Building and Environment 46 (2011) 807–823

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

The fluid mechanics of the natural ventilation of a narrow-cavity double-skin facade

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ARTICLE INFO

Article history:
Received 27 June 2010
Received in revised form
16 September 2010
Accepted 29 September 2010

Keywords:
Natural ventilation
Seasonal control
Buoyancy
Double-skin facade
Heating
Energy consumption

ABSTRACT

This paper investigates the natural ventilation of a double-skin facade connected to a room in a multi-storey building. The room and the facade are connected to the exterior through vents at different levels. The room contains a horizontally distributed heat source analogous to occupants in an open-plan office or an underfloor heating system. The facade cavity contains a vertically distributed heat source analogous to a shading blind/louvers heated by solar radiation. These two sources of heat combine to provide buoyancy driving the ventilation. Two basic modes of facade operation are proposed and investigated. These two modes of operation should be alternated according to exterior climatic conditions. In colder seasons, the room draws air from the portion of the facade which extends one floor below the room, and solar radiation on the facade preheats supply air into the room. In warmer seasons, the room vents to the exterior through the portion of the facade which extends one floor above the room, and solar radiation on the facade enhances the ventilation and prevents overheating in the system. A quantitative model is developed to describe the fluid mechanics of the ventilation in these two modes of operation. The model is successfully tested with laboratory experiments. It shows how the height of the facade and the size of the openings can be adjusted to maximise the preheating of the room in colder seasons, and to prevent overheating in the room and the facade in warmer seasons. The model is used to explore the principles for design and control in different climatic and occupancy conditions.

1. Introduction

Double-skin facades can be generally defined as *"envelope constructions, which consist of two transparent surfaces separated by a cavity, which is used as an air channel"* [1]. The outer layer of the facade provides added protection from the weather and external noise. Both internal and external layers usually contain openings which allow the ventilation of the cavity and of any room connected to the facade. Air flows through the cavity are often driven by fans and, in a smaller number of cases, by wind or by thermal buoyancy created by solar radiation. Although the width of the facade cavity can vary significantly, from a few centimetres to several meters, depending on architectural requirements, a narrow cavity–generally between 10 and 30 cm–is normally used when the floor area of the room connected to the facade is to be maximised [2,3]. In this system, louvers or blinds are usually incorporated within the cavity to provide solar shading and glare control [2,3]. The present paper investigates the working of such a narrow-cavity facade.

A number of investigations have been carried out to explore the behaviour of narrow-cavity double-skin facades. Some of them focus on facades which are not connected to occupied rooms, the latter being assumed to be independently ventilated (e.g. Refs. [4–9]). In these conditions, where the ventilation of the facade is separated from that of the adjacent room, heat transfer between the facade and the room takes place primarily through conduction and radiation; and the amount of heat transferred will depend largely on the behaviour of air flows within the facade cavity and the design of the facade components such as glazing and shading devices. Several investigations focus on how to best control these variables to minimise heat transfer from the facade to the room in warmer seasons or climates. Balocco [4], for instance, shows that the ventilation and temperature in the facade depend on the width of the cavity: the narrower the cavity is, the higher the risk is of facade overheating in summer. Pappas and Zhai [9], using a combination of an energy simulation programme and a CFD package, study a facade whose cavity contains a shading device

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doi:10.1016/j.buildenv.2010.09.015