Building and Environment 111 (2017) 180–191

Contents lists available at ScienceDirect

Building and Environment

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

An attempt to improve indoor environment by installing humidity-sensitive air inlets in a naturally ventilated kindergarten building

Maciej Mijakowski*, Jerzy Sowa

Warsaw University of Technology, Faculty of Building Services, Hydro and Environmental Engineering, 20 Nowowiejska St., 00-653 Warsaw, Poland

ARTICLE INFO

Article history:
Received 16 August 2016
Received in revised form
13 October 2016
Accepted 4 November 2016
Available online 5 November 2016

Keywords:
Indoor CO_2 concentration
Indoor relative humidity
Natural ventilation
Humidity controlled ventilation
Kindergarten

ABSTRACT

Proper values of hydro-thermal parameters and good air quality indoors are known to have a great influence on human comfort, health and performance, and children are particularly susceptible to poor indoor air quality. On the other hand, there is a tendency in developed countries to modernise educational buildings to reduce energy use, and as a result, outdoor air frequently can no longer penetrate into the buildings through thermally insulated exterior walls or through airtight window frames. This may lead to high concentrations of pollutants generated indoors, increased levels of relative humidity and, often, to overheating. Installation of extra air vents (trickle vents) is sometimes recommended as a solution. The present study focuses on a comparison of passive stack ventilation performance as well as indoor conditions before and after installation of humidity-sensitive air inlets in a kindergarten building. The comparison was based on two one-month-long series of monitoring of temperature, humidity and CO_2 concentration which took place before and after the installation. The results were assessed against current recommendations, and the effectiveness of the improvement was discussed. Unfortunately, the analysis of indoor conditions and ventilation performance showed that although humidity-sensitive air inlets improved performance of passive stack ventilation, the effect was not sufficient to meet current Polish and European standards and recommendations for indoor environment in newly designed kindergarten buildings.

1. Introduction

1.1. Objectives of the work

The present study focuses on a comparison of passive stack ventilation performance before and after installation of humidity-sensitive air inlets in a kindergarten building located in Warsaw, Poland. The case study object may be regarded as quite typical for Polish kindergartens. Selected conditions of indoor environment were measured for a period of one month before and one month after the improvements, and the results were compared. The building was typically used during the measurements, which did not allow the authors to fully control the experiment.

The impact of different weather conditions was reduced by means of a selection of shorter periods of time with comparable weather conditions, and thus evaluation of improvement effectiveness was possible. Additionally, the results were assessed against current standards and recommendations.

1.2. Background

Proper values of hydro-thermal parameters and good air quality indoors are known to have a great influence on human comfort, health and performance [1,2]. Children are particularly susceptible to poor indoor air quality, therefore Children's Environment and Health Action Plan for Europe – CEHAPE [3] – expresses the need for developing indoor air quality strategies which take specific needs of children into account. Moreover, Regional Priority goal III provides for the application and enforcement of regulations to improve indoor air quality, especially in housing, child care centres and schools, with particular reference to construction and furnishing materials. Studies around the world show that poor IAQ conditions in educational buildings affect children's health and learning abilities [4–8]. However, one should remember that differences in teaching results can be affected by many other factors

* Corresponding author. Warsaw University of Technology, Faculty of Building Services, Hydro and Environmental Engineering, 20 Nowowiejska St., 00-653 Warsaw, Poland.

E-mail address: maciej.mijakowski@is.pw.edu.pl (M. Mijakowski).

http://dx.doi.org/10.1016/j.buildenv.2016.11.013

such as thermal comfort, light, colours, level of personalisation as well as adaptation of space for different teaching techniques [9].

Nevertheless, an analysis based on a literature review [10] indicates that children could perform better at school by as much as 30% if indoor environment was improved. A number of studies present the influence of indoor environment in schools and kindergartens on absenteeism [11–13].

At the same time indoor environment may strongly affect the process of aging of materials, thus reducing durability of the buildings. In particular, bio-deterioration is observed when moisture exceeds the levels of tolerance of structures [14].

Unfortunately, numerous studies show poor indoor climate in educational buildings in developed countries [15–17]. Common problems are: insufficient amount of outside air supplied to occupied spaces, elevated and varying temperatures, water leaks, inadequate exhaust air flows, poor air distribution or balance as well as poor maintenance of heating, ventilation and air-conditioning systems [18]. The WHO report on methods for monitoring indoor air quality in schools [19] also states that the problem of insufficient ventilation in schools is common. Moreover, one should remember that furnishings and textiles in the classroom may act as significant reservoirs of irritants and allergens [20].

Numerous studies indicate that, statistically, classrooms with mechanical ventilation have better IAQ than classrooms ventilated in a natural way [21–23]. Frequently, to improve situation in naturally-ventilated classrooms, teachers are advised to open windows during breaks between classes [24]. Gao et al. [23] found that in Danish schools pupils open the windows regardless of the type of ventilation, which indicates that this behaviour can be just a function of habit.

