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Distribution of Ventilation Air and Heat by Buoyancy Forces Inside Buildings

An experimental study

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Abstract

The main task of the ventilation system in a building is to maintain the air quality and (together with the heating or cooling system) the thermal climate at an acceptable level within the building. This means that a sufficient amount of ventilation air at the appropriate temperature and quality must be supplied to satisfy thermal comfort and air quality demands and that this air is distributed to the parts of the building where people reside.

Air movements caused by buoyancy forces can determine the distribution of ventilation air within buildings. The purpose of this thesis is to advance the state of knowledge of buoyancy-driven air movements within buildings and to determine their importance both for ventilation air distribution and the maintenance of thermal comfort and air quality in buildings. The work is focused on studying thermally-driven air movements through large openings, both horizontal and vertical (i.e. doorways). The properties of a special type of thermally-driven currents, so called gravity currents, have also been explored.

Large vertical openings like doorways are important for air exchange between rooms within a building. Air movements through doorways separating rooms with different air temperatures are often bidirectional and the buoyancy-driven flow rates are often greater than those caused by the mechanical ventilation system alone. Bidirectional flows through doorways can effectively spread contaminants, for example, from a kitchen or a hospital rooms, yet the results of this study indicate that the conversion of a thermally-driven bidirectional flow to a unidirectional flow via an increase of the mechanically forced flow rate requires forced flows that are more than three times greater than the thermally-driven flows.

Experiments conducted in this project indicate that the resistance to buoyancy-driven flows in horizontal openings is significantly greater than that in vertical openings. Model tests have shown, however, that this problem may be mitigated if a simple model of a staircase located in the centre of the room (being ventilated) is linked to the horizontal ventilation opening.

Gravity currents in rooms occur in connection with so called displacement ventilation as cool gravity currents propagate along the floor that are driven by the density difference of the ventilation air and the ambient, warmer air within the room. As these gravity currents easily pass obstacles and to a certain extent are self-controlling, they can effectively distribute the cool air within rooms in a building.

Likewise, warm gravity currents occur when warmer air introduced in a room rises and spreads along the ceiling plane. One application where warm gravity currents may be used to advantage is when converting buildings from electric heating to district hot water heating thus, avoiding the introduction of an expensive hydronic heating system. This report includes a full-scale laboratory study of the basic properties of thermally-driven warm air gravity currents in a residential building and examines the possibilities of using the resulting air movements for the distribution of ventilation air as well as heat. Results from laboratory tests show that this conversion method may prove effective if certain conditions on the layout of the building are fulfilled.

Keywords: building ventilation, thermal forces, buoyancy, gravity currents, large openings, heating, air quality, forced convection, free convection