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ScienceDirect

Energy Procedia 132 (2017) 333–338

Energy Procedia

www.elsevier.com/locate/procedia

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

Thermal insulation performance of reflective foils in floor cavities - Hot box measurements and calculations

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Abstract

In the present study both experimental measurements and calculation models have been used to investigate the practical performance of reflective foils in air filled floor cavities. The laboratory measurements were performed in a pivotal guarded hot-box. Both heat flow down through the floor area and the temperature distribution in the cavities were measured. The number of reflective foils and the amount of edge insulation at the edge beams has been varied as well as the environmental temperature conditions. Measured and calculated results show good agreement for most of the tested timber floor variants.

Keywords: Heat transfer; Themperature distribution; Floor cavities; Reflective foils

1. Introduction

Reflective foils may be applied, on certain conditions, as a supplement or a substitute to traditional thermal insulation in cavities in building envelope parts [1]. In roofs and walls in cold climate, the practical application is limited to thin cavities, giving R-values equivalent to a few cm of mineral wool. In thicker cavities in walls and roofs, natural convection will develop and dominate the heat transfer [1,2,3,4]. The thermal resistance will remain relatively constant when the air layer thickness exceeds 2 and 3 cm in roofs and walls respectively. In floors however, the thermal insulation potential of reflective foils is high [1,4,5]. In air-filled floor cavities and crawl spaces, where the heat flow direction is downwards, the air can be relatively stable and the heat transfer by convection limited even in thick air layers. The heat transfer by conduction in the stagnant air will also be small, because the thickness of the cavity is high and the thermal conductivity of air is low, about 0.025 W/(mK). In cavities with ordinary surfaces with high emissivity,

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10.1016/j.egypro.2017.09.742

the heat transfer is dominated by net thermal radiation from the hot, uppermost surface down to the colder surface of the floor cavity or to the ground. The radiation heat transfer can be limited by use of one or several reflective foils mounted horizontally in the cavity, parallel to the floor area, and on all bounding surfaces.

Low temperatures at the cold edges of the floor structure can cause considerable convection in the peripheral areas and hence a higher heat loss through the floor structure. The risk of convection in the cavities can be reduced by use of edge insulation, for instance of mineral wool, at the peripheral edges of the floor structure. Edge insulation reduces the temperature difference between the cold edge of the cavities and the air temperature in the cavities and thereby reduces the driving force for natural convection. Most serious studies of reflective foils used in building elements apply to roofs and walls, while there are relatively few studies of full scale floors, [2,3].The main objective of the present study [6] was to investigate the performance of reflective foils as thermal insulation of cavities in floors in general and in timber frame cavities in particular.

2. Methods

The study comprises full-scale measurements on a timber frame floor section in a pivotal guarded hot box as well as heat flow calculations for the same element. For building elements where the heat flux is unevenly distributed over the surface, such as timber frame structures and structures with air cavities and possible convection, it is important to make full-scale measurements to obtain representative results. Measurements by use of heat flow meters will not give reliable results. Both the heat flow down through the floor and the temperature distribution in the cavities was measured, first with the cavities filled with mineral wool, with thermal conductivity 0.035 W/mK, and thereafter with eight different combinations, variants, of cold edge insulation and reflective foils. The positions of reflective foils, with total emissivity of 0.032, are marked with red lines in the figures 4 to 6.

The overall size of the test floor structure was 3.0 m x 3.0 m and the metering area of the hot-box is 2.46 m x 2.46 m. Fans were used to apply forced convection at both the cold and hot surface of the test specimen. The air speeds were adjusted to provide surface heat transfer resistances of 0.04 and 0.11 m²K/W at the cold and hot sides respectively.

In a real house the floor structure is exposed to exterior temperature conditions both on the underside and at the edges of the floor. To study the risk of convection in the cavities at the external edges of the floor structure we had to establish realistic temperature conditions also in the hot-box set up. This was achieved by use of heat sinks of 5 mm thick aluminum plates mounted on the exterior side of the edge beams. The aluminum plates were exposed to the air in the cold box, as shown in Figure 3.

The same nine variants has also been simulated using a program for 2-dimensional heat flow, COMSOL Multiphysics® 5.2a. (https://www.comsol.com/). The modeling domain covers the entire cross section, including parts of the hot-box. The 2D-model includes heat transfer by conduction, convection and radiation which is implemented as described in [7]. Laminar flow is assumed in the cavities. In the Comsol models direction-dependent values of thermal conductivity of wood and plywood was used. The thermal conductivity in the fibre direction is estimated to twice the measured value perpendicular to the fibre direction.

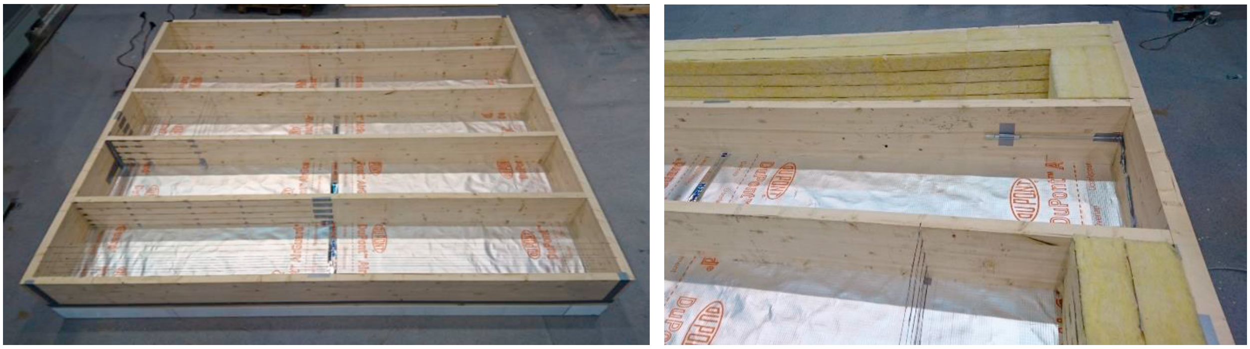

Fig. 1. Photo showing the timber frame test section under construction with a reflective foil at the hot side of the cavities and thermocouples mounted for measuring temperatures inside the cavities. Edge insulation partly mounted, (right).