Available online at www.sciencedirect.com
ScienceDirect
Solar Energy 81 (2007) 435–448
SOLAR ENERGY
www.elsevier.com/locate/solener

Guidelines for improving natural daytime ventilation in an office building with a double-skin facade

Elisabeth Gratia *, Andrè De Herde

Université Catholique de Louvain, Architecture et Climat, Place du Levant 1, B-1348 Louvain-La-Neuve, Belgium

Received 12 July 2004; received in revised form 17 August 2006; accepted 21 August 2006
Available online 29 September 2006

Communicated by: Associate Editor Deo Prasad

Abstract

In recent years, there has been a great deal of interest in double-skin facades due to the advantages claimed for this technology in terms of energy saving in the cold season, protection from external noise and wind loads and their high-tech image.

The advent of computers and other office equipment has increased the internal heat gains in most offices. Highly glazed facades, together with the extra heat gains from the electric lighting made necessary by deep floor plans and the wider use of false ceilings, have increased the risk of overheating. To preserve comfort and reduce cooling loads, it is important to apply natural cooling strategies, including natural ventilation.

Some argue that double-skin facades are designed to improve natural ventilation in buildings by the stack effect, and to allow this even in situation in which it is generally not possible due to high outdoor noise levels and/or high wind speeds.

But poor operation of the double-skin facade openings can generate disastrous scenarios such as the injection of hot air from the double-skin facade into the offices and the contamination of offices on the upper floors by used air from the offices on the lower floors.

This article examines how natural ventilation can be utilised in an office building with a double-skin facade during a sunny summer's day. It mainly considers natural daytime ventilation in relation to the orientation of the double skin and the speed and direction of the wind.

Keywords: Double-skin facade; Thermal modelling; Office building; Natural ventilation; Cooling strategies

1. Introduction

The double-skin facade is an architectural phenomenon driven by an aesthetic desire for an all-glass facade.

Transparency is often seen as the main architectural reason for a double-skin facade, because it allows close contact with the surroundings. From the client's point of view, physical transparency may appear to indicate a transparent organisation with a large degree of openness (Hendriksen et al., 2000).

This "emerging technology" of heavily glazed facades is also often associated with buildings whose design goals include energy efficiency, sustainability, and a "green" image.

So there has been an increase in the numbers of this type of building. The success of these facades also lies in the fact that they admit a large amount of daylight, exhibit a uniform exterior, and have attractive aesthetics.

The costs of double-skin facades are higher than those of normal facades, but claims of energy and productivity savings are used to justify some of these increased costs (Poirazis, 2004).

The advent of computers and other electric office equipment has increased the internal heat gain in most offices. Highly glazed facades, often with poor shading, have

* Corresponding author. Tel.: +32 10 47 22 23; fax: +32 10 47 21 50.
E-mail addresses: elisabeth.gratia@uclouvain.be (E. Gratia), deherde@arch.ucl.ac.be (A. De Herde).

0038-092X/$ - see front matter
doi:10.1016/j.solener.2006.08.006

become very common. This, together with the extra heat gain from the electric lighting made necessary by deep floor plans, and the widespread use of false ceilings, has increased the risk of overheating (Gratia and De Herde, 2003).

In the 1990s, concern about global warming resulted in a resurgence of interest in naturally ventilated offices (Allard, 1998; Liddament, 1996; Dickson, 1998).

There is also an increasing demand for high-quality office buildings. The occupants and developers of office buildings require healthy and stimulating working environments (Rennie and Parand, 1998). This is usually provided by an air conditioning system. But in many cases, with some effort to reduce internal heat gain (solar protection and well chosen equipment), natural ventilation may be sufficient to ensure good comfort levels for the buildings' occupants.

In that case, air conditioning system will not be necessary, which will result in considerable energy and cost savings. It will also indirectly reduce the burden on the environment, since the use of energy is always associated with the production of waste materials (Wong et al., 2003).

Some aspects of comfort are even improved by the use of natural ventilation:

- In a mechanically ventilated building, air movement is likely to be associated with noise while, in a quiet environment, natural ventilation is silent.
- Most people appreciate having windows they can open for natural ventilation (Aggerholm, 2002). Moreover, studies of sick building syndrome (SBS) have indicated that perception of greater control over ventilation, lighting and temperature is associated with decreased prevalence of symptoms. In many recreational and public buildings users do not expect to have control over the environment, but office workers are likely to demand a high degree of control. If this is not available, they feel "uncomfortable" and suffer real "sickness" symptoms even when the comfort conditions are apparently within accepted limits (Allard, 1998; Liddament, 1996).

The Belgian climate is particularly well adapted to cooling by natural ventilation. Indeed, except for a few days a year, the outdoor air temperature is lower than the indoor temperature not only during the night, but also during the day. Therefore most of the time opening a window is enough to cool the building (Gratia and De Herde, 2002, 2003).

One of the advantages cited by the defenders of double-skin facades is that this method of construction allows natural ventilation to be used to improve indoor air quality without the acoustic and security constraints of naturally-ventilated single-skin facades.

Double-skin facades are assuming an ever-greater importance in modern building practice. They are already a common feature in architectural competitions in Europe; but there are still relatively few buildings in which they have actually been used, and there is too little information on their behaviour in operation (Zöllner et al., 2002; Zalewski et al., 2002).

There are many unknowns: optical and thermal modelling of these systems is not routine and coupling heat transfer and air flows from an isolated facade system to the whole building is complex. A variety of thermal coupling strategies must be simulated (Gratia and De Herde, 2004a).

Moreover, although subjective claims abound in the architectural literature, it is extremely difficult to find any objective data on the actual performance of buildings with double-skin facades.

So it is important to verify whether natural ventilation is in fact possible when the building is equipped with a double skin. Faulty operation of the double-skin facade could generate catastrophic scenarios such as the injection of hot air from the double skin into the offices, or contamination of the offices on the upper floors with polluted air from offices on the lower floors (Gratia and De Herde, 2004b,c).

To improve the stack effect in the double skin, some authors have suggested adding a thermal storage space called a solar chimney above the double-skin space. Reduced-scale-model experiments and computational fluid-dynamic analyses have been carried out to evaluate the performance of the natural ventilation in the prototype building (Ding et al., 2005). This system improved the chimney effect of the double skin but necessitated a chimney reaching at least 11 m above the building, which is a significant aesthetic constraint.

This article examines how natural ventilation can be provided during a sunny summer day in an office building with a double-skin facade. It concentrates on the possibility of natural ventilation during the daytime in relation to the orientation of the double skin and the speed and orientation of the wind.

To undertake the study, we chose an office building with a high level of thermal insulation. With the thermal program TAS we simulated various features of the double skin. The research will help us to understand how the double skin operates.

Many studies have already simulated the behaviour of double-skin facades (Balocco, 2002; Pasquay, 2001; Mei et al., 2003; Manz, 2003; Von Grabe, 2002). This research is only one step in the search for a better understanding, in a qualitative way, of the thermal behaviour of one particular type of double skin.

Architectural design guidelines would help architects and owners achieve a better understanding of the applicability of various concepts to their specific building projects.

2. Method

2.1. TAS program

TAS is a software package for the thermal analysis of buildings. It includes a 3D modeller, a thermal/energy analysis module, a systems/controls simulator and a 2D CFD package. There are also CAD links into the 3D modeller as well as report generation facilities. It is a complete solution for the thermal simulation of a building, and a