Paper 7

Evaluation of Local Thermal Discomfort in a Classroom Equipped with Cross Flow Ventilation

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Abstract

This paper presents an evaluation of the local thermal discomfort level in a classroom equipped with cross ventilation, for a typical moderate summer day in Portugal. Three different ventilation configurations based on window and door opening were considered. In each, the thermal comfort, air quality and acoustical comfort conditions were also evaluated.

This experimental study was made in the South of Portugal, exposed to a Mediterranean climate. Thermal comfort was based on the PMV index, the air quality was based on the air renovation rate and acoustical comfort levels were based on the reverberation time, voice clarity, definition and early reflection ratio. The detailed local thermal discomfort analysis was based on draught risk and uncomfortable air velocity fluctuations. Other measurements included relative humidity, the radiative mean temperature, carbon dioxide concentration (tracer gas decay), and noise level decay of impulsive response. Results showed that for the warmest of weather open windows and classroom door gave the best air quality and comfort conditions.

Key words: natural ventilation, cooling, school, Mediterranean climate, indoor air quality, comfort, acoustic conditions.

1. Introduction

Clean air is needed to provide a pleasant micro-climate around the occupants, assure good air quality in the breathing area and extract the contaminants released by the occupants. Nevertheless, the ventilation system can affect local thermal discomfort levels.

Natural ventilation presents the main ventilation method for school classrooms in the Algarve Region in the South of Portugal. In general, ventilation is guaranteed by small open windows placed above the door and above the main windows (see Figure 1), providing cross flow ventilation. In summer, when the air temperature increases due to solar radiation, fabric curtains or blinds can be closed. In addition the main windows and classroom door should also be open, to guarantee acceptable conditions.

To evaluate the thermal comfort level, in moderate environments equipped with air-conditioning systems, the PMV (Predicted Mean Vote) and the PPD (Predicted Percentage of Dissatisfied) indices, developed in Fanger (1970) are used. The PMV index is given as a value on a seven-point comfort scale. This is based on four environmental parameters (air mean temperature, air velocity, relative humidity and radiant mean temperature) and two personal factors (clothing and metabolic activity level). In accordance with these PMV and PPD indices, the thermal neutrality of an individual person is obtained when the body heat loss is equal to the body metabolic heat (PMV=0).

An extension of the PMV model was developed by Fanger and Toftum (2002) to be used in non-air-conditioned buildings in warm climates. This extension, for warm environments, combines the "static" PMV model with an "adaptive" model which takes into account that people in non-air-conditioned environments in warm climates perceive the environment in a less severe way than the "static" PMV people.

Local thermal discomfort sensations in localized regions of the body may occur by incident airflows from ventilators, due to their intrinsic characteristics such as exit air velocity, airflow symmetry and their location in relation to the occupants. In accordance with Fanger et al. (1988) the local thermal discomfort (draught risk) depends on the local air temperature, velocity and turbulence intensity. According to Fanger and Pedersen (1977) the local discomfort sensation is associated with air velocity frequency fluctuations at frequencies between 0.3 and 0.5 Hz.

The airflow rate inside an occupied space may be calculated using different recommendations and methodologies presented in national and international standards (see also Olesen, 1997). For example, the ANSI/ASHRAE Standard (2004) and the Portuguese standard (Decreto-Lei nº 79, 2006) present some recommended airflow rate values per person, while the CR 1752 (1998) presents some airflow rate values based on occupants comfort level. In the latter Standard it is also necessary to consider the pollution load caused by the building itself (including furnishing, carpets and ventilation systems).

To evaluate acoustical comfort, the Reverberation Time (T_{30}), Voice Clarity (C_{50}), Definition (D) and Early Reflection Ratio (ERR), of a classroom, were used. In Portugal, the regulation Decreto-Lei nº 129 (2001) established requirements only for Reverberation Time. For the remaining parameters good practice requirements based on Isbert (1998) were used.

In the present study, experimental monitoring in a real classroom under typical summer conditions were made. The thermal comfort, air quality, acoustical comfort and, in detail, the local thermal discomfort were analyzed for three typical situations as described in the next Section.