Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 78 (2015) 639 – 644
Energy Procedia

6th International Building Physics Conference, IBPC 2015

Analysis of indoor climate and occupants' behaviour in traditional Scottish dwellings

Daniel Herrera Gutierrez-Avellanosa[a,]*, Amar Bennadji[a]

[a]Robert Gordon University, Garthdee Road, Aberdeen AB10 1NN, United Kingdom

Abstract

Due to the relevance of the internal boundary conditions and the lack of specific data for the Scottish context, an exploration of the internal environment of traditional dwellings is needed. In this study the indoor climate of 24 properties with different levels of insulation and air-tightness was analysed using a combination of quantitative and qualitative data. Temperature and relative humidity were recorded at 15 minutes intervals in two rooms per property. The analysis was complemented with semi-structured interviews with the occupants. Based on temperature and relative humidity, the moisture loads were calculated. Results in non-insulated properties showed indoor temperatures lower than the minimum level of thermal comfort, especially in winter, and high values of relative humidity during the warm season. The humidity levels in upgraded buildings are consistently lower despite the greater variability found in the internal temperatures.

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL
Keywords: indoor climate; dwellings; traditional buildings; hygrothermal loads; thermal comfort.

1. Introduction

Thermal improvement of traditional and historic buildings, representing around 20% of the total built stock in Scotland [1], is going to play a crucial role in the achievement of established carbon emission targets (80% reduction, respect 1990 levels, by 2050 [2]). However, the long term effect of insulation on the conservation of the solid masonry walls remains unclear. Additionally, there is some uncertainty regarding the rebound effect and the actual reduction of energy consumption. Previous research has shown significant variability in the hygrothermal

* Corresponding author. Tel.: +44(0)1224363731.
E-mail address: d.herrera-gutierrez-avellanosa@rgu.ac.uk

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL
doi:10.1016/j.egypro.2015.11.046

conditions of the living spaces depending on the building age and the level of insulation [3]. The analysis of indoor climate is important both to define reasonable boundary conditions for the hygrothermal simulation of the envelope and to assess the thermal comfort of the occupants.

2. Methods

In this study the indoor climate of 24 traditionally constructed dwellings with different levels of insulation and air-tightness was analysed during 2014-2015 using quantitative and qualitative data. The sample was formed by buildings located in the North-East of Scotland with similar construction characteristics (solid masonry granite walls and pitched roofs covered with slates). Although most of the buildings had some energy related improvements (mainly the substitution of the original single glazed windows), the dwellings were at different levels of conservation; while some of the buildings had kept the original lath and plaster others were completely renovated internally. For analysis, buildings were categorised as “retrofitted” or “non-retrofitted” according exclusively to the insulation of the external wall. Two of the houses were monitored before and after the insulation and therefore were considered as different households, resulting in a total of 26 dwellings.

Temperature and relative humidity were monitored at 15 minutes intervals in two rooms per property (living room and bedroom) along with recordings of external conditions by a dedicated weather station. Air pressure tests were carried out in 9 of the dwellings to measure the permeability of the envelope and its effect on the internal climate. The analysis of the indoor environment was complemented with qualitative information obtained by means of semi-structured interviews with the occupants. The interviews were focused on users’ perception of comfort and their energy related patterns. Information regarding the heating, ventilation and moisture production habits was collected in order to achieve a better understanding of the physical measurements.

For analysis, the data was sorted according to seasons. Winter season was analysed using the measurements from December to March, while the summer season only included the measurements from June to September. Based on the measurement of temperature and relative humidity, risk of mould growth and moisture loads were calculated. Using the air permeability values, daily moisture production rates were estimated.

Analysis of the internal temperature in the living spaces was done according to the standard EN 15251:2007 [4]. The design criteria proposed in this standard assumes 3 classes with different levels of predicted percentage of dissatisfied (PPD: <6%, <10%, <15%). Within these classes, the minimum operative temperatures for heating during the winter season (assuming 1 clo) are as follows: Class I, 21°C; Class II, 20°C; Class III, 18°C. Unlike internal temperature, relative humidity is not clearly defined in the standards. CR1752 [5] establishes generic criteria for human comfort and indoor air quality: "*normally few problems occur when the relative humidity is between 30 % and 70 %, assuming that no condensation takes place*". Using the same classes based on the PPD established for the operative temperature, EN 15251 proposes the following levels of humidity for buildings equipped with humidification (or dehumidification) systems: Class I, 30%-50%; Class II, 25%-60%; Class III, 20%-70%. Although the standard acknowledges that humidification or dehumidification is usually only needed in special buildings such as museums, health care facilities, etc. these categories have been used in this paper as they provide a useful framework to interpret the results.

3. Results

3.1. Internal temperature and relative humidity

Figure 1 shows the results of the internal temperature as a function of the external temperature for summer and winter. In summer the average internal temperature was 19.8°C for non-treated houses, with minimum and maximum values of 13°C and 28.6°C respectively, and 18.8 °C for retrofitted buildings (min=15.5°C; max=28.5°C) (Fig 1a). The internal temperature was strongly dependent on the external conditions, especially in non-retrofitted buildings. For external values under 15°C, retrofitted buildings fell below the lower threshold of Class III (18°C). Class I was only achieved by non-retrofitted buildings and only when the external temperature exceeded 17 °C. The results are homogeneously distributed between the percentiles 10 and 90. The lines are almost parallel and the difference between them is around 4 °C (Fig. 1a).