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ScienceDirect

Energy Procedia 132 (2017) 153–158

Energy Procedia

www.elsevier.com/locate/procedia

11th Nordic Symposium on Building Physics, NSB2017, 11-14 June 2017, Trondheim, Norway

Thermal comfort condition assessment in test buildings with different heating/cooling systems and wall envelopes

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Abstract

The main aim of this study is a comprehensive analysis of long-term monitoring data of thermal comfort and discomfort parameters in small identical test buildings equipped with different heating/cooling systems. Calculations of PPD index expressed the human perception of thermal comfort and such discomfort factors like draught rate and vertical air temperature difference are provided for the room in winter season running three different heating systems – electric heater, air-air heat pump and air-water heat pump, as well as for the summer cooling with split type air conditioning systems. It is shown that the type of heating/cooling system and its working regime has a significant impact on thermal comfort conditions in the room. Recommendations for the optimal operating regimes and choice of the heating system from the thermal comfort point of view are provided.

Peer-review under responsibility of the organizing committee of the 11th Nordic Symposium on Building Physics.

Keywords: Test buildings; thermal comfort; PPD; categories of thermal environment; local thermal discomfort; heating system; cooling sytem.

1. Introduction

Five small experimental test buildings with internal dimensions 3×3×3 m have been built in Riga, Latvia (Fig. 1). They have identical constructions of floor, ceiling, also the door and window. Only buildings' walls have been built with different materials typically used in Latvia – aerated concrete, ceramic blocks, wooden logs, plywood frame and rock wool insulation (see more in [1]). It is important to note that the thickness of used materials for the walls is chosen in such a way to get the same calculated thermal transmittance (U-value) of 0.16 W/ (m2K). After 4 years of the project running, a huge amount of various measured data points is collected and the resultant analysis (mostly linked to the energy consumptions, mathematical modelling, humidity monitoring, indoor air quality including mould growth

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1876-6102
Peer-review under responsibility of the organizing committee of the 11th Nordic Symposium on Building Physics
10.1016/j.egypro.2017.09.668

risk analysis) are widely published [1-5]. Similar studies were performed on a variety of building design solutions and material effect on energy consumption and indoor climate also in other countries and for other climatic zones, e.g., in Finland [6], Spain [7] and Italy [8].

All the test buildings are equipped with identical air-air heat pumps used for the heating/cooling and electric convection heaters; two buildings are additionally equipped with air-water heat pumps. Three ventilation modes may be provided with the help of installed systems. Long-term measurement data for several heating and cooling seasons can be used to evaluate and analyse the differences in thermal comfort conditions and local discomfort factors (vertical temperature difference and draught rate) for different types of heating and cooling systems under real operating conditions. The analysis of this data allows selection of the optimal heating system and its operating regimes not only for better energy efficiency, but also in terms of thermal comfort conditions.

Fig. 1. Testing buildings: (a) site overview; (b) cross-section of the building with main temperature and air humidity sensor location.

2. Experimental set-up and used evaluation methods

Installed data loggers collect the measurement data every minute from the weather station (air temperature, relative humidity, wind speed and solar irradiation), as well as from each building (temperature and humidity at heights of 0.1/0.6/1.1/1.7/2.9 m, air velocity, solar irradiation, electric powers and energy consumption for heating/cooling systems, CO2 concentration, heat flux etc.). A placement of main temperature/humidity sensors is shown in Fig. 1(b). Additional to fixed temperature sensors mean radiant temperature has been periodically evaluated using portable microclimate measuring device DeltaOHM HD 32.1 [9].

Identical split-type air conditioning systems with indoor unit placed above the door on the north facade are used for the cooling. The following four different types of heating are installed and used for the heating (Fig. 2):

- an air-air heat pump with an indoor unit (same as for cooling) placed above the door on the north facade (A-A);
- an air-water heat pump with low-temperature large convectors placed on the floor near the outer wall (A-W.F);
- an air-water heat pump with heating capillary mats placed on the ceiling (A-W.C);
- a standard electric heater placed near the window on the south facade (EL)

The type of heating system, the placement of heat exchanger and corresponding different air movement regimes in a room influence the temperature distribution (stratification) in the room, affecting also the thermal comfort conditions. The PMV/PPD model described in ISO 7730 standard [10] for predicting the general thermal sensation and degree of discomfort was developed by Fanger [11] using heat balance equations and empirical studies about skin temperature to define comfort. Four environmental parameters – air temperature, mean radiant temperature, air velocity, and relative humidity – as well as two assumptive factors – human metabolic rate (*met*) and clothing insulation (*clo*) – are used for the calculation of thermal sensation. The last two parameters generally are unknown, but we will use in calculations values according to sedentary activities (*met*=1, 2) during heating and cooling seasons