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ScienceDirect

Procedia Engineering 146 (2016) 166 – 173

Procedia Engineering

www.elsevier.com/locate/procedia

8th International Cold Climate HVAC 2015 Conference, CCHVAC 2015

Energy-efficient building in Greenland: investigation of the energy consumption and indoor climate

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Abstract

Recently, a brand new single family home was built in Sisimiut, Greenland. The building was constructed as a wooden house typical for Greenland. However, some non-traditional measures were implemented in order to reduce the energy consumption and improve indoor air quality. Assessment of the influence of these measures is essential for their implementation on a wider scale. In particular, functionality of the state of the art ventilation system is of large concern as these systems have not been commonly used for their sensitivity towards the extremely cold climate. A detailed monitoring system was installed in the house. It enables the evaluation of the indoor air quality, as well as building's energy performance.

The aim of this investigation was to evaluate the performance of the newly constructed house by and compare it with the performance of identical house built in a traditional way by using a computer model. The data obtained from the measurements in the new house were used to verify the model. Significant energy savings and improvements of indoor air quality were found in the new house when compared to the traditional one. Moreover, all the extra measures have a feasible payback time despite high prices of labor and transportation to Greenland.

Peer-review under responsibility of the organizing committee of CCHVAC 2015

Keywords: Energy efficient buildings in Arctic; Energy savings; Ventilation; IDA ICE

1. Introduction

Until recently, little attention was paid to the energy efficiency of the buildings constructed in Greenland. This coupled with extreme climatic conditions (very low temperatures over long periods of time, lack of sun in the winter

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Peer-review under responsibility of the organizing committee of CCHVAC 2015
doi:10.1016/j.proeng.2016.06.368

period and strong winds) results in high energy consumption for heating [1]. Additionally, the buildings are usually poorly ventilated, what results in a poor indoor air quality (IAQ), mold growth and greater exposure to indoor air pollutants. Assuming that people in Greenland spend a significant part of the long winters indoors, the risk of health problems due to poor IAQ is considerable.

The first step to minimize heat losses from buildings in the Arctic is to optimize the building shape and amount of insulation [2]. Additionally, the air tightness of the building envelope has to be ensured, together with the utilization of solar heat gains. Also, heat recovery from the exhaust air should be used. However, more difficult than decreasing the annual heating demand is in fact lowering the peak heat load of the building. It is due to the combination of very low temperatures with no solar gain on the design days. Vladyková and Rode [2] concluded that fulfilling the requirement of maximum 10 W/m2 of peak demand required for the building to fulfil the passive house requirements [3], would require the use of economically unreasonable technical solutions.

Mechanical ventilation systems besides allowing heat recovery from the exhaust air also permit for better control of the air change and control of indoor air parameters, e.g. humidity or CO_2 concentration. For Arctic dwellings, 20% relative humidity (RH) during winter is considered optimum. If the value drops below this point, discomfort perceived by the occupants increases significantly. The risk for condensation and consequent mold growth is increasing at RH above 20%, what consequently leads to the indoor air quality decrease and may affect residents' health [4]. During cold periods there is a high risk of frosting of the heat exchanger when the humid exhaust air stream is cooled below its dew point and moisture condensation on the surface below the freezing temperature occurs [5]. This issue has to be taken into account when designing the system.

Apart from improved IAQ, using mechanical ventilation can be economically justified thanks to energy savings due to heat recovery. A study of buildings constructed in Kotzebue, Alaska showed simple payback time (SPBT) of mechanical ventilation of 7 years [4]. Since 1995 (when the research was performed) the energy prices have increased and technology became cheaper, therefore, the SPBT for similar investment nowadays would be even shorter.

1.1. Aim of the paper

The aim of this investigation was to compare the performance of the newly constructed energy-efficient single family house with the performance of a standard house of the same kind in Arctic conditions by means of computer simulation.

2. Methods

2.1. Description of the building

The investigated building is a 122.2 m^2 single family house located in Akia neighbourhood in Sisimiut, Greenland. The building was constructed as wooden house typical for Greenland. However, in comparison to standard type houses, several improvements were implemented. The thermal insulation in external walls and ceiling below the loft was made significantly thicker ($U_{ext.\ wall}$ = 0.14 $W/(m^2 \cdot K)$ in comparison to $U_{ext.wall}$ = 0.20 $W/(m^2 \cdot K)$ required by Greenlandic Building Regulations [6], $U_{ceil.bel.loft}$ = 0.093$W/(m^2 \cdot K)$ in comparison to $U_{ceil.bel.loft}$ = 0.15 $W/(m^2 \cdot K)$). Additionally, a mechanical ventilation system with rotary heat exchanger was installed in the building. The windows in the building are triple-glazed. The layout of the building is presented in Fig. 1.

2.2. Description of the building models used for the simulations

The simulation of building operation was made in IDA ICE 4.6.2 and the weather file used was Test Reference Year (TRY) for Sisimiut. The setpoint temperatures during the heating season were set according to the setpoints used by the occupants. The temperature setpoints are presented in Table 1. The design power of the floor heating was assumed to be the same in all rooms where heating floor was located and calculated as 30 W/m^2. The thermal bridges were set as "Good" in IDA ICE setup. The leakage of the building envelope was set to 3 h^{-1} at 50 Pa over- and underpressure, value similar to 3.2 h^{-1} measured in the Low Energy House in Sisimiut, Greenland [7].