Energy for Sustainable Development 29 (2015) 38–46

Contents lists available at ScienceDirect

Energy for Sustainable Development

Redeveloping industrial buildings for residential use: Energy and thermal comfort aspects

Kęstutis Valančius *, Violeta Motuzienė, Sabina Paulauskaitė

Vilnius Gediminas Technical University, Vilnius, Lithuania

ARTICLE INFO

Article history:
Received 14 July 2014
Revised 18 May 2015
Accepted 12 September 2015
Available online xxxx

Keywords:
Building redevelopment
Energy demand
CFD
Glazing
Thermal comfort

ABSTRACT

The old industrial buildings, now located near the city centres, redeveloping into commercial or residential use is very popular, but energy and especially comfort conditions not analysed because usually the specific projects are not made. This article provides an analysis of various aspects of energy demand and indoor thermal comfort when old, often unused industrial buildings are redeveloped for residential use. The results of the analysis, if the buildings are in use, show such redevelopment to be very efficient in terms of saving energy resources. In order to analyse thermal comfort of the redeveloped building, two different heating systems, radiator heating and floor heating, were examined. The performance of these systems was analysed with respect to three different room heights and window-to-wall ratios (hereinafter referred to as WWR). In order to simulate temperature distribution, computational fluid dynamics (hereinafter referred to as CFD) software SolidWorks®FlowSimulation was used. The results of the research demonstrate the acceptability of the heating systems in terms of indoor climate and thermal comfort as well as facilitate further discussion for future research in the field.

Introduction

A great deal of old unused industrial facilities built in the Soviet era exists in various towns of Lithuania and in other Eastern European countries alike. These buildings are usually large in volume (i.e., tall and big facilities) and large areas of the façades of these buildings are glazed (Fig. 1). In Lithuania a lot of these buildings were constructed in the downtown area; beneficial location and features of the industrial architecture resulted in the fact that instead of demolishing these buildings they are now being redeveloped in order to convert their building type to administrative or residential, the latter being the most common. In order to keep the industrial style intact, the window area is not amended during the redevelopment (Fig. 2).

Redevelopment of old industrial buildings used for production or storage to new residential homes increases energy efficiency of said buildings and helps to solve the issue of sustainable urban development while maintaining the specific industrial style of the buildings.

Such projects have already been launched, but due to lack of experience, the specifics of apartment buildings with high ceilings and large glazed areas are not always taken into account when designing heating systems that should ensure sufficient thermal comfort.

Large glazing areas are typical of newly constructed buildings as well. The transparency of the façade not only provides a unique architectural effect but also creates a pleasant visual contact with outdoors, natural lighting and potential energy savings in terms of lighting, provided that the systems function properly (Ge and Fazio, 2004). However, the still relevant tendency to use a fair amount of glass in the façade results in certain problems as well (Goia et al., 2013). First of all, such buildings are not energy efficient: in summer, they require more energy for cooling, whereas in winter, more for heating. Another problem that has been proved by a great deal of research is the difficulty of ensuring proper indoor thermal comfort near large glass partitions (Ge and Fazio, 2004; Kim et al., 2007; Šeduikytė and Paukštys, 2010; Jurelionis and Isevičius, 2010; Hassan, 2012). Due to these reasons, window size should be optimised following certain criteria (Ochoa et al., 2012; Menzies and Wherrett, 2005). A lot of research has been conducted in order to examine the effects of the area and characteristics of glazing on heat transfer through partitions as well as energy savings (Susorova et al., 2013; Poirazis et al., 2008; Jaber and Ajib, 2011; Jonsson and Roos, 2010). To summarise the aforementioned research, it can be concluded that large glazed façades are undesirable except in cases of double façades or smart glazing such as PCM (Goia et al., 2013; Coussirat et al., 2008).

One the main difference between newly constructed buildings and old redeveloped factory buildings is that great height (volume) is typical to the latter. It is well-known that buoyancy-driven currents cause heterogeneous air temperature and velocity fields in large-volume rooms (Šeduikytė and Paukštys, 2010). Due to convection, warm air tends to move upwards thus creating a positive temperature gradient between the floor and the ceiling. This phenomenon is known as stratification and is especially typical to the high and large-volume buildings (e.g., airship hangars, high schools, atriums, lofts, factories, etc.) (Said et al., 1996). A few authors who analysed different types of large-volume buildings (i.e., factories, airship hangars, aviaries) that measure from

* Corresponding author at: Vilnius Gediminas Technical University, Sauletekio al. 11, LT–10223 Vilnius. Tel.: +370 5 2744718.

http://dx.doi.org/10.1016/j.esd.2015.09.004
0973-0826/

Fig. 1. Example of old unused industrial buildings in Vilnius.

Fig. 2. Examples of industrial buildings in Vilnius redeveloped into residential buildings.

6 m to 17 m in height discovered that the temperature discrepancy between the floor and the ceiling amounts from 5.6 °C up to 20 °C, whereas in the buildings that have atriums, this discrepancy amounted for only up to 2 °C (Said et al., 1996). The problems of cold air development and stratification are especially relevant in cases of residential large-volume rooms with large windows.

Both the stratification phenomenon and thermal comfort depend on the heating system installed in the building. The most common heating systems for residential and administrative buildings in the European Union are water based (Ploskić and Holmberg, 2011). Traditional radiator heating systems are also planned and designed for the buildings that are being redeveloped into residential buildings, a fact that suggests that thermal comfort in such buildings is poor. It would seem that tall and large-volume rooms should benefit most from floor heating since this way the vertical temperature gradient is negative (Karadağ et al., 2007). In comparison with other heating systems, floor heating systems have been used for a very long time because of such benefits. A study in Sweden has also demonstrated that low-temperature enhances thermal comfort since it leads to lower air agility and lower temperature difference as compared to high-temperature radiator heating (Myhren and Holmberg, 2008). Cold air currents that form near glass partitions and cause discomfort may be blocked by providing warm air nearby (Zukowski, 2007). Ge and Fazio (2004) presented an experimental study on comfort in a carcass building with a large one-piece glazing area in the façade and drew conclusions that in order to avoid formation of cold air currents near windows one should install perimeter heating near the base of glazing.

Due to the reasons mentioned above, the choice of the heating and ventilation systems for large-volume and tall buildings is of crucial importance. A detailed assessment of thermal comfort in such buildings is performed using the CFD analysis that requires expert mathematics and computer knowledge. Consequently, methods that are simplified and suitable for practical application in engineering should be discovered and applied. For example, Voeltzel et al. (2001) developed AIRGLAZE, a research code that is intended to analyse thermal processes of large highly-glazed spaces, the object of this article.

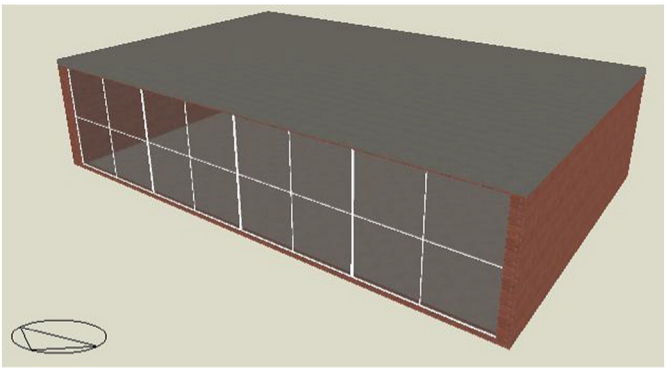

Fig. 3. Model of the room used for simulation.