model and much faster than that of the CFD transient analysis.

1. Introduction

Since houses and office buildings are being built with high air tightness and thermal insulation in recent years, the capacity to remove moisture is relatively decreased, and the humidity of the indoor environment may be high. High indoor humidity can induce condensation on windows and within components of the building envelope and stimulate the growth of mold and dust mites, causing occupant dissatisfaction, material deterioration, and the development of respiratory discomfort and allergies [1–4]. In airtight and thermally insulated buildings, excessive drying can also occur, even during the winter when condensation is decreased. Low humidity environments are associated with dry skin, eye and mucous membrane irritation [5–7], and the development of static electricity [8]. To ensure indoor air quality (IAQ) and to assist the energy performance and sustainability of buildings, it is important to maintain indoor humidity at an appropriate level. Indoor humidity is influenced by many indoor and outdoor factors (e.g., the presence of occupants, hot-water supply equipment, the use of hygroscopic materials, and ventilation). Moisture-buffering materials are widely used in buildings because of their ability to control humidity [9]. To efficiently design and control the indoor humidity environment, the mechanisms of high or low humidity formation must be clarified, and a transient prediction of indoor humidity that accounts for moisture-buffering materials must be developed.

Several numerical models that account for the buffer effect of materials have been proposed to predict indoor humidity. A well-mixed zonal simulation model that considers the adsorption and desorption phenomena of interior materials has been widely used [10–13]. In this type of model, the temperature and humidity of the entire room are considered to be uniform (perfect mixing), and the entire air volume is represented by a single node for which the heat and moisture balance equations are solved. The well-mixed zonal

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