Aalto University
School of Engineering

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A nodal model for displacement ventilation in commercial buildings

Title of the dissertation	A nodal model for displacement ventilation in commercial buildings.
Contents of the dissertation	The design of displacement ventilation (DV) is usually based on controlling the desired air temperature in the occupant zone. A heat balance-based method is applied in displacement ventilation design when overheating is the primary indoor climate concern. The vertical temperature gradient in DV systems is usually calculated with lumped-parameter nodal models. An accurate vertical temperature gradient calculation is essential for displacement ventilation system design since it directly relates to the calculation of supply airflow rate. This study is focused on temperature gradient modelling and design of supply airflow rate in rooms with DV. The research methods include physical measurements and modelling methods. The measurements in steady-state conditions with typical buoyant flow elements, heat gain combinations and room heights showed that the major part of the vertical temperature gradient occurs at a low level of a room. The study also reveals that commonly used linear DV design models are not able to estimate vertical air temperature gradient accurately. As a result, the calculated air temperature in the occupied zone can defer from the real one by 2–3 °C, which causes poor thermal comfort and inadequate sizing of the ventilation and cooling systems. The developed steady-state model takes into account the types and locations of the heat gains and can accurately predict the temperature gradient in a room with DV. However, in practical applications, steady-state conditions do not exist, and heat gains vary significantly during operation hours. In addition, the thermal mass of building structures affects the room air temperature. This study presents a new dynamic displacement ventilation calculation model, the results of which are compared with the traditional method in a few typical applications. The study presents the calibration method of the dynamic model parameters of the building structures with the use of building simulation software IDA-ICE. The dynamic model was compared with the measurement results in a lecture room with DV. The dynamic multi-nodal model of displacement ventilation design is able to take into account the effect of building thermal mass and varying internal heat gains on the vertical temperature gradient. The airflow rate calculated by the dynamic model could be up to 50% lower than the airflow rate calculated with the steady-state models for heavyweight constructions. The dynamic DV model can be applied in DV design with various applications where heat gains varied, and thermal mass plays a significant role. The dynamic model can significantly decrease the design airflow rate of DV, which can result in a reduction of investment costs and electrical consumption of fans.
Field of the dissertation	Mechanical Engineering
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Opponents	Professor Per Heiselberg, Aalborg University, Denmark

The dissertation is publicly displayed online 10 days before the defence at
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