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The night purging of a two-storey atrium building

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ABSTRACT

We examine the fluid mechanics of night purging in a two-storey naturally ventilated atrium building. We develop a mathematical model of a simplified atrium building and focus on the rate at which warm air purges from each storey and the atrium by displacement ventilation into a still cool night environment of a constant temperature. To develop a first insight into how the geometry of the building influences the rate at which warm air purges from each storey via the atrium we neglect heat exchange with the fabric (so there is no thermal buffering) and furthermore assume that the warm air layers in each storey and the atrium are of uniform temperature.

The plumes of warm air that rise from the storeys into the atrium, causing the atrium to fill with warm air, have a very strong influence on the night purge. Modelling these as axisymmetric turbulent plumes, we identify three forms of purging behaviour. Each purge is characterised by five key times identified in the progression of the night purge and physical rationale for these differing behaviours is given. An interface velocity deficit and volumetric purge deficit are introduced as measures of the efficiency of a night purge.

1. Introduction

'Night purging' refers to the removal of warm and/or polluted air from a building during periods of low occupancy, generally at night. The objectives of night purging are to improve the indoor air quality by clearing excess heat or pollutants, and to cool the thermal mass of the building by drawing in cool night air, thereby reducing the peak daytime temperature and cooling demand, and potentially improving the comfort of occupants. Local studies into the effectiveness of night purging have been carried out in several countries including the USA [1], Greece [2] and Israel [3]. Ruud et al. [1] found that night purging reduced cooling energy demand by almost 20% for an office building in Jacksonville, Florida. Geros et al. [2] showed that the effectiveness of night purging is dependent on the relative difference between indoor and outdoor temperatures during the night period, the air flow rate achieved during the night and the thermal capacity of the building. They found that for a particular, high thermal mass building in Athens, night purging reduced the daytime peak temperature by 3°C, and daytime cooling demand by between 48% and 94%, depending on the air flow rate achieved overnight. Shaviv et al. [3] found that night purging produced a reduction in daytime temperature of 3–6°C in a high thermal mass building in the hot, humid climate of Israel. However, Ardehali and Smith [4] found that the potential reduction in energy use offered by night purging can be largely offset by the energy cost required to forcibly purge the air using mechanical ventilation. Natural ventilation offers a potentially attractive solution to this problem, as a *passive* night purge can, in principle, be achieved with little or no energy use. Artmann et al. [5] showed that there is significant potential for the use of passive night purging to cool buildings throughout Northern and Central Europe, and even some regions of Southern Europe. The challenge for the designer is to establish a design for a passively ventilated building that enables efficient night purging over a time scale that is known, and that may be controlled.

The intention of this paper is to model and explain the characteristic behaviour of warm air as it is night purged from an insulated multi-storey atrium building and to investigate the typical time scales that characterise and are required for a complete night purge. Our aim is to enhance basic understanding of the mechanisms involved in the purge and to provide insight into the design of effective multi-storey, naturally ventilated atrium buildings.

An understanding of the night purging of heat from a building has considerable implications for the ventilation performance of that building. For example, it may be attractive to fully flush the storeys of buoyant air overnight so that the occupied spaces are replenished with fresh air, and the thermal mass is cooled at the beginning of the next working day; while on other occasions it may be advantageous to only partially flush the atrium, so that a warm air layer is retained in order to induce ventilation naturally through

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