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Numerical investigations of buoyancy-driven natural ventilation in a simple atrium building and its effect on the thermal comfort conditions

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A B S T R A C T

In the present study use of solar-assisted buoyancy-driven natural ventilation in a simple atrium building is explored numerically with particular emphasis on the thermal comfort conditions in the building. Initially various geometric configurations of the atrium space were considered in order to investigate airflows and temperature distributions in the building using a validated computational fluid dynamics (CFD) model. The Reynolds Averaged Navier–Stokes (RANS) modelling approach with the SST-k–ω turbulence model and the Discrete Transfer Radiation Model (DTRM) was used for the investigations. The steady-state governing equations were solved using a commercial CFD solver FLUENT©. From the numerical results obtained, it was noted that an atrium space integrated with a solar chimney would be a relatively better option to be used in an atrium building. In the geometry selected, the performance of the building in response to various changes in design parameters was investigated. The produced airflows and temperature distributions were then used to evaluate indoor thermal comfort conditions in terms of the thermal comfort indices, i.e. the well-known predicted mean vote (PMV) index, its modifications especially for natural ventilation, predicted percent dissatisfied (PPD) index and Percent dissatisfied (PD) factor due to draft. It was found that the thermal conditions in the occupied areas of the building developed as a result of the use of solar-assisted buoyancy-driven ventilation for the particular values of the design parameters selected are mostly in the comfortable zone. Finally, it is demonstrated that the proposed methodology leads to reliable thermal comfort predictions, while the effect of various design variables on the performance of the building is easily recognized.

1. Introduction

In recent years energy efficiency demands and environmental concerns have prompted building designers to reconsider natural ventilation in summer, solar heating in winter and the use of daylighting to save energy consumed by buildings. The advanced technology of highly glazed atriums is currently being incorporated in the design of large modern buildings in order to take advantage of day lighting, solar heating and buoyancy-driven natural ventilation. Atrium spaces, when properly integrated with the building design, complement the building's functionality, provide vibrant space, provide daylighting deep into the building interior and also save energy. There have been several studies that support this view e.g. see Refs. [1–6].

Atrium design is complex and creates unique interrelationships between various parameters that must be understood and accounted for in the final design. Good atrium design will maximize the natural environment to minimize energy consumption. Atriums can be configured in an infinite number of ways, but atrium configurations should be always a reasoned response to the climatic and life safety goals. Typical atrium configurations may be completely surrounded by building elements or may be partially enclosed. They may be top lit, side lit or a combination of both. The configuration of the atrium will dictate many of the features of the atrium. The shape and geometry of an atrium depend upon the intended functions of the adjoining occupied portions of the building. There are several simple and complex basic configurations of an atrium space. The configuration selected by an individual designer is a function of (among other issues) personal taste, life safety issues, proposed uses of both the atrium and adjoining spaces, impact the atrium is wished to have climatically.

Natural ventilation in atria buildings can be achieved with solar-driven, buoyancy-induced airflows through the use of an atrium space, a solar chimney channel or a combination of both. In the past the use of solar chimneys or an atrium space in buildings has been examined i.e., see Refs. [7–14,38]. However, the integration of the

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