Kindergartens in Poland are usually located separately from schools and provide different services. According to the Central Statistical Office of Poland, depending on the region, from 48.8% to 63% children aged 3–5 attend kindergartens, while in the group aged 6 this ratio exceeds 90% of the population. Children spend from 5 to 10 h a day in kindergarten buildings, typically in the same room, with possible short visits outdoors in case of nice weather. The vast majority of existing kindergarten buildings in Poland are made of bricks or prefabricated concrete elements and are equipped with passive stack ventilation. Until the 1990s, leaky windows provided air supply, while the air was supposed to leave classrooms via stacks made of bricks. Many of these kindergartens have recently been modernized to comply with the demand for lower energy consumption. Typical investments include additional insulation of external walls, replacement of windows and regulation of the heating system. An unfavourable effect of such modernisation is that outdoor air can no longer penetrate into these buildings through airtight window frames, which typically leads to high concentrations of pollutants generated indoors [25–27], increased levels of relative humidity and, frequently, to overheating [25,28,29]. The results of a survey on schoolchildren's estimation of indoor environment, carried out in 2002 in 235 randomly selected classrooms/schools all over Poland [30] showed that among the most commonly reported problems were: stuffy air (~54% of the classrooms), dry air (~46% of the classrooms), too high air temperature (~44% of the classrooms), unpleasant smell (~37% of the classrooms), stale air (~33% of the classrooms) and changes in temperature in time (~31% of the classrooms).

Moreover, Wargocki and Wyon [10] showed that reduction of ventilation and allowing for temperatures to vary over a wider range, being the most popular "investment-free" ways of conserving energy in schools, are in fact frequently counterproductive, in the sense that while saving energy, they actually tend to decrease pupils' school performance. Therefore, Polish schools after thermo-modernisation need to be retrofitted once again, this time with systems that ensure better indoor air quality.

There are many ways of improving IAQ but, as stated by Wargocki and Da Silva [31], installation and maintenance of new systems may again generate high costs, as well as take many years to complete. Therefore, they claim, simple retrofit solutions are needed.

Opening the windows seems to be the simplest solution to enhance natural ventilation efficiency [24]. The present study, however, examined another relatively cheap solution – installation of humidity-sensitive air inlets. Although there are some studies on indoor air quality in buildings with humidity sensitive air inlets [32,33], the present study aims to give an exceptional comparison of indoor air conditions in a kindergarten room, before and after installation of such devices.

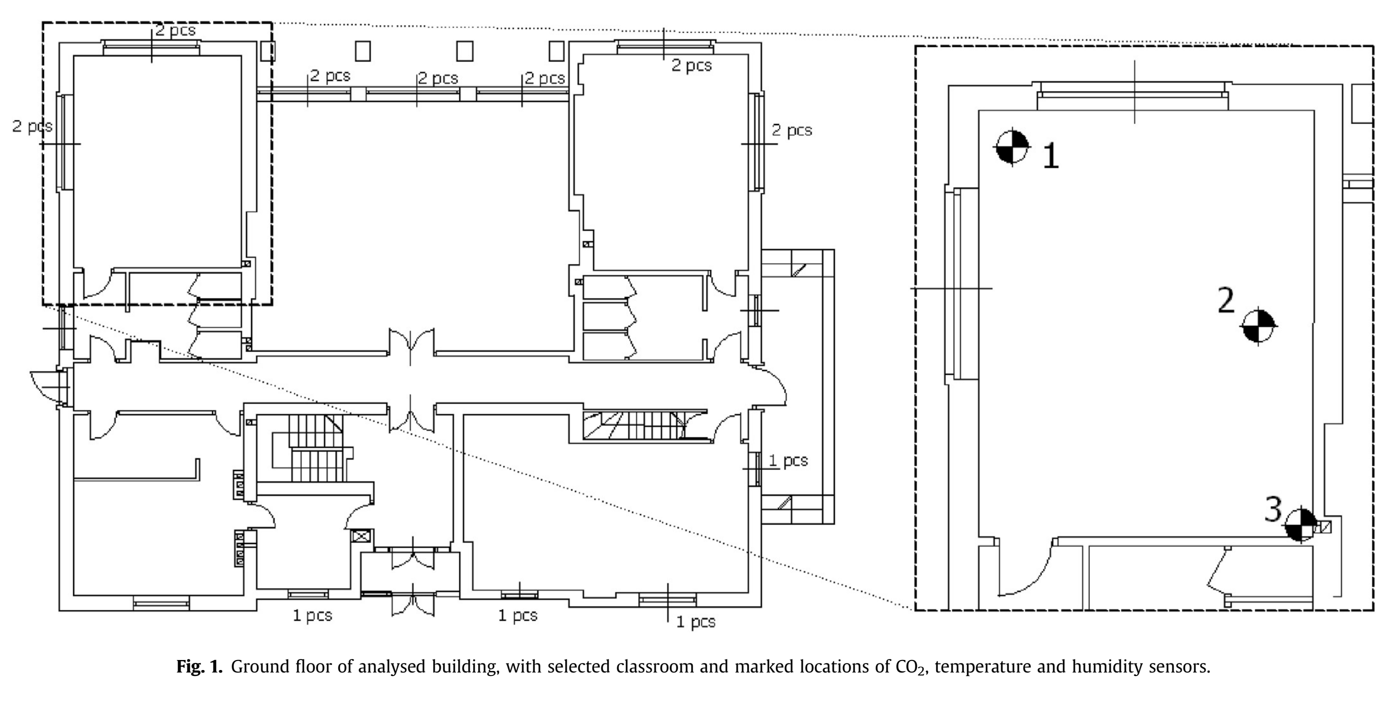

Fig. 1. Ground floor of analysed building, with selected classroom and marked locations of CO_2, temperature and humidity sensors